THE EARLY STAGES OF FISHES IN THE CALIFORNIA CURRENT REGION

CALIFORNIA COOPERATIVE OCEANIC FISHERIES INVESTIGATIONS

ATLAS NO. 33

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PACIFIC OUTER CONTINENTAL SHELF REGION

Editor

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THE CALCOFI ATLAS SERIES

This is the thirty-third in a series of atlases containing data on the hydrography and plankton from the region of the California Current. The field work was carried out by the California Cooperative Oceanic Fisheries Investigations, a program sponsored by the following agencies:

California Department of Fish and Game
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University of California, Scripps Institution of Oceanography

CalCOFI Atlases are issued as individual units as they become available. They provide processed physical, chemical, and biological measurements of the California Current region and life history information on planktonic organisms of the region. Each number may contain one or more contributions. A general description of the CalCOFI program with its objectives appears in the preface of Atlas No. 2.

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Recent CalCOFI atlases related to the subject of Atlas No. 33:

No. 31. Moser, H. G., R. L. Charter, P. E. Smith, D. A. Ambrose, S. R. Charter, C. A. Myer, E. M. Sandknop, and W. Watson. 1993. Distributional atlas of fish larvae and eggs in the California Current region: Taxa with 1000 or more total larvae, 1951 through 1984. 233 pp.

No. 32. Moser, H. G., R. L. Charter, P. E. Smith, D. A. Ambrose, S. R. Charter, C. A. Myer, E. M.Sandknop, and W. Watson. 1994. Distributional atlas of fish larvae in the California Current region: Taxa with less than 1000 total larvae, 1951 through 1984. 181 pp.

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PREFACE

The origins of this guide are with the scientific investigations on the collapse of the Pacific sardine population in the late 1940s and the founding of the California Cooperative Sardine Research Program, later renamed CalCOFI, the California Cooperative Oceanic Fisheries Investigations. Among the diverse assemblage of scientists investigating the sardine and its environment was Dr. Elbert H. "Ahlie" Ahlstrom, who quickly took the lead role in early life history studies. One of Ahlie's scientific talents was taxonomy and he saw a great potential for learning about the many other fish species whose eggs and larvae were collected in plankton tows with those of the sardine. He began a vigorous research program to increase the number of identifiable taxa and documented this progress with a series of papers describing the eggs and larvae of a variety of species.

In 1978, Ahlie and I began work on an identification guide to the early life history stages of about 100 of the most common species encountered in the CalCOFI ichthyoplankton collections. Early progress on this ended with his untimely death in 1979 and, shortly thereafter, five of his colleagues (William J. Richards, Daniel M. Cohen, Michael P. Fahay, Arthur W. Kendall, Jr., and Sally L. Richardson) joined me in organizing an international symposium to honor Ahlie and his scientific achievements. Ahlie's notes and unpublished manuscripts were made available to the contributors and the symposium was held at the University of California, San Diego in 1983. The symposium volume entitled, "Ontogeny and Systematics of Fishes," was published by The American Society of Ichthyologists and Herpetologists in 1984.

In 1988, I sought funding from the Minerals Management Service, U.S. Department of the Interior, to begin the illustrations required to publish a more comprehensive version of the guide originally envisioned by Ahlie and me. The proposal was successful, largely through the efforts of Dr. Gary D. Brewer of MMS. In September 1989, Barbara Sumida McCall began the illustrations and my research group, William Watson, David A. Ambrose, Sharon R. Charter, and Elaine M. Sandknop, began to work on the various chapters of the guide. Initially, we planned to produce a book of about 500 pages covering about 250 taxa but it soon became obvious that this was an underestimate. Work on each chapter became a significant research project, with exciting new discoveries. What was to be a three-year project has taken six years to complete. Consequently, the book tripled in size and includes more than twice the planned number of taxa and illustrations. A total of 1171 original illustrations was completed over the six years. With the 181 unpublished illustrations on hand before the project began, the book has a total of 1352 original illustrations. The extra time spent on the book has increased its scope and coverage and its usefulness to scientists studying ichthyoplankton in all oceans.

Members of our research group have labored prodigiously on this project, showing great patience and forbearance while being asked to complete their sections of the book along with the other duties of the research division. William Watson, as sole author or in collaboration, wrote more than half the chapters, produced many of the illustrations, was responsible for the reduction of original illustrations and the paste-up of the plates, and assisted all of us with his writing skills during the development of our chapters. His central role in the realization of this book will be obvious to anyone using it. David Ambrose made major advances in our knowledge of the ontogeny of Alepocephaloidei, Alepisauroidei, Gadiformes, Cottoidei, and Scombroidei. He was responsible for paste-up of the figure captions and headers and took the lead role in preparing the indexes for the book. Sharon Charter was responsible for most of the Elopomorpha chapters and greatly improved our knowledge of eel leptocephali. Also, she was responsible for the sections on the Lampridiformes, Mirapinnidae, Pleuronectidae, and Cynoglossidae, and made important contributions to chapters on the Carangidae and Bothidae. She shared responsibility with David Ambrose for production of the indexes. Elaine Sandknop was responsible for chapters on the Melamphaidae, Apogonidae, Mugilidae, Polynemidae, Howellidae, and Trichiuridae, and worked closely with William Watson on the Clupeiformes, Scopelarchidae, and other chapters in the book. Her comprehensive knowledge of egg and yolk-sac stages was helpful to each of us as we developed our chapters. The editing of the manuscript for this book was a long and arduous process and could not have been accomplished without the assistance of each member of our research team. I am deeply indebted to them for the enormous effort they extended during this process and for their dedication throughout this project.

Former La Jolla Laboratory scientists were important contributors and authors on chapters of the guide. Elbert H. Ahlstrom's work on Bathylagidae and Myctophidae was important to the completion of those sections. Elizabeth G. Stevens retired soon after work on the book began but made important contributions to sections on Bregmacerotidae and Synodontidae. Barbara Sumida MacCall worked out the larval series for the numerous sanddab species in the CalCOFI collections and this was crucial to the completion of the chapter on Paralichthyidae. John L. Butler, who currently leads research on age and growth of fishes in the La Jolla Laboratory, contributed much to the chapter on Microstomatidae.

The following scientists from other laboratories contributed chapters in special areas of their expertise: Dr. Michael W. Brogan, School of Fisheries, University of Washington, Seattle, Washington—Lutjanidae; Mr. Bruce C. Mundy, National Marine Fisheries Service, Southwest Fisheries Science Center, Honolulu Laboratory, Honolulu, Hawaii—Bramidae; Dr. William J. Richards, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami Laboratory, Miami, Florida—Triglidae; and Mr. Michael A. Shane, Hubbs-Sea World Research Institute, San Diego, California—Polyprionidae.

The illustrations are the heart of the guide. George Mattson produced many illustrations during his career in our laboratory and his images, some previously unpublished, are found throughout the chapters. He used a split-point pen for all his illustrations and the depth of field achieved with this technique is unique in line drawings of the early life stages of fishes. The two years given to the project by Barbara Sumida McCall set the standard for the other illustrators. Her images, exquisite in their detail and accuracy, follow from her experience as an accomplished biologist and from her great artistic talent. The same is true for William Watson's illustrations. Nancy Arthur and Robert C. Walker worked on the project for more than two years and Mary T. Vona was with us for a year. All are fine artists and had no experience in the illustration of fish eggs and larvae before joining the project. They were trained by William Watson and guided by each of the authors as they worked on their chapters. Esther M. Perez did all the word processing and formatting of the guide. Her talents in design and editing and her dedication became increasingly more important as the book progressed. This book could not have been completed without her. We are deeply grateful for her efforts.

The suggestion to publish this book in the CalCOFI Atlas series came from Dr. John R. Hunter, Chief of the Coastal Fisheries Resources Division of the La Jolla Laboratory. This idea was enthusiastically accepted by the CalCOFI Committee and the collaboration with George T. Hemingway, the CalCOFI Coordinator, was an enjoyable experience. Mistakes and inadequacies are part of any undertaking of this scope and complexity and ultimately come to rest with the editor. I offer my apologies to all for any shortcomings that come to light.

H. Geoffrey Moser
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ACKNOWLEDGEMENTS

This guide is a joint project of the Southwest Fisheries Science Center (SWFSC), the Minerals Management Service (MMS) of the Department of the Interior, and the California Cooperative Oceanic Fisheries Investigations (CalCOFI). The enthusiastic support afforded by Dr. Gary D. Brewer of MMS was critical to obtaining the initial funding. Dr. Frank J. Manago of MMS provided support throughout the course of the project. Dr. John R. Hunter, Chief, Coastal Fisheries Resources Division, gave us the opportunity to carry out the research for the guide and encouraged us throughout the project. Dr. Izadore Barrett, Science Director of the Southwest Fisheries Center at the start of the project, Dr. Michael F. Tillman, current Science Director, and Dr. Richard A. Neal, Deputy Director of the SWFSC have heartily encouraged and supported the work. Additional funds needed to enlarge the coverage and scope of the guide were made available by Drs. Hunter, Tillman, and Neal and by MMS, through the efforts of Dr. Manago. Dr. Neal and Susan E. Smith generously permitted Esther M. Pérez to take time from her many duties to do the word processing and formatting for the entire manuscript. Esther's contributions were central to the completion of this book.

Many people at the SWFSC helped with various aspects of this guide. The study was based on an ichthyoplankton collection accumulated over a period of 45 years and we owe a great debt to all the scientific and ships' crews who carried out those cruises. We are indebted to the many sorters and identifiers who skillfully separated the fish eggs, larvae, and juveniles from the plankton. Richard L. Charter, CalCOFI ichthyoplankton data manager, is our partner in all CalCOFI ichthyoplankton work and his computer support has been essential from the beginning of this project. Mark Yip, Eric Frostad, and several student interns from the Harvey Mudd College Upward Bound Program aided in the search for larval specimens and Leo Smith, Mark Yip, and the student interns helped produce radiographs and meristic data. Debra Losey, SWFSC librarian, made numerous literature searches for us during the entire project. The assistance given by Barbara Engstrand and Barbara Watkins on contracts and supplies was essential to the completion of the project. Virginia Hostler assisted us with the many personnel actions associated with this project. We thank Benjamin Remington and Sherrie Rasmussen for their assistance in the administration of the MMS grant. Ken Raymond and Roy Allen provided helpful advice on graphics.

We are deeply indebted to the many people who produced original illustrations used in this guide: Barbara Sumida MacCall, Nancy Arthur, Robert C. Walker, Mary T. Vona, George Mattson, Henry M. Orr, Bruce C. Mundy, Kenneth S. Raymond, Richard F. Feeney, Gary A. Jordan, Atsuhiro Kubo, Eloisa Matus-Nivón, and Beverly M. Vinter. Attributions for each illustration are given in the species descriptions.

The Marine Vertebrates Collection of the Scripps Institution of Oceanography was a major resource throughout this project, as was the advice and assistance given by Dr. Richard H. Rosenblatt, curator of the collection, and by H. J. Walker, Jr. and Cynthia Klepadlo. The collection was our principal source of specimens for gathering meristic data to supplement the literature and was an important source of transforming and juvenile specimens needed for the identification of larval series and for species descriptions. Computer summaries of capture localities for specimens in the collection were useful in establishing geographic ranges of species and were always graciously provided. This guide could not have been completed without the availability of the SIO Marine Vertebrates Collection and the assistance and encouragement of Dr. Rosenblatt and his staff.

Another major source of larval, juvenile, and adult fishes was the Natural History Museum of Los Angeles County. Throughout the course of this project, Dr. Robert J. Lavenberg kindly loaned us numerous specimens that were needed to complete ontogenetic series and meristic lists. We are deeply grateful to Bob and his assistant curators, Dr. Jeffrey A. Seigel and Richard F. Feeney for their much needed support. Dr. Daniel M. Cohen, Chief Curator, Life Sciences Division. LACM, offered helpful advice and support throughout this project.

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We gratefully acknowledge all authors of journal papers or manuscripts from which illustrations were obtained. The following publications were major sources for illustrations used in this guide and we thank the publishers, authors, and editors of those publications for permission to reproduce those illustrations: Ontogeny and Systematics of Fishes (1984), American Society of Ichthyologists and Herpetologists; Studies on the Oceanic Ichthyoplankton in the Western North Pacific, Kyushu University Press, T. Ozawa, ed. (1986g); An Atlas of the Early Stage Fishes in Japan, Tokai University Press, M. Okiyama, ed. (1988a); Laboratory Guide to the Early Life History Stages of Northeast Pacific Fishes, A. C. Matarese, A. W. Kendall, Jr., D. M. Blood, and B. M. Vinter (1989).

All chapters of this guide received rigorous scientific reviews from experts on each group of fishes. The drafts of many of these sections were lengthy and all contained detailed descriptions that required much effort and patience. We are deeply grateful to each of these reviewers for taking valuable time from their research to help us with this project. Their comments, criticisms, and suggestions vastly improved the quality and usefulness of the guide. Reviewers and the sections they reviewed are as follows: K. W. Able (Cyprinodontiformes), L. G. Allen (Gobiesociformes), C. C. Baldwin (Aulopiformes, Serranidae), E. G. Barham (Paralichthyidae), M. W. Brogan (Blennioidei), M. S. Busby (Agonidae, Cyclopteridae), D. M. Cohen (Salmoniformes), B. B. Collette (Beloniformes, Scombroidei), J. G. Ditty (Echeneidae, Coryphaenidae, Lobotidae, Sciaenidae, Ephippidae, Stromateidae), W. N. Eschmeyer (taxonomic names and classification), M. P. Fahay (Gadiformes, Ophidiiformes), R. F. Feeney (Cottidae, Psychrolutidae), R. A. Fritzsche (Syngnathiformes), F. J. Gago (Trichiuridae), D. A. Hensley (Pleuronectiformes), M. H. Horn (Stromateoidei), E. D. Houde (Clupeiformes, Bregmacerotidae, Callionymidae), G. D. Johnson (Polyprionidae, Serranidae, Bramidae, Caristiidae, Malacanthidae, Howellidae), D. L. Jones (Labroidei), K. Kawaguchi (Myctophiformes), A. W. Kendall, Jr. (Scorpaenidae, Anoplopomatidae, Hexagrammidae, Psychrolutidae, Icosteidae), C. Klepadlo (Stomiiformes, Myctophiformes, Batrachoidiformes, Triglidae, Carangidae, Mullidae, Kyphosidae, Mugilidae, Gobioidei, Sphyraenidae, Pleuronectiformes, Tetraodontiformes), T. E. Laidig (Scorpaenidae), R. J. Lavenberg (Salmoniformes, Atheriniformes, Exocoetidae), J. M. Leis (Priacanthidae, Apogonidae, Nematistiidae, Lutjanidae, Chaetodontidae, Pomacentridae, Cirrhitidae, Labridae, Tetraodontiformes), K. C. Lindeman (Lutjanidae, Haemulidae), V. J. Loeb (Scorpaenidae), D. F. Markle (Alepocephaloidei, Gadiformes), A. C. Matarese (Hexagrammidae, Psychrolutidae, Zoarcoidei, Trachinoidei, Pleuronectidae), J. E. McCosker (Anguilliformes), B. C. Mundy (Stomiiformes, Aulopiformes, Myctophiformes, Beryciformes, Caristiidae, and the introductory sections), D. Oda (Pleuronectiformes), M. Okiyama (Aulopiformes), J. E. Olney (Lampridiformes), J. R. Paxton (Aulopiformes, Myctophiformes), T. W. Pietsch (Lophiiformes), W. J. Richards (Aulopiformes, Myctophiformes, Serranidae, Priacanthidae, Lutjanidae, Haemulidae, Labroidei, Scombroidei), R. H. Rosenblatt (Elopomorpha, Gerreidae, Sparidae, Opistognathidae), K. M. Sakuma (Scorpaenidae), D. G. Smith (Elopomorpha), V. G. Springer (Blennioidei), B. M. Vinter (Hexagrammidae, Psychrolutidae, Pleuronectidae), H. J. Walker, Jr., (Batrachoididae, Triglidae, Carangidae, Mullidae, Kyphosidae, Mugilidae, Polynemidae, Gobioidei, Sphyraenidae, Pleuronectiformes, Tetraodontiformes), and J. T. Williams (Blennioidei).

We are grateful to George T. Hemingway, CalCOFI Coordinator, and the CalCOFI Committee (Doyle A. Hanan, Michael M. Mullin, and Michael F. Tillman) for their support of this project and their willingness to publish this guide in the CalCOFI Atlas series. George Hemingway was instrumental in many aspects of the development and publication of this guide. Without his efforts in gaining funding for the book it would never have been published. His unwavering support and encouragement to all of us during this project is truly appreciated. We thank Roy Allen for drafting the maps in the introductory section and for his help in producing the advertisement brochure for the book. Valerie Philbrick provided much needed computer assistance in preparing mailing lists for the brochure. Kohichi Kawaguchi, Jeffrey M. Leis, William J. Richards, Cynthia Klepadlo, J. C. Quéro, Debra Losey and H. J. Walker, Jr. were instrumental in making the prepublication brochure available to a wide scientific audience; their help is greatly appreciated. We thank Diane Foster for secretarial assistance.

Finally, we owe a great debt to Elbert H. Ahlstrom who started us on the path leading to the publication of this book and taught us much along the way.

INTRODUCTION

H. G. Moser

Background

In 1865, the Norwegian biologist G. O. Sars discovered that cod had free-floating eggs, thus revealing the potential for gaining knowledge of both parent stocks and recruits of marine fishes by sampling their relatively easily-captured planktonic stages. Sars' discovery stimulated intensive investigations directed towards rearing and describing the early life history (ELH) stages of fishes of the European seas (see Russell 1976; Hempel 1979; Ahlstrom and Moser 1981). Hensen's (1895) development of the gear and techniques for quantitatively sampling ichthyoplankton (fish eggs and larvae) provided the impetus for plankton surveys aimed at determining the timing and extent of spawning of important fish stocks and estimating their biomass. The results of plankton surveys off Norway conducted by Johannes Hjort in the first decade of this century led him to postulate that fluctuations in year-class strength were due to interannual variation in survival of the first-feeding larval stage (Hjort 1914). Hjort proposed that starvation was the principal causal factor in early mortality and that year-to-year fluctuations in populations of prey organisms and their availability to first-feeding fish larvae ultimately determined the size of the future year class. Hjort incorporated oceanography in his hypothesis by suggesting that ocean currents could reduce survival by transporting eggs and larvae away from favorable feeding areas. Much debate has followed Hjort's seminal hypothesis and the focus has shifted to stage-specific growth rates and size-specific predation as principal factors determining early survival and year-class strength (Anderson 1988); however, research on the early life history stages of marine fishes continues to provide practical means for assessing the size and extent of spawning populations and is central to the search for factors regulating fluctuations of these populations.

The importance of taxonomic competency in ichthyoplankton research cannot be overestimated. Marine fish eggs and larvae have evolved an enormous array of forms, morphological specializations, and pigmentation patterns that provide characters for identifying them. Effective use of these characters for identification requires knowledge of their intra- and interspecific variation and an understanding of how each character varies among higher taxonomic categories (Fahay 1983). At present, most larvae collected in plankton samples can be identified at least to family; however, the proportion of species whose larvae are known varies regionally from a maximum of >80% in the northeast Atlantic to ca. 10% in the Indo-Pacific (Kendall and Matarese 1994). The use of ontogenetic characters in systematic research has provided new insights into phylogenetic relationships among teleost fishes. Contributors to the "Ahlstrom Symposium" summarized available information on the early life stages of teleosts and integrated it with systematic information on adults (Moser et al. 1984b); this comprehensive evaluation of early life history characters has greatly enhanced our ability to identify fish eggs and larvae. Likewise, recently published regional ELH identification guides aid greatly in ichthyoplankton investigations (see Kendall and Matarese 1994). Scientists of the National Marine Fisheries Service have produced such guides for the Northwest Atlantic (Fahay 1983) and the Northeast Pacific (Matarese et al. 1989).

This guide to the early stages of teleost fishes of the California Current region, the third in the series of NMFS regional guides, is the result of five decades of ichthyoplankton research sponsored by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) and its predecessor, the California Cooperative Sardine Research Program. CalCOFI evolved from the practical need to understand the reasons for the demise of the Pacific sardine and the founding scientists realized that such a complex problem would require a comprehensive program that integrated population analyses, marine ecology, and investigations of the physical dynamics of the California Current. Among the results of this effort are the discovery of new fish stocks and new plankton-based techniques to measure biomass of important stocks, the development of physical and biological time series, and a vast fund of published information on the biology and oceanography of the California Current region. As a consequence of these advances, CalCOFI has become a model for the development of other biological/oceanographic fisheries programs in this country and internationally.

Geographic Coverage

The core region covered in this guide is defined by the CalCOFI survey pattern which extends over a >1 million km^2 area from the Oregon-California border to the southern tip of Baja California Sur and offshore to ca. 400 n.mi. (Figures Introduction 1–3). The sampling grid overlays the California Current, three coastal zoogeographic provinces (the Oregonian, San Diegan, and Panamic), a coastal upwelling zone, and three oceanic water masses (Subarctic-Transitional, Central, and Eastern Tropical Pacific) (Figure Introduction 4). CalCOFI made 38,735 plankton tows (33,876 oblique tows, 4,859 neuston tows) from 1951 to 1994. The oblique tows yielded ca. 28.6 million fish eggs and 13.6 million fish larvae distributed in approximately 152 families (Moser et al. 1993, 1994a)

Spatial and temporal coverage was most complete during the early years of the surveys (1951–1960) when multi-vessel cruises occupied most of the survey pattern at monthly intervals. Subsequently, reduced ship availability and funding limitations resulted in a reduction of the number of cruises and in their areal coverage. Surveys were made annually from 1951 to 1969 and from 1985 to 1995 and triennially during 1969–1984. Since 1985, the survey pattern has been limited to quarterly coverage within the Southern California Bight (Moser et al. 1993).

The survey lines, perpendicular to the coastline, are 40 n.mi. apart and principal stations are placed at 40-n.mi. intervals on the lines (Figure Introduction 1). Usually stations are occupied at 20-n.mi. intervals on the inner half of the pattern and at closer intervals near the coast and islands to accommodate these features. At each station a double oblique plankton net tow is made to a standard depth (to 140 m during 1951–1968 and to 210 m thereafter). Neuston (Manta net) tows were taken on each station from 1978 to 1995. Details of CalCOFI sampling methods and laboratory procedures are described in Kramer et al. (1972), and in a series of 24 data reports that list ichthyoplankton and associated station data for each CalCOFI survey conducted from 1951 (Ambrose et al. 1987) to 1984 (Stevens et al. 1990). Summaries of the geographic, interannual, and seasonal distribution of all fish larvae collected on CalCOFI surveys from 1951 to 1984 are presented in CalCOFI Atlases 31 and 32 that precede this guide (Moser et al. 1993, 1994a). Since larvae collected in plankton nets generally are small and fairly recently spawned, their relative abundance in plankton reflects the spawning activity of the parent population. Thus, the summaries provided in CalCOFI Atlases 31 and 32 are used extensively in this guide to provide information on geography and seasonality of spawning of the species described.

In addition to the ELH specimens obtained from regular CalCOFI survey cruises, other cruises, expeditions, and research programs were important sources of early life history material (Table Introduction 1). Some of these (e.g., NORPAC, CalCOFI cruises 7205 and 7210, the CalCOFI cruises to the Gulf of California, EASTROPAC I and II) were special extended cruises or expeditions associated with the CalCOFI program. Survey cruises off the California and Oregon coasts conducted by the Coastal Fisheries Resources Division of the SWFSC were a valuable source of material. Cruises of the SWFSC Marine Mammal Observation Program and the SIO Tuna-Oceanography Program provided many specimens from waters south of the CalCOFI pattern. Likewise the sampling program of the IATTC Laboratory at Achotines, Panama was a rich source of material. Important sources for specimens from the central water mass were the cruises of the SWFSC Honolulu Laboratory, the cruises of Dr. Thomas A. Clarke (Hawaii Institute of Marine Biology, University of Hawaii), and many SIO expeditions to that region.

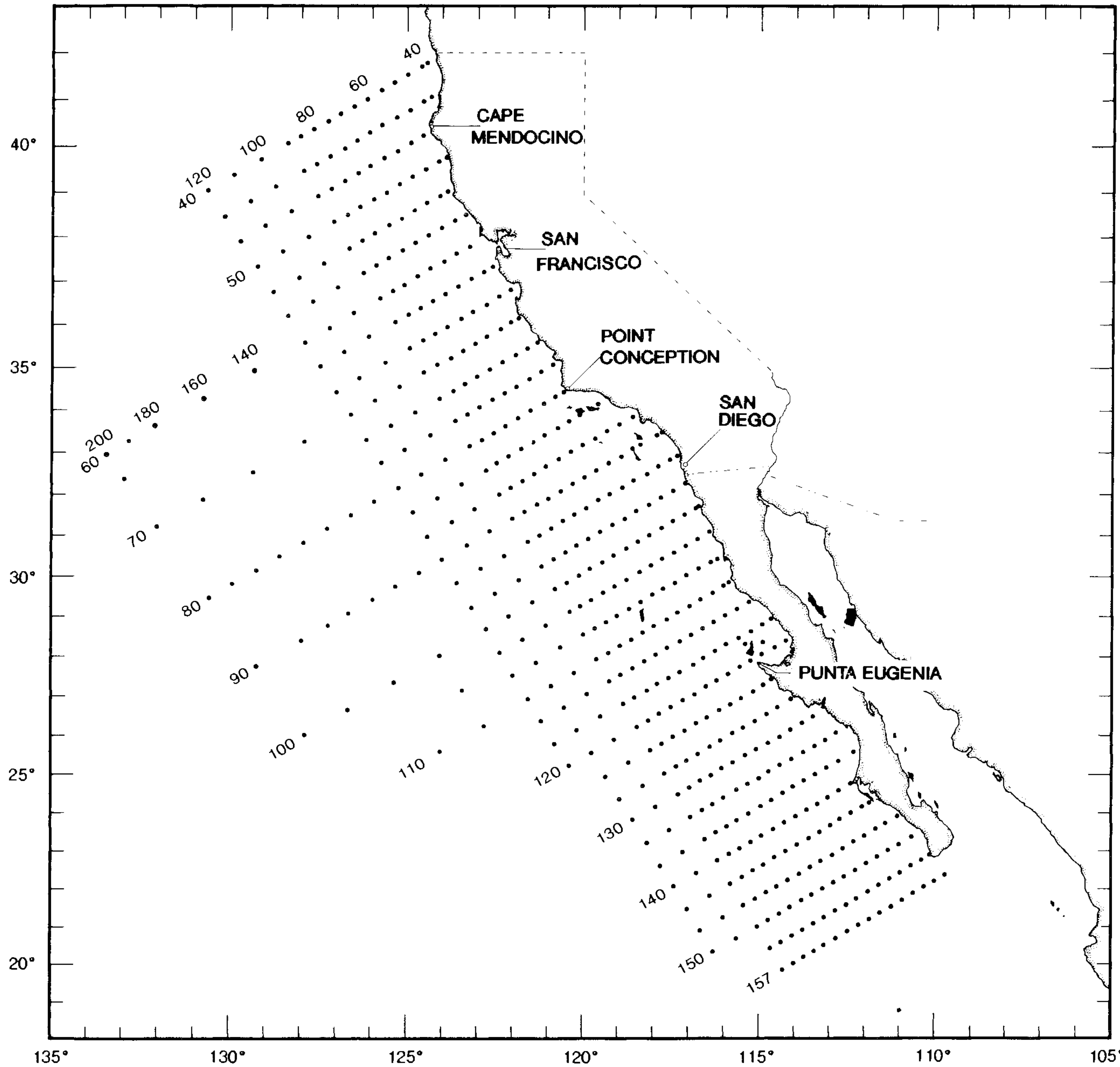


Figure Introduction 1. The CalCOFI survey pattern extending from the California-Oregon border (line 40) to south of Cabo San Lucas, Baja California Sur, Mexico (line 157). Numbers at the ends of onshore-offshore lines indicate major survey lines; major station numbers are shown on line 40. Stations on extended lines 60 through 110 were occupied infrequently during 1951-1984. Since 1985, the survey has been limited to the Southern California Bight, lines 77 to 93, with a maximum seaward extent to station 120 (from Moser et al. 1993).

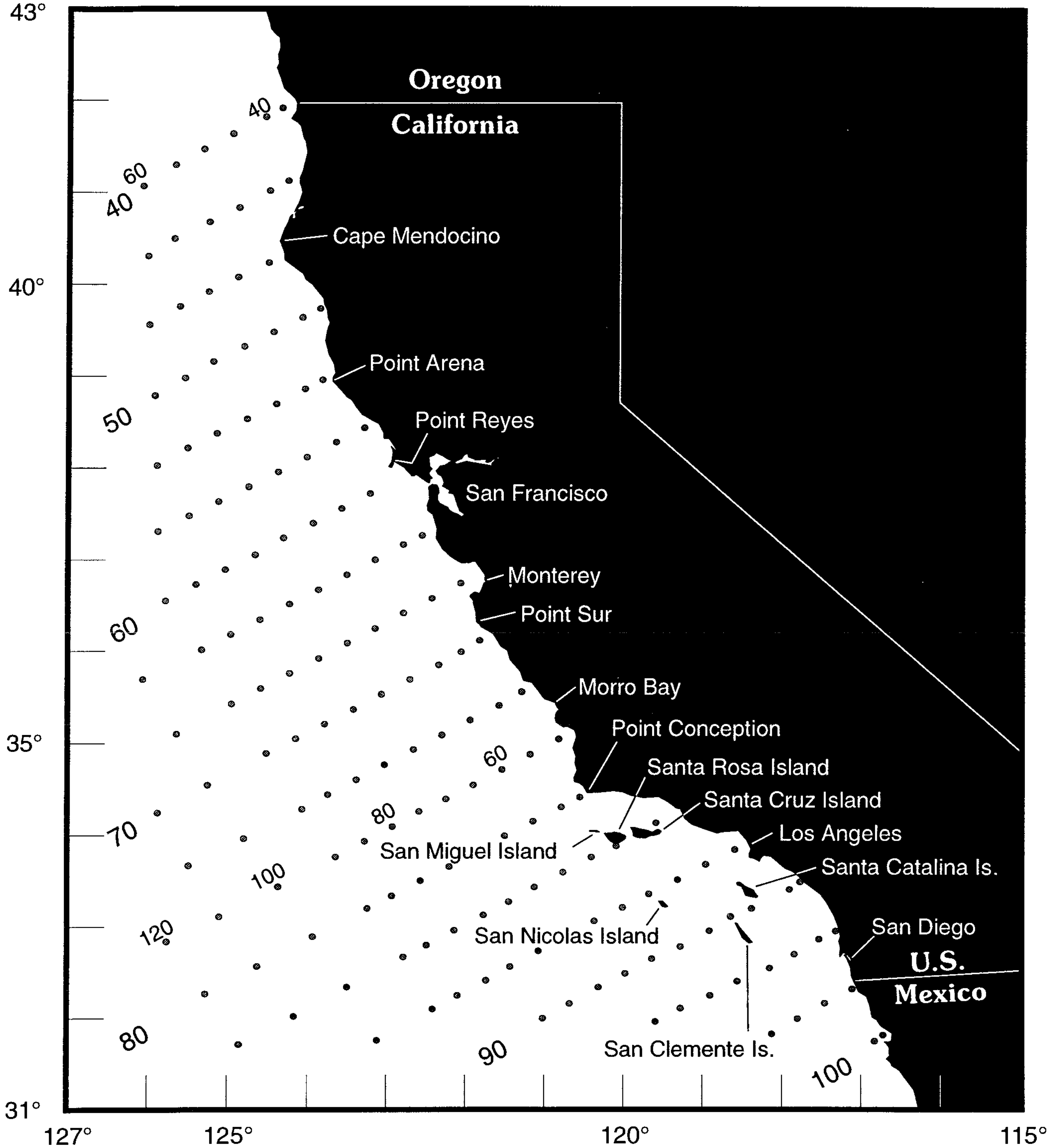


Figure Introduction 2. Part of the northern section of the CalCOFI survey pattern showing geographic features.

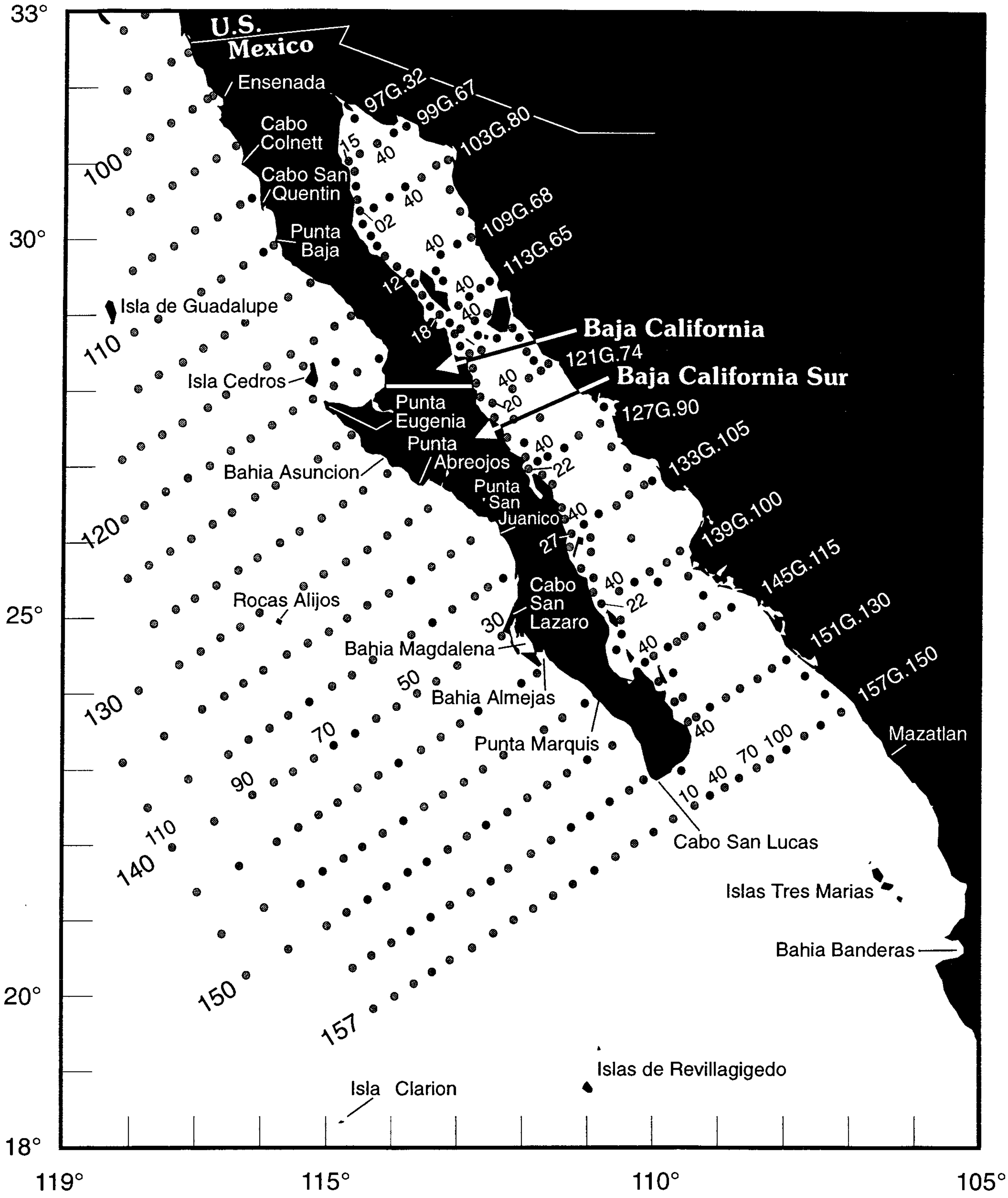


Figure Introduction 3. Part of the southern section of the CalCOFI survey pattern, including the Gulf of California, showing geographic features.

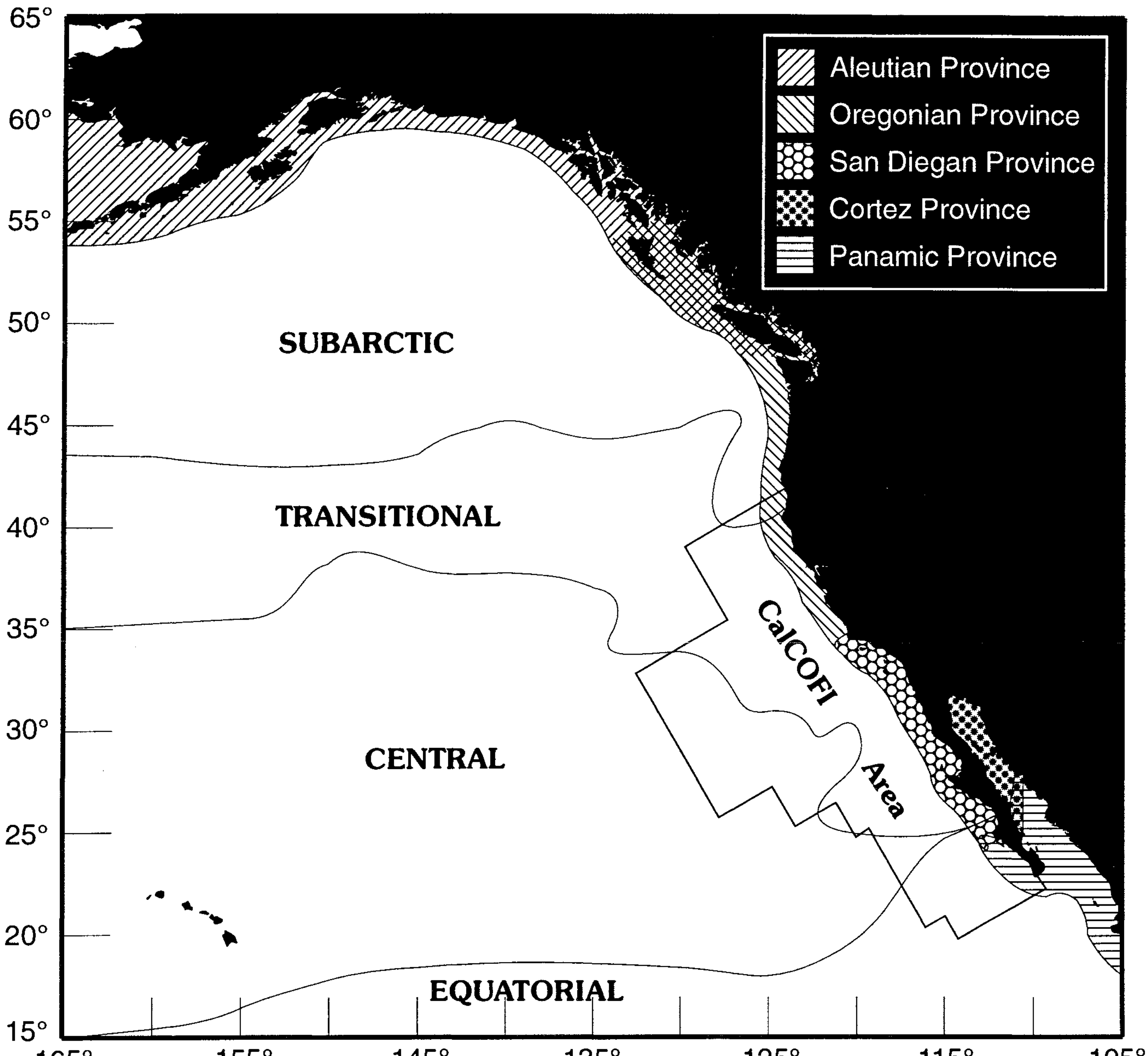


Figure Introduction 4. Water masses and zoogeographic provinces of the northeast Pacific in relation to the CalCOFI survey area. Boundaries of water masses are from Brinton (1962) and Moser et al. (1987); zoogeographic provinces are modified from Allen and Smith (1988). The CalCOFI survey area is outlined.

Table Introduction 1. Cruises, expeditions, and research programs that were major sources of early life history specimens used in this guide. Coordinates are approximate and include stations occupied enroute to the survey area. Specimens from programs, cruises, or expeditions listed below are archived in the CFRD Reference Collection (CFRD Ref. Coll.); the collection contains specimens from sources other than those listed in this table. The SIO Marine Vertebrates Collection and the Natural History Museum of Los Angeles were major sources for specimens used in this guide but are not included in this table; their acronyms are SIO and LACM, respectively.

Program, Cruise, or Expedition	Acronym	Locality	Years	Number of Cruises
California Coastal Commission study at San Onofre Nuclear Generating Station, conducted by MEC Analytical Systems, Inc.	MEC	Nearshore coastal zone between San Onofre and Santa Margarita River, California; 33°N, 117°W	1977–1986	126
California Cooperative Oceanic Fisheries Investigations	CalCOFI	California Current region; 20°–42°N, 110°–123°W	1949–present	258
CalCOFI Extended Cruise 1972 (station numbers on extended lines are "degrees latitude.degrees longitude")	CalCOFI 7205, 7210	California Current west to Central Water Mass; 20°–31°N, 121°–145°W	1972	2
CalCOFI Gulf of California Cruises (distinguished from regular CalCOFI cruises by a "G" after line number in station designation)	CalCOFI 5602, 5604, 5612, 5702, 5704, 5706, 5708, 5902	Gulf of California; 23°–32°N, 107°–115°W	1956–1959	8
CalCOFI NORPAC Expedition (CalCOFI 5508)	NORPAC	Northeast Pacific; 20°–48°N, 111°–154°W	1955 (August–September)	1
CalCOFI NORPAC Expedition (R/V *Hugh M. Smith*; NMFS Honolulu Laboratory)	HMS–30	Northeast Pacific; 29°–48°N, 157°W–180°W	1955 (July–August)	1
Coastal Fisheries Resources Division (SWFSC)	CFRD 8701, 8803, 8903, 9001, 9104, 9107, 9203	Eastern Pacific off California and Oregon; 34°–46°N; 121°–129°W	1987–1992	7
Danish R/V *Dana* Expedition	Dana	Worldwide	1928–1930	1
EASTROPAC I	EASTROPAC I	Eastern Tropical Pacific; 20°N–20°S, 76°–126°W	1967 (February–March)	4
EASTROPAC II	EASTROPAC II	Eastern Tropical Pacific; 20°N–15°S, 77°–119°W	1967 (August–September)	3
Hawaii Institute of Marine Biology Oahu cruises conducted by Thomas A. Clarke	Clarke-Hawaii	Leeward (west) coast of Oahu, Hawaii; 21°N, 158°W	1970–1972	6
IATTC Achotines Laboratory Collections	IATTC	Eastern Tropical Pacific; 7°N, 80°W	1985–present	numerous cruises

Table Introduction 1. Continued.

Program, Cruise, or Expedition	Acronym	Locality	Years	Number of Cruises
IATTC Mazatlán Project	IATTC Mazatlán Project	Eastern Tropical Pacific; 21°–23°N, 106°–110°W	1966–1967	8
Marine Mammal Division (SWFSC) MOPS Cruises	MOPS	Eastern Tropical Pacific; 31°N–12°S, 78°–154°W	1986–1990	5
Marine Mammal Division (SWFSC) PODS Cruise 1992	PODS 92	Eastern Tropical Pacific; 2°–27°N, 77°–115°W	1992 (July–December)	1
Marine Mammal Division (SWFSC) PODS Cruise 1993	PODS 93	Coastal California, Coastal Mexico, & Gulf of California; 18°–42°N, 105°–131°W	1993 (July-November)	1
Sharon H. Kramer collections	SK	Nearshore coastal zone between Mission Bay and San Onofre, California; 32°–33°N, 117°W	1986–1988	24
SIO Aries IX	Aries IX	North Pacific central gyre; 27°–32°N, 124°–155°W	1971 (September–October)	1
SIO Cato I	Cato I	North Pacific central gyre; 25°–31°N, 133°–156°W	1972 (June–July)	1
SIO Cato II	Cato II	North and South Pacific central gyres; 1°N–26°S, 155°W	1972 (July)	1
SIO Climax I	Climax I	North Pacific central gyre; 27°–29°N, 155°–158°W	1968 (September)	1
SIO Climax II	Climax II	North Pacific central gyre; 28°–29°N, 151°–155°W	1968 (August–September)	1
SIO Eastropic	Eastropic	Eastern Tropical Pacific; 30°N–7°S, 78°–122°W	1955 (October–December)	2
SIO FRONTS 85	FRONTS 85	Ensenada Front; 31°–33°N, 119°–122°W	1985 (July)	1
SIO Northern Holiday	Northern Holiday	Northeast Pacific; 28°–56°N, 127°–160°W	1951 (August–September)	1
SIO Scope Expedition	Scope	Eastern Tropical Pacific; 4°–27°N, 79°–114°W	1956 (November–December)	1
SIO SCOT Expedition (TO 58–1)	TO 58–1	Eastern Tropical Pacific; 4°–28°N, 78°–119°W	1958 (April–June)	1
SIO Shellback Expedition	Shellback	Eastern Tropical Pacific; 28°–15°N, 78°–125°W	1952 (May–August)	1

Table Introduction 1. Continued.

Program, Cruise, or Expedition	Acronym	Locality	Years	Number of Cruises
SIO Southtow XIII Expedition	Southtow XIII	North Pacific central gyre; 28°–32°N, 124°–155°W	1973 (January–February)	1
SIO Tasaday I Expedition	Tasaday I	North Pacific central gyre; 28°-30°N, 155°W	1973 (June)	1
SIO Tasaday II Expedition	Tasaday II	North Pacific central gyre; 25°-28°N, 155°W	1973 (July)	1
SIO Tasaday XI Expedition	Tasaday XI	North Pacific central gyre	1974 (March)	1
SIO Tuna-Oceanography Cruise 58–2	TO 58–2	Eastern Tropical Pacific; primarily Gulf of Tehauntepec; 12°–26°N, 91°–114°W	1958 (November–December)	1
SIO Tuna-Oceanography Cruise 59–1	TO 59–1	Eastern Tropical Pacific; primarily Gulf of Tehauntepec; 8°–29°N, 87°–116°W	1959 (January–February)	1
SIO Tuna-Oceanography Cruise 59–2	TO 59–2	Eastern Tropical Pacific; primarily Gulf of Tehauntepec; 14°–27°W, 94°–117°W	1959 (August–September)	1
SWFSC, Honolulu Laboratory, R/V *Townsend Cromwell* Hancock Seamount Cruises	TC 8405, TC 8501, TC 8605	SE Hancock Seamount, Northern Hawaii Ridge, 29 °N–30°N, 179°–180°W1	1984 (July) 1985 (February) 1986 (August)	3
SWFSC, Honolulu Laboratory, R/V *Townsend Cromwell* Johnston Atoll Cruise	TC 8406	Johnston Atoll, 16°–17°N, 169°–170°W	1984 (November)	1
SWFSC, Honolulu Laboratory, R/V *Townsend Cromwell* Oahu Ichthyoplankton Vertical Distribution Cruises	TC 8504 TC 8505 TC 8602 TC 8604	East and west coasts of Oahu, Hawaii; 22°N, 158°W and 21°N, 158°W	1985 (September–December) and 1986 (April–June)	4

Taxonomic Coverage

The guide includes full descriptions of 467 species contained in 340 genera, 141 families, and 25 orders. Partial descriptions and representative illustrations of 119 species are included in the introductions to orders and families; these add 17 families and 78 genera to the total represented in the guide. Of the species with full descriptions, 127 (27%) are new to science. New illustrations of previously undescribed stages are presented for 364 species (62%) and new information is included for nearly all 586 species in the guide. With few exceptions, the species included in this guide are those with planktonic or pelagic early life history stages that may be found in coastal, oceanic, or estuarine waters of the CalCOFI area and adjacent regions. Early stages of freshwater and anadromous species are not described, nor are the viviparous surfperches (Embiotocidae) whose advanced new-born young remain in the surf or subtidal zone. Most fishes included in the guide spawn free-floating eggs that progress through a distinct planktonic larval stage before transforming into a pelagic or demersal juvenile. Many shorefish groups included in this guide (e.g., cottids, pomacentrids, blenniids, labrisomids, gobiids) produce planktonic larvae from demersal eggs. When known, the demersal eggs of these species are described. The rockfishes (*Sebastes*) are viviparous but give birth to planktonic larvae that are at a stage of development equivalent to the first-feeding larvae of typical oviparous species with planktonic eggs. There are many rockfish species (ca. 60) in the CalCOFI region and their larvae are an important component of the CalCOFI ichthyoplankton. Also included are fishes such as alepocephalids, which have planktonic eggs and larvae (or pelagic juveniles) that are relatively deep in the water column and are rarely collected in standard CalCOFI plankton tows.

The guide includes taxa whose distributional boundaries lie within the CalCOFI survey area and taxa from water masses and coastal zoogeographic provinces that impinge on the core of the CalCOFI region from the north, south, and west. Faunal boundaries may fluctuate in response to the dynamic seasonal, interannual, and climatic shifts that characterize the California Current system and this is reflected in the faunal composition in the various subregions of the CalCOFI survey area (Loeb 1983; Moser et al. 1987, 1993, 1994a; Moser and Smith 1993). Because of this, we have attempted to be inclusive rather than exclusive in selecting the species described. In the southern part of the pattern, taxa were included if their ELH stages or adults have been recorded from the Pacific coast of Baja California Sur or the Cabo San Lucas area. If a taxon met either of these criteria, specimens from the Gulf of California or more southern localities were used to augment the material that formed the basis for the description. Analogous criteria were applied in selection of taxa in the western and northern regions of the CalCOFI area. These criteria were modified somewhat in the northern part of the CalCOFI region because of the availability of a comprehensive identification guide to ELH stages of fishes of the northeast Pacific (Matarese et al. 1989). Taxa in some groups (e.g., gadids, some *Sebastes* species) whose ELH or adult stages are rare in the CalCOFI area and treated fully in Matarese et al. (1989), were not described in this guide although information on them was included in meristic tables and in the text of chapter introductions.

The following list contains the species whose early life history stages are described in this guide and the page number where the description may be found. Classification and nomenclature follow Eschmeyer (1990; pers. comm., December 1995 – February 1996); species are listed alphabetically within each family.

List of Taxa

Principles and Terminology

A large proportion of marine fishes are oviparous and produce separate, buoyant eggs that develop in the upper part of the water column and hatch in a relatively undifferentiated state with unpigmented eyes, unformed mouth, and a prominent yolk-sac. Development of these yolk-sac larvae progresses rapidly, with nutrition supplied by the yolk, producing larvae that are capable of feeding on small planktonic organisms. Larvae reside in the upper water column where they continue to develop and grow, and eventually transform into juvenile fishes. The duration of the larval stage varies greatly among species, from several days to many months. At the end of the larval stage, bottom living (demersal) species must settle to the juvenile habitat whereas larvae of pelagic species remain in the water column. Eggs of many beloniform and atheriniform fishes have filaments with which they attach their eggs to floating algal mats or flotsam. Eggs of some demersal fishes (e.g., most lophiiforms, scorpinines) are extruded in a gelatinous mass that floats to the surface, where development to the yolk-sac or first-feeding stage occurs prior to hatching. Many shorefishes (those species inhabiting the waters of the continental shelf and upper slope) have demersal eggs that are deposited on the substrate, either individually, in masses, or in nests that are tended by one or more of the parents. In these species development often proceeds beyond the yolk-sac stage before hatching. Upon hatching, the first-feeding larvae travel to the upper water column where they continue to develop and eventually transform and settle back to the bottom as juveniles. In some species with either planktonic or demersal eggs, development within the egg progresses beyond the first-feeding stage, and newly hatched individuals have well formed fins and other morphological features, and advanced larval pigmentation. In viviparous fishes, eggs are fertilized and retained in the ovaries where development takes place. In *Sebastes*, young are released as first-feeding larvae and they continue their larval development in the upper water column just as in typical oviparous species. The young of the surfperches, family Embiotocidae, are born as transforming larvae or juveniles (or even as mature males in some species) and do not become part of the plankton.

Egg Stage

Most marine fish eggs encountered in plankton samples are spherical, transparent, and ca. 1 mm in diameter; the overall size range is ca. 0.5–5.5 mm with ca. 70% of the species ranging between 0.7 and 1.6 mm (Ahlstrom and Moser 1980). Species in some groups produce planktonic eggs that are ellipsoidal (e.g, engraulids, ophidiids, some scarids) whereas demersal eggs may be spherical (e.g., some gadoids and blennioids), somewhat flattened (e.g., some blennioids), spindle-shaped or urn-shaped (e.g., some gobioids). Eggs are enclosed in a thin shell or chorion that appears smooth under the dissecting microscope but has fine-scale surface features and pores when analyzed by electron microscopy. The shell may be distinctly ornamented with spines or filaments (e.g., some beloniforms, atheriniforms, and aulopiforms), hexagonal or polygonal networks of various sizes (e.g., some clupeids, stomiiforms, aulopiforms, macrourids, and pleuronectiforms), pustules on the inner surface of the chorion (argentinoids), or a single protuberance or swelling (e.g., some engraulids and pleuronectiforms) (Figure Introduction 5). In a few groups of fishes (e.g., some anguilliforms and stomiiforms) there is a second, internal egg membrane free from the chorion.

The space between the chorion and the yolk mass (perivitelline space) is usually small, but in some fishes (e.g., anguilliforms, clupeoids, stomiiforms, and pleuronectiforms) the yolk mass is considerably smaller than the shell and the relative width of the perivitelline space is a useful taxonomic character. The yolk is segmented in anguilliforms, clupeiforms, salmoniforms, stomiiforms, myctophiforms, and most aulopiforms, whereas it is homogeneous in most higher teleosts. The size of the yolk segments can be a useful taxonomic character. In a few perciforms (e.g., *Trachurus*, sphyraenids), and pleuronectiforms (e.g., some soleids) the yolk is initially homogeneous but becomes segmented in later developmental stages. The presence or absence of oil globules within the yolk mass is a useful taxonomic character. Among species whose eggs have been described, approximately 60% have a single oil globule, 15% have multiple oil globules, and 25% lack them (Ahlstrom and Moser 1980). The size, number, and position, of oil globules are important taxonomic characters.

Teleosts have telolecithal eggs, with the yolk mass separate from the developing embryo. This type of egg undergoes meroblastic or discoidal cleavage, where yolk is not incorporated in the cells during cell division. This contrasts with most invertebrate eggs which have holoblastic cleavage (yolk incorporated in the dividing cells) and provides a means of distinguishing the two kinds of eggs. Development of the teleost egg begins with initial cell division that produces a mound of cells, the blastodisc, at one pole of the egg. With continued cleavage the individual cells (blastomeres) become smaller and more difficult to distinguish. A syncytial zone, the periblast, is present at the base of the blastodisc and is continuous around the yolk mass; one of its functions may be to transfer nutrients from the yolk to the developing embryo. At the end of this early stage of development a region at the base of the blastodisc begins to proliferate cells, forming a thickened peripheral zone, the germ ring. A thickened cell mass, the embryonic shield, forms at one part of the germ ring, marking the future longitudinal axis of the embryo. Cell proliferation continues in the blastodisc and germ ring, gradually enclosing the yolk mass by a process known as epiboly. As this process continues, the embryonic shield develops into a rod-like primordial embryo and, at the completion of epiboly (marked by closure of the "blastopore"), optic vesicles, brain lobes, otic capsules, and some myomeres typically are recognizable. With continued organogenesis, the tail lifts off the yolk sac and begins to elongate and the gut, heart, and other organs become apparent. Initial pigmentation usually forms at this stage when melanophores develop from the neural crest region located dorsolaterally along the embryonic axis. Later in the embryonic period, the median finfolds and pectoral fin buds form and the eyes, brain, myomeres and other structures continue to differentiate. Melanophores proliferate and may remain in rows along the dorsum or migrate ventrad on the body, onto the yolk sac and oil globule, and to the median finfolds. In some species the melanophores begin to assume the pattern found on post-hatching stages and are useful in identification. In others, particularly neustonic species (those living at or

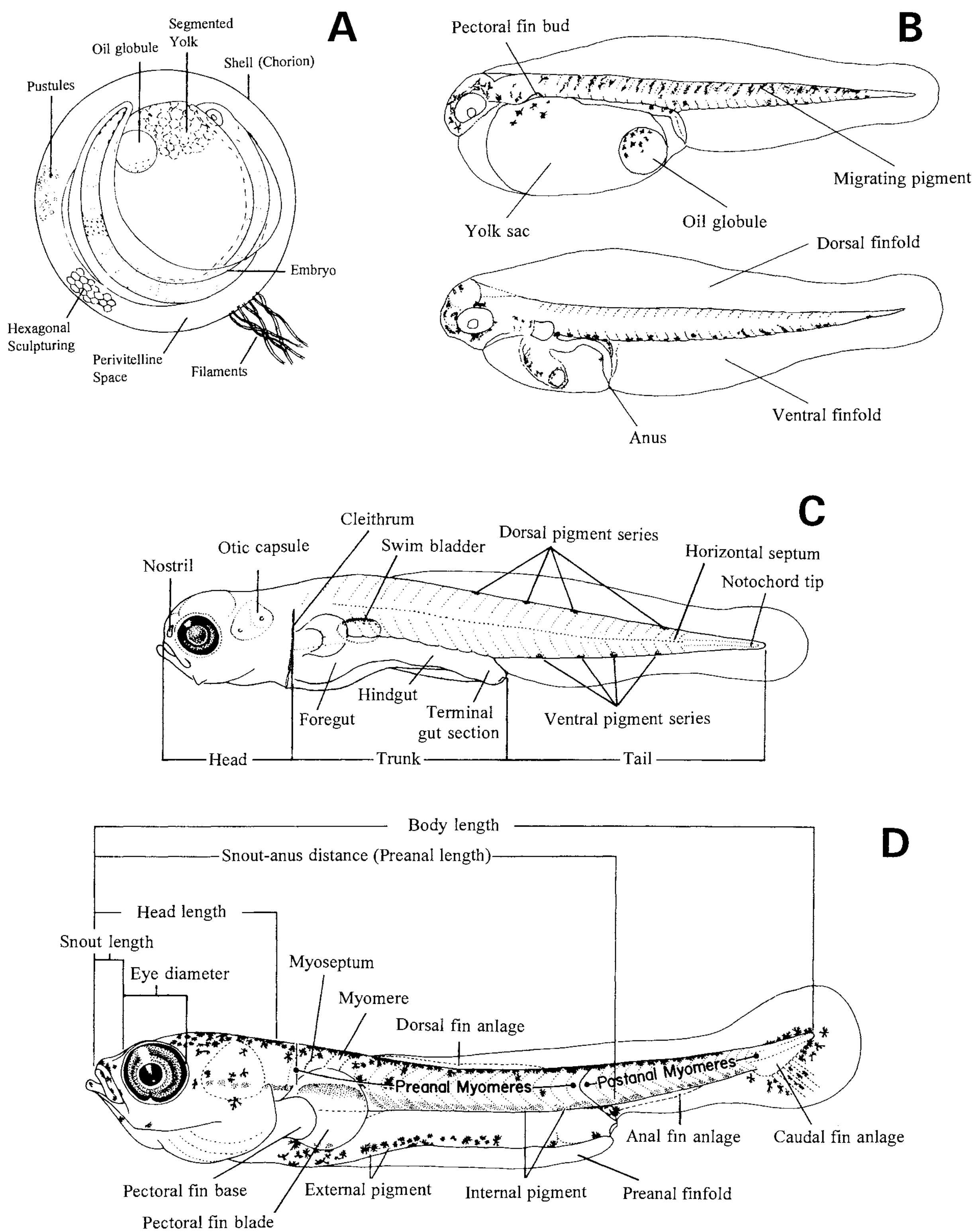


Figure Introduction 5. Anatomical and morphometric features of the early stages of fishes. (A) Composite illustration of a fish egg modified from Matarese et al. (1989). (B) Early and late yolk-sac larvae modified from Kramer (1960). (C) Preflexion larva modified from Fahay (1983). (D) Late preflexion larva modified from an original illustration by William Watson.

near the sea surface), pigmentation is dense and covers the embryo before hatching.

For comparative purposes we divide egg development into stages as follows: 1) early stage, from extrusion to the formation of an advanced blastodisc, 2) middle stage, from the beginning to the end of epiboly, and 3) late stage, from the end of epiboly to hatching. The degree of development and the appearance of organs, structures, and pigmentation in middle- and late-stage eggs provides a useful suite of taxonomic characters. Additional information on the identifying characteristics of marine fish eggs may be found in Watson and Leis (1974), Russell (1976), Ahlstrom and Moser (1980), and Matarese and Sandknop (1984).

Yolk-sac Larva Stage

In this guide we follow the stage criteria of Kendall et. al. (1984) and refer to individuals with a yolk-sac or remnants of yolk as yolk-sac larvae, those that have utilized all their yolk as larvae, and those that are in the process of changing from larvae to juveniles as transforming or transformation stage specimens. The size and state of development at hatching varies greatly among marine fishes but generally is related to egg diameter or, more precisely, yolk diameter. Typically, body length at hatching is 2.5–3.0 times the diameter of the yolk (or shell in species with a narrow perivitelline space). Generally, yolk-sac larvae hatching from eggs <1.5 mm have an unformed mouth, unpigmented eyes, and pectoral fin buds, whereas yolk-sac larvae hatching from larger eggs are comparatively well developed, with the mouth formed, eyes pigmented, and larval pectoral fins developed. In both cases, locomotion is aided by a prominent median finfold that extends from the top of the head around the caudal region and forward to the posterior margin of the yolk sac (Figure Introduction 5). Most species with demersal eggs essentially go through the yolk-sac stage before hatching. The state of development at hatching is remarkably advanced in the eggs of a few families of pelagic fishes. For example, beloniforms typically have well developed median fins and notochord flexion is either underway or complete before hatching. In lampridiforms, the extremely elongate dorsal and pelvic rays are beginning to form and are clearly visible in advanced eggs. In some species with large eggs, newly hatched yolk-sac larvae are comparatively undeveloped; for example, the eggs of *Argentina silus* are 3.0–3.5 mm in diameter and, at hatching, the yolk-sac larvae are at approximately the same stage of development as those hatching from eggs of ca. 1.0 mm diameter (Ahlstrom and Moser 1980).

The size of the yolk sac is related to initial egg size and to the amount of yolk used before hatching. Typically, the yolk sac is off-round to oval at hatching but may be elongate and tear-shaped in species with an elongate gut (e.g., clupeoids and stomiiforms). If an oil globule is present it may be located anteriorly or posteriorly or in an intermediate position in the yolk sac. Multiple oil globules may be evenly distributed or clumped in patches. Location of the oil globule(s) in the yolk sac is an important character in identification.

The yolk-sac stage is characterized by the migration, coalescence, and rearrangement of pigment cells. Melanophores containing black or brown pigment (melanin) are the principal pigment cells used for the identification of most fish eggs and larvae. Other kinds of pigment cells also may be present (e.g., erythrophores with red pigment, xanthophores with yellow pigment); however, only melanistic pigment remains in specimens fixed in formalin and preserved in formalin or alcohol. Silvery pigment produced in guanophores in juveniles remains in specimens fixed in alcohol. Melanophores are amoeboid and capable of migrating from their source in the neural crest to various sites on the larva. This migration may begin or may be completed in late-stage embryos but, in the majority of species, it occurs during the yolk-sac stage. The principal migration is ventrad to sites along the gut and ventral body margin but melanophores may also migrate to the finfolds and to various regions of the head. In some fishes (e.g., engraulids), the first melanistic pigment to appear on yolk-sac larvae is above the gut and on the ventral margin of the body; apparently, the melanophores complete their ventral migration before melanin synthesis begins. By the end of the yolk-sac stage, melanophores usually are coalesced and arranged in specific patterns characteristic of first-feeding larvae.

At the end of the yolk-sac stage the yolk and oil globule(s) have been used up and the major organ and sensory systems required to capture prey are functional. The mouth and gut have formed, the anus is open at the margin of the ventral finfold, the eyes are pigmented, and the primordial pectoral fins are present.

Larval Stage

Following Ahlstrom et al. (1976) and Kendall et al. (1984), we divide the larval stage into three sub-stages (preflexion, flexion, and postflexion), based on the degree of flexion of the terminal section of the notochord during formation of the caudal fin. This system is convenient and reduces morphometric bias caused by the slower increase in body length relative to other structures during the flexion of the notochord.

Development of the caudal fin begins with the initial formation of the fin supports on the ventral surface of the notochord near its tip (Figure Introduction 5). These flattened plates (hypural and parhypural elements) are formed first in cartilage and subsequently become ossified. The caudal fin rays are attached to these elements and, at about the time when ray formation begins, the tip of the notochord begins to flex upward. When flexion is completed, the developing rays are in a longitudinal position and the posterior margin of the hypural plate(s) is vertical. The preflexion stage begins at the termination of the yolk-sac stage and ends at initial notochord flexion. The flexion stage ends (postflexion stage begins) when the notochord tip is in its final position at approx. 45° from the notochord axis. At this stage, the posterior margin of the upper hypural plate is vertical (90° from the notochord axis); however, the margin of the lower plate may not be completely vertical or may not be aligned fully with the posterior margin of the upper plate (Figure Introduction 6). The postflexion stage ends when transformation from the larval to the juvenile stage begins (see sections on transformation and juvenile stages for defining criteria).

The process described above produces what is termed a homocercal caudal fin, the basic type of caudal fin in teleosts. An exception to this is found in the gadoids, where the terminal section of the notochord remains straight and the fin rays form symmetrically above and below it. Some other groups have highly reduced caudal fins (e.g., anguilliforms) or lack caudal fins entirely (e.g., macrourids). In cases where larval substages based on notochord flexion are not applicable, substages usually are based on the initiation of dorsal and anal fin development. In anguilliforms, larval substages are based on tooth morphology and several other characters.

The remarkable diversity of marine teleost larvae reflects an evolutionary process that has produced an immense array of specializations in form, pigment pattern, and behavior and is equal in scope, if not scale, to that of the adults (Orton 1953b; Moser 1981; Kendall et al. 1984). Body length at the beginning of the larval stage is approximately 4 to 5 times the diameter of the egg, therefore most first-feeding fish larvae are ca. 3–6 mm in length. The ultimate size attained varies greatly among species, with some (e.g., achirids) transforming at <5 mm and others (e.g., some pleuronectiforms) reaching >100 mm before transformation. Most species reach maximum larval size within the 10–30 mm range. Shape varies greatly, from slender and elongate (e.g., clupeoids), to elongate and compressed (e.g., elopomorphs), to short and compressed (e.g., acanthurids), to globular (e.g., tetraodontiforms).

The basic organ systems differentiate during the larval stage; however, the structure of these systems varies greatly within and between orders and a large array of specializations is unique to the larval stage. One of the obvious features of larvae is the series of muscle segments or myomeres along the body (Figure Introduction 5). In most species, the adult complement of myomeres is present by hatching and, since myomere number is approximately equal to the number of vertebrae that will form, one is provided with an important characteristic linking early larval and adult stages.

Another feature obvious in preflexion larvae, the gut, exhibits some basic trends in form among major teleost groups (Figures Introduction 5 and 6; and refer to Figure Introduction 7 at the end of the introductory section for inter-family comparison of gut shape in mid-stage larvae). Generally, it is elongate and straight in lower teleosts (e.g., elopomorphs, clupeiforms, salmoniforms, some stomiiforms, some aulopiforms). In some anguilliforms it may have undulations with nodular structures and in clupeiforms, salmoniforms, stomiiforms, and other primitive groups it is differentiated into a foregut, a hindgut with prominent mucosal folds, and a short terminal section. It trails freely from the body in many stomiiforms. In some aulopiforms it is saccular and voluminous (e.g., scopelarchids) and in others (e.g., some paralepidids) it is short initially and lengthens markedly during larval development. In myctophids it varies from short, to long, to trailing, but

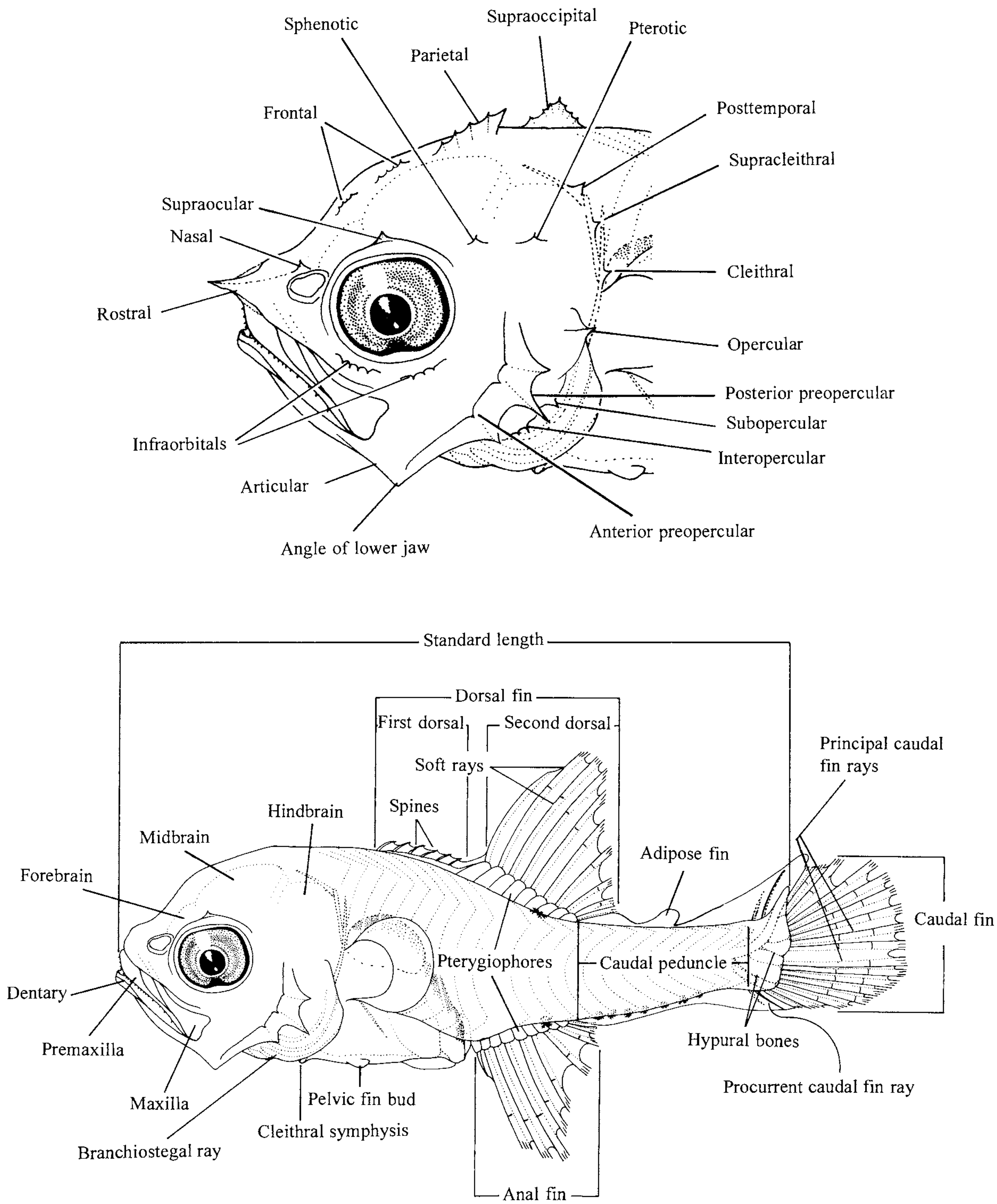


Figure Introduction 6. Postflexion stage of a fish larva showing anatomical and morphometric features; the enlargement (above) shows examples of head spines. Modified from an original illustration by William Watson.

usually is moderate in length, slightly sigmoid, and has prominent mucosal folds. The gut is coiled in gadoids and higher teleosts, marking a major evolutionary shift. The gut mass varies in form from rounded, with a compact coil and short terminal section (e.g., gadoids, lophiiforms), to relatively elongate (e.g., beloniforms, ophidiiforms, some zoarcoids) but, in the majority of higher teleosts, is roughly triangular and extends to about midbody. The gut mass may extend well beyond the ventral profile of the body (e.g., cynoglossids) or develop an elaborate trailing appendage (e.g., some bythitids).

The relative size and shape of the head, jaws, and eyes provide a large suite of identifying characteristics in larvae (Figure Introduction 5). The head may be small with a pointed snout and small mouth (e.g., clupeoids), small and rounded with a small mouth (e.g., hexagrammoids), large and globose with a small mouth (e.g., tetraodontiforms), large with a large mouth and heavily toothed jaws (e.g, scombroids), or in a variety of forms intermediate between these extremes. Larval teeth are highly varied in size, shape, and pattern and afford many identifying characteristics. The eyes are remarkably diverse. Yolk-sac larvae of most teleosts have elliptical, dorsoventrally compressed eyes that become rounded, off-round, oval, or elliptical and anteroventrally compressed early in the preflexion stage. In many lower teleosts (e.g., clupeiforms, salmoniforms, stomiiforms, aulopiforms) the eyes are relatively small and oval to strongly elliptical. In some species within these groups, a mass of choroid tissue lies within the scleral envelope at the base of the eye and, in other species, the eyes are borne on stalks of various lengths. A wide range of sizes, shapes, and specializations is found in larvae of the Myctophidae; larvae of the subfamily Myctophinae have oval or elliptical eyes, some with choroid tissue, and some stalked, whereas larvae of Lampanyctinae generally have round or off-round eyes with little or no choroid tissue. Usually, in higher teleosts, the eyes are round to slightly oval, with oval eyes becoming round in later larval stages.

Initial fin development may occur as early as the embryonic or yolk-sac stage but, in most teleosts, the median fins begin to develop in preflexion larvae. The sequence of formation of individual fins can be a useful character at specific or higher taxonomic levels. The primordial pectoral fin consisting of a peduncular base and a thin blade is usually the first fin to appear, typically in the late embryonic or yolk-sac stage (Figure Introduction 5). Although the fin is functional, ray differentiation is delayed until transformation in many lower teleosts and in some higher fishes (e.g., flatfishes). In the majority of fishes, pectoral fin-ray formation begins late in the preflexion stage to early postflexion and the adult pectoral fin-ray complement is present by mid- or late postflexion. In some fishes, usually those in which the pectoral fins become highly developed, rays form early, before or simultaneously with the caudal fin rays. In some fishes (e.g., some anguilliforms and cynoglossids), the pectoral fins are present in larvae but absent in juveniles and adults. There is great diversity in the size and shape of the pectoral fin and in some groups (e.g., macrourids, some myctophids) the fin base may be enlarged and have a distinctive shape. Such characters often are useful in identifying species or genera.

The caudal fin usually is the next to appear. The first rays to form in the caudal finfold are those that articulate with the primary supporting elements of the fin (hypurals and parhypural) (Figure Introduction 5 and 6). These principal rays form in upper (superior) and lower (inferior) groups associated with the superior and inferior hypural elements. The full complement of principal rays usually is present by the completion of notochord flexion or early in the postflexion stage. The numbers of principal rays tends to be consistent within orders or ordinal clusters, thus providing another clue linking early larvae with adults. Many lower teleosts (clupeiforms, salmoniforms, stomiiforms, aulopiforms, myctophiforms) have 19 principal rays with 10 superior and 9 inferior rays (indicated as 10+9). The 10+9 formula also is found in beryciforms but the formula varies widely in other higher teleosts, with the exception that percoids usually have 17 (9+8) principal caudal rays. Formation of principal rays begins at the center of the fin and progresses (usually symmetrically) dorsally and ventrally. Additional caudal fin rays, the procurrent rays, are formed anterior to the principal rays. The inferior procurrent rays are supported by haemal spines and the superior procurrent rays are supported by neural spines or elements derived from neural spines. The numbers of procurrent rays generally are not consistent in major phylogenetic groups but are often specifically distinct. The unique structure of the gadiform caudal fin provides an identifying characteristic for that group as do unique arrangements in other taxa.

The dorsal and anal fins usually form simultaneously in the dorsal and ventral finfolds in the approximate positions they will occupy in adults and this, along with the numbers and type of fin rays (only soft rays in most lower teleosts), furnishes another set of characters that help link larvae and adults. First to appear is a series of thickenings at the base of the finfold; these are the primordia of the pterygiophores, the elements that constitute the fin base (Figure Introduction 5 and 6). In argentinoids, the bases form in the finfold at some distance from the body and are connected to the body by hyaline strands. In fishes with spinous and soft-rayed dorsal and anal fins, primordial pterygiophores in the soft-rayed part usually are larger and more pronounced than in the spinous part, and typically begin forming earlier. The rays appear in the finfold as thickenings (bundles of actinotrichia) contiguous with the developing pterygiophores. Typically, differentiation of the dorsal and anal fins begins somewhat anterior to the middle of the soft-rayed portion of the fin and continues anteriad and posteriad throughout the larval stage, with the adult complement becoming apparent by late postflexion. In larvae of some gadoids with multiple dorsal and anal fins, the posterior two dorsal and anal fins differentiate within separate centers, more or less simultaneously, whereas differentiation of the anterior dorsal fin is delayed. Segmentation of the soft rays usually is apparent in postflexion larvae and becomes more pronounced by the end of the larval stage. In larvae of some species, the posteriormost spine of the dorsal and anal fins also becomes segmented and its tip is fimbriated as in soft rays. Transformation of this apparent soft ray into a spinous ray occurs at the end of the larval stage or in early juveniles, when the segments become obscured and the tip becomes pointed (Mansueti 1958; Berry and Richards 1973; Matarese et al. 1989). In many species the posteriormost soft ray of the dorsal and anal fins is divided at its articulation with the fin base. In some fishes (e.g., clupeids) the dorsal and anal fins may migrate forward from their initial position during the larval stage and in others (e.g., some myctophids) there is an apparent shift in position caused by allometric growth of the posterior region of the tail.

The pelvic fins typically are the last fins to begin forming and, in many lower teleosts, do not begin to differentiate until the end of the larval period, just before transformation (Figure Introduction 6). In some groups (e.g., some aulopiforms, myctophiforms, lampridiforms, beryciforms), the pelvic fins form early in preflexion and are enlarged and highly developed during the larval stage. Phylogenetic trends in the position and composition of the pelvic fins are apparent when they begin forming in larvae, thus providing another set of identifying characteristics. For example, the pelvic fins are abdominal in position in lower teleosts and generally are thoracic (chest area below the pectoral fins) or jugular (throat region) in higher fishes. The number of pelvic fin rays varies greatly within and among major fish groups but some trends are apparent: usually, the number of rays ranges between 7 and 12 in lower teleosts but in most higher groups (e.g., perciforms, scorpaeniforms), one spinous ray and five (or fewer) soft rays are present.

Elongation and elaboration of fin rays occurs in larvae throughout the major teleost groups. Often the entire fin becomes enlarged but, in many cases, one to several rays become elongate and ornamented. A common site is the anterior region of the dorsal fin, where a single spine or ray may be elongate (e.g., melamphaids, bothids) or a group of spines or ray(s) are elongate, sometimes forming a crest (e.g., lampridiforms, paralichthyids, achirids). Another common site for elongation is the pelvic fin where the entire fin is often enlarged (e.g., gadiforms, lophiiforms, beryciforms) or one to several rays may become elongate and ornamented (e.g., lampridiforms, paralichthyids). Likewise the pectoral fins are enlarged in some species of many groups (e.g., aulopiforms, myctophiforms, lophiiforms, scorpaeniforms, perciforms) or, rarely, one to several rays may become elongate (e.g., myctophiforms, peristidiines). Elongation of anal fin rays is rare; the elongate anterior anal fin ray in *Alectis* provides one of the few examples.

Where enlargement or elongation of fin rays occurs, ray formation is usually initiated at an early stage, often early in preflexion or even in the egg or yolk-sac stage. Elongation is usually associated with the development of structural elaborations and special pigment patterns. A recurrent theme in these specializations is their apparent mimicry of coelenterate structures, as exemplified by the dorsal fin of carapids, lampridiforms, and some epinephaline serranids (*Liopropoma* and *Diploprion*), the elongate pectoral rays in some myctophids (*Loweina* and *Tarletonbeania*), and the elongate dorsal and pelvic rays of some bothid and paralichthyid flatfishes. The recurrence of such similar structures in unrelated groups invites speculation on their possible function. If they are mimicking siphonophores or other poisonous coelenterates they could function in discouraging potential predators as Moser (1981), Govoni et al. (1984) and Kendall et al. (1984) have suggested or they may serve to attract food, since many siphonophores have commensal or parasitic hyperiid amphipods of appropriate prey size for fish larvae (Baldwin et al. 1991). Also, these complex larval structures may be involved with sensory or hydrodynamic functions, or they may have multiple functions.

The median finfold may become highly specialized in some fish larvae. In higher teleosts, it usually becomes reduced as the median fins form and is relatively insignificant in postflexion larvae; however, it may remain a prominent feature throughout the larval stage in lower teleosts (e.g., argentinoids, stomiiforms, some myctophids). The preanal finfold (portion of the finfold anterior to the anus) may persist into the postflexion stage and often is well developed in lower teleosts. The entire median finfold may become voluminous and have an inflated appearance in some fishes (e.g., the myctophids *Loweina* and *Tarletonbeania*).

In addition to the specialization of fin spines in larvae of many higher teleosts, there has been a remarkable evolution of larval head and body spination that rivals spination in adults (particularly in Scorpaeniformes and Perciformes). One of the most common sites for larval spine development is on the preopercular bone, where angulate anterior and posterior series develop with an enlarged, often serrated spine at the angle of the posterior series (Figure Introduction 6). Another common site is above the eye, where one or more spines may be present in a bony crest projecting from the frontal bone. Many scorpaeniforms develop a pair of dorsolateral parietal crests (usually serrated) terminating in spines, whereas in many perciforms a single serrated crest terminating in a spine develops in the midline of the supraoccipital region. Spines often develop on other cranial bones (e.g., infraorbitals, pterotic, opercular, posttemporal), on the bones of the shoulder girdle (supracleithrum and cleithrum), or on specialized bones or scales of the body (e.g., in agonids, malacanthids, chiasmodontids, achirids). In most fishes these spines are transient larval features and are lost or reduced in juveniles and adults. Even in scorpaenids, a group that has spiny-headed adults, the head spines are more prominent in larvae and many spines that are present in larvae are lacking in adults.

Pigmentation is highly evolved in larval fishes and provides a wealth of useful identifying characteristics. Since our observations are usually limited to preserved material, in which only the melanistic pigment remains, we see only a part of the overall pigment pattern. Melanophore size, shape, pattern, and sequence of formation are important taxonomic features (Figure Introduction 5 and 6). Individual melanophores may be round, linear (streaks or dashes), dendritic or stellate, open circles, rectilinear, or in other shapes based on the shape of the melanophore and the distribution of melanin within it. Melanophores may be located superficially beneath the epidermis, in the dermis, or internally in muscle tissue, the cranial cavity, or on membranes of the perivisceral cavity and gas bladder. Since melanophores are amoeboid and melanin can be redistributed within them, there is great potential for change in the appearance of individual pigment cells and in their aggregate pattern. These changes can occur over short time periods, such as when a melanophore contracts, changing its apparent form from stellate to round, or when pigment patterns develop through proliferation, migration, and coalescence. This is first apparent during the yolk-sac stage when the initial larval pigment pattern is formed. Pigment pattern is genetically determined; many species have unique patterns, and often there are pigment arrangements that typify higher taxa from genus to order. Apart from such unique patterns are many convergent pigment loci and arrangements that have evolved independently in unrelated clades, apparently in response to common selective pressures. Examples are the rows of melanophores above the gut in larvae with an elongate intestine, the melanistic shield that overlies the gut mass in larvae with coiled intestines, the shield overlying the gas bladder, the melanophore series on the ventral margin of the tail, melanophores that cover the brain lobes, paired rows of melanophores along the dorsal margin of the body, and, in many neustonic species, the solid sheath of pigment covering the entire larva (except for the caudal region). The functions of these convergent and highly specific patterns are open to speculation (Moser 1981; Govoni et al. 1984) but their usefulness as identifying characteristics of fish larvae at all taxonomic levels is unquestionable.

There are numerous other features of the larval stage, in addition to those summarized above, that are useful in recognizing species and higher taxa. One of these is the presence of photophores in larvae as early as the preflexion stage. These are most apparent in myctophid larvae where there are specific patterns of early-forming photophores and patterns common to genera or groups of genera (Moser and Ahlstrom 1970, 1972, 1974). Other larval specializations are the balloon-like outer skin of lophiiforms and the specialized body form of elopiform leptocephali. Surveys of the many specializations of larval fishes and their potential use in identification may be found in Orton (1953b), Berry and Richards (1973), Moser (1981), Govoni et al. (1984), and Kendall et al. (1984).

Transformation Stage

The larval stage is followed by a transformation stage characterized by changes in general form and structural detail that involve the acquisition of adult characters and loss of larval characters. The change from larva to juvenile may be abrupt or gradual and may involve relatively small or large changes. In the great majority of fishes, larval shape is different from that of the juvenile, requiring substantial and sometimes rapid allometric growth of muscle and bony tissue. Usually the larval gut is different from that of the juvenile and transformation involves the formation of a stomach and the further development of other digestive organs. Since most larvae have thin transparent skin, transformation requires the development of the much thicker, solidly pigmented juvenile skin. Silvery pigment, produced in guanophores, appears in many fishes at this time. Scale formation usually begins during transformation in species that have scales, and often this is the most useful defining characteristic of the transforming stage. Fin development has progressed to the point where adult ray complements are present or nearly complete. Larval structures such as enlarged fins, elongate fin rays and appendages, stalked eyes, barbels, free-trailing extensions of the gut, specialized larval teeth, and voluminous finfolds are resorbed or lost through allometric growth. Larvae with relatively small eyes may experience a rapid increase in eye size and, in those with narrow elliptical or oval eyes, the shape changes rapidly to achieve the round eye of juveniles and adults that have round eyes. In some clupeoids, the dorsal, anal, and pelvic fins may shift position. In luminous fishes, photophores and other luminous tissue develop rapidly.

Transformation is accompanied by changes in behavior and often in habitat. Epipelagic species may form schools and remain in the same habitat or move to inshore nursery areas. Demersal species must leave the surface waters and settle to the juvenile habitat; the mechanisms by which they accomplish this critical life history process are largely unknown. The larval stage is protracted in some demersal species where the larvae may remain pelagic for many months and often attain a large size. Numerous examples of this may be found in several families of flatfishes (paralichthyids, bothids, and pleuronectids); achirid flatfishes provide an example of the other extreme where the larval stage is brief and settlement occurs at <5 mm. Larvae of mesopelagic and bathypelagic fishes descend to their juvenile habitat, which often is different from that of the adult, to complete transformation.

Juvenile Stage

Successful transformation produces a juvenile which is defined generally as a pre-reproductive individual that is morphologically similar to the adult with complete fin-ray complements and squamation. Juveniles may occupy the adult habitat or often live separately until they grow to near adult size. Some fishes (e.g., lampridiforms, oreosomatids, polyprionids) have juveniles that differ markedly in form and pigmentation from adults and in many shorefish families (e.g., serranids, carangids, sciaenids, lutjanids, pomacentrids, labrids) the juvenile and adult color patterns are markedly different. Many shorefishes (e.g., mugilids, hexagrammids, cottids) have a special pelagic stage with a dark dorsum and silvery sides that generally is herring-like in appearance and behavior (Kendall et al. 1984). Other pelagic and demersal fishes have highly modified juvenile stages that may remain pelagic for extended periods. Such pelagic stages are common in many tropical reef families and were often described mistakenly as unique species (Hubbs 1958; Leis and Rennis 1983; Kendall et al. 1984). In the California Current region scorpaenid species in the genera *Sebastes* and *Sebastolobus* have pelagic juveniles that may remain offshore for months before settlement.

Many of the terms used in the above summary are abbreviated in the descriptive accounts of this guide; these and other terms used in these descriptions are defined in the following list of abbreviations and in the glossary following it. Acronyms for institutions, expeditions, and research programs are given in Table Introduction 1.

Abbreviations

1D	first dorsal fin
2D	second dorsal fin
A	anal fin
A_{30}	number of anal fin rays anterior to the 31st vertebra (carapids)
A_{200}	number of anal rays anterior to the 201st vertebra (nemichthyids)
Ad	adipose fin
AF	the stage after initial anal fin development (e.g., macrourids)
AFO	number of vertebrae anterior to anal fin origin
BbL	length of mandibular barbel
BD	body depth at pectoral fin base
BDA	body depth at anus, including gut protrusion if present (e.g., flatfishes)
BDi	body depth exclusive of inflated epidermis
BJuv	benthic juvenile
BkL	length of beak (e.g., hemiramphids)
BL	body length
BrR	branchiostegal rays
C	caudal fin
Ca	caruncle
C_1	principal caudal fin rays
C_2	procurrent caudal fin rays
CL	length of choroid tissue below eye
CPL	length of caudal peduncle, measured from anal fin insertion (e.g., apogonids)
CV	caudal vertebrae
D	dorsal fin
D_{30}	number of dorsal fin rays to the 31st vertebra (carapids)
D_{200}	number of dorsal fin rays to the 201st vertebra (nemichthyids)
DFO	number of vertebrae anterior to D origin
DLR	dorsolateral bony plates (agonids)
DSL	length of longest dorsal spine
DW	disk width (maximum width of head in ogcocephalids)
ED	eye diameter (in round eye)
EL	eye length (long axis of oval or elliptical eye)
ELH	early life history
ESL	eye stalk length
EW	eye width (short axis of oval or elliptical eye)
F	flexion stage
GD	greatest depth of body
GO_2	gular photophore (platytroctids)
GR	gill rakers
HL	head length
HW	head width
IL	illicium length (lophiiforms)
InW	internasal width; the distance between nasal capsules (tetraodontids)
IVO	photophore between bases of pelvic fins (platytroctids)
JD	jaw depth (ventral margin of eye to angle of lower jaw; in lampridiforms)
Juv	juvenile stage
L	lower
LL	lateral line
LVL	length of liver (e.g., *Bathophilus*)
LVBV	last vertical blood vessel
MDR	mid-dorsal bony plates (agonids)
ML	length of the lower jaw, measured from the anterior margin of the eye (belonids)
MVR	mid-ventral bony plates (agonids)
MxL	distance from snout to posterior margin of maxilla
NL	notochord length
OG	oil globule
OO	light organ on anterior margin of eye (platytroctids)
ORL	length of occipital dorsal fin-ray (bregmacerotids)
P_1	pectoral fin
P_1BL	length of pectoral fin base (macrourids)
P_1L	length of pectoral fin (length of longest ray; greatest length of blade before ray formation)
P_1LL	length of elongate lobe of pectoral fin (e.g., *Ichthyococcus*)
P_1D	depth of pectoral fin base
P_2	pelvic fin
P_2DL	longitudinal diameter of pelvic disc, measured to the outer edges of disk (cyclopterids)
P_2L	pelvic fin length
P_2SpL	pelvic fin spine length (gempylids)
PAL	preanal length; the same as Sn-A length
PaSL	length of parietal spine
PdL	distance from tip of snout to dorsal fin origin
PJuv	pelagic juvenile
PoF	postflexion stage
PrAF	prior to initial anal fin development (e.g., macrourids)
PrCV	precaudal vertebrae
PrF	preflexion stage
PrSL	length of longest preopercular spine
PrVL	distance from snout to vexillum base (carapids)
RL	rostrum length
SBO	subopercular light organ (platytroctids)
SL	standard length
Sn-A	snout-to-anus distance
Sn-AO	distance from snout to anal fin origin
Sn-GL	distance from snout to tip of gut loop
SnL	snout length
SoCL	length of supraoccipital crest or spine
sp.	species (singular)
sp(p).	species (may be one or more species)
spp.	species (plural)
TGL	length of trailing section of gut
TL	total length
Tr	transformation stage
U	upper
V	vertebrae
VDO	number of vertebrae to dorsal fin origin (carapids)
VLR	ventrolateral bony plates (agonids)
VVO	number of vertebrae to vexillum origin (carapids)
Y-S	yolk-sac (as used for yolk-sac stage)
YS	yolk sac (referring to yolk sac itself)

Glossary

(As used in Jones et al. 1978, Fahay 1983, Leis and Trnski 1989, and in this study)

Actinotrichia. Threadlike fibers in the finfolds of fish larvae that eventually develop into fin rays.

Adhesive. Sticking; adhesive eggs stick to the substrate or to other eggs.

Adipose fin. Fleshy fin posterior to the dorsal fin.

Aliform. Wing-like; usually referring to the shape of the pectoral fin.

Anadromous. Referring to fishes that ascend rivers to spawn.

Anal fin. Fin (usually single but double in some gadiforms) on the ventral margin of the tail.

Angle of jaw. Bony prominence posterior to gape of jaw; region of the junction of the angular, articular, and quadrate bones.

Angular. The bone at the angle of the jaw or that region; used in this guide in reference to pigmentation at, or near, the angular bone.

Anlage. Primordial form of an organ or anatomical structure; plural is anlagen.

Anterior. Towards the front; cephalad.

Antrorse. Angled forward; usually referring to direction of a spine.

Anus. Orifice and surrounding tissue at the terminus of gut.

Aorta. Main blood vessel lying below the spinal chord that supplies blood from the heart.

Articular. A bone of the lower jaw between the dentary and angular bones (some consider it part of the angular); used in this guide in reference to pigment anterior to the angle of the upper jaw).

Band. A strip of pigment that contrasts with the adjacent background pigment or unpigmented area; it may be on any part of the head, body, or fins and may be oriented in any position; in this guide, a vertical band occurring laterally on the head or body is referred to as a bar and a horizontal band is referred to as a stripe.

Bar. A vertical band of pigment on the lateral surface of the head or body; often ocurring in a series.

Barbel. Slender sensory projection on the lips or chin; barbel length measured from the point of attachment on the head to the tip of the barbel.

Basipterygium. Bone or process that supports the pelvic fin.

Bathypelagic. Zone below 1,000 m depth in the open ocean.

Benthic. Living on or in the bottom (substrate).

Blastodisc. Early embryo of teleosts consisting of a disc- or cap-like mass of cells on the yolk.

Blastomere. Individual cells forming the early embryo of teleosts.

Blastopore. Circular area on the yolk of teleost fish eggs that has not been covered by the advancing germ ring during epiboly; not homologous with the blastopore of amphibians and some other vertebrates where there is invagination of surface cells to the interior of the embryo through the blastopore (see Ballard 1964).

Body depth. The vertical distance from the dorsal margin of the body to the ventral margin of the body measured at the base of the pectoral fin where it attaches to the body; fins or fin bases are not included in the measurement.

Body length. General term used to indicate the size of a larva; equivalent to notochord length (distance from the tip of the snout to the tip of the notochord) in preflexion and flexion stage larvae and equivalent to standard length (distance from the tip of the snout to the posterior margin of the hypural plate) in postflexion larvae, juveniles, and adults.

Branchiostegal rays. Ray-like bony elements attached to the hyoid arch, extending under the gill openings and connected by a membrane.

Bud. The undifferentiated bump or protuberance that appears at the initial formation of the paired fins.

Caruncles. Fleshy outgrowths; modified dorsal fin rays in ceratiids.

Caudal fin. Median fin at the posterior end of the fish.

Caudal peduncle. Narrow part of the tail between the posterior end of the anal or dorsal fin and the base of the caudal fin; caudal peduncle length measured from the insertion of the posteriormost ray of the anal or dorsal fin (whichever is most posteriad) to the insertion of the anteriormost caudal fin-ray.

Caudal vertebrae. The posterior group of vertebrae extending from the centrum bearing the first haemal spine to the urostyle.

Chorion. The shell or surrounding membrane of an egg.

Centrum. The body of a vertebra.

Choroid fissure. Indentation at the ventral margin of the eye marking the invaginated borders of the optic cup in larval fish.

Choroid tissue. Mass of primordial vascular tissue of various shapes lying below the eye; usually associated with narrow eyes; often pigmented; its length measured along its longitudinal axis from the interface with pigmented portion of the eye to the tip of the choroid mass.

Cleithral symphysis or junction. Where the ventral ends of the cleithral bones meet.

Cleithrum. Elongate vertical bone in pectoral girdle at the junction of the head and body of the fish; one of the first bones to form in the body; demarcates the junction of the head and body.

Coiled. Condition of the gut where it is twisted or convoluted.

Compressed. Laterally flattened.

Crown. Top of the head.

Dash (pigment). An elongate or streak-like melanophore.

Demersal. At the ocean bottom; used in reference to life stages from eggs to adults.

Dendritic. Highly branched; usually used in reference to a melanophore.

Dentary. Major bone of lower jaw, usually bearing teeth.

Disk. Flat cup-like structure formed from modified pelvic fin rays (also pectoral fin rays in some fishes) used for holding onto the substrate or structures on the substrate (e.g., gobiesocids, cyclopterids, gobioids); its diameter (P_2DL) is measured longitudinally from one margin to the opposite margin; in echeneids, the disk is on the top of the head and formed from modified dorsal fin spines; also refers to the disk-shaped head of ogcocephalids where disk width (DW) is the greatest transverse dimension of the disk.

Distal. Remote from the point of attachment; opposite to proximal.

Dorsal. Upper part of body; opposite of ventral.

Dorsal fin. Fin or fins on dorsal margin of the body.

Dorsum. Uppermost part of body; dorsal body margin; opposite to ventrum.

Early life history. The early phase in life spanning the developmental stages from egg to juvenile.

Emarginate. Indented; used to describe caudal fin shape.

Embryo. Organism at an early stage of differentiation and growth; in this guide, refers to the stage of development between fertilization and hatching.

Embryonic shield. Thickened area of the germ ring representing the future longitudinal axis of the embryo.

Engyodontic stage. Early stage of anguilliform larvae (preceding euryodontic stage) characterized by few needle-like teeth, the upper and lower jaws equal in length, no nasal capsule, an undifferentiated finfold, no hypurals, the notochord tip straight, and the head and preanal region of the body relatively large.

Epaxial. The part of the myomeres above the lateral midline (horizontal septum).

Epibenthic. Zone at the interface with the sea bottom; refers to organisms living in contact with the sea bottom.

Epiboly. Movement of the embryonic cell mass over the surface of the yolk; the germ ring marks the boundary of the advancing sheet of cells.

Epipelagic. Zone from the surface to 200 m depth in the open ocean.

Erythrophores. Red pigment cells.

Esca. The lure at the tip of illicium in most lophiiform fishes; commonly luminous in deepsea species.

Euryodontic stage. Advanced stage of anguilliform larvae (following engyodontic stage) characterized by a relatively smaller head and preanal region, three series of relatively short, broad teeth, a relatively shortened lower jaw, the formation of nasal capsules, fins, and hypurals, and the flexion of the notochord.

Eye diameter. In larvae with round eyes, the diameter of the pigmented part of the eye, usually measured through the horizontal midline; in larvae with oval or elliptical eyes, the horizontal dimension is given first, followed by the vertical dimension.

Eye length. The longer axis of an oval or elliptical eye measured through the midline from the pigmented margin of one side of the eye to the other side.

Eye width. The shorter axis of an oval or ellipical eye measured through the midline from the pigmented margin of one side of the eye to the other side.

Eye stalks. Movable peduncles of varying length bearing the eyes; eye stalk length measured from the point where the stalk attaches to the head to the point of attachment at the eye.

Fin elements. Fin spines, rays, and supporting bones (pterygiophores).

Finfold. Median fold of skin surrounding the body within which the dorsal, anal, and caudal fins develop; the part of the ventral finfold in which the anal fin develops is referred to as the anal finfold.

Finlet. Small fin-like structures posterior to the dorsal and anal fins.

First-feeding larvae. Larvae that have used all or most of their yolk and are capable of capturing prey.

Flexion. Stage (or the process) when the urostyle bends dorsally concurrently with the development of principal rays and hypural bones in the caudal fin; also, the process of notochord flexion; preflexion refers to the stage prior to the initial bending of the notochord tip and postflexion refers to the stage after the completion of the notochord flexion. Refer to the Principles and Terminology section for additional explanation.

Forebrain. Anterior region of the developing brain that includes the olfactory lobes.

Foregut. Anterior part of the primitive alimentary canal from which the esophagus and stomach develop.

Frontal bones. Large paired (fused in some species) bones that form the top of the cranium anteriorly; they often form a ridge over each orbit (supraocular crest) that may bear one or more spines.

Gargaropteron stage. Pelagic stage of the chiasmodontid genus *Kali*, characterized by greatly elongate pectoral and pelvic fin rays.

Gas bladder. Gas-filled sac lying beneath the spinal column in the abdominal region; also referred to as air bladder or swim bladder.

Germ ring. Thickened margin of the blastodisc that advances over the yolk during epiboly.

Guanophores. Silvery pigment cells containing iridescent crystals of guanine.

Gular. Ventral region of the head anterior to the isthmus and below the lower jaw.

Gut. Alimentary tube and associated organs.

Gut loop. Loop, fold, or curve found along the axis of the gut.

Haemal spine. A median spine on the ventral surface of a vertebral centrum, attached to the centrum by two bones that form an arch (haemal arch).

Head length. Horizontal distance from the tip of the snout to the posterior margin of the cleithrum.

Head width. Transverse distance between the lateral margins of the head measured at the posterior margin of the orbit.

Hindbrain. Posterior region of the developing brain that includes the medulla.

Hindgut. Posterior part of the alimentary canal that includes the intestine and rectum.

Homocercal. Type of caudal fin in teleosts where the upper and lower lobes are symmetrical; internally, the major structural elements of the fin are an upturned urostyle (several fused vertebrae) that articulates with flattened bones (hypurals and parhypural) that support the principal fin rays.

Homogeneous. Uniform in composition; opposite to segmented in referring to egg yolk.

Horizontal septum. A sheet of connective tissue (in the horizontal plane) that separates the epaxial and hypaxial muscle masses; the lateral midline area in reference to pigmentation.

Hyomandibular. Bone or cartilage (usually elongate) in the cheek region that functions in jaw suspension.

Hypaxial. The part of the myomeres below the lateral midline (horizontal septum).

Hypurals. A series of bones derived from the haemal spines of the last vertebrae which support principal caudal fin rays.

Ichthyoplankton. That part of the zooplankton consisting of the egg and larval stages of fishes.

Illicium. Tentacle-like spine of the dorsal fin located on the snout of most lophiiform fishes, used as a lure to attract prey; illicium length measured from the point of insertion of the illicium on the head to the tip of the structure.

Inferior. Spatial anatomical term meaning lower in position; opposite to superior.

Insertion. Posterior (usually) point of attachment of a fin.

Interopercle. Lower bone of the gill cover lying below the preopercle.

Interorbital. Region on top of the head between the orbits of the eyes.

Isthmus. Ventral region of the head below the gills, often narrow, connecting the gular and cleithral regions.

Jugular. Referring to the throat region; usually used to indicate the position of the pelvic fin in some fishes.

Juvenile. Stage after transformation from the larval stage that is like the adult but not yet reproductively active; there is a full complement of fin rays, scales are formed (in species that have them), and the form is fundamentally similar to the adult.

Lachrymal. The anteriormost of the infraorbital (circumorbital) bones; enlarged and with spines in some species.

Larva. Stage following hatching that is unlike the juvenile or adult in form and pigmentation and must transform or metamorphose before assuming juvenile/adult characteristics.

Last vertical blood vessel. The posteriormost large blood vessel extending from the dorsal aorta to the kidney (nephros); used as reference point and taxonomic character in eel leptocephali.

Lateral line. A line along the lateral surface of the body formed by a series of sensory pores that usually are associated with modified scales.

Lateral midline. The region of the body between epaxial and hypaxial myomeres; the region of the horizontal septum.

Lepidotrichia. Scale-like structures that form the segments of soft rays in bony fishes.

Leptocephalus. Transparent, ribbon-like, often large larvae of elopiform fishes with an internal cavity filled with acellular mucinous material; leptocephali usually have a small head and prominent teeth.

Live-bearing. Type of reproduction where the eggs develop within the ovaries and the young are born as larvae or juveniles; viviparous.

Longitudinal septum. A sheet of connective tissue that separates the muscle masses on the right and left sides; the dorsal longitudinal septum separates the epaxial muscle masses and the ventral longitudinal septum separates the hypaxial masses.

Lunate. Crescent shaped.

Maxillae. Longest paired bones of the upper jaw; located above the premaxillae.

Median. Referring to the midline plane that divides a bilaterally symmetrical animal into right and left halves; usually synonymous with mesial.

Melanophore. A cell containing melanin; ameboid black or brown pigment cells of various shapes and sizes derived from the neural crest region of the embryo.

Meristic characters. Countable structures occurring in series (e.g., myomeres, vertebrae, fin rays).

Mesopelagic. Zone from 200 m to 1000 m depth in the open ocean.

Metamorphosis. A marked change in form or structure at the end of the larval stage involving acquisition of adult characters and loss of larval characters; synonymous with transformation.

Midbrain. Region of the developing brain that includes the optic and cerebellar lobes.

Midline. The median plane or line of the body either on the dorsal or ventral surface; sometimes used as the middle of a body part.

Mucosal folds. Folds of tissue lining the cavity of the intestine; pronounced in some fish larvae giving a striated or rugose appearance.

Myomeres. Muscle segments of the body occurring in series; approximately equal to number of vertebrae in adults; in this guide, the preanal myomeres are defined as all myomeres anterior to a vertical from the posterior margin of the anus and the postanal myomeres are those myomeres posterior to a vertical from the posterior margin of the anus; in many fishes the number of preanal and postanal myomeres approximate the number of precaudal (abdominal) and caudal vertebrae, respectively.

Myomere formula. Preanal myomeres + postanal myomeres = total myomeres.

Myosepta. Connective tissue between adjacent myomeres.

Nape. Dorsal region of the body immediately behind the head.

Nares. The openings of the nasal organs or rosettes.

Nasal capsule. Paired, more-or-less spherical structures on the snout that contain the olfactory organs.

Nekton. Motile, marine organisms living in open water (rather than the sea floor) and capable of swimming against currents; small to moderate-sized nektonic organisms (e.g., midwater fishes, juvenile fishes, some cephalopods) are referred to as micronekton.

Nephros. Kidney; often used to refer to larval kidney.

Neritic. Pelagic coastal zone extending seaward to the margin of the continental shelf.

Neural spine. A median spine on the dorsal surface of a vertebral centrum, attached to the centrum by two bones that form an arch (neural arch) through which the spinal cord passes.

Neural crest. Region of the neural ridge of the developing embryo that differentiates into many kinds of tissue and cells, including melanophores.

Neustonic. Inhabiting the surface of the ocean; plankton living in this zone are referred to as neuston.

Notochord. Longitudinal cartilaginous rod that supports the axis of the body.

Notochord length (NL). The distance from the tip of the snout to the posterior tip of the notochord.

Nuchal. Referring to the region of the nape; immediately behind the head, dorsally.

Occipital crest. Bony ridge located posteriorly on top of the head.

Oceanic. Open sea zone seaward of the continental shelf or slope.

Oil globule. Spheres of oil or fatty material within the yolk of some fish eggs.

Ontogenetic characters. Those characters associated with developmental stages.

Opercle. Upper posterior and usually largest bone of the gill cover of a fish; often used as synonym of operculum.

Operculum. Bony plate of the gill cover.

Ophioblennius stage. Pelagic stage of some salariin blenniids characterized by enlarged pectoral fins and enlarged, hooked teeth anteriorly in the lower jaw or in both jaws.

Opisthonephros. The embryonic or larval kidney.

Orbit. The bony socket of the eye.

Organogenesis. The relatively advanced period of embryonic development characterized by formation of the organ systems.

Origin. Anterior (usually) point of attachment of a fin.

Ossification. Process of bone formation involving calcification of cartilage or connective tissue.

Otic. Region of the head containing the auditory or hearing organs.

Oviparous. Producing eggs that develop outside the maternal body.

Paedomorphic. Referring to the phylogenetic retention of juvenile (or larval) characters in the adult stage.

Palatine. Bones lying on the outer margin of the roof of the mouth; often bearing teeth.

Papilla. A fleshy projection or protuberance.

Parhypural. Lowermost supporting bone of the principal caudal fin rays.

Pectoral fin. Paired lateral (sometimes ventrolateral) fins behind the head; prior to ray formation, pectoral fin length is measured from the base of the blade (finfold) to the greatest distal margin of the blade; after ray formation, pectoral fin length is measured from the point of insertion of the longest ray to the tip of the ray.

Pectoral fin base. Supporting structure of the pectoral fin; in larvae it is peduncular and contains the muscles that operate the fin; its length is measured along the longitudinal axis from the point of insertion on the body to the point of attachment of the fin blade or rays; its depth is measured on the transverse axis at its widest (usually most distal) point.

Pedicel. A small, short stalk.

Peduncle. A narrow part or stalk that connects a structure to the body (e.g., caudal peduncle connecting caudal fin to body).

Pelagic. Free-living in the sea away from the sea bottom, usually beyond the continental shelf.

Pelvic fins. Paired fins usually located ventrally on the body; various in position from beneath the head (jugular), to below the pectoral region (thoracic), to the gut region (abdominal); high on the sides in some stomioids; prior to ray formation, pelvic fin length is measured from the base of the blade (finfold) to the greatest distal margin of the blade; after ray formation pelvic fin length is measured from the point of insertion of the longest ray to the tip of the ray.

Periblast. Thin membrane lying below the embryo and surrounding the yolk in teleosts; the space surrounding the yolk is invaded by nuclei, forming a syncytial region of unknown function.

Peritoneal. Region of the body associated with the gut or the membrane of the peritoneum; often synonymous with perivisceral.

Peritoneum. The membrane and associated connective tissue lining the gut cavity.

Perivitelline space. Fluid-filled space between the embryo and shell or chorion of an egg.

Photophores. Luminous organs.

Phylogenetic. Referring to the evolutionary lineage of an organism.

Plankton. Small, free-living, weakly swimming or passively floating marine or fresh water organisms that drift with the currents.

Postanal. Posterior to the anus.

Posterior. Towards the back or caudal region; opposite to anterior.

Postorbital. Behind the eye or eye socket.

Posttemporal spine. A spine that emerges from the posttemporal bone located on the posterolateral upper region of the skull.

Preanal. Located anterior to the anus; preanal length (synonymous with snout-anus distance) measured from the tip of the snout to the posterior margin of the anus.

Precaudal vertebrae. The anterior group of vertebrae that includes all centra anterior to the centrum with the first heamal spine.

Precocious. As used in this guide, specialized early formation of a structure (e.g., fins or fin elements) compared to typical developmental sequences in most fishes; does not infer abnormality.

Premaxillae. Paired bones of the upper jaw anterior to the maxillae and usually bearing teeth; often protrusile, and extending ventrad of most of the maxillae in advanced teleosts.

Preopercle. Upper anterior bone of the gill cover, often bearing serial spines; spines at the margin of the bone are referred to as posterior preopercular spines and those on a bony ridge forward of the margin are referred to as anterior preopercular spines.

Principal caudal fin-rays. Caudal-fin rays originating on the hypural and parhypural elements.

Procurrent caudal fin-rays. Small dorsal and ventral rays of the caudal fin located anterior to the principal rays and not supported by hypural/parhypural elements.

Proximal. Near the point of attachment or origin; opposite to distal.

Pterotic spines. Spines emerging from the pterotic bone located posterior to the upper region of the orbit in the temporal region of the skull.

Pterygiophores. Cartilaginous or bony elements that form the fin base and support the fin rays of a fish.

Punctate melanophore. Round or dot-like melanophore.

Querimana stage. Silvery pelagic juvenile stage of mugilids.

Rays. Segmented fin supports that are usually bilaterally paired and often branched.

Reticulated. Net-like or web-like in appearance.

Retrorse. Angled backward; usually referring to direction of a spine.

Rhynchichthys stage. Pelagic juvenile stage of holocentrids, characterized by the presence of rostral, preopercular, opercular, and supraoccipital spines and silvery color.

Rostrum. A prolongation of the snout, sometimes ending in a spine (rostral spine); rostrum length measured from the anterior edge of the upper jaw to the tip of the rostrum or spine (holocentrids).

Rugose. Having a wrinkled appearance; often used to describe bone with a highly textured surface; sometimes used to describe the appearance of the gut, caused by numerous mucosal folds.

Saddle. A broad band of pigment that straddles the dorsum and extends ventrad on each side of the body.

Sculptured. Referring to an egg shell with ornamentation or surface features of various shapes and textures.

Scutatus stage. Pelagic juvenile stage of antennariids, characterized by bony plates extending posteriorly from the cranium.

Segmented. Particulate or divided; opposite of homogeneous in referring to egg yolk.

Shell. The membrane that encloses an egg; generally, equivalent to chorion.

Snout. Forward part of the head anterior to the eye; snout length measured in the longitudinal axis from the anteriormost pigmented surface of the eye to the tip of the snout.

Snout-anus (Sn-A). Distance from the tip of the snout to the posterior margin of the anus, measured at the longitudinal axis; equivalent to preanal length (PAL).

Spatulate. Flattened or spoon-shaped.

Sphenotic. Bone at the upper part of the skull, often forming part of the orbit.

Spines. Supporting elements in the fins that are unsegmented, unpaired, unbranched, and usually stiff and sharp (sometimes referred to as spinous rays); also, refers to pointed projections arising from various bones, usually on the head.

Spinous scale. Specialized larval scales with spines (not the serrated ctenoid scale of adult fishes).

Stalked eye. Eye borne on a stalk or peduncle.

Standard length (SL). The distance from the tip of the snout to the posterior vertical margin of the hypural plate.

Stellate melanophore. A star-shaped or dendritic melanophore; the stellate condition can be temporary and the melanophore can become punctate after contraction.

Striations. Surface features in the form of lines or bands.

Stripe. A horizontal band of pigment on the lateral surface of the head or body; sometimes occurring in a series.

Subcutaneous. Occurring beneath the skin.

Subopercle. Posterior bone of the gill cover lying below the opercle.

Subterminal mouth. Underneath or set back from the tip of the snout, sometimes referred to as an inferior mouth.

Superior. Spatial anatomical term meaning upper in position; opposite to inferior.

Supracleithral spine. A spine originating from the supracleithrum located near the upper posterior margin of the head.

Supraoccipital spine. Spine or crest on the midline of the back of the head originating from the supraoccipital bone.

Supraorbital spine. One or more spines on a crest above the eye in some fishes.

Syncytium. A multinucleate mass of protoplasm.

Tail. Portion of the body posterior to the anus; the postanal region.

Telescopic eye. Type of elongate, cylindrical eye that protrudes forward or upward within an envelope of skin.

Tenuis stage. Specialized benthic developmental stage following the larval stage in carapids; characterized by a small head, thin body, and lack of a vexillum.

Terminal mouth. Type of mouth that opens anteriorly; typical of most fish larvae.

Tholichthys stage. Pelagic juvenile stage of chaetodontids, characterized by broad, enlarged preopercular spines, supracleithral and posttemporal plates, and often silvery pigmentation.

Thoracic. Referring to the chest area; usually the region of the body of a fish below the pectoral fin base.

Total length (TL). Measurement from the anterior tip of the fish to the most posterior part, including the caudal finfold or caudal fin rays.

Transformation. The process (synonymous with metamorphosis) at the end of the larval stage, characterized by a marked change in form or structure and involving acquisition of juvenile or adult characters and loss of larval characters; also refers to the stage where this process occurs; the term "transitional" is used sometimes for larvae that undergo a gradual transformation (e.g., in scombrids).

Trunk. Portion of the body between the head and the anus.

Tubercle. Small knobby protuberance.

Urohyal. A median bone in the throat region to which the sternohyoid muscles attach; not part of the hyoid arch.

Urostyle. Complex bony structure (usually upturned) at the terminus of the vertebral column formed from the fusion of several vertebrae; the supporting elements of the caudal fin are attached to it.

Vent. Opening on the ventral surface of a fish where the alimentary and urinary canal open; essentially equivalent to the anus in larval fin.

Ventral. Lower part of body; opposite to dorsal.

Ventral fins. Pelvic fins.

Ventrum. Lowermost part of body; ventral body margin; opposite to dorsum.

Vertical blood vessel. One or more of the vertically oriented blood vessels connecting the aorta with the gut or kidney in leptocephali.

Vexillifer stage. Larval stage of carapids characterized by the tentacle-like dorsal fin ray.

Vexillum. Highly modified elongate anterior dorsal-fin ray in larval carapids.

Viviparous. Type of reproduction where the embryos develop within the ovary and receive maternal nutrition.

Vomer. Elongate bone that forms the roof of the palate.

Xanthophores. Yellow pigment cells.

Yolk. Nutritive material of the egg or in a sac-like mass (yolk sac) below the abdominal region of a newly hatched larva.

Yolk-sac larva. Early larval stage with yolk present in a sac-like region of the gut.

Explanation of Format and Methods

Introductions to Orders

The descriptive accounts in this guide generally follow the formats used in guides for ELH stages of fishes of the Northwest Atlantic (Fahay 1983) and the Northeast Pacific (Matarese et al. 1989). Orders and subordinal taxa to subfamily are presented sequentially as they appear in the classification of Eschmeyer (1990). Likewise, nomenclature follows Eschmeyer's (1990) classification and generic listings. Within families or subfamilies, the genera and species are listed alphabetically. Occasionally, the classification and phylogenetic sequence in this guide differ from that in Eschmeyer (1990) when warranted by recent studies (e.g., Johnson 1993; Nelson 1994).

For most orders and some suborders, there is an introductory section that briefly summarizes its systematic status, salient defining characteristics, taxonomic components, and lists pertinent literature. These summaries were based on the most recent available literature, primarily Nelson (1994), papers in the proceedings of a symposium on percomorph phylogeny (see Johnson 1993), volumes in the Fishes of the western North Atlantic (see Bigelow 1963), Smith and Heemstra (1986), Masuda et al. (1984), Moser et al. (1984), Whitehead et al. (1984,1986), Paxton and Eschmeyer (1994), Fischer et al. (1995), and individual systematic revisions. Usually, this is followed by brief characterizations of the kinds of fishes found in the order and, in some cases, their reproductive modes and ELH stages. Finally, the representatives of the order in the CalCOFI area are indicated along with a list of the families treated in the guide.

Where ELH information is scanty for the order or for certain of its families, brief descriptions of known larval stages are given in this section, sometimes accompanied by illustrations of single larval stages. For some orders (e.g., Lophiiformes) containing numerous families with few representatives in the CalCOFI area, a summary table of meristics for all taxa in the area is included at the end of this section. Tables containing information needed to interpret descriptive accounts of families in the order may be included in this section. For example, definitions and diagrams of photophores are listed in the introduction to Stomiiformes. In a few cases, where an order is represented by a single family in the CalCOFI area (e.g., Batrachoidiformes), general information on the order is included in the family introduction. Figures and tables in this section, and throughout the guide, are numbered sequentially within each section (e.g., Table Introduction 1 or Figure Anguilliformes 2).

Introductions to Families

This section provides basic information on the adults and ELH stages of each of the 152 families included in the guide. This information is intended to help orient users of the guide and aid in the interpretation of the descriptive accounts of individual species. These introductions are not intended to be complete or exhaustive reviews of the family, rather they serve as a starting point for users of the guide and in some cases to suggest future research on that family. The introduction begins with some brief information on the taxonomic definition, composition, and distribution of the family. This information is based largely on Nelson (1994) and the other sources cited in the preceding section. Next is an overview of the adult and ELH stages of the species occurring in the CalCOFI area. For families with significant representation in the CalCOFI area, meristic characters of adults of these species are listed in an accompanying table at the end the introduction. Other sources for species lists and detailed information on the adults in the region are cited; primarily, these are Fitch and Lavenberg (1968, 1971, 1975), Miller and Lea (1972), Hubbs et al. (1979), Thomson et al. (1979), Eschmeyer et al. (1983), Robins et al. (1991), Allen and Robertson (1994), and Fischer et al. (1995). Comprehensive information on the seasonal and interannual distribution and abundance of larvae in the CalCOFI time series is available in CalCOFI Atlases 31 and 32 (Moser et al. 1993, 1994a). These atlases are the basis for much of the information given on larval distribution throughout the guide but, to avoid repetition, are not cited. A second paragraph briefly describes the adult morphology and ecology of the family, giving general information size, shape, fin arrangement, scales, color, habitat, and commercial importance. This summary is based on the literature sources cited above.

Next are paragraphs giving an overview of reproduction, and the ELH stages of the family. Where available, general information on spawning, mode of reproduction, and fecundity are given along with features (e.g., planktonic or demersal, size, shape, color, identifying characteristics) of the eggs of the family. Breder and Rosen (1966), Moser et al. (1984b), and Matarese et al. (1989) were major sources for general information on reproduction and eggs. Next, larval features are summarized, such as size at hatching, maximum size, general morphology (shape of head and body, shape and relative length of gut, shape and location of fins), myomere counts, pigment pattern, stage-specific development (if warranted), unique specializations, and, in some cases, ecology and behavior. If larvae are similar to those in other families, brief comparisons may be given to aid in identification. Comparisons of species within the family in the CalCOFI area are provided where larvae are likely to be confused; these usually are limited to important species with very similar larvae, since diagnostic features are presented in the species descriptions. If necessary, more comprehensive comparisons of diagnostic features for one or more stages are presented in tabular form in this section.

A final paragraph documents the specimens and literature sources on which the species descriptions are based. The numbers of specimens measured, with size ranges for each stage, are given for each species described; in families where two or more species are described, this information usually is given in a table following the meristic table at the end of the section. Numbers of specimens and size ranges in this table represent only specimens measured in the study and not those from the literature. Literature sources used in the descriptions are cited in the paragraph or in footnotes in the table. Tables and figures (including the species illustration plates) are numbered sequentially within each family (e.g., Table Muraenidae 1 or Figure Ophichthidae 2).

Species Descriptions

A large proportion (ca. 23%) of the early life stages of species described in this guide are new to science. The identification of these stages was accomplished primarily by establishing ontogenetic series based on morphology and pigment. Once a series was established, it was identified through several means. Countable structures (myomeres or vertebrae, fins, scales, gill rakers, etc.) were matched with counts of possible species. For some species, transformation series exhibiting both larval and juvenile characters (meristics, morphology and pigment) were available. Sometimes a juvenile specimen with remnants of a unique larval pigment pattern provided the identification. Another method for identifying ELH series was to rear developmental series in the SWFSC experimental aquarium and at other facilities. Developmental series from artificially spawned and field-collected eggs were grown to identifiable juveniles. Methods employed in these aquarium studies have been described elsewhere (Moser and Butler 1981, 1987; Butler et al. 1982; Stevens and Moser 1982; Ambrose et al. 1983; Moser et al. 1983; Hunter 1984; Ambrose and Moser 1988; Stevens et al. 1989).

Descriptions for each species are presented on two facing pages with the written description on the left page and the illustrations of developmental stages on the right page. On the left page, the family name (upper case font) is located in the upper left corner and the species name is in the upper right corner. For simplicity, only the binomial portion of the species name is given here; the full species name with describer and date may be found in the list of taxa at the beginning of the introduction to the guide. On the right page, the species name is in the upper right corner and the common name is in the upper left corner. Nomenclature for families and genera follows Eschmeyer (1990) and species nomenclature is consistent with the catalogue of fish species of the world being prepared by W. N. Eschmeyer (pers. comm.). Nomenclature for common names follows Miller and Lea (1972), Hubbs et al. (1979), Eschmeyer et al. (1983), and Robins et al. (1991). Other sources used to supply common names were Thomson et al. (1979), Allen and Robertson (1994), and Fischer et al. (1995). Where different common names for the same species were given in these publications, we selected the most frequently used name for this guide.

The format for the description page consists of two columns; sections on meristics, life history, ELH pattern, literature, and a list of original illustrations are in the left column and the description of early life history stages and a morphometric table are in the right column. The contents of these sections and explanations pertaining to them are discussed below.

Meristics. This table list ranges and modal counts (usual count, not statistical mode) for vertebrae, fin rays, gill rakers (if available), and branchiostegal rays (if available). Information for these tables was gathered from literature sources listed in the introduction to the family and from original observations. The literature was augmented primarily by counts made on specimens from the SIO Marine Vertebrates Collection. Usually 10 or more specimens of each species were examined if available. Counts of vertebrae and median fins were taken from radiographs prepared in our laboratory and counts of paired fins and other structures were taken directly from the specimens. Basally divided posteriormost dorsal or anal rays were counted as a single spine. The range represents the highest and lowest counts obtained from all sources. Generally, the modal counts represent our original observations since they are not often given in the literature. For wide-ranging species or those with worldwide distributions the ranges usually represent the extreme counts for the species and the modal counts are representative of specimens from the CalCOFI area. If a nominal worldwide species has counts in the CalCOFI region that are disjunct from counts in other localities, the ranges and modes represent only the population from the CalCOFI region. Blank cells in the table indicate that information was lacking in the literature or counts were not made. If there was insufficient information to determine a modal count, one was not given. Counts critical to the identification of ELH stages were obtained in nearly all cases. A "0" in the table indicates a count of zero for that category; that is, meristic elements are absent for structure in the species considered.

Three categories of vertebral counts are given: precaudal, caudal, and total vertebrae. Precaudal (abdominal) vertebrae include all centra anterior to the centrum with the first haemal spine; the caudal vertebrae include the centrum with the first haemal spine and all those posterior to it, including the urostyle (counted as a single vertebra). The sum of precaudal and caudal vertebrae counts may not equal the total count, since total counts usually represent a larger sample than samples for precaudal and caudal vertebrae. Precaudal and caudal counts are rarely given in the literature and most of these counts were made during the preparation of this guide, usually from 10 or fewer radiographed specimens. In the fins, counts for spinous rays are given as roman numerals and soft rays are indicated by arabic numerals. Where both spinous rays and soft rays occur in the same fin, they are separated by a comma. Multiple fins are separated by a "+". Where appropriate, principal and procurrent ray counts are given for the caudal fin; superior and inferior principal ray counts are separated by a "+". Counts for upper (superior) and lower (inferior) procurrent rays are listed separately. In some cases (e.g., gadoids) only the total count is given. Gill rakers are given for the upper and lower limb of the first gill arch; the total count for the first arch is given when data was not available for upper and lower limbs. The sum of the gill rakers on the upper and lower limbs may not equal the total number for the reason given above for vertebral counts. In fishes with a gill raker at the angle between the upper and the lower limb, the raker at the angle is included in the count for the lower limb.

Life History. Basic information on geographic range, habitat, spawning season, and ELH pattern is given in this section. Geographic ranges are based on literature and on original data from capture localities of specimens in museums (primarily the SIO Marine Vertebrates Collection). Usually the extreme north–south ranges are given for shorefishes; distributions of wide-ranging species may be generalized to zoogeographic provinces (e.g., tropical, temperate) or water masses. Major geographic landmarks are shown in Figures Introduction 2 and 3. Spellings of geographic localities south of the U.S. border follow those listed in the Sailing Directions for the West Coasts of Mexico and Central America published by the U.S. Defense Mapping Agency (DMA 1991).

The brief habitat description usually includes information on depth zone (e.g., epipelagic, mesopelagic) for oceanic species and on coastal life zones (e.g., continental shelf, slope), bottom type (for demersal species), and maximum recorded depths for shorefishes. This information is based largely on the literature, primarily Miller and Lea (1972), Eschmeyer et al. (1983), and other sources cited in the introduction to each family. Information on spawning season of some species in the CalCOFI area is available from sources such as Fitch and Lavenberg (1968, 1971, 1975), Feder et al. (1974), Matarese et al. (1989), Love (1991), Doyle (1992), and Leet et al. (1992) and from studies on specific groups of fishes, such as rockfishes (e.g., Phillips 1964; Wyllie Echeverria 1987; Love et al. 1990). Seasonality of occurrence of larvae is included since a large proportion of larvae captured on ichthyoplankton surveys are recently spawned and are reflective of spawning activity in the parent populations. This information was obtained primarily from CalCOFI Atlases 31 and 32 (Moser et al. 1993, 1994a); supplemental information was obtained from Matarese et al. (1987), Walker et al. (1987), and Doyle (1992). The last part of this section, ELH pattern, gives mode of reproduction (e.g., oviparous), the egg habitat (e.g., planktonic, demersal), and the habitat of the larvae or special juvenile stage. This information came from literature cited above and from original observations.

Literature. Listed here are publications that contain descriptions and/or illustrations of ELH stages of this species. Literature pertaining to other aspects of this species usually is cited in the introduction to the family.

Original Illustrations. Original, previously unpublished illustrations are listed by stage and size in mm, with the illustrator acknowledged in parentheses.

Early Life History Description. This section gives detailed information intended to aid in the identification of the ELH stages of the species, listed under egg stage and larval and juvenile stages. These accounts are based on previous descriptions (see literature citations in left column) and on original observations.

If the eggs of the species are known, information is given in a format that includes shell diameter, yolk characteristics, number and diameter of oil globules, nature of the shell (chorion) surface, pigmentation, and diagnostic features. Measurements <1.0 mm are given to 0.01 mm and those >1.0 mm are given to 0.1 mm. The nature of the yolk (e.g., segmented, homogenous) is given, along with the yolk diameter when available. In species with a relatively wide perivitelline space, the width of the yolk mass usually is listed so that it can be compared with shell width to give an estimate of the width of the perivitelline space. A range of diameters is given for multiple oil globules along with a description of their arrangement, when available. Surface features and ornamentations of the inner and outer shell surface are described, if visible with a dissecting microscope. The arrangement and sequence of development of melanophores on the embryo, yolk, and oil globule are briefly described. Information on the color of the chorion, yolk, or oil globule(s) of pelagic eggs refers to the color in preservative. The final section provides diagnostic features of the egg, that may include one or a combination of the characters given above or other unique features.

The section on larval and juvenile stages includes estimates of size ranges at developmental milestones (hatching, flexion, transformation), the sequence of fin formation, pigment patterns, and a summary of diagnostic features of these stages. Smallest and largest sizes at developmental milestones represent the ranges of sizes at these stages obtained from the literature or from original observations. There may be overlap in size ranges for any of these developmental milestones; for example, the largest known preflexion larva may be larger than the smallest flexion larva and the largest flexion larva may be larger than the smallest postflexion larva. In such cases, size ranges for initiation and for completion of flexion are given. Criteria for determining the beginning and end of each stage are explained in the introductory section on general principles and defined in the glossary. Specimen size in this section and throughout the guide is given as "body length" (BL); whether the indicated body length is "notochord length" (NL) or "standard length" (SL) can be ascertained by referring to size-at-stage data given in this section.

The sequence of fin formation is based on the first appearance of fin support elements or fin rays for each fin, determined most accurately from examination of cleared and stained developmental series. Observations made on cleared and stained material, either original or from the literature, were used when available; otherwise, observations on unstained material formed the basis for estimating sequence of fin development. The sequence is given in a formula with the abbreviations for successively appearing fins separated by a comma and simultaneously appearing fins united by an ampersand ("&"). In cases where fin development appeared to be simultaneous but larvae of appropriate sizes were unavailable to confirm this, the fins were shown as simultaneously forming.

Descriptions of melanophore patterns are given for each larval stage and for transforming and early juvenile stages when appropriate. The intention is to give a broad-brush description of the main components of the pattern and no attempt is made to describe every melanophore; however, the general patterns of melanistic pigment are always given. In some cases, illustrations include melanophores that are not in these descriptions and, conversely, sometimes melanophores are described that were not present on the specimen illustrated, or could not be portrayed in the illustration. The descriptions and illustrations are intended to be mutually supplementary. Major melanistic features are described when they appear in a specific stage and generally are described in subsequent stages only when their arrangement changes or they are significantly augmented or depleted. The description of pigment pattern is emphasized because of its importance in identifying larvae at all stages and at all taxonomic levels (Russell 1976). In these descriptions, the words "melanophore" or "pigment" usually are left out since it is understood that they are the subject of the majority of descriptive phrases and their constant repetition would be inefficient. Words indicating specific types of melanistic pigment, such as "series" (equivalent to "row") or "patches" (of individual melanophores), "blotches", or "dashes" are indicated when appropriate. To conserve space, the descriptions are presented in abbreviated, semi-telegraphic style with verbs and articles included only when needed for clarity. Numbers in the descriptions refer to the number of melanophores in the area or in the series being described. Other conventions are used to conserve space, for example, "1D" (the abbreviation for the first dorsal fin) may be used to indicate the spinous portion of the dorsal fin, even though the spinous and soft-rayed portions of the fin are continuous or not completely separate.

The diagnostic features section presents characteristics that will help separate larvae, transformation specimens, or early juveniles of a species from all others in the same family or genus. Usually, a combination of characters is needed to accomplish this but sometimes a single character is diagnostic. Often, total myomere counts and/or preanal and postanal myomere counts are given because of their paramount importance in identification.

Morphometrics. Comprehensive morphometric information is important in separating species and higher taxa. Stage-specific morphometrics of key features are given in a fixed-format table. The table is a quantitative portrayal of basic form; this is especially important in demonstrating structures that are not usually shown in illustrations (e.g., head width). Also, the morphometric tables in this guide may prove useful in comparative hydrodynamic and ecological studies of a broad array of teleost taxa. Proportions of snout-anus distance, body depth, head length, pectoral fin length, and pelvic fin length are presented as percentage of body length and head width, snout length, and eye diameter are given as percentage of head length. When available, the range and mean values are given for each of these features for yolk-sac, preflexion, flexion and postflexion larvae and for transformation specimens and juveniles (sometimes specified as pelagic or benthic juveniles). Where appropriate, proportions of other key features are given (e.g., body depth at anus, depth of pectoral fin base). In cases where the stages based on notochord flexion are not applicable (e.g., eels, macrourids) ranges and means were calculated for other stage categories or for size intervals. For some species, information for this table was taken from the literature, either directly or after calculation from published measurements; however, for most species, the information represents original observations. Measurements >1.0 mm were made to the nearest 0.1 mm and those <1.0 mm were made to the nearest 0.02 mm (estimated to 0.01 mm). Literature sources and specimens used for original measurements are given in the introduction to the family, either in the text or in a table. Published morphometric descriptions do not always include data on all of the features and stages used in this guide. Generally, we included only the data available from these descriptions and did not measure additional specimens to fill out missing sections of the table. A zero (0%) in the table indicates the absence of the feature and a blank indicates the feature was not measured.

Illustrations. The plate containing illustrations of selected developmental stages of the species is on the right hand page of each species description, facing the descriptive account. If available, illustrations of an egg and yolk-sac larva (sometimes more than one) are at the top of the plate with illustrations of preflexion, flexion, postflexion, transformation, and juvenile stages in sequence below. Each illustration has a label indicating the size of the specimen (diameter for eggs, body length for larvae, transforming specimens, and juveniles). Usually, the size of the illustration increases (not necessarily proportionally) with specimen size to permit more illustrations to be included. Detail is not lost by reducing the illustration size of the earlier stages because usually they are less complex in structure and pigment pattern compared with later stages.

Most of the illustrations were produced with a camera lucida attached to a dissecting microscope, thus assuring accurate proportions and pigment placement. Initial drawings were made in pencil and then finished using india ink and line-and-stipple technique. The specimen was checked constantly during this process. Illustrations are semi-diagrammatic in style, with body outline and major surface features shown with solid or dashed lines and pigment indicated by stippling or line. Internal pigmentation is lightly stippled. No attempt was made to show depth perspective with stippling because that interferes with the portrayal of pigment pattern. Where appropriate, enlarged sections, or dorsal or ventral views of specimens are illustrated to aid in identification.

The figure captions list specimens by stage and size, followed in parentheses by the localities of capture for original illustrations or by the literature citations for previously published illustrations. Where the collection locality or literature citation is the same for two or more sequential illustrations, the locality or citation is given at the end of the series. The cruise number and station are given for specimens from CalCOFI and other survey cruises. For CalCOFI specimens, these localities can be found on the maps of the CalCOFI survey pattern in Introduction Figures 1–3. Where no cruise and station number are given for CalCOFI specimens (i.e., only the attribution "CalCOFI" is given), cruise and station data are not available. Information on other sources (research programs, expeditions, cruises) is summarized in Table Introduction 1. Catalogue numbers are given for specimens from the Marine Vertebrates Collection, Scripps Institution of Oceanography (SIO), Section of Fishes, Natural History Museum of Los Angeles County (LACM), and other museum fish collections (acronyms according to Leviton et al. 1985).

How to Identify Early Stages of Fishes with this Guide

Identification of the early stages of fishes is challenging for many reasons. First, their size presents a problem for those not experienced in working with small specimens. A good dissecting microscope solves part of this problem but it may take considerable time to develop the manipulative and observational skills necessary to work with material of this size. Another problem is the large variety of species and the diversity of sizes, shapes, and pigmentation one may encounter in an ichthyoplankton sample. Workers familiar with using dichotomous keys to identify organisms are frustrated to find these are not generally applicable in identifying ontogenetic stages. This is true because the nature of any individual character usually changes over the course of development and few species have unique characters that are consistently recognizable throughout the entire early life history. Also, keys are inappropriate because large portions of the ichthyoplankton of a region may be unknown. Our intention in this guide is to summarize knowledge gained over years of studying the ELH stages of fishes in the California Current region as an aid to their identification by novices as well as experts.

A knowledge of the general early life history patterns of marine fishes is essential for interpreting this guide and gaining competency in identification of fish eggs, larvae, and juveniles. A basic summary of this information is presented in the section on Principles and Terminology. In the Explanation of Format and Methods the structure and components of each section of the guide are described along with the methodology used to obtain and present the information contained in them. Familiarity with this will aid greatly in the use and interpretation of the guide.

The first impression one gains from examining a fish larva is important and sometimes may permit immediate identification. Its size, overall shape (also shape of head, eyes, body, and gut), stage of development, pigment pattern, and myomere count are basic features that should be noted. If fins are present, their shape and structure, location, and the number and arrangement of spinous and soft rays within them are important characters. The presence of early-forming ("precocious") fins is an important identifying characteristic. Also, other prominent features such as head spines, barbels, and markedly elongate or ornamented fin rays are important. With this information one should be able to identify the specimen to order by matching the characteristics of the specimen with the ordinal characters summarized in Introduction Table 2. To determine the family, one should compare the total myomere count of the specimen with the range of total vertebral counts for families present in the California Current region (Introduction Table 3). If the larva has fins, the ray counts for dorsal and anal fins can be compared with the ranges for families in the region (Introduction Tables 4 and 5). Next, the overall shape and the shape of major structures should be compared with those on the outline illustrations of typical mid-stage larvae of each family in the CalCOFI area (Figure Introduction 7). This procedure should identify the family of the specimen, or at least several possible families. The identification can then be carried further by consulting the information in the introductory accounts of the order and family(ies). If this information is consistent with the preliminary identification, the table of meristics for the family may narrow the possible species identification before one consults the descriptive accounts and illustrations for individual species. This procedure should permit identification of most larvae of the CalCOFI region, for which descriptions exist.

Identification of eggs presents a more difficult challenge since they are known for far fewer species compared with larvae. During the initial examination of a specimen, the following structural characteristics should be noted: egg size; shape; nature of the shell surface; color of the shell; presence or absence of inner membranes; width of the perivitelline space; the nature of the yolk and, if segmented, the type of segmentation; and the number, size, location, and arrangement of oil globules. Among the characters that should be note in late-stage eggs are: state of development at blastopore closure; state of development of the eyes, mouth, fins, finfold, gut, and myomeres of late-stage embryos. Also, the sequence of appearance of pigment on the yolk, oil globule, and embryo are important features for identification. These characters can be compared with those in the ordinal summary of egg characters (Introduction Table 2) and with the brief summaries in the introductions to orders and families. If the identification can be narrowed down to family, a browsing of the species accounts may reveal its identity.

Other sources may be helpful in confirming egg and larval identifications made with the aid of this identification guide. Matarese et al. (1989) includes species from the northern boundary of the CalCOFI area not treated in this guide. Often, juveniles can be identified by using the keys and descriptions in Miller and Lea (1972) and Eschmeyer et al. (1983). Martin and Drewry (1978; and other volumes in the series), Leis and Rennis (1983), Moser et al. (1984b), Ozawa (1986g), Okiyama (1988a), and Leis and Trnski (1989) present much information on identification of early life history stages, although most of the species that they cover do not occur in the CalCOFI region.

Table Introduction 2. Characters useful for the identification of early stages of fishes, listed by order or suborder. Information from Ahlstrom and Moser (1976), Fahay (1983), Leis and Trnski (1989), Matarese et al. (1989), and from authors of chapters in this guide.

Character	Elopiformes/ Albuliformes	Notacanthiformes	Anguilliformes	Saccopharyngiformes	Clupeiformes
Eggs	Undescribed	Undescribed		Undescribed	
Planktonic or Demersal			P		P; rarely D
Shape			Round		Round to oval
Shell surface			Smooth		Smooth
Yolk			Segmented		Segmented
Perivitelline space			Wide		Narrow to wide
Oil globules			0,1, or more		0, 1 to many
Larvae					
Body shape	Leptocephalus; forked tail	Leptocephalus	Leptocephalus	Leptocephalus	Elongate, slender
Preanal length (% BL)	Elopiformes, 75–80; Albuliformes, 90–95	>95	40–95	50–80	48–95
Gut type	Straight	Straight; looped in some	Straight; some with loops; rarely trailing	Straight, with 1 or more loops	Straight
Eyes	Round to oval	Round to oval	Round to oval; choroid tissue in some; some telescopic	Round to oval	Round to slightly oval
Head spines	No	No	No	No	No
Vertebrae	Elopiformes, 51–82; Albuliformes, 65–92	225–330	97–400+ (most 100–250)	68–250	39–76
Early forming fins	No	No	No	No	No
Transformation	Marked; shrinkage & growth	Marked; shrinkage & growth	Marked; shrinkage & growth	Marked; shrinkage & growth	Marked; D, A, & P_2 migrate
Special pelagic juveniles	No	No	No	No	No
Type of fin elements	Rays	Spines & rays	Rays	Rays	Rays
Pectoral fin formation	Late	Late	Late	Late	Late
Pelvic fin formation	Late	Late	Absent	Absent	Late
Pelvic fin position	Abdominal	Abdominal	Absent	Absent	Abdominal
Pelvic fin formula	Elopiformes, 10–16; Albuliformes, 9–11	Var., 7–11; some with spines	Absent	Absent	Var., usually 7–10
Dorsal fin	1 fin	1 fin	1 fin	1 fin	1 fin
Anal fin	1 fin	1 fin	1 fin	1 fin	1 fin
Adipose fin	No	No	No	No	No
Principal caudal fin rays	19 (10+9)	Reduced or absent	Usually 5–11; absent in some	0–4; absent in some	19 (10+9)

Table Introduction 2. Continued.

Character	Salmonoidei	Argentinoidei	Stomiiformes	Aulopiformes	Myctophiformes
Eggs					
Planktonic or Demersal	D	P	P	P	P
Shape	Round to oval	Round	Round	Round	Round
Shell surface	Smooth; attachment disc in some	Smooth; pustulate chorion in many	Smooth (most); some double membrane; some with facets	Smooth (most); hexagonal pattern in synodontids	Smooth
Yolk	Segmented	Segmented	Segmented	Homogeneous or segmented	Segmented
Perivitelline space	Narrow	Narrow	Wide to narrow	Narrow	Narrow
Oil globules	0 to many	1 to many	0 or 1	0 or 1	1
Larvae					
Body shape	Elongate, slender	Elongate & slender; some stout	Elongate; some compressed	Var., elongate to moderately stout	Var., elongate to moderately stout
Preanal length (% BL)	60–80	70–95	30–95	20–80	40–70
Gut type	Straight	Straight; folded or saccular in some	Straight; trailing & ornamented in some	Straight; saccular in some	Straight; var. shapes; trailing in 1 species
Eyes	Round to oval	Round to oval, sometimes stalked	Round to very narrow; stalked in *Idiacanthus*	Round to very narrow; choroid tissue in some	Round to very narrow; choroid tissue in some; stalked in some
Head spines	None	None	None	Usually none	Usually none
Vertebrae	42–74	40–85	30–100+	45–120 (most 45–65)	28–45
Early forming fins	No	No	P_1 in *Ichthyococcus*	D & P_1 in some	P_1 & P_2 in some
Transformation	Marked in osmerids; gradual in alepocephalids	Marked	Marked; photophore formation prolonged in some	Var.; marked , prolonged, or delayed	Marked
Special pelagic juveniles	No	No	No	Present in some	No
Type of fin elements	Rays	Rays	Rays	Rays	Rays
Pectoral fin formation	Late in osmerids	Late; elongate in some	Late in most; elongate in *Ichthyococcus*	Var.; early & elongate in some	Var.; early & elongate in some
Pelvic fin formation	Late in osmerids	Usually late; elongate in some	Late	Var.; early & elongate in some	Var.; early & elongate in some
Pelvic fin position	Abdominal	Abdominal	Abdominal	Abdominal	Abdominal
Pelvic fin formula	5–11	Var., usually 8–12	Var., usually 5–8; up to 26 in *Bathophilus*	Var., usually 7–11	Var., usually 8–10
Dorsal fin	1 fin	1 fin	1 fin	1 fin; elongate rays in some	1 fin
Anal fin	1 fin	1 fin	1 fin	1 fin	1 fin
Adipose fin	Present in osmerids	Usually present	Often present	Usually present	Usually present
Principal caudal fin rays	19 (10+9)	19 (10+9)	19 (10+9)	19 (10+9)	19 (10+9)

Table Introduction 2. Continued.

Character	Gadiformes	Ophidiiformes	Batrachoidiformes	Lophiiformes	Gobiesociformes
Eggs					
Planktonic or Demersal	P; rarely D	P; some live-bearers	D; nests in some	P; often in rafts	D
Shape	Round	Round to slightly oval	Round	Round to slightly oval	Round or var. shapes
Shell surface	Usually smooth; hexagonal pattern in some macrurids	Smooth	Smooth	Smooth	Smooth
Yolk	Homogeneous	Homogeneous	Homogeneous	Homogeneous; rarely segmented	Homogeneous
Perivitelline space	Narrow	Narrow	Narrow	Narrow	Narrow
Oil globules	0, 1, or more	0 or 1	0–several	0 or 1	1 to many
Larvae					
Body shape	Var., elongate to moderately stout	Elongate	Stout	Globular	Moderate to stout
Preanal length (% BL)	Usually <50	33–55	38–44	30–90; usually >75	50–85
Gut type	Usually coiled	Coiled	Coiled	Coiled, voluminous	Initially straight, later coiled
Eyes	Round	Round	Round	Round	Round to oval
Head spines	Usually none	Opercular spines in some	Opercular spines	Rarely	0 or 1 opercular spine
Vertebrae	44–66 in most; 80–116 in macrourids	40–150	30–58	18–31	21–54
Early forming fins	P_2 in some	P_1 in some; vexillum in carapids	Fins form in yolk-sac stage	Often D, P_1, P_2	No
Transformation	Gradual	Gradual	Gradual	Marked	Marked to gradual
Special pelagic juveniles	Present in some	Present in some	No	No	No
Type of fin elements	Rays	Rays	Spines & rays	Spines & rays	Rays
Pectoral fin formation	Late in some	Early in some	In yolk-sac stage	Late in most	Late
Pelvic fin formation	Early in some	Late	In yolk-sac stage	Often absent; early to late	Late
Pelvic fin position	Thoracic or jugular	Jugular	Jugular	Thoracic	Thoracic
Pelvic fin formula	Var., 2–8	0–2	I, 2–3	0 or I, 3–5	I, 4 or I, 5
Dorsal fin	1 to 3 fins	1 fin	2 fins	2 fins; anterior fin an illicium	1 fin
Anal fin	1 or 2 fins	1 fin	1 fin	1 fin	1 fin
Adipose fin	No	No	No	No	No
Principal caudal fin rays	Total rays 8–70; lacking in some	0–14	12–14	8–10	8–14

Table Introduction 2. Continued.

Character	Atheriniformes	Cyprinodontiformes	Beloniformes	Lampridiformes	Beryciformes
Eggs					
Planktonic or Demersal	D	D; many live-bearers	Var., P or D	P	P
Shape	Round	Round	Round to oval	Round	Round
Shell surface	Smooth or with filaments or other ornamentation	Usually ornamented; many with filaments	Smooth or with filaments or spines	Usually smooth; some with spinules	Smooth
Yolk	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
Perivitelline space	Narrow	Narrow	Narrow	Narrow	Narrow
Oil globules	Usually many	Many	Usually 0; some with many; often minute	0 to many	1
Larvae					
Body shape	Moderately elongate	Moderately stout	Moderately elongate to elongate	Usually elongate & compressed	Slender to stout
Preanal length (% BL)	20–50; increases with development	ca. 47–59	65–80	45–90	30–60
Gut type	Coiled	Coiled	Straight	Coiled	Coiled
Eyes	Round	Round	Round	Round	Round
Head spines	No	No	No	No	None to heavy
Vertebrae	21–55	24–54	36–97	33–200	Usually 23–33
Early forming fins	No	C (often before hatching)	C & often other fins (before hatching)	1 or more anterior D rays & P_2	Often P_2, D in some
Transformation	Gradual	Gradual	Gradual	Gradual	Usually gradual; marked in some
Special pelagic juveniles	No	No	No	Present in some	Present in some
Type of fin elements	Spines & rays	Rays	Rays	Rays	Spines & rays
Pectoral fin formation	Late	Var.; early in some	Late	Late	Intermediate
Pelvic fin formation	Late	Late	Late	Usually early; 1 or more elongate, usually heavily ornamented	Early in many
Pelvic fin position	Abdominal to thoracic	Abdominal	Abdominal	Abdominal to thoracic	Var., thoracic, abdominal, or jugular
Pelvic fin formula	I, 5	4–7, usually 6	6	0–17	Var.; usually I, 6 or I, 7; not I, 5
Dorsal fin	2 fins	1 fin	1 fin	1 fin; 1 or more anterior rays elongate & highly ornamented	1 or 2 fins
Anal fin	1 fin, 0–1 spines	1 fin	1 fin	0 or 1 fin	1 fin, usually 1–4 spines
Adipose fin	No	No	No	No	No
Principal caudal fin rays	17	11–18	15	3–32	19 (10+9)

Table Introduction 2. Continued.

Character	Syngnathiformes	Scorpaeniformes	Perciformes	Pleuronectiformes	Tetraodontiformes
Eggs					
Planktonic or Demersal	D; some brooded	D or P; some in rafts; some live-bearers	P or D	P; rarely D	P or D
Shape	Var., some round	Round or slightly oval	Var., round in most	Round	Round
Shell surface	Smooth	Smooth	Usually smooth	Usually smooth	Smooth or sculptured
Yolk	Homogeneous	Homogeneous	Homogeneous; rarely secondarily segmented; granular in blennioids	Homogeneous; rarely secondarily segmented	Homogeneous
Perivitelline space	Narrow	Narrow	Narrow	Usually narrow; rarely wide	Narrow to moderate
Oil globules	0 to many	0 to many	0, 1, or more	0, 1, to many	Many
Larvae					
Body shape	Var.; often elongate	Var.; usually stout	Var.; moderately elongate to stout	Var.; markedly compressed	Stout to globular
Preanal length (% BL)	45–90	35–60	20–80	Usually <40	40–90
Gut type	Usually straight	Coiled	Var.; coiled in most	Coiled; distended in some	Coiled; voluminous
Eyes	Round	Round	Usually round; some narrow; some with choroid tissue	Round	Round
Head spines	None to heavy; often on bony plates	Usually present; heavy in some	Var.; none to heavy	Present often; heavy in some	Rarely present
Vertebrae	19–87	25–65	20–100+ ; many 24–28	25–65	16–30
Early forming fins	None	None; P_1 can be large	1 or more in some; 1st D spine, P_2 spine & rays	Often; anterior D rays, 2 or 3 P_2 rays	Usually none; D spine, P_1 rays in some
Transformation	Gradual	Gradual	Usually gradual	Marked; eye migrates	Gradual
Special pelagic juveniles	Rarely	Often; e.g., scorpaenids	Present in some	Rarely; prolonged larval stage in many	No
Type of fin elements	Spines & rays	Spines & rays	Spines & rays	Rays; spines in 1 family	Spines & rays or rays only
Pectoral fin formation	Late	Var.; not late	Var.; not late; early in some	Late	Early in some
Pelvic fin formation	Often absent; late	Intermediate	Var., early in some	Early in some	Often absent; late
Pelvic fin position	Abdominal	Thoracic	Usually thoracic; some abdominal or jugular	Thoracic to jugular	Thoracic
Pelvic fin formula	0–6	I, 5 or fewer	I, 5 or fewer	Var., e.g., 6/6, 5/5, 0/4	0–I, 5
Dorsal fin	1 or 2 fins	1 or 2 fins	1 or 2 fins; 3 in tripterygiids	1 fin	1 or 2 fins
Anal fin	1 fin, 0–1 spine	1 fin, 0–3 spines	1 fin, usually 1–3 spines	1 fin	1 fin
Adipose fin	No	No	No	No	No
Principal caudal fin rays	0–15	Var., <17	Usually 17 (9+8); fewer in some	Var., usually 10–23 total rays	9–12

Table Introduction 3. Ranges of total vertebral counts for fish families in the CalCOFI region. Only species found in the region are included in the ranges. Vertebral counts for Macrouridae and Carapidae are given rarely in the literature and are not listed in this table. Counts of body rings are given instead of vertebrae for Syngnathidae. Counts furnished by authors of chapters in this guide.

18	Ostraciidae	24–29	Labridae
17–19	Molidae	24–36	Gobiesocidae
17–19	Tetraodontidae	25	Kuhliidae
18–19	Balistidae	25	Scaridae
18–19	Ogcocephalidae	25–26	Polyprionidae
19	Chaunacidae	25–27	Kyphosidae
19	Lophiidae	25–27	Triglidae
19	Antennariidae	25–28	Eleotridae
19–20	Linophrynidae	25–29	Anoplogastridae
19–21	Oneirodidae	25–30	Uranoscopidae
20	Melanocetidae	25–48	Cottidae
20	Ceratiidae	26	Cirrhitidae
20	Caulophrynidae	26	Haemulidae
20–23	Diodontidae	26	Howellidae
21	Callionymidae	26	Pomacentridae
21	Centrophrynidae	26	Xiphiidae
21	Monacanthidae	26–27	Holocentridae
21–22	Thaumatichthyidae	26–27	Malacanthidae
21–23	Gigantactinidae	26–30	Achiridae
22–23	Acanthuridae	26–38	Gobiidae
22–23	Luvaridae	26–41	Echeneidae
23	Priacanthidae	27–29	Diretmidae
23–24	Centriscidae	27–37	Cyprinodontidae
23–26	Carangidae	27–46	Myctophidae
23–31	Melamphaidae	28–30	Opistognathidae
23–31	Scorpaenidae	29–31	Giganturidae
24	Apogonidae	29–32	Neoscopelidae
24	Chaetodontidae	29–37	Stromateidae
24	Ephippidae	29–41	Sternoptychidae
24	Gerreidae	29–42	Zeidae
24	Istiophoridae	29–50	Blenniidae
24	Lobotidae	29–52	Agonidae
24	Lutjanidae	29–99	Gonostomatidae
24	Mugilidae	30–34	Coryphaenidae
24	Mullidae	30–41	Embiotocidae
24	Polynemidae	30–42	Nomeidae
24	Pomacanthidae	30–66	Scombridae
24	Nematistiidae	31–61	Gempylidae
24	Sparidae	32–40	Paralichthyidae
24	Sphyraenidae	32–47	Labrisomidae
24–25	Pentacerotidae	33–35	Psychrolutidae
24–26	Sciaenidae	33–43	Tripterygiidae
24–26	Serranidae	33–46	Chiasmodontidae
24–27	Rondeletiidae	33–83	Melanostomiidae

Table Introduction 3. Continued.

34–66	Pleuronectidae	48–54	Bregmacerotidae
34–83	Cyclopteridae	49–51	Cetomimidae
34–84	Opisthoproctidae	49–65	Bythitidae
35–40	Caristiidae	50	Stylephoridae
35–50	Microstomatidae	52–100	Paralepididae
35–60	Chaenopsidae	53–72	Osmeridae
35–72	Syngnathidae	54–58	Malacosteidae
36–63	Hexagrammidae	55–91	Ophidiidae
37–46	Bramidae	56–62	Chauliodontidae
37–54	Atherinidae	57–74	Ammodytidae
37–74	Alepocephalidae	58–61	Centrolophidae
38–41	Bothidae	61–62	Scytalinidae
38–47	Phosichthyidae	61–62	Zaproridae
38–48	Batrachoididae	62–69	Scomberesocidae
39–40	Oreosomatidae	62–99	Belonidae
39–47	Engraulidae	62–111	Trachipteridae
39–51	Exocoetidae	65–70	Icosteidae
39–52	Dactyloscopidae	68–74	Albulidae
39–55	Bathylagidae	69–74	Stomiidae
40–44	Barbourisiidae	70–80	Cyematidae
40–58	Clupeidae	71–85	Cryptacanthodidae
42–52	Platytroctidae	75–86	Fistulariidae
42–61	Notosudidae	75–127	Zoarcidae
43–83	Stichaeidae	78–82	Elopidae
44–47	Trichodontidae	79–80	Anotopteridae
44–55	Scopelarchidae	80–108	Pholidae
44–58	Moridae	81–85	Idiacanthidae
44–58	Tetragonuridae	84–158	Trichiuridae
45–56	Microdesmidae	97–125	Eurypharyngidae
45–66	Anoplopomatidae	101–175	Muraenidae
46	Lamprididae	105–120	Monognathidae
46–58	Astronesthidae	114–121	Radiicephalidae
46–61	Cynoglossidae	116–199	Congridae
47–49	Argentinidae	124–153	Lophotidae
47–52	Alepisauridae	126–136	Derichthyidae
47–52	Evermannellidae	143–151	Regalecidae
47–52	Leptochilichthyidae	144–162	Ophichthidae
47–55	Merlucciidae	151–153	Serrivomeridae
42–55	Mirapinnidae	175–220	Saccopharyngidae
47–58	Clinidae	177–203	Nemichthyidae
47–63	Synodontidae	221–251	Anarhichadidae
47–75	Hemiramphidae	223–258	Nettastomatidae
48	Aulopidae	225–255	Notacanthidae
48–51	Bathymasteridae		

Table Introduction 4. Ranges of total dorsal-fin ray counts (counts for spinous and soft rays combined) for fish families in the CalCOFI region. Fin formulas (spinous rays shown in bold type) are given after each family, except for families with single fins lacking spinous rays. Only species found in the region are included in the ranges. Macrourids have 2 spinous rays and 8–16 soft rays in the first dorsal fin; counts for the second dorsal fin are not available since they are given rarely in the literature. The range for Carapidae is for total rays anterior to the 31st vertebra. Counts for Echeneidae do not include the laminae of the disc. Counts for finlets (Scomberesocidae, Carangidae, Gempylidae, Scombridae) are in parentheses. Counts furnished by authors of chapters in this guide.

0	Anotopteridae		12–25	Hemiramphidae	
3	Linophrynidae		12–37	Alepocephalidae	
3–5	Ceratiidae		13	Luvaridae	**13**
4–6	Ogcocephalidae		13–14	Callionymidae	**4**+9–10
4–7	Gigantactinidae		13–15	Lophiidae	**3**+**3–4**,7–8
4–20	Agonidae	**0–11**+4–9	13–16	Rondeletiidae	
5–7	Chauliodontidae		13–17	Melanocetidae	
5–8	Oneirodidae		13–18	Diodontidae	
5–16	Gobiesocidae		13–28	Gobiidae	**2–9**+**0–3**,8–19
6–7	Centrophrynidae		14	Chaunacidae	**3**+11
6–7	Thaumatichthyidae		14–15	Aulopidae	
6–10	Scopelarchidae		14–16	Sphyraenidae	**5**+**1**,8–10
6–11	Sternoptychidae		14–18	Eleotridae	**5–8**+**1**,8–9
6–14	Bathylagidae		14–20	Fistulariidae	
7–13	Paralepididae		14–21	Centriscidae	**4–8**+10–13
7–13	Tetraodontidae		14–22	Caulophrynidae	
8–11	Microstomatidae		14–34	Cottidae	**5–18**+8–30
8–13	Osmeridae		15–17	Antennariidae	**3**+12–14
8–21	Astronesthidae		15–17	Mullidae	**6–8**+**1**,8
9	Ostraciidae		15–18	Uranoscopidae	**0–5**,13–16
9–12	Notosudidae		15–20	Albulidae	
9–12	Scomberesocidae	9–12+(4–6)	15–20	Platytroctidae	
9–15	Cyprinodontidae		16–17	Apogonidae	**6**+**1**,9–10
9–15	Exocoetidae		16–19	Giganturidae	
9–16	Opisthoproctidae		16–20	Mirapinnidae	
9–18	Gonostomatidae		16–20	Stomiidae	
9–24	Myctophidae		17–19	Molidae	
10–13	Argentinidae		17–20	Anoplogastridae	
10–13	Evermannellidae		17–20	Gerreidae	**9**,8–11
10–17	Synodontidae		17–40	Echeneidae	
10–30	Melanostomiidae		17–48	Syngnathidae	
11–13	Neoscopelidae		18–19	Howellidae	**8**+**1**,9–10
11–15	Leptochilichthyidae		18–43	Scombridae	**8–27**+**0–3**, 9–10+(4–10)
11–16	Phosichthyidae		19	Kuhliidae	**10**,9
11–22	Clupeidae		19	Scaridae	**9**,10
11–27	Belonidae		19–22	Barbourisiidae	
11–37	Notacanthidae	**9–37**+0–2	19–43	Carapidae	
12–14	Mugilidae	**4**+**1**,7–9	20–23	Labridae	**0–2**+**7–12**,9–14
12–19	Engraulidae		20–23	Polynemidae	**8**+**1**,11–14
12–21	Melamphaidae	**2–3**,9–18	20–24	Priacanthidae	**10**,10–14
12–24	Atherinidae	**2–9**+**1**,8–14	20–27	Elopidae	

Table Introduction 4. Continued.

20–30	Scorpaenidae	**12–17**,8–17	36–43	Oreosomatidae	**6–7**,30–36
20–30	Triglidae	**9–12**+10–12	36–51	Clinidae	**31–38**,5–13
20–32	Serranidae	**1–11**,11–27	36–51	Monacanthidae	2,**34–49**
20–39	Embiotocidae	**6–18**,9–28	39–46	Centrolophidae	**3**,36–43
21–23	Cirrhitidae	**10**,11–13	41–51	Scytalinidae	
21–23	Polyprionidae	**11**+**1–2**,9–10	42–47	Bathymasteridae	**1–6**,37–45
21–25	Malacosteidae		42–50	Xiphiidae	**38–45**,4–5
21–25	Pentacerotidae	**13–15**,8–10	43–52	Stromateidae	**2–4**,41–49
21–26	Lutjanidae	**10–12**,11–15	43–59	Istiophoridae	**36–53**,6–7
21–37	Kyphosidae	**9–14**,11–27	43–78	Moridae	4–13+39–67
22–28	Opistognathidae	**10–11**,12–17	44–53	Bregmacerotidae	1+43–52
22–30	Pomacentridae	**11–13**,10–17	45–60	Microdesmidae	**15–19**,28–43
22–37	Tripterygiidae	**3–4**+**12–19**+7–14	46–57	Merlucciidae	**0–1**,10–13+36–44
22–45	Blenniidae	**7–13**,11–36	46–63	Ammodytidae	
22–78	Stichaeidae	**22–78**+0–43	48–52	Lamprididae	
23–26	Holocentridae	**11**,12–15	50–56	Icosteidae	
23–26	Sparidae	**12–13**,11–13	52–117	Pleuronectidae	
23–31	Haemulidae	**10–14**,12–18	52–66	Coryphaenidae	
24–38	Tetragonuridae	**14–21**,10–17	53–63	Achiridae	
24–48	Carangidae	**3–8**+**1**,17–39+(0–1)	54–57	Zaproridae	**54–57**
24–77	Gempylidae	**8–36**+**0–2**, 15–41+(0–7)	54–66	Idiacanthidae	
			60–77	Cryptacanthodidae	**73–77**
26–29	Lobotidae	**11–13**,15–16	60–102	Paralichthyidae	
26–29	Psychrolutidae	**7–9**+19–20	70–128	Zoarcidae	
26–30	Diretmidae	**1**,25–29	74–98	Pholidae	**74–98**
26–35	Caristiidae		75–102	Bothidae	
26–37	Balistidae	**3**,23–34	79–150	Trichiuridae	**3–46**,54–128
26–41	Labrisomidae	**0–4**+**17–33**,0–13	80–114	Cynoglossidae	
26–46	Nomeidae	**0–12**+**1–13**,15–32	82–116	Monognathidae	
26–51	Sciaenidae	**7–15**+**1–2**,18–41	85–229	Ophidiidae	
27–32	Ephippidae	**8**+**1**,18–23	85–93	Cyematidae	
27–42	Chiasmodontidae	**7–14**,18–29	95–115	Bythitidae	
27–51	Anoplopomatidae	**12–30**+15–21	115–122	Stylephoridae	
28–54	Hexagrammidae	**15–28**,11–30	120–197	Trachipteridae	
28–59	Chaenopsidae	**18–46**,0–38	145–148	Serrivomeridae	
28–78	Cyclopteridae		152–160	Radiicephalidae	
29–35	Malacanthidae	**7–10**,22–27	155–196	Eurypharyngidae	
29–37	Chaetodontidae	**11–13**,18–25	162–432	Nemichthyidae	
30–31	Cetomimidae		202–647	Congridae	
30–45	Alepisauridae		206–263	Lophotidae	
31–36	Pomacanthidae	**11–14**,17–25	218–250	Anarhichadidae	**218–250**
32–36	Trichodontidae	**14–16**+18–20	224–285	Saccopharyngidae	
32–50	Acanthuridae	**7–9**,22–43	226–262	Derichthyidae	
32–55	Bramidae		258–344	Ophichthidae	
33–36	Zeidae	**8–9**,25–27	260–412	Regalecidae	
33–41	Batrachoididae	**2**+31–39	367	Muraenidae	
33–50	Dactyloscopidae	**7–22**,18–36	370–382	Nettastomatidae	
34–37	Nematistiidae	**7–8**+**1**,26–28			

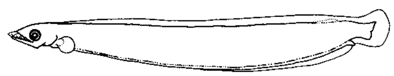
Table Introduction 5. Ranges of total anal-fin ray counts (counts for spinous and soft rays combined) for fish families in the CalCOFI region. Fin formulas (spinous rays shown in bold type) are given after each family, except for families with single fins lacking spinous rays. Only species found in the region are included in the ranges. Counts for Macrouridae are given rarely in the literature and are not listed here. Counts for Carapidae are for total rays anterior to the 31st vertebrae. Counts for finlets (Scomberesocidae, Carangidae, Gempylidae, Scombridae) are in parentheses. Counts furnished by authors of chapters in this guide.

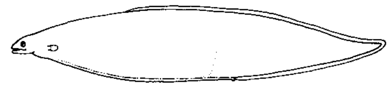
0	Regalecidae	
0	Trachipteridae	
2–5	Syngnathidae	
3	Linophrynidae	
3–5	Melanocetidae	
4	Ceratiidae	
4	Ogcocephalidae	
4	Thaumatichthyidae	
4–6	Oneirodidae	
4–7	Gigantactinidae	
4–14	Agonidae	
5–6	Centrophrynidae	
5–6	Chaunacidae	
5–10	Albulidae	
5–15	Gobiesocidae	
5–20	Lophotidae	
6–7	Lophiidae	
6–7	Radiicephalidae	
6–12	Tetraodontidae	
6–14	Scorpaenidae	**3**,3–11
6–25	Cottidae	
7–9	Mullidae	**1–2**,6–7
7–10	Anoplogastridae	
7–11	Microstomatidae	
7–14	Exocoetidae	
7–19	Gobiidae	**0–3**,7–18
8–9	Antennariidae	
8–9	Callionymidae	
8–12	Melamphaidae	**1**,7–11
8–13	Cyprinodontidae	
8–14	Opisthoproctidae	
8–15	Synodontidae	
8–25	Sciaenidae	**1–2**,6–23
9–10	Cirrhitidae	**3**,6–7
9–10	Eleotridae	**1**,8–9
9–10	Ostraciidae	
9–11	Gerreidae	**3**,6–8
9–12	Sphyraenidae	**1–2**,8–10
9–12	Triglidae	**1**,8–11
9–14	Chauliodontidae	
9–14	Pentacerotidae	**3–5**,6–9
9–22	Serranidae	**0–3**,6–19
9–23	Scombridae	9–23+4–10
9–27	Clupeidae	
9–46	Melanostomiidae	
10	Apogonidae	**2**,8
10	Howellidae	**3**,7
10–12	Mugilidae	**2–3**,7–10
10–14	Lutjanidae	**3**,7–11
10–17	Haemulidae	**2–3**,10–14
10–17	Tetragonuridae	**1–2**,9–15
10–28	Bathylagidae	
11–12	Polyprionidae	**3**,8–9
11–13	Leptochilichthyidae	
11–14	Giganturidae	
11–15	Argentinidae	
11–18	Diodontidae	
11–24	Hemiramphidae	
11–26	Sternoptychidae	
11–27	Myctophidae	
11–37	Gempylidae	**1–3**+10–35+(0–7)
11–51	Alepocephalidae	
12	Scaridae	**3**,9
12–13	Aulopidae	
12–14	Neoscopelidae	
12–14	Psychrolutidae	
12–15	Scomberesocidae	12–15+(4–7)
12–16	Labridae	**3**,9–13
12–17	Holocentridae	**4**,8–13
12–17	Phosichthyidae	
12–17	Pomacentridae	**2**,10–15
12–18	Elopidae	
12–19	Caulophrynidae	
12–23	Osmeridae	
12–24	Kyphosidae	**3**,9–21
12–28	Astronesthidae	
13	Kuhliidae	**3**,10
13–14	Sparidae	**3**,10–11
13–14	Uranoscopidae	
13–15	Lobotidae	**3**,10–12
13–16	Rondeletiidae	
13–18	Alepisauridae	
13–18	Priacanthidae	**3**,10–15
14	Luvaridae	**14**

Table Introduction 5. Continued.

14-17	Anotopteridae		27	Cetomimidae	
14-17	Platytroctidae		27–29	Zeidae	
14–19	Fistulariidae		27–32	Centrolophidae	**3**,24–29
14–19	Molidae		27–32	Evermannellidae	
14–32	Blenniidae	**2**,12–30	27–38	Batrachoididae	
15–18	Barbourisiidae		28–34	Zaproridae	**4**,24–30
15–18	Mirapinnidae		28–38	Microdesmidae	
15–18	Polynemidae	**3**,12–15	28–43	Dactyloscopidae	**2**,26–41
15–20	Opistognathidae	**2–3**,13–17	28–43	Idiacanthidae	
15–20	Xiphiidae	**12–16**,3–4	28–52	Monacanthidae	
15–23	Caristiidae		28–56	Stichaeidae	**1–3**,26–55
15–28	Hexagrammidae	**0–4**,12–28	29–30	Trichodontidae	**1**,28–29
15–29	Belonidae		30–36	Oreosomatidae	
16–17	Stylephoridae		30–55	Pholidae	**1–2**,29–53
16–21	Notosudidae		33–35	Bathymasteridae	**1–2**,31–33
16–22	Stomiidae		33–42	Lamprididae	
16–26	Anoplopomatidae	**2–3**,14–23	34–44	Icosteidae	
16–34	Nomeidae	**1–3**,14–31	36–41	Scytalinidae	
16–38	Echeneidae		36–44	Merlucciidae	
16–72	Gonostomatidae		36–54	Carapidae	
17–20	Nematistiidae	**2–3**,15–17	36–76	Moridae	17–76+0–29
17–22	Chaetodontidae	**3**,14–19	37–47	Stromateidae	**2–3**,35–44
17–29	Scopelarchidae		38–102	Pleuronectidae	
17–30	Tripterygiidae	**2**,15–28	41–47	Achiridae	
17–33	Engraulidae		43–106	Trichiuridae	**1–2**,41–105
17–34	Carangidae	**1–2+1**,14–33+(0–1)	45–51	Cryptacanthodidae	**2–3**,43–49
18–19	Centriscidae		45–60	Bregmacerotidae	
18–23	Ephippidae	**2–3**+16–20	46–81	Paralichthyidae	
18–29	Labrisomidae	**1–2**,16–27	55–88	Monognathidae	
18–30	Chiasmodontidae	**0–1**,17–29	58–85	Bothidae	
19–25	Diretmidae	**1**,18–24	62–114	Zoarcidae	
19–27	Istiophoridae	**13–20**,6–7	62–181	Ophidiidae	
20–30	Balistidae		63–98	Cynoglossidae	
20–32	Atherinidae	**1**,19–31	72–86	Cyematidae	
20–38	Paralepididae		72–91	Bythitidae	
20–41	Chaenopsidae	**2**,18–39	118–147	Eurypharyngidae	
21–25	Pomacanthidae	**3**,18–22	118–201	Notacanthidae	**14–59**+104–142
21–28	Malacanthidae	**1–2**,20–26	139–460	Congridae	
21–38	Embiotocidae	**3**,18–35	143–152	Serrivomeridae	
21–73	Cyclopteridae		155–180	Derichthyidae	
22–32	Ammodytidae		170–372	Nemichthyidae	
22–37	Clinidae	**1–3**,21–35	180–234	Anarhichadidae	**0–1**,180–233
22–38	Acanthuridae	**3**,19–35	190–256	Ophichthidae	
23–31	Coryphaenidae		226	Muraenidae	
25–29	Malacosteidae		235–284	Saccopharyngidae	
25–43	Bramidae		283–317	Nettastomatidae	

Figure Introduction 7. Outline illustrations of representative larvae of families of fishes present in the CalCOFI survey area. Flexion stage larvae were illustrated if they were available. Original Illustrations prepared by W. Watson and R. C. Walker.


Elopidae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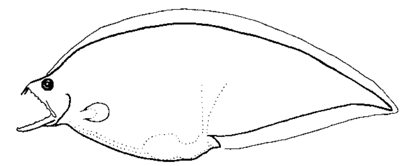
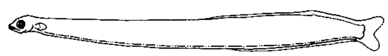
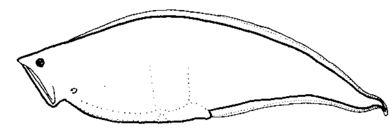

Saccopharyngidae


Albulidae


Nemichthyidae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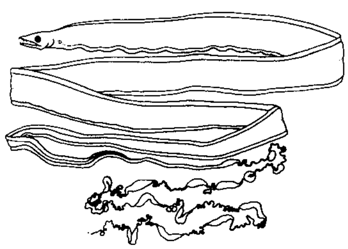
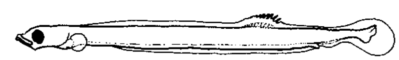

Notacanthidae


Nettastomatidae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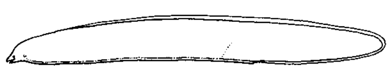
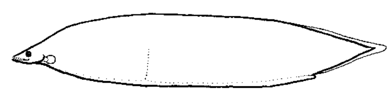
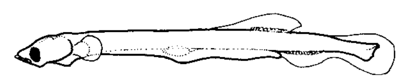
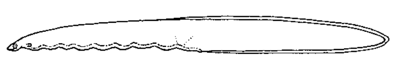
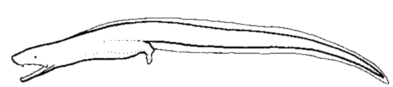

Muraenidae

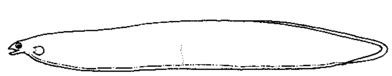

Serrivomeridae

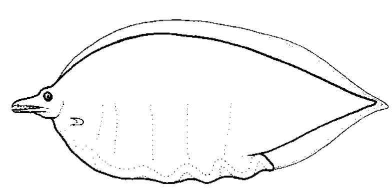

Engraulidae

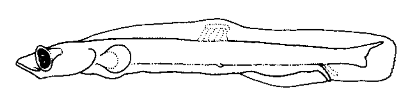

Ophichthidae

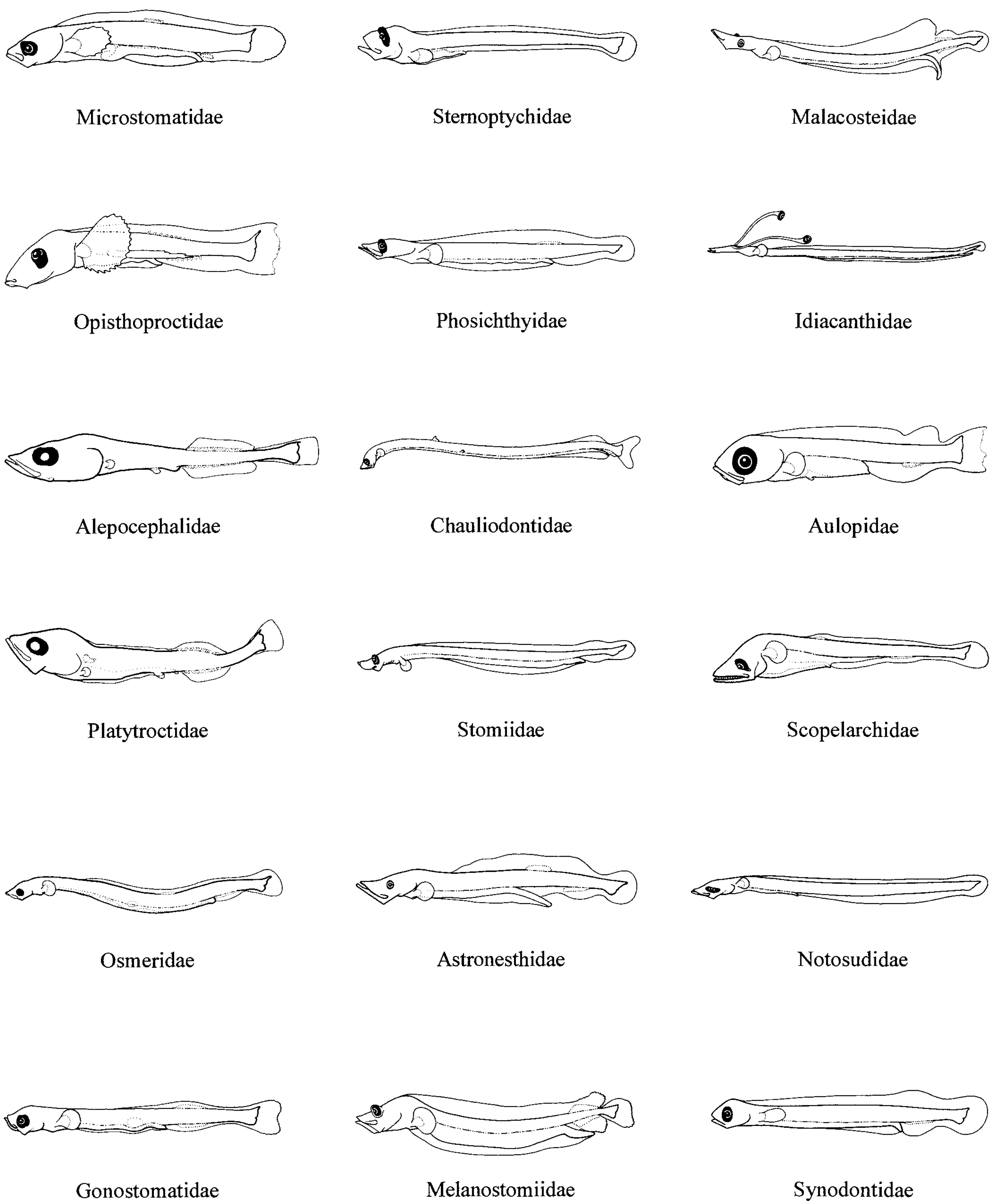

Monognathidae


Argentinidae


Congridae


Cyematidae


Bathylagidae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Opisthoproctidae
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Alepocephalidae
Chauliodontidae
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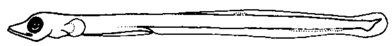
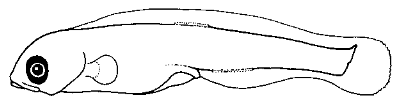
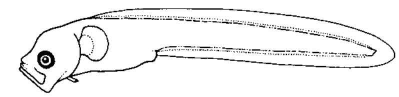
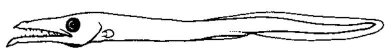
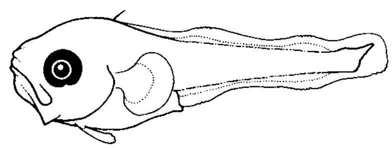
Platytroctidae
Stomiidae
Scopelarchidae
Osmeridae
Astronesthidae
Notosudidae
Gonostomatidae
Melanostomiidae
Synodontidae


Paralepididae

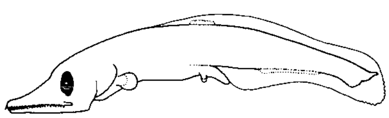

Myctophidae

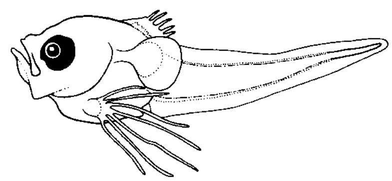

Ophidiidae

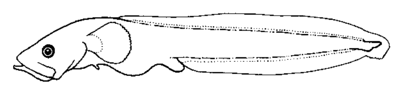

Anotopteridae

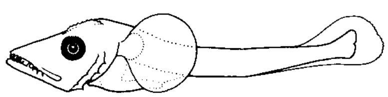

Bregmacerotidae

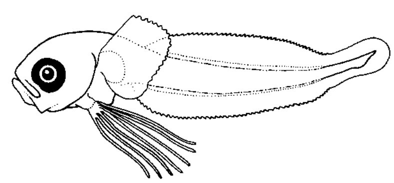

Carapidae

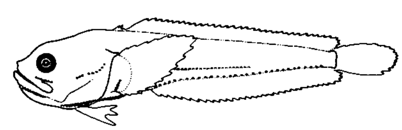

Evermannellidae

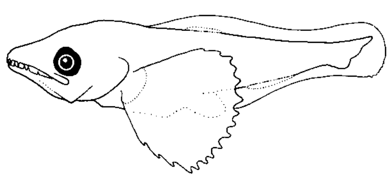

Macrouridae

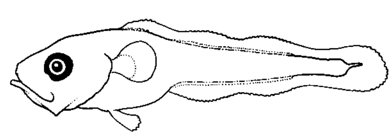

Bythitidae


Alepisauridae


Moridae


Batrachoididae


Neoscopelidae


Merlucciidae

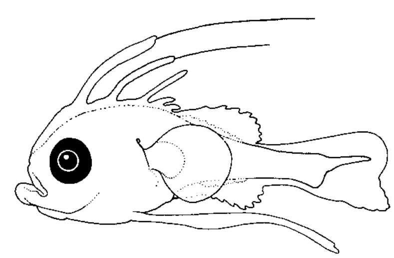
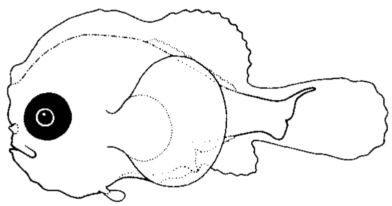
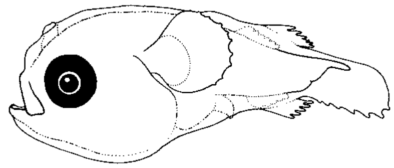
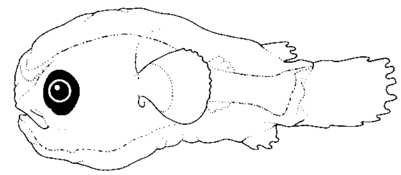
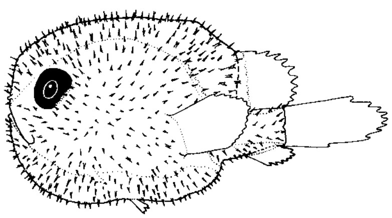

Lophiidae

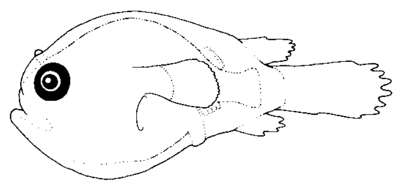
Figure Introduction 7. Continued.


Antennariidae

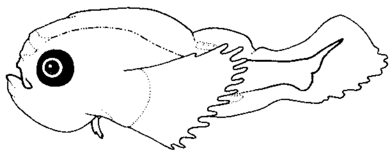

Oneirodidae

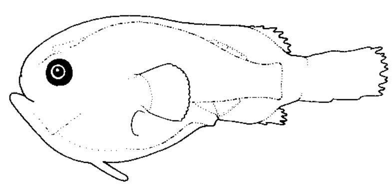

Linophrynidae


Chaunacidae

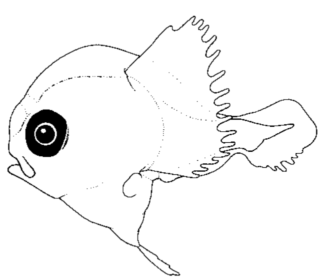

Thaumatichthyidae

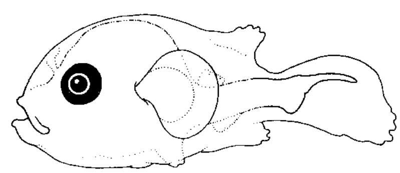

Gobiesocidae

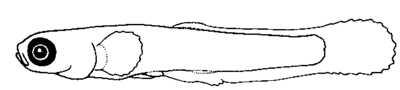

Ogcocephalidae

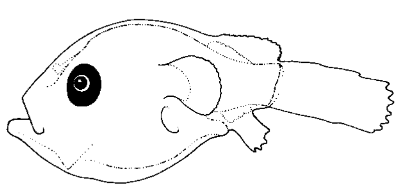

Centrophrynidae

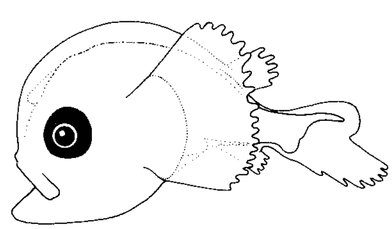

Atherinidae

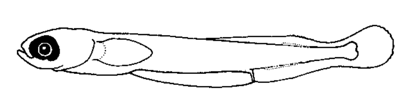

Caulophrynidae

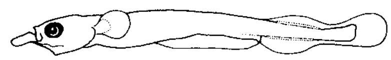

Ceratiidae


Cyprinodontidae

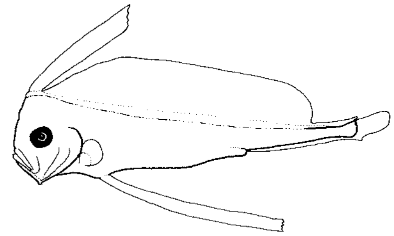

Melanocetidae


Gigantactinidae

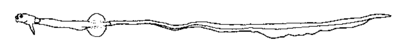

Scomberesocidae



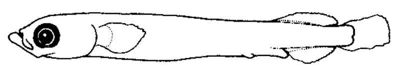
Belonidae



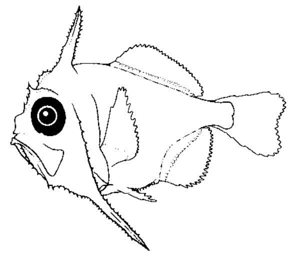
Trachipteridae



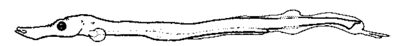
Mirapinnidae



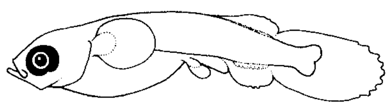
Hemiraphidae



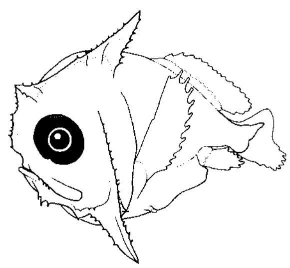
Diretmidae



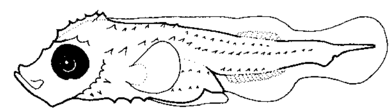
Fistulariidae



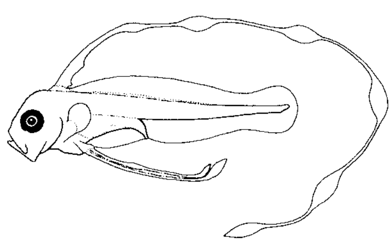
Exocoetidae



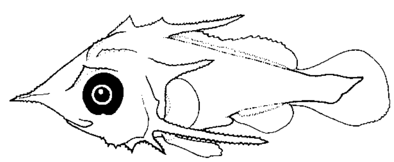
Anoplogastridae



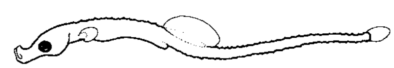
Centriscidae



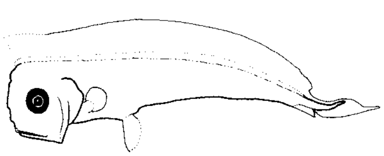
Lophotidae



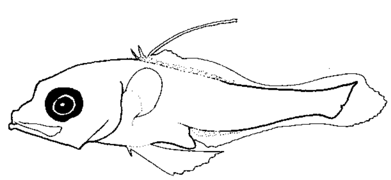
Holocentridae



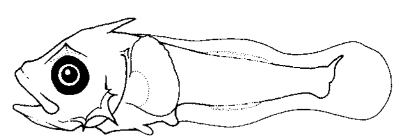
Syngnathidae



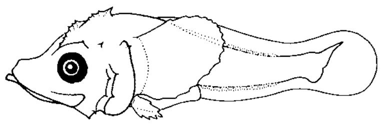
Radiicephalidae



Melamphaidae

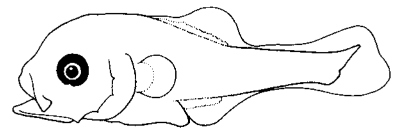


Scorpaenidae

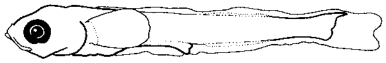


Triglidae

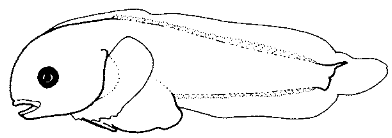
Agonidae



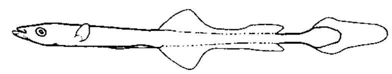
Apogonidae



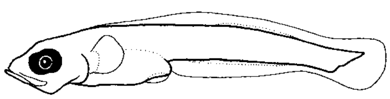
Anoplopomatidae



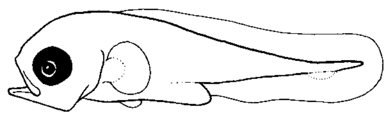
Cyclopteridae



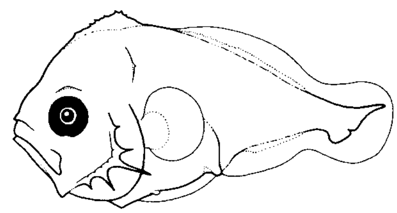
Echeneidae



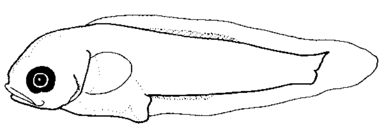
Hexagrammidae



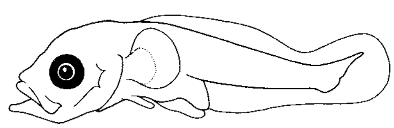
Polyprionidae



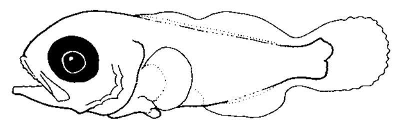
Carangidae



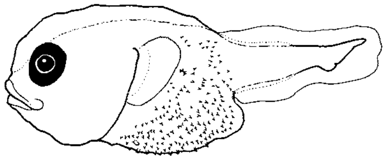
Cottidae



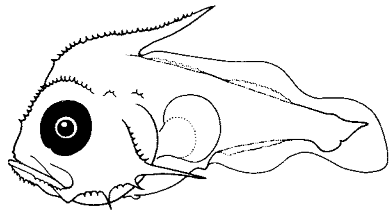
Serranidae



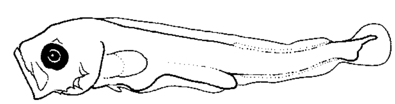
Nematistiidae



Psychrolutidae



Priacanthidae



Coryphaenidae

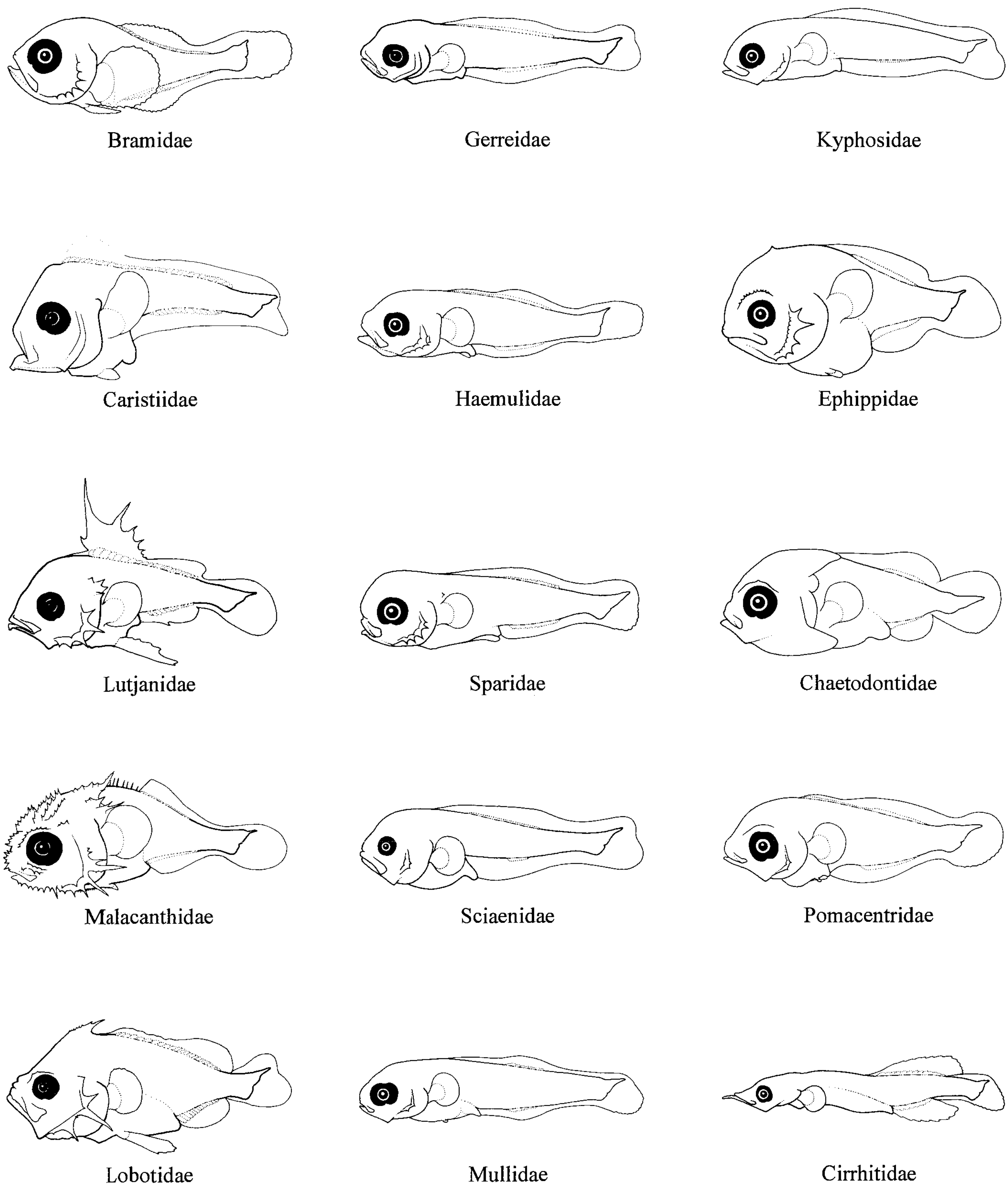

Bramidae
Gerreidae
Kyphosidae
Caristiidae
Haemulidae
Ephippidae
Lutjanidae
Sparidae
Chaetodontidae
Malacanthidae
Sciaenidae
Pomacentridae
Lobotidae
Mullidae
Cirrhitidae

Figure Introduction 7. Continued.

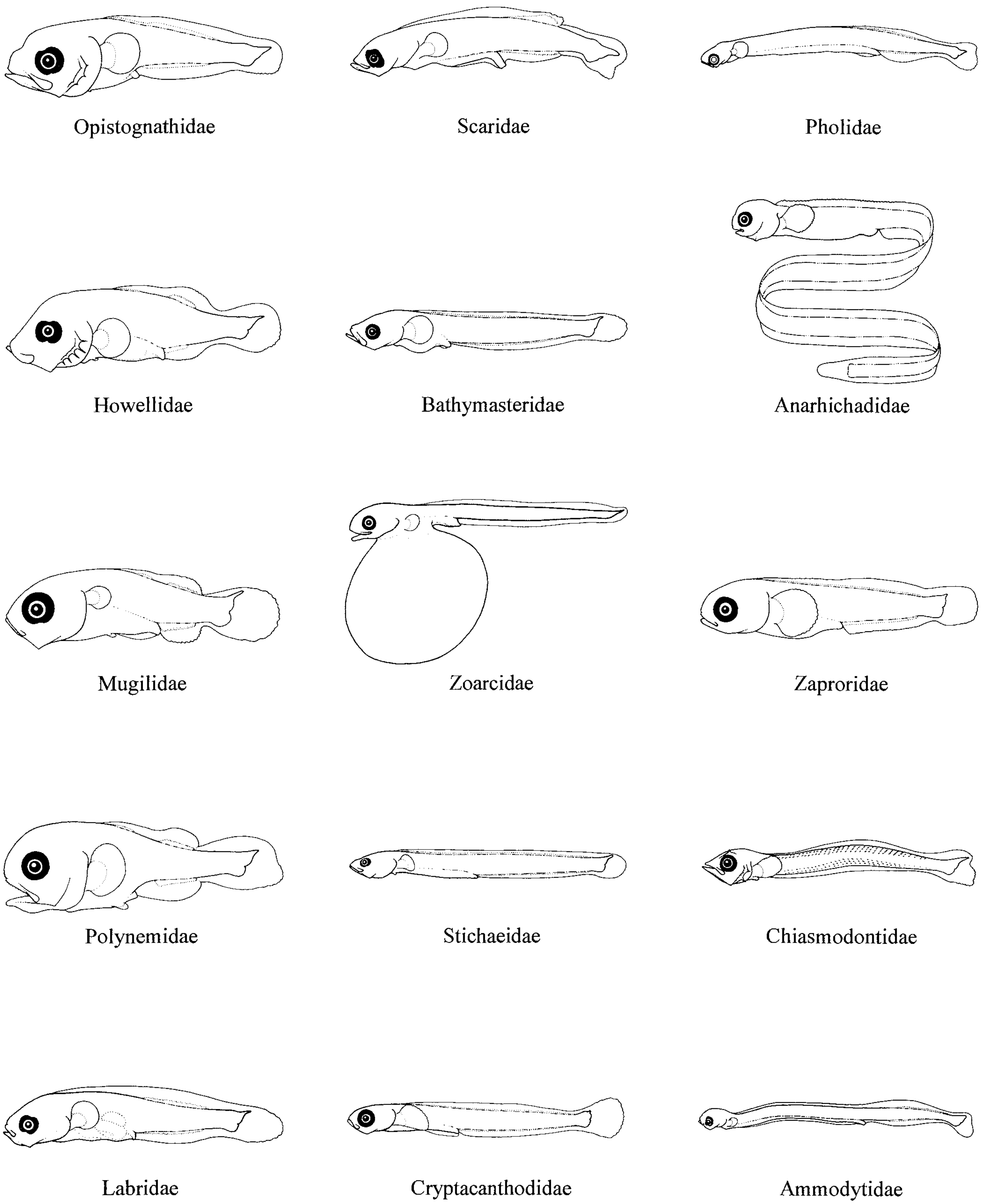
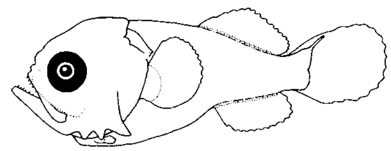
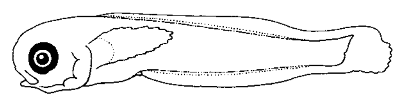


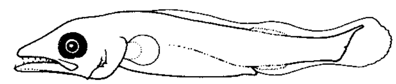
Figure Introduction 7. Continued.



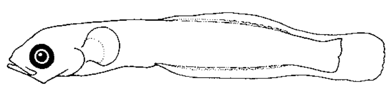
Uranoscopidae



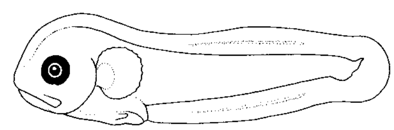
Blenniidae



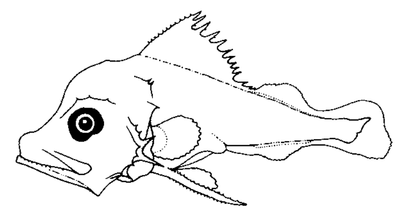
Sphyraenidae



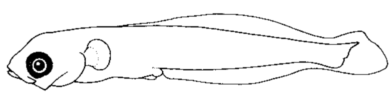
Tripterygiidae



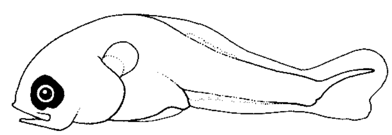
Icosteidae



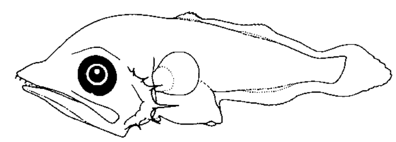
Gempylidae



Labrisomidae

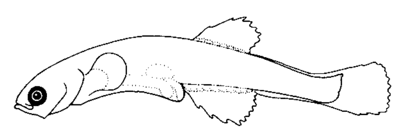


Callionymidae

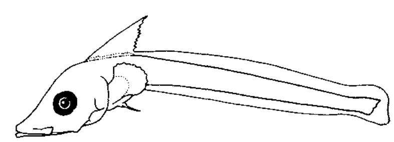


Scombridae

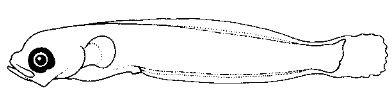
Clinidae



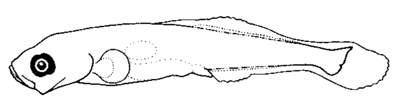
Eleotridae



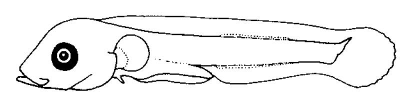
Trichiuridae



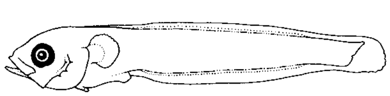
Chaenopsidae



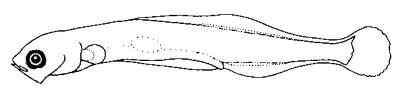
Gobiidae



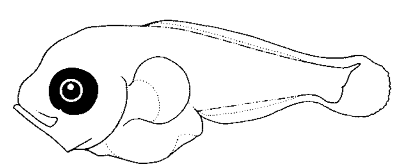
Centrolophidae



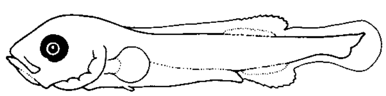
Dactyloscopidae



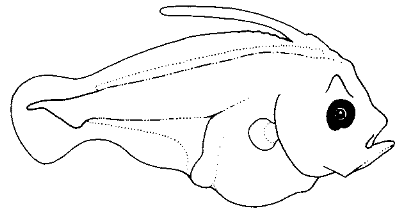
Microdesmidae



Nomeidae



Tetragonuridae



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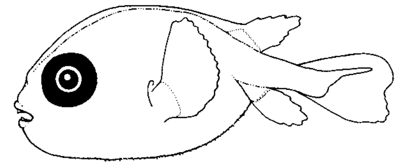

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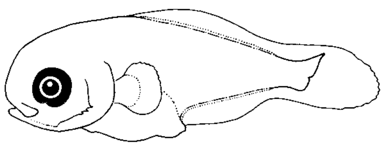

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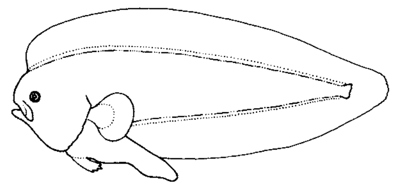
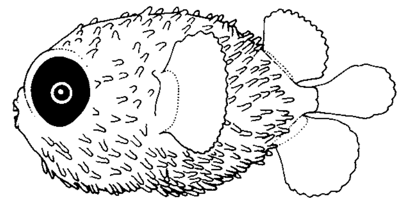
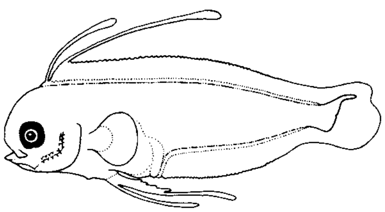


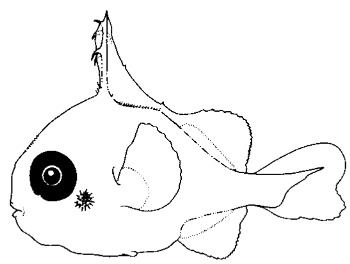
Cynoglossidae



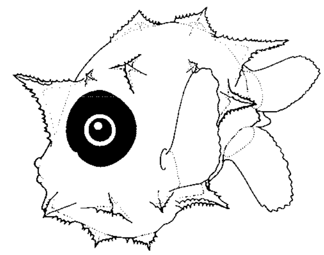
Diodontidae



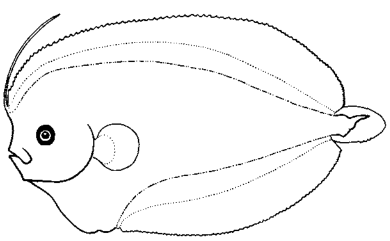
Paralichthyidae



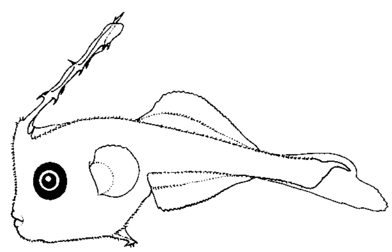
Balistidae



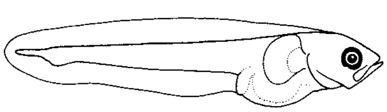
Molidae



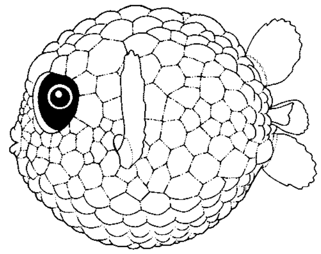
Bothidae



Monacanthidae



Pleuronectidae



Ostraciidae

DESCRIPTIONS

ELOPOMORPHA

S. R. Charter and H. G. Moser

Greenwood et al. (1966) grouped the orders Elopiformes, Anguilliformes, and Notacanthiformes together in the superorder Elopomorpha based on cranial osteology and the presence of a leptocephalus larva. In their classification, the Elopiformes includes two suborders: the Albuloidei, consisting of the Albulidae (bonefishes), and the Elopoidei composed of the Elopidae (ladyfishes) and the Megalopidae (tarpons).

Since Greenwood et al. (1966), much debate has surrounded elopomorph relationships, with some workers assigning ordinal status to the albulids (Nelson 1973a; Greenwood 1977; Eschmeyer 1990) and others listing them as a suborder (Patterson and Rosen 1977). Recent workers generally agree that albulids are more closely related to the anguilliforms and notacanthiforms than they are to elopids and megalopids. We follow Eschmeyer's (1990) classification in which the elopomorphs are divided into five orders, the Elopiformes, Albuliformes, Notacanthiformes, Anguilliformes, and Saccopharyngiformes. Elopiformes consists of the Elopidae, with one genus and six species, and Megalopidae, with one genus and two species, whereas Albuliformes consists of a single family, the Albulidae, with two genera and at least five species. Characteristics of Elopiformes and Albuliformes are summarized in the introductory sections for Elopidae and Albulidae. Notacanthiformes, Anguilliformes, and Saccopharyngiformes have separate introductory sections.

Orders included: Elopiformes
Albuliformes
Notacanthiformes
Anguilliformes
Saccopharyngiformes

ELOPIDAE: Tenpounders

S. R. CHARTER AND H. G. MOSER

The only elopid in the California Current region, *Elops affinis*, ranges from Ventura, California, to Peru (Regan 1909a; Whitehead 1962; Fitch and Schultz 1978; Eschmeyer et al. 1983). The adults are uncommon north of Bahía Magdalena, Baja California Sur, and larvae have not been collected in regular CalCOFI ichthyoplankton samples. Yolk-sac larvae and later-stage larvae occur in ichthyoplankton samples from the Gulf of California (pers. obs.) and south to Panama (Hildebrand 1963a).

The family Elopidae consists of six subtropical to tropical shallow-water species that may enter estuaries. They are prized by light-tackle anglers. *Elops affinis* may reach 4.5 kg and 91 cm (Miller and Lea 1972). Elopids may be recognized by a bony plate in the gular region, a terminal mouth with a large gape extending beyond the eye, and 23–35 branchiostegals (Hildebrand 1963a). The pectoral fins are low on the body and the pelvic fins are abdominal. All *Elops* species are slender bodied, with a bluish dorsum, silvery sides, and slightly yellowish ventral regions. The dorsal and anal fins lack filaments attached to the last rays (Hildebrand 1963a). *Elops affinis* and other species have a small dark spot at the lower jaw symphysis (Nybelin 1979). Also, *E. affinis* has a high gill raker count (16–20) (Regan 1909a; Hildebrand 1943; Whitehead 1962; Whitehead and Rodriguez-Sánchez 1995b).

Elopids are oviparous (Hildebrand 1963a); their eggs have not been described. Elopid leptocephali are small to moderate in length and moderate in depth (BD 5–12% BL). The head is depressed and the snout is relatively short. The origin of the anal fin is under the dorsal fin base or just behind it. Midlateral pigment is persistent from yolk-sac larvae (four postanal melanophores) through postflexion (vertical dashes between myomere segments). *Elops affinis* leptocephali have a lower myomere count (78–82) than any eel leptocephali except Cyematidae (72–120), and more myomeres than larval albulids (70–72). They also differ from albulid leptocephali in the relative positions of the dorsal and anal fins, presence of lateral pigmentation, and in having a vertical gas bladder. Elopid larvae transform at a smaller size (40–50 mm) than albulids (60–70 mm). *Elops* larvae resemble larval *Megalops* but have more myomeres than *Megalops* larvae (51–68). The head is depressed in *Elops* larvae but not in *Megalops*. *Elops* have more dorsal than anal fin rays while *Megalops* have more anal than dorsal fin rays (Richards 1984; Smith 1989m).

Hildebrand (1963a) reported captures of *E. affinis* leptocephali in February, August, and in the autumn along the Pacific coast of Panama. Our larvae were collected in February, June, and August, from the Gulf of California. Detailed examination of two yolk-sac (5.4, 5.8 mm), one flexion (12.3 mm), and four postflexion (16.9–33.6 mm) larvae provided the meristic and morphometric data for this description.

MERISTICS

	Range	Mode
Vertebrae:		
Total	78–82	80
Precaudal	52–54	54
Caudal	25–29	27
Fins:		
Dorsal spines	0	
Dorsal rays	20–27	
Anal spines	0	
Anal rays	12–18	
Pelvic	12–16	
Pectoral	17	17
Caudal:		
Principal	10+8–9	10+9
Procurrent:		
Upper	8	
Lower	8	
Gill rakers:		
Upper	10–12	
Lower	12–20	
Branchiostegals	23–35	

LIFE HISTORY

Range: Eastern Pacific from Ventura, California, to Peru; generally rare north of Baja California Sur

Habitat: Shallow inshore areas; in schools

Spawning season: Larvae collected in February, June & August

ELH pattern: Oviparous; planktonic eggs & leptocephali

LITERATURE

Hildebrand 1943, 1963a
Richards 1984
Smith 1989m

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.8 mm (N. Arthur)
Flexion larva, 12.3 mm (N. Arthur)
Postflexion larva, 16.9 mm (B. Sumida MacCall)
Head of 16.9 mm postflexion larva (B. Sumida MacCall)

* One yolk-sac larva with near-round eye intact; eye becomes slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <5.4 mm
Flexion length: <12.3 mm
Transformation length: >33.4 mm
Fin development sequence: P_1, C_1 & D, A, C_2 & P_2
Pigmentation: *Yolk-sac–preflexion*—Eye pigment not complete at 5.8 mm; 4 midlaterally starting at anus; scattered over anus; around notochord tip; dorsally on gut; on ventral margin of tail. *Flexion*—1 over eye & heart; midlaterally beginning at ca. 23% BL, ending over anus; less over anus; over notochord; on developing C rays & vertically along hypurals; dorsally on gut; on ventral margin of caudal peduncle. *Postflexion*—Increasing over eye to form a crescentic patch; enlarging over heart; midlaterally becoming vertical dashes between myomere segments; on dorsal surface of gut from throat, becoming horizontal dashes.
Diagnostic features: Leptocephalus; total myomeres ca. 79 (77–81); D & A overlap or nearly so; midlateral pigment; depressed head; forked tail; long gut; at transformation, body shrinks & thickens, becoming opaque; apparent forward movement of D & A.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	81–88 85		97	93–98 96		
BD/BL	11–12 12		7	5–7 6		
HL/BL	12–16 14		13	8–12 10		
HW/HL	64–67 66		54	51–55 52		
SnL/HL	31–37 34		34	34–34 34		
ED/HL	28*		20×22	14–18× 17–22 16×20		
P_1L/BL	3–3 3		3	2–4 3		
P_2L/BL	0–0 0		0	0–0 0		

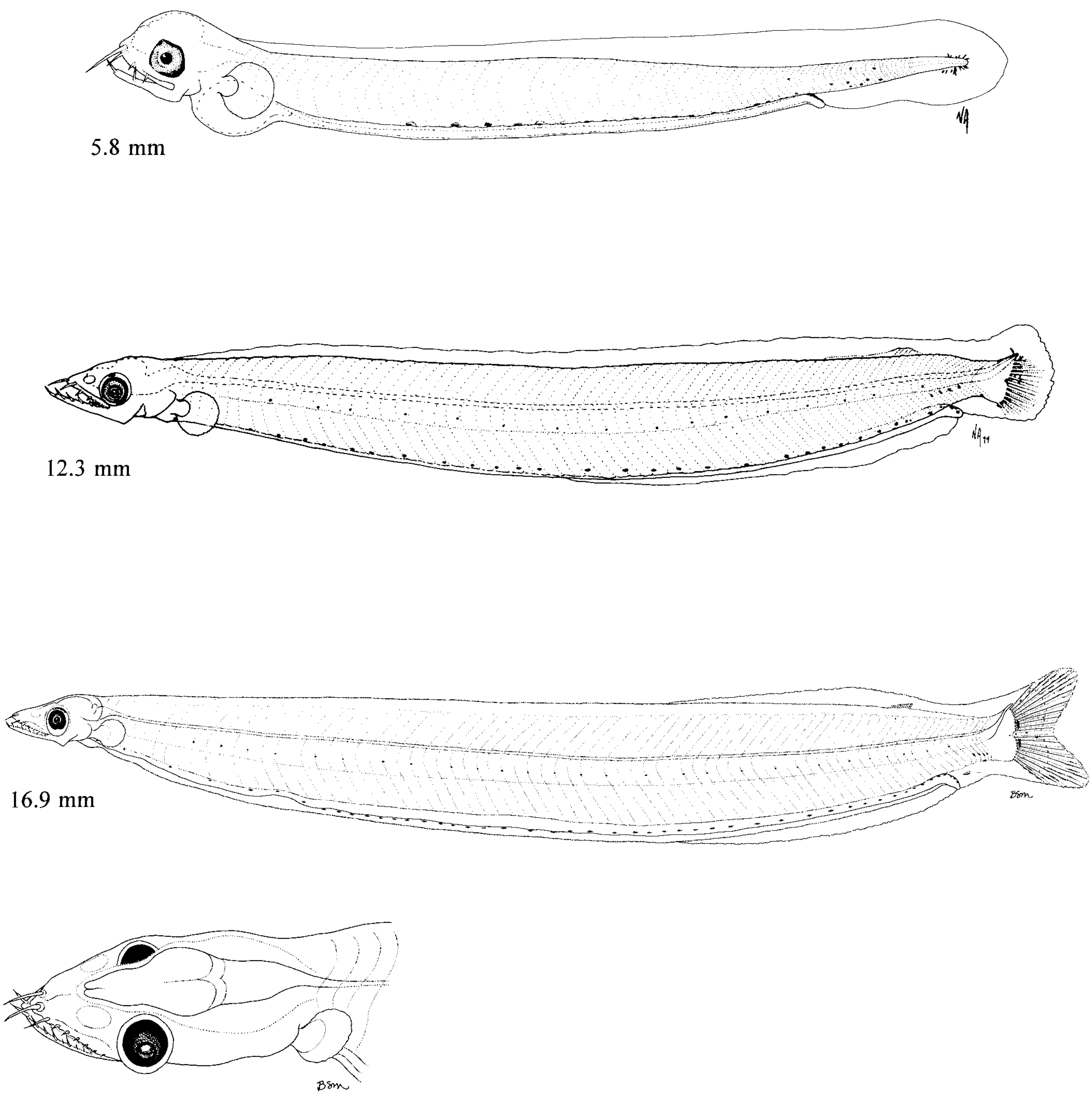


Figure Elopidae 1. Yolk-sac larva, 5.8 mm (CalCOFI 5607, station 145G.40); flexion larva, 12.3 mm (CalCOFI 5708, station 103G.70); postflexion larva, 16.9 mm, whole body and head (CalCOFI 5708, station 131G.94).

ALBULIDAE: Bonefishes

S. R. CHARTER AND H. G. MOSER

A single albulid species occurs in the CalCOFI survey area. Regional identification guides (Fitch and Lavenberg 1971; Miller and Lea 1972; Castro-Aguirre 1978; Eschmeyer et al. 1983) list this species as *Albula vulpes*; however, the discovery of two Hawaiian and Indo-West Pacific species of *Albula* through electrophoretic analysis (Shaklee and Tamaru 1981; Shaklee et al. 1982) brought into question the identity of the eastern Pacific species and the concept that *Albula vulpes* is a single circumtropical species. Pfeiler (1981) and Smith (1989m) suggested that the bonefish in our region, here referred to as *Albula* sp., is an undescribed species; this hypothesis is supported by electrophoretic evidence (Pfeiler 1996).

Bonefish inhabit nearshore tropical waters throughout the world and are a valuable recreational fish prized for their fighting ability. Bonefish in the CalCOFI area may reach ca. 46 cm and 0.8 kg (Miller and Lea 1972). They prefer shallow water with mud or sand bottoms. They are recognized by a conical snout that projects beyond the lower jaw, an inferior almost horizontal mouth ending before the eye, low pectoral fins, and abdominal pelvic fins. Coloration is grey-brown above the lateral line and silvery below.

Larval albulids are rare in CalCOFI collections from the Pacific coast of Baja California. Juveniles and adults occur as far north as San Francisco, California (Fitch 1950). There are 15 occurrences of *Albula* sp. larvae (5.7–53.5 mm) in CalCOFI samples in the nearshore region of southern Baja California between Punta Abreojos and Cabo San Lucas. No larvae have been collected off California or northern Baja California although transformation specimens and demersal juveniles as small as 18.6 mm have been collected from bays in southern California (pers. obs.). In contrast, *Albula* sp. larvae are common and widespread in the Gulf of California (Pfeiler 1984; Pfeiler et al. 1988). A single CalCOFI cruise in the Gulf of California in August 1957 yielded 574 larvae (3.2–48.2 mm) from all regions of the Gulf (pers. obs.).

Bonefish are oviparous and presumably have planktonic eggs, although they have not been described. Larvae as small as 3.2 mm, with unpigmented eyes, nonfunctional mouths and large yolk reserves have been collected in the Gulf of California. Albulids have leptocephalus larvae that can be distinguished from those of most eels by myomere count; albulids have <100 total myomeres while eel leptocephali have >100 (Smith 1979, 1989d; Richards 1984). Total myomere count in the saccopharyngiform family Cyematidae is <100 but their leptocephali are extremely deep-bodied and unique in other characteristics. The large forked caudal fin and distinctly separate anal and dorsal fins of mid- and late-stage albulid leptocephali distinguish them from anguilliform and notacanthiform leptocephali. Albulid leptocephali differ from larvae of elopids in gut length, position of the anal fin, and lateral pigmentation. In albulids the gut extends almost the entire length of the body and the origin of the anal fin is well behind the dorsal fin. In elopids the gut is relatively shorter and the anal fin origin is below the dorsal fin. Also, albulid larvae lack lateral melanophores present in elopids.

The larval series described by Alexander (1961) as *A. vulpes* is similar to a partial series (12 mm NL to 26 mm SL) of *Albula* sp. described by Pfeiler et al. (1988) from the Gulf of California. We assume that the complete larval series described herein is conspecific with the partial series of Pfeiler et al. (1988). We use 30 specimens (3.8–117.2 mm) from the Pacific coast and the Gulf of California in the following description.

MERISTICS

	Range	Mode
Vertebrae:		
Total	68–74	
Precaudal	52–65	
Caudal	5–16	
Fins:		
Dorsal spines	0	
Dorsal rays	3–20	16
Anal spines	0	
Anal rays	4–10	9
Pelvic	9–11	
Pectoral	15–18	
Caudal:		
Principal	8–11+9–12	11+11
Procurrent:		
Upper	4–9	
Lower	3–8	
Gill rakers:		
Upper	15–17	
Lower		
Branchiostegals	10–16	

LIFE HISTORY

Range: Eastern Pacific from San Francisco, California, throughout the Gulf of California, south to Panama

Habitat: Shallow tropical or subtropical waters, occasionally enters fresh or brackish water; on soft mud & sand flat bottom

Spawning season:

ELH pattern: Oviparous; planktonic leptocephali, found in shallow tide pools to 60 miles offshore; transformation specimens in shallow bay areas, around piers, settling to sand bottom; juveniles in shallow tide pools over hard sand & shell bottom

LITERATURE

Alexander 1961
Fitch 1950
Pfeiler 1984
Pfeiler et al. 1988
Richards 1984
Smith 1979, 1989d, 1989m

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.2 mm (B. Sumida MacCall)
Preflexion larva, 10.6 mm (B. Sumida MacCall)
Flexion larva, 23.6 mm (N. Arthur)
Postflexion larva, 33.4 mm (B. Sumida MacCall)
Transformation specimen, 34.2 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

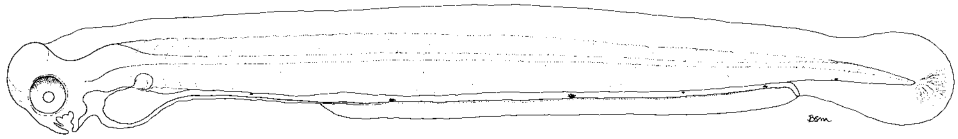
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

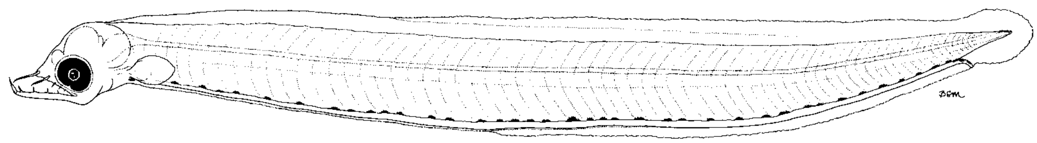
Hatching length: <3.2 mm
Flexion length: ca. 15.5 mm
Transformation length: ca. 71.0 mm
Fin development sequence: P_1, C_1, D, A, P_2, C_2
Pigmentation: *Yolk-sac*—4 along ventral edge of gut; 1 on yolk sac; on caudal finfold radiating from notochord. *Preflexion*—Paired rows of dashes along dorsal edge of gut from throat to anus; on caudal finfold by ca. 16 mm. *Postflexion*—A crescentic patch over eye by ca. 29 mm; initially dusky blotches mixed with yellow; becoming dusky silver. *Juvenile*—ca. 12 crossbands on back extending to lateral line; on snout & above eye; on D & C; by ca. 82 mm, grey-brown above lateral line, silvery white below, D & C yellowish-brown on margins.
Diagnostic features: Leptocephalus; total myomeres ca. 71 (70–72); gut longer than in elopiforms; no overlap of D & A; no lateral pigment; forked tail; at transformation, body shrinks & thickens; occurs at larger size than in elopids; apparent forward movement of D & A.

MORPHOMETRICS (range & mean in %)

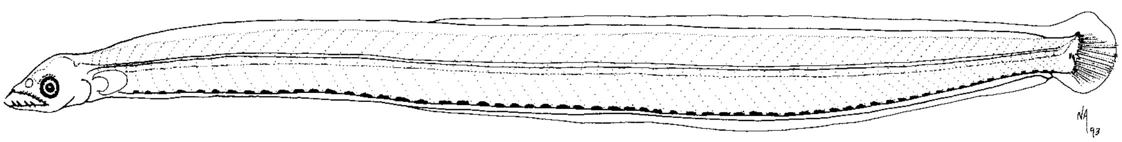
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	7–87 83	87–98 93	94–97 96	98–99 99	76–90 84	68–73 71
BD/BL	7–14 11	6–9 7	4–5 5	4–4 4	10–30 16	18–20 19
HL/BL	7–9 8	9–12 10	8–10 9	6–9 8	16–32 21	26–32 31
HW/HL	51–95 80	38–54 46	40–47 44	35–43 39	44–47 46	36–52 44
SnL/HL	25–33 30	17–29 22	25–32 28	29–36 33	27–30 29	34–40 37
ED/HL	49–58 53	25–34 29	24–26 25	21–26 23	23–26 24	21–27 24
P_1L/BL	0–1 0.3	2–4 3	2–3 3	2–3 2	6–16 9	15–32 20
P_2L/BL	0–0 0	0–0 0	0–0 0	0–1 0.1	5–14 8	14–28 17



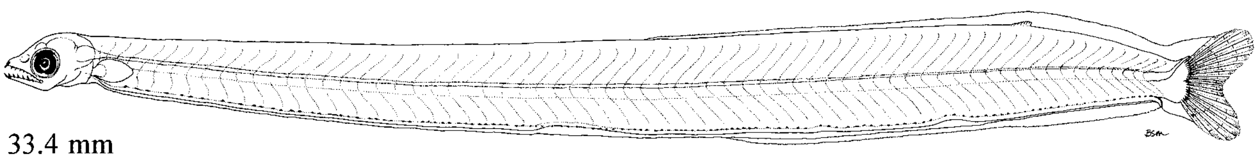
5.2 mm



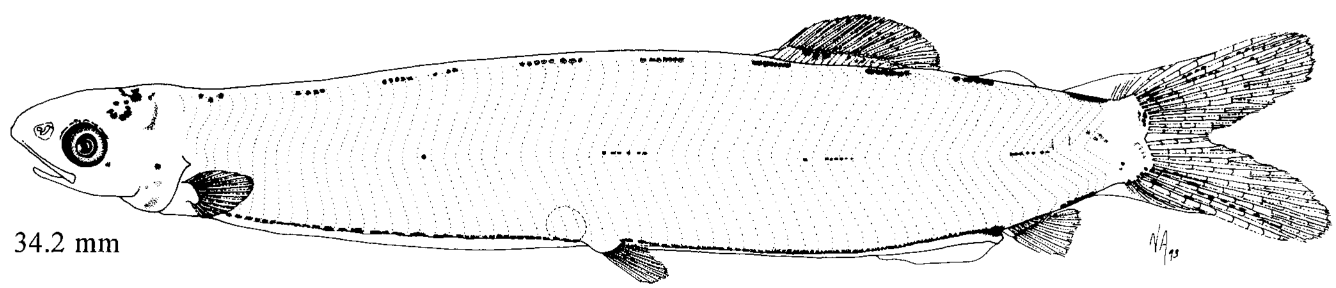
10.6 mm



23.6 mm



33.4 mm



34.2 mm

Figure Albulidae 1. Yolk-sac larva, 5.2 mm (CalCOFI 5708, station 105G.70); preflexion larva, 10.6 mm (CalCOFI 5708, station 129G.89); flexion larva, 23.6 mm; postflexion larva, 33.4 mm (CalCOFI 5708, station 131G.94); transformation specimen, 34.2 mm (SIO 68–168).

NOTACANTHIFORMES

H. G. MOSER AND S. R. CHARTER

Notacanthiforms are eel-like fishes recognized by the presence of a backwardly directed spine on the upper posterior margin of the maxilla, a projecting snout, abdominal pelvic fins connected by a membrane, pectoral fins high on the body, and tapering tail with a long anal fin ending posteriorly at a reduced caudal fin (caudal fin absent in some species). The eye is covered by a transparent membrane that is continous with the skin covering the head. McDowell (1973) reviewed the order and recognized 3 families, 6 genera, and 22 species. Their relationships with other elopomorphs are unsettled. Nelson (1973a) proposed that they are closest to albulids based on a similar arrangement of the mandibular sensory canal in the two groups, whereas Marshall (1962) suggested they are closer to anguilliforms based on similarities in the swim bladder.

The order Notacanthiformes is represented in the California Current region by two species in the family Notacanthidae. Notacanthids inhabit deep-shelf, continental slope, and abyssal regions throughout the world. Owing to their deep distribution, few captures of these fishes have been documented for the eastern North Pacific. The monotypic Lipogenyidae is known from the North Atlantic, New Zealand, and Japan (D. G. Smith, pers. comm.). Representative of the Halosauridae have not been reported from the California Current region although this may be a result of limited sampling in their deep continental slope to abyssal plain habitat.

Notacanthiforms have leptocephalus larvae that can reach a remarkably large size (1–2 m) and have numerous distinctive features, including a long straight gut that extends the entire length of the body, a short-based dorsal fin, late-developing pelvic fins, V-shaped myomeres, and a delicate caudal filament (Smith 1970, 1989l; Castle 1984). The caudal filament is broken off in all larvae described in the literature. The presence of pelvic fins, a compact dorsal fin, and V-shaped myomeres clearly separate notacanthiform leptocephali from those of Anguilliformes. Three types of notacanthiform leptocephali are recognized primarily by eye shape and relative snout length; however, none has been definitively assigned to a family (Smith 1970, 1989l; Castle 1984). One larval type, *Leptocephalus giganteus*, supposedly has a worldwide distribution although it is apparent that larvae from different regions vary in structure and pigment. We describe a fairly complete developmental series of specimens (18–560 mm) from the CalCOFI region.

NOTACANTHIDAE: Spinyeels

H. G. MOSER AND S. R. CHARTER

Adult notacanthids are represented in the CalCOFI region by two species, *Notacanthus chemnitzi* and *Polyacanthonotus challengeri*. Six specimens of *N. chemnitzi* have been recorded from central California to British Columbia at depths of 1100–1500 m (Peden 1976; Lea and Rosenblatt 1987) and four *P. challengeri* have been reported from Vancouver Island to Oregon at depths of 2100–2450 m (Peden 1968; Stein and Butler 1971). We examined three additional *N. chemnitzi* and one *P. challengeri* and include counts and measurements with those from the literature (Table Notacanthidae 1).

Adult notacanthids are small to medium-sized (up to ca. 125 cm but most species <50 cm) eel-like fishes with short, isolated dorsal spines and a long anal fin consisting of spines anteriorly that grade posteriorly to rays. The body and head are compressed and covered with small, cycloid scales. The mouth is small and inferior; teeth are small and arranged in a single comb-like row. The pelvic fins are abdominal and have one to several spines. The caudal fin is minute (McDowell 1973; Eschmeyer et al. 1983; Sulak 1986).

The notacanthiform leptocephalus series described herein appears to represent a single type, possibly a single species, whose characters are similar to those of *Leptocephalus giganteus* (e.g., Castle 1959, 1967, 1973; Nielsen and Larsen 1970; Tabeta 1970). One of our specimens has a relatively intact caudal filament, demonstrating the remarkable morphology and pigmentation of that structure, and the 18–22 mm specimens are the first early larvae of *L. giganteus* to be reported. All of our specimens ≥108 mm have a series of paired lateral gut pouches which appear to be similar to the "fleshy tubercles" observed by Tabeta (1970) on a 75 cm *L. giganteus* captured off Peru. They develop along the entire hindgut, initially as slight protrusions along the lateral gut wall. In our largest specimen (560 mm) they appear as hollow outpouchings of the gut and body wall that project ca. 0.5 mm beyond the lateral body contour. They may have a nutritional function by increasing the absorptive surface of the hindgut.

The presence of early stage *L. giganteus* larvae in the CalCOFI samples indicates local origin. No notacanthiforms are known to occur in the region except *N. chemnitzi* and *P. challengeri*. The southernmost record of *P. challengeri* is off Newport, Oregon, at ca. 45°28′ N while specimens of *N. chemnitzi* have been captured on several occasions off central California. The occurrence of early larval stages of *L. giganteus* in CalCOFI samples at localities ranging from Pt. Conception, California, to Punta Eugenia, Baja California, leads us to suspect that this form of *L. giganteus* may be the larva of *N. chemnitzi*. Other than *N. chemnitzi* and *P. challengeri*, the only notacanthiform reported from the CalCOFI survey area is a mutilated specimen (identification uncertain) of the halosaur *Halosaurus attenuatus* off central Baja California (Townsend and Nichols 1925). It is possible that the CalCOFI leptocephali are the larvae of halosaurs whose adults have not been collected; however, this is unlikely since larvae and transforming specimens of halosaurs (Mead 1965; Harrisson 1966; Smith 1989l) have characteristics different than from those of notacanthids (Merrett 1981; Smith 1989l).

A number of morphological features of *L. giganteus* match those of adult *N. chemnitzi*. The positions of the dorsal and pelvic fin anlagen in relation to myomeres in the larval form are similar to the positions of these fins in relation to vertebrae in the adult. The number of developing dorsal fin pterygiophores in *L. giganteus* is similar to the dorsal ray count in *N. chemnitzi*. The only major difference is in the number of larval myomeres and adult vertebrae. When countable, total myomeres in our larvae ranged from 330 to 350. The range in the literature is 300–486 (Smith 1989l). The range of vertebral number in *N. chemnitzi* from the northeast Pacific is 225–239 (Lea and Rosenblatt 1987; this study). This difference could be explained if vertebrae do not form in association with the myomeres in the posterior region of the larva. Myomeres in this region are minute and difficult to count. The last 100 myomeres occupy only about 10% of the body length and their coalescence or degeneration at transformation could produce a vertebral count much lower than the 1:1 ratio found in other fishes. However, loss of large numbers of myomeres at transformation seems unlikely, and we know of no documentation of this in other fishes. The few vertebral counts for notacanthiforms in the literature are <250 while myomere counts for other types of putative notacanthiform leptocephali (e.g., *Tiluropsis*) range from 229 to 331 (Smith 1989l). It is possible that the adult forms of *L. giganteus* have not been collected, although this seems unlikely given the worldwide distribution of the larvae. A comprehensive review of vertebral counts in existing notacanthiform specimens, including the frequency and degree of caudal regeneration, would provide valuable clues to the identification of their larvae.

The following description of *L. giganteus* is based on detailed examination of nine larvae of the following lengths: 18.4, 20.3, 22.0, 108, 191, 301, 311, 314, and 560 mm. Meristic data were obtained from several sources (Peden 1968, 1975; Stein and Butler 1971; Lea and Rosenblatt 1987) and from counts made during this study.

Table Notacanthidae 1. Meristic characters for the notacanthid species recorded from the California Current region. Vertebral counts are given as precaudal + caudal = total. The origins of the dorsal, anal, and pelvic fins are indicated by the sequential vertebral number at the point of origin.

Species	Vertebrae	Fin rays					D origin	A origin	P_2 origin
		D	A	P_1	P_2	C			
Notacanthus chemnitzi	54–58+171–183=225–239	IX–X,2	XIV–XVII,104–133	14–16	III–IV,6–7	5	41–48	42–55	38–47
Polyacanthonotus challengeri	55–58+187–197=242–255	XXXIII–XXXVII	XXXIX–LIX, 126–142	11–15	I+8–10	5	12	55	45

MERISTICS

	Range	Mode
Vertebrae:		
Total		
Precaudal		
Caudal		
Fins:		
Dorsal spines		
Dorsal rays		
Anal spines		
Anal rays		
Pelvic		
Pectoral		
Caudal:		
Principal		
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Apparently worldwide; in eastern Pacific from central California to Peru

Habitat: Adult notacanthids are demersal from deep-shelf to abyssal depths

Spawning season: Smallest larvae (18–22 mm) collected September–December in California Current

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Castle 1967, 1973, 1984
Nielsen & Larsen 1970
Smith 1970, 19891
Tabeta 1970

ORIGINAL ILLUSTRATIONS (Illustrator)

Early larva, 22.0 mm (M. T. Vona)
Head of 22.0 mm early larva (M. T. Vona)
Mid-stage larva, 314.0 mm (B. Sumida MacCall)
Head & body section of 314.0 mm mid-stage larva (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: Reduced C
Transformation length:
Fin development sequence: P_1, D, A, P_2, C
Pigmentation: Paired ventral blotches that increase in number throughout larval period, 9–11 in 18–22 mm larvae, ca. 35 at 108 mm, 75 at 191 mm, 104–122 at 301–314 mm, 340 at 560 mm; as blotches enlarge they fuse across ventral midline & extend dorsad to trunk, with new blotches added between larger ones; embedded median pair between gut & ventricle of heart; in large larvae an embedded pair develops above atrium of heart; leaflike, heavily pigmented, structures on caudal filament.
Diagnostic features: Leptocephalus body form with straight gut extending almost entire length of body; >300 myomeres; caudal filament (usually broken) has series of pigmented leaflike structures; short D with ca. 10 pterygiophores appears at ca. 100 mm; P_2 appears at ca. 300 mm; eye nearly round; hindgut with lateral outpouchings.

MORPHOMETRICS (range & mean in %)

	18–22 mm	108–314 mm	560 mm
Sn-A/BL*		99–99	
	87	99	99
BD/BL	5–5	2–3	
	5	3	2
HL/BL	8–9	3–4	
	9	3	2
HW/HL	30–44	23–42	
	35	29	21
SnL/HL	26–28	26–43	
	27	36	46
ED/HL†	20–25× 23–30	12–19× 13–22	
	23×27	15×17	11×12
P_1L/BL	0–0	0–0.03	
	0	0.02	0.02
P_2L/BL	0–0	0–0	bud
	0	0	

* No range given for 18–22 mm since gut was intact only in 22–mm larva.
† Eye is slightly elliptical in larvae <314 mm; horizontal axis is given first, vertical axis second.

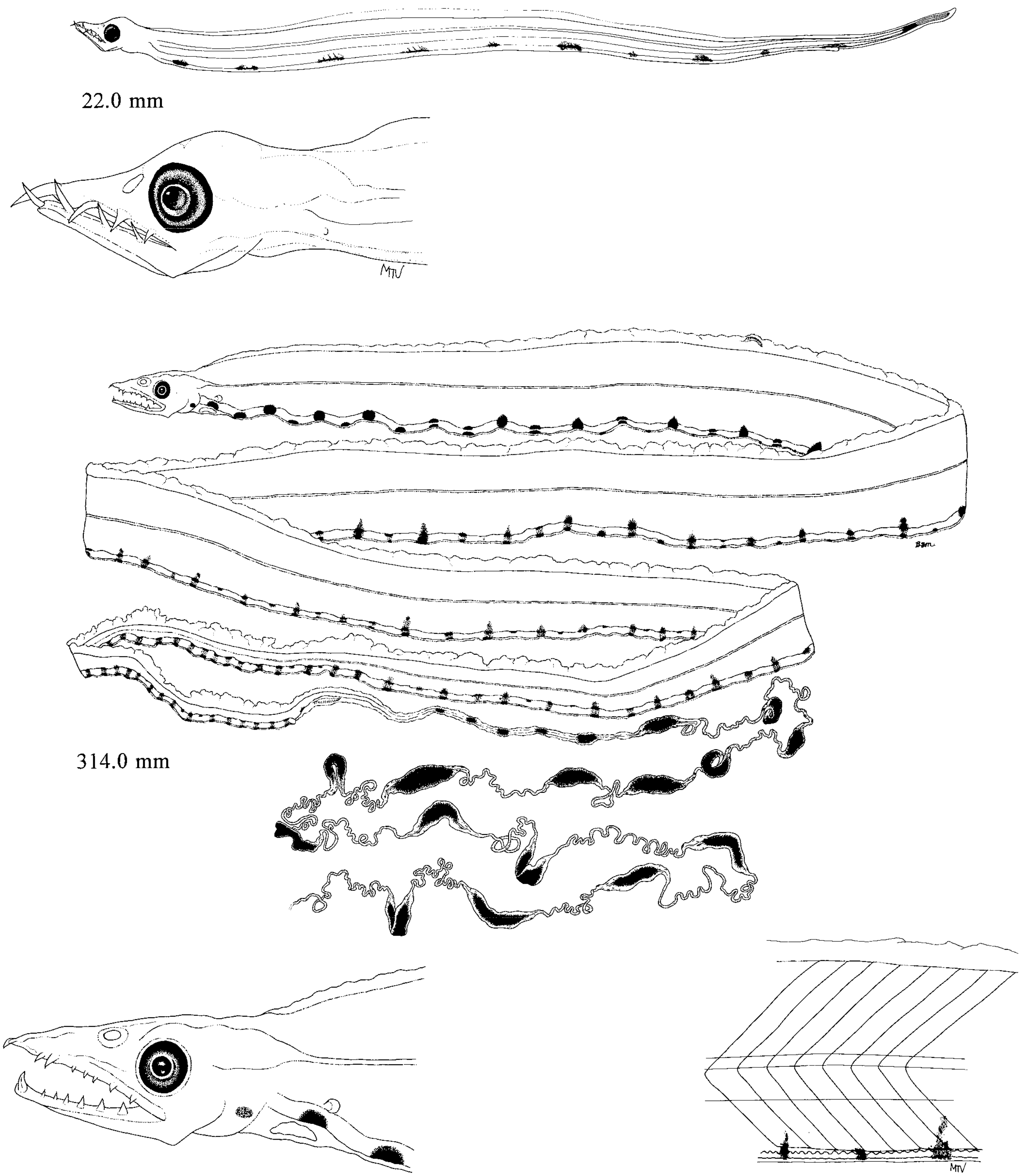


Figure Notacanthidae 1. Early larva, 22.0 mm, whole body and enlargement of head (CalCOFI 6612, station 120.55); mid-stage larva, 314.0 mm, whole body and enlargements of head and body section (hindgut region) (CalCOFI 8410, station 110.45).

ANGUILLIFORMES

S. R. CHARTER AND H. G. MOSER

Anguilliform eels comprise a large and diverse order of 15 families and ca. 600 species. They inhabit the benthic and midwater regions of all oceans and enter brackish and freshwater. Seven families with a total of 20 species, including one species not presently assigned to a family, have been identified in the California Current region.

Robins (1989) summarized the order and listed a total of 42 anguilliform characters, including: very elongate body and head with the gills extending well behind neurocranium, confluent vertical fins, no pelvic fins or girdle, pectoral fins high on the body or absent, leptocephalus larva, gill membranes united to the isthmus and gill openings reduced, nostrils widely separated in all but one family, scales absent or reduced and embedded, lack of pyloric caeca, and numerous osteological characters. Most of these characters represent losses or reductions and may be convergent; however, Robins (1989) argued that the large number of such characters, many not found in other elopomorphs, support anguilliform monophyly.

Apparently, all anguilliforms are oviparous, although spawning is known for only a few species. Eggs are planktonic, relatively large (3–4 mm in some species), have a wide perivitelline space and a segmented yolk (Eldred 1969). Like other elopomorphs they have a planktonic leptocephalus larva with a large transparent body filled with an acellular mucinous material, a small head, a tubular gut with loops or thickenings in some species, and a pectoral fin that may be lost at transformation. Anguilliform leptocephali have W-shaped myomeres, a rounded or pointed caudal fin confluent with the dorsal and anal fins, and lack pelvic fins. Larvae of other elopomorphs have the following characters: (1) elopiforms and albuliforms—W-shaped myomeres, a well developed forked caudal fin that is separate from short-based dorsal and anal fins, and pelvic fins present; (2) saccopharyngiforms—V-shaped myomeres, a pointed tail with confluent dorsal and anal fins, and no pelvic fins; and (3) notacanthiforms—V-shaped myomeres, short-based dorsal and long-based anal fins, an elongate caudal filament, pelvic fins present (Smith 1989d).

Anguilliform leptocephali have a diverse array of morphological and pigment characters that allowed early workers to describe species even though their adult stages were unknown. This resulted in a dual taxonomy of larvae and adults (Smith 1989d). This problem has been resolved largely by progress made during the past several decades in linking larval and adult stages of eels; almost all larvae can be identified to family and many to genus or species (Castle 1969, 1984; Smith 1984, 1989d; Raju 1985).

Developmental stages based on notochord flexion are not appropriate for eel leptocephali because of their markedly reduced caudal fin. Leiby (1979, 1989) divided pretransformation development into two stages. Engyodontic larvae have a few needle-like teeth, the lower jaw equal to or longer than the upper jaw, no nasal capsule, undifferentiated finfold, no hypurals, unflexed notochord, and head and preanal lengths relatively long with respect to total length. In the euryodontic stage the needle-like teeth are shed and replaced by three series of relatively shorter, broader teeth. Also, the lower jaw becomes shorter than the upper, a nasal capsule forms, fins differentiate, hypurals form, the notochord flexes, and head and preanal lengths become relatively smaller. Most CalCOFI anguilliform larvae are euryodontic; however, when engyodontic larvae were identified, the morphometric tables include both ontogenetic stages. In these tables, values for engyodontic larvae are listed under the smaller of two size ranges. Morphometric values were calculated for yolk-sac and transforming larvae when specimens were identified.

Methods of counting myomeres follow Leiby (1989). The first myomere may or may not reach the midline, but is still counted. Nephric myomeres are counted caudad along the midline to a vertical from the terminus of the nephros, most easily determined as the point where the last vertical blood vessel (LVBV) enters the kidney. Preanal and predorsal myomeres are counted to a vertical from the terminus of the anus and the origin of the dorsal fin, respectively. All of these counts are helpful in larval identification but total and nephric myomere counts are the most useful since they approximate total and precaudal vertebral counts in adults. The greatest body depth (GD) was usually measured at ca. 50% body length or at the vent. The predorsal length (PdL) was measured when the dorsal fin muscle bundles were formed, prior to attachment to developing pterygiophores (Leiby 1989).

Suborders and families included:
- Muraenoidei
  - Muraenidae
- Congroidei
  - Ophichthidae
  - Congridae
  - Derichthyidae
  - Nemichthyidae
  - Serrivomeridae
  - Nettastomatidae

MURAENIDAE: Morays

S. R. CHARTER AND H. G. MOSER

Muraenids live in all tropical and subtropical oceans and seas; a few species inhabit temperate waters and some enter freshwater as juveniles and adults (Böhlke et al. 1989). Four species occur in the CalCOFI region (Table Muraenidae 1): *Echidna nebulosa*, the California moray *Gymnothorax mordax*, *G. verrilli*, and *Muraena lentiginosa*. Five species have been recorded in the Gulf of California (*Anarchias galapagensis*, *Enchelycore octavianus*, *Gymnomuraena zebra*, *Gymnothorax castaneus*, and *G. panamensis*) and six species range from the Gulf of California south along the Central American coast (*Echidna nocturna*, *Gymnothorax dovii*, *G. equatorialis*, *Muraena argus*, *M. clepsydra*, and *Uropterygius macrocephalus*). Muraenid leptocephali are rare in CalCOFI ichthyoplankton collections but are relatively common south of the CalCOFI region.

Adults are common medium to large (ca. 1.2–3 m) benthic residents of rock or coral reefs, occupying crevices and caves from the shallow subtidal zone to ca. 500 m (usually shallower than ca. 20 m). Morays are elongate and slightly compressed, with confluent dorsal, caudal, and anal fins. They lack both lateral line and pectoral fins. The gill opening is small, round, and may be low on the body. The mouth is large; some species have strong, sharp canine teeth. The posterior nostril is located above the eye. The thick, scaleless skin is light or dark brown to greenish in color with spots, bars, or mottling. Presently, 15 genera with approximately 200 species are recognized (Nelson 1994; Eschmeyer 1990).

Muraenid eggs are large (3–4 mm) with a wide perivitelline space (Eldred 1969). Muraenid leptocephali are moderate in length and strongly compressed (BD 5–15% BL), with a moderate to long preanal length (59–87% BL, depending on species). The posterior nostril is above mid-eye. The liver is undivided and the gut is a simple straight tube. Morays are the only eel larvae to completely resorb the pectoral fins during transformation. The caudal region is broadly rounded. The dorsal fin may be 20–98% of body length and, depending on genus, the anal fin may originate immediately or at a distance behind the anus.

Muraenid leptocephali are similar morphologically, but genera and species may be separated by a combination of characteristics: pigmentation, myomere count at nephros terminus, total myomere count, and position of dorsal fin origin and anus. *Gymnothorax mordax* is identified by the nephros terminus and total myomere counts (77–84 and 146–154, respectively), dorsal fin origin (myomere 19–53, usually 24), and pigmentation. Two other distinct muraenid leptocephali occur in the Gulf of California and south of the CalCOFI area; they cannot be identified without critical transformation specimens. Lopez (1983) identified a larva of *Gymnothorax verrilli* from Costa Rica.

Literature is sparse for eastern Pacific muraenid leptocephali. Castle (1965b) described Australasian species, Smith (1979, 1989g) described western north Atlantic species and Castle (1984) and Smith (1984) provided general summaries. Detailed examination of 46 larval specimens (36.5–108.0 mm) of *G. mordax* provided the morphometric and meristic data for this study.

Table Muraenidae 1. Ranges (above) and means (below) of vertebral counts for muraenid species in the California Current region based on this study and McCleneghan (1976). Geographical ranges are based on Miller and Lea (1972), McCosker and Rosenblatt (1975), McCleneghan (1976), McCosker et al. (1984), Böhlke et al. (1989), and specimens in the SIO Marine Vertebrates Collection. Abbreviations: DFO, number of vertebrae anterior to dorsal fin origin; AFO, number of vertebrae anterior to anal fin origin; Gulf, Gulf of California; Galápagos, Galápagos Islands; CA, California; BCS, Baja California Sur.

		Vertebrae				
Species	Number	DFO	AFO	PrCV	Total	Geographical ranges
Anarchias galapagensis	11	102	103	56	101–109 105	Gulf & Galápagos
Echidna nebulosa	14	5–6 6	56–58 57	64–66 65	120–128 123	Cabo San Lucas to Costa Rica, Clipperton Is. & Eniwetok
E. nocturna	11	6–9 7	56–59 58	65–67 66	118–122 120	Gulf, Galápagos, Clipperton Is., Cocos Is., Panama
Enchelycore octavianus	8	8–9 8	56–59 57	67–70 68	141–146 143	Gulf & Galápagos
Gymnomuraena zebra	7	14–14 14	84–85 85	ca. 95–97 ca. 96	128–137 131	Gulf & Galápagos
Gymnothorax castaneus	11	6–8 7	57–59 58	66–68 67	138–146 142	Gulf & Galápagos
G. dovii	10	5–7 6	57–59 58	68–71 70	140–147 143	Gulf to Panama, Galápagos
G. equatorialis	8	7–7 7	53–54 53	ca. 61–62 ca. 61	141–147 144	Gulf to Panama
G. mordax	21	5–17 9	64–66 65	77–81 79	145–152 148	Pt. Conception, CA to Bahía Magdalena, BCS, Santa Catalina Is., Isla de Guadalupe, Gulf, Galápagos
G. panamensis	20	13–14 13	51–52 51	58–60 59	123–131 126	Gulf & Galápagos
G. verrilli	4	6–6 6	76–77 77	ca. 89–92 ca. 91	173–175 174	Bahía Magdalena, BCS, Gulf, Panama
Muraena argus	2	4	49	57	124–124 124	Rocas Alijos, BCS to Peru, Gulf, Galápagos
M. clepsydra	10	3–5 4	50–52 51	59–59 59	124–131 128	Cabo San Lucas, BCS, Gulf, Panama, Galápagos
M. lentiginosa	15	3–5 4	46–49 47	53–56 55	114–119 117	Bahía Magdalena, BCS, Gulf, Costa Rica, Panama, Galápagos
Uropterygius macrocephalus	15	86–88 87	88–91 90	52–56 54	106–111 108	Gulf, Islas de Revillagigedo, Clipperton Is., Panama, Colombia, Galápagos

MERISTICS

	Range	Mode
Vertebrae:		
Total	146–154	150
Precaudal		74
Caudal		84
Fins:		
Dorsal spines	0	
Dorsal rays	367	
Anal spines	0	
Anal rays	226	
Pelvic	0	
Pectoral	0	
Caudal:		
Principal	3+3	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Point Conception, California to Bahía Magdalena, Baja California Sur, Santa Catalina Island, Isla de Guadalupe, Gulf of California, & Galápagos Islands

Habitat: Common in shallow reef areas; <1–40 m depth; usually <20 m

Spawning season:

ELH pattern: Oviparous; planktonic leptocephali; benthic transformation stage

LITERATURE

Castle 1965b, 1984
Smith 1979, 1984, 1989g

ORIGINAL ILLUSTRATIONS (Illustrator)

Larvae, 44.1 mm, 97.7 mm (N. Arthur)
Head, body, & caudal sections of 44.1 mm larva (N. Arthur)
Head, body, & dorsal fin of 97.7 mm larva (N. Arthur)
Caudal section of 71.1 mm larva (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: <108.0 mm*
Fin development sequence: A & C, D, P_1, P_1 (resorbed)
Pigmentation: Similar through all stages; medium on head & over heart; heavy on ethmovomer; dorsally & ventrally on gut; on bases of all median fins; preceding D; internal ventrally along spinal cord in posterior one-third of body.
Diagnostic features: Nephros at ca. myomere 79 (77–84); total myomeres ca. 150 (146–154); D origin at myomere 19–53 (usually 24); anus ca. 71% BL; heavy pigment on ethmovomer; dorsal & ventral pigment on gut.

MORPHOMETRICS (range & mean in %)

	36.5–108.0 mm
Sn-A/BL	63–77 71
BD/BL	5–8 6
GD/BL	11–15 13
HL/BL	4–9 6
HW/HL	24–44 32
SnL/HL	26–40 35
ED/HL	13–22 18
P_1L/BL	0–1 0.2
PdL/BL	16–38 20

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* Early juvenile collected from *Macrocystis* holdfast, near San Onofre, California (R. Lavenberg, LACM, pers. comm., September 1992).

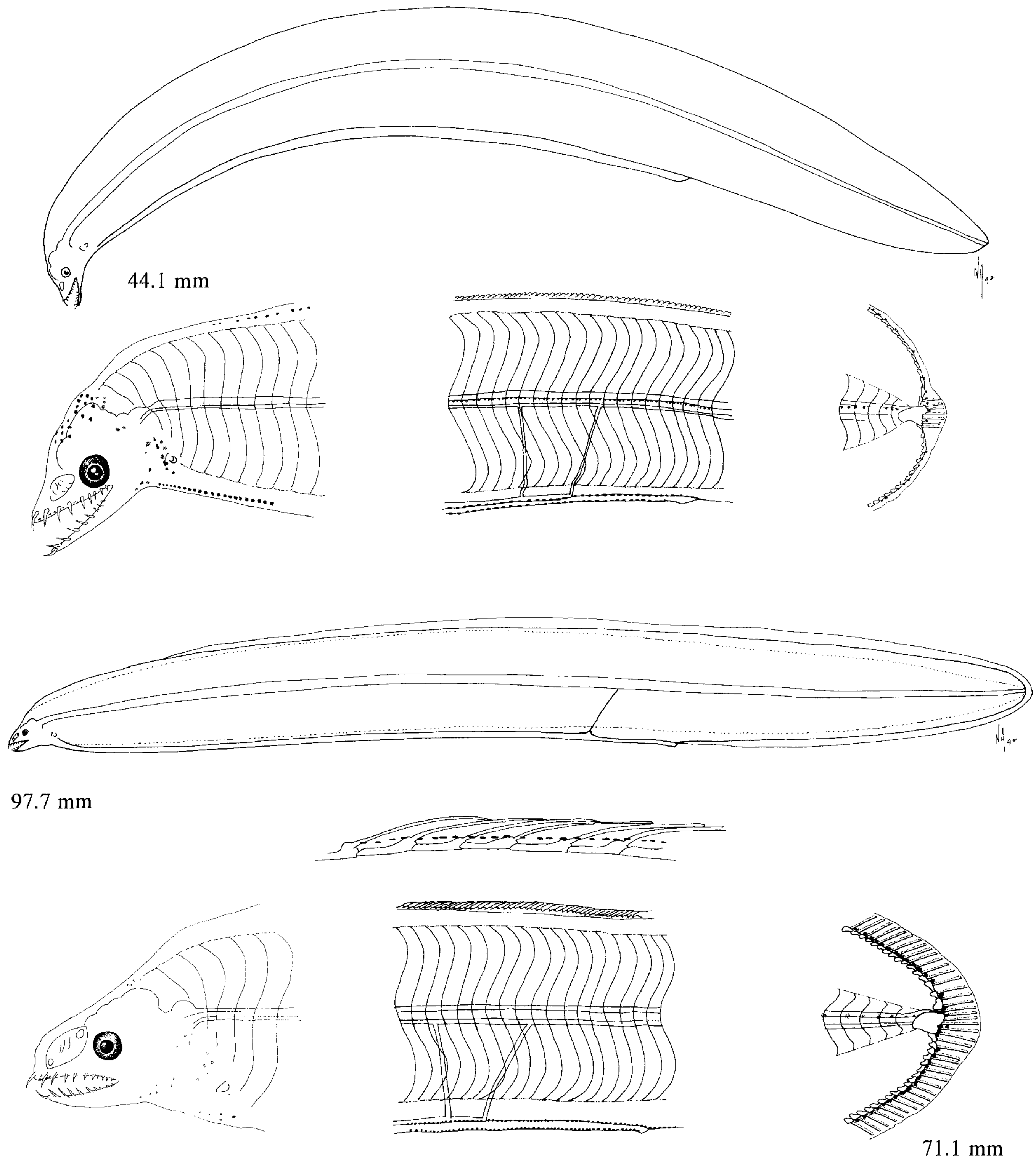


Figure Muraenidae 1. Larvae, 44.1 mm, whole body and sections showing head, nephros, and caudal regions; 97.7 mm, whole body and sections showing head, detail of dorsal fin base pigment, and nephros regions (SIO 73–263); caudal region of a 71.1 mm larva (lower right) (CalCOFI 5708, station 116G.37).

OPHICHTHIDAE: Snake eels and worm eels

S. R. CHARTER

Ophichthidae is the largest eel family, with two subfamilies, six tribes, 55 genera, and 250 species (McCosker et al. 1989). Six species occur in the CalCOFI study area: *Ethadophis merenda, Myrichthys xysturus*, *Myrophis vafer*, *Ophichthus triserialis*, *O. zophochir*, and *Scytalichthys miurus*. A single specimen of *E. merenda* was taken from the stomach of a white seabass caught in Bahía de Thurloe, Baja California Sur. *M. xysturus* ranges from Bahía Magdalena, Baja California Sur to the Galápagos Islands, including the Gulf of California. *M. vafer* and *O. zophochir* range from Peru to San Pedro and Humboldt Bay, California, respectively, including the Gulf of California. *O. triserialis* ranges from Humboldt Bay, California to Peru, including the Gulf of California and the Galápagos Islands. *Scytalichthys miurus* ranges from Isla de Guadalupe to the tip of Baja California. Apparently, all are relatively rare north of Baja California, although their fossorial habits make them inaccessible to most collecting methods (Rosenblatt and McCosker 1970). At least 20 additional ophichthid species occur in the Gulf of California. Leptocephali have been collected in coastal CalCOFI ichthyoplankton samples at the southern end of the study area. *O. triserialis* and *O. zophochir* leptocephali range from Punta San Juanico, Baja California Sur south and into the Gulf of California. Larval *M. vafer* range from Punta Marques, Baja California Sur south and into the Gulf of California. *E. merenda*, *M. xysturus*, and *S. miurus* larvae are unknown.

Adult ophichthids occupy a variety of habitats in temperate to subtropical waters, including the intertidal zone, coral reefs, shallow soft substrates, and the midwater realm (McCosker 1982). They are small to moderate-sized, scaleless, and almost round in cross section. The posterior nostril is usually within or piercing the upper lip (Nelson 1994). Branchiostegal rays are numerous (15–49) and overlap at the midventral line in a branchial apparatus that strengthens the gill basket, presumably to hold struggling prey (McCosker et. al. 1989). The caudal fin may be confluent with the dorsal and anal fins (Myrophinae) or reduced to a hard tip containing embedded rays (Ophichthinae) (Leiby 1989).

Ophichthids are oviparous. Eggs are unknown. Leptocephali attain a moderate length (maximum ca. 150 mm), with two or three liver lobes and at least two gut swellings or loops. The nephros terminates 0–15 myomeres anterior to the anus (Leiby 1989). Pigmentation is found frequently on the myosepta midlaterally and postanally just ventral to the notochord in most species (Leiby 1989). Larval ophichthids may be separated by a combination of characters: number and morphology of the liver lobes and gut loops, myomere counts at the dorsal and anal fin origins and nephros terminus, preanal and total myomere counts, and pigmentation patterns (Leiby 1989). In late transformation specimens the number of branchiostegal rays, number and placement of cephalic sensory pores, and gill arch and caudal osteology may separate species (Leiby 1989). *M. vafer* leptocephali have three liver lobes with three gut swellings, the nephros typically at myomere 60 (55–63), closely matching the adult precaudal vertebral count of 58–62, and a total myomere count (152–164) that overlaps the adult vertebral count (146–155). *O. triserialis* and *O. zophochir* may be separated by the number of gut loops (9 vs. 8, respectively). *O. triserialis* leptocephali identifications were based on an early juvenile (99.9 mm EASTROPAC I, station 14.069), which retained larval pigmentation and had: 22 branchiostegal rays, the nephros at myomere 63, and a total myomere count of 150. *O. zophochir* leptocephali were identified by matching nephric myomere counts (56–62) and adult precaudal vertebral counts (57–58), and total myomere and adult vertebral counts (146–163 and 144–162, respectively). Five other distinctive kinds of ophichthid leptocephali were examined from CalCOFI ichthyoplankton samples, but could not be linked with adults. Meristic and morphological data were taken from 31 *M. vafer* leptocephali, 10 *O. triserialis* leptocephali and 1 juvenile, and 21 *O. zophochir* leptocephali. Additional ecological information was taken from Fitch and Lavenberg (1968), Rosenblatt and McCosker (1970), Eschmeyer et. al. (1983), Leiby (1989), McCosker et. al. (1989), and Nelson (1994).

MERISTICS

	Range	Mode
Vertebrae:		
Total	146–155	
Precaudal	58–61	60
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	344	
Anal spines	0	
Anal rays	256	
Pelvic	0	
Pectoral		
Caudal:		
Principal	3+3	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	49	

LIFE HISTORY

Range: San Pedro, California to Peru, including the Gulf of California

Habitat: Temperate to subtropical waters; tide pools & shallow water to 11 m; benthic but not burrowing

Spawning season: Leptocephali caught throughout the year

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 80.5 mm (N. Arthur)
Head, body, & caudal sections of 80.5 mm larva (N. Arthur)

* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

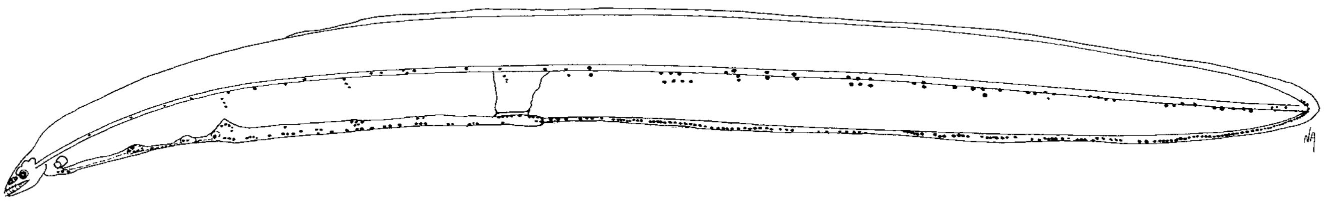
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C, A, D, P_1
Pigmentation: Few on upper jaw; anterior & posterior to heart; irregular on notochord & often just below notochord; irregular on ventral body wall; laterally on liver lobes; few dorsolaterally on gut; patchy on A pterygiophores; on C pterygiophores.
Diagnostic features: Nephros at ca. myomere 60 (55–63); total myomeres ca. 156 (152–164); 3 liver lobes; 3 gut swellings (not looped); gut length usually <50% of body length; midlateral pigmentation not limited to myosepta.

MORPHOMETRICS (range & mean in %)

	38.6–98.0 mm
Sn-A/BL	41–53 45
BD/BL	3–4 3
GD/BL	7–11 9
HL/BL	4–7 5
HW/HL	21–34 27
SnL/HL	25–44 35
ED/HL*	14–19× 16–22 17×19
P_1L/BL	0.4–1 0.8
PdL/BL	22–33 26



80.5 mm

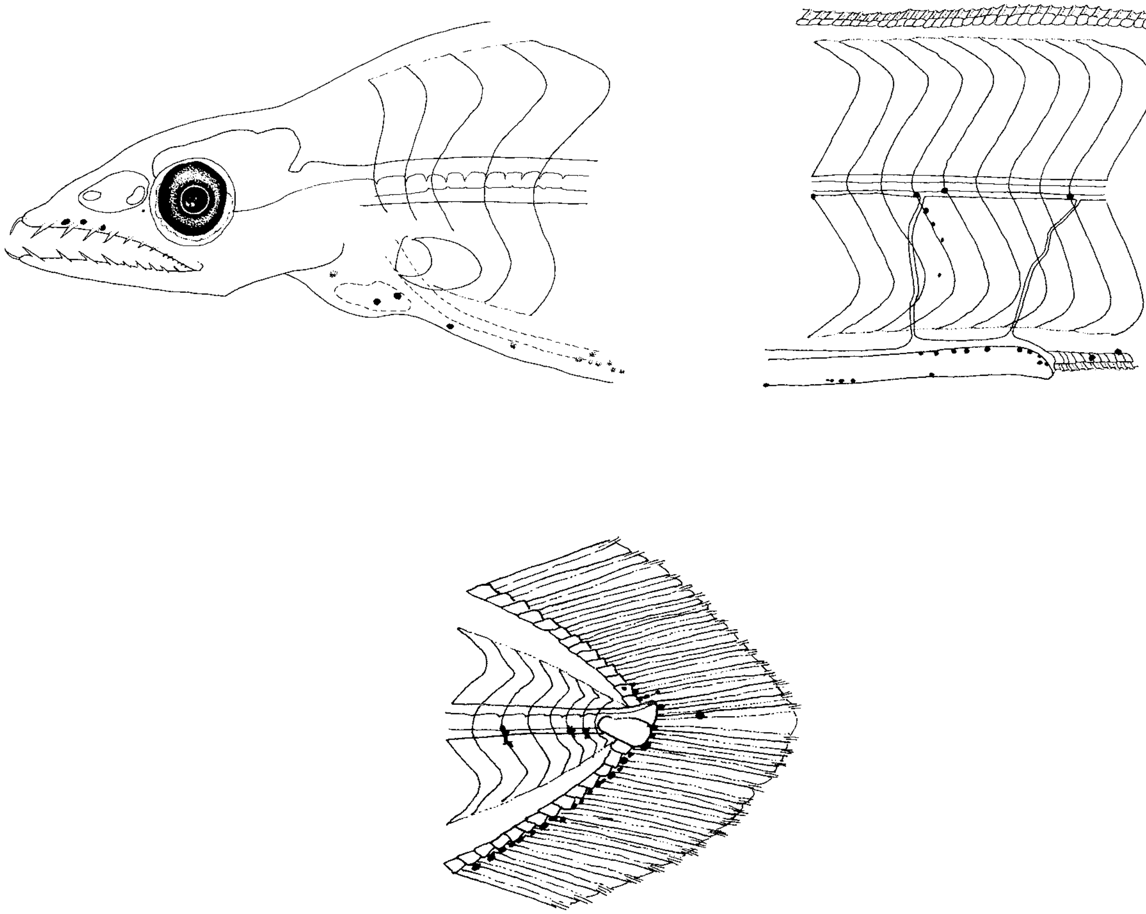


Figure Ophichthidae 1. Larva, 80.5 mm, whole body and sections showing head, nephros, and caudal regions (CalCOFI 5612, station 140G.20).

MERISTICS

	Range	Mode
Vertebrae:		
Total	144–160	150
Precaudal	67–68	68
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	296	
Anal spines	0	
Anal rays	197	
Pelvic	0	
Pectoral		
Caudal:		
Principal	3+3	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	22	

LIFE HISTORY

Range: Humboldt Bay, California, to Peru, including the Gulf of California & Galápagos Islands; rare north of Baja California

Habitat: Temperate to subtropical waters; shallow water to 23 m; burrows in soft bottoms

Spawning season: Leptocephali caught in April, June, & September

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 99.5 mm (R. C. Walker)
Head, body, & caudal sections of 99.5 mm larva (R. C. Walker)

* Eye is slightly oval, becoming round in juvenile stage; horizontal axis is given first, vertical axis second.
† Predorsal length measured on one larva.

EARLY LIFE HISTORY DESCRIPTION

EGGS

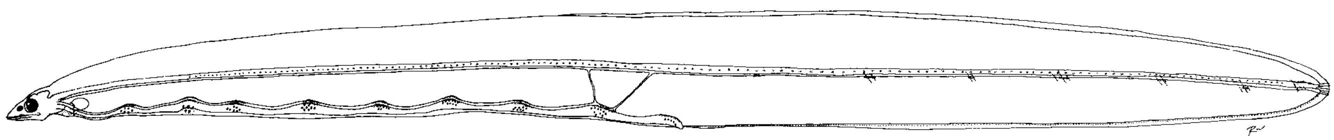
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <8.1 mm
Flexion length:
Transformation length: ≥123.0 mm shrinking to ≤99.9 mm
Fin development sequence: C, A, D, P_1
Pigmentation: On tip of lower jaw; on esophagus dorsally near P_1; 9 patches dorsally on gut; 4–5 patches ventrally on gut; ventrally on postanal myomeres; dorsally & ventrally on tail tip; by 10.6 mm, 2 postanal patches; by 13.3 mm, 4 postanal patches; by ca. 20 mm, 5 subcutaneous postanal patches in hypaxial myomeres; by ca. 27 mm, 6 subcutaneous patches in hypaxial myomeres, on A pterygiophores, & on each myoseptum. *Transformation*—Series on A pterygiophores. *Juvenile*—Internally anterior & posterior to heart; 9th gut patch posterior to anus at nephros; 6 subcutaneous patches barely visible.
Diagnostic features: Nephros at ca. myomere 66 (61–68); total myomeres ca. 149 (146–158); 2 liver lobes; 9 gut loops, straightening at transformation; pigment on loops into juvenile stage; pigmentation midlaterally on each myoseptum; at transformation, C rays enclosed in skin, appear spike-like.

MORPHOMETRICS (range & mean in %)

	10.6–21.3 mm	28.4–123.0 mm	Tr 113.6 mm	Juv 99.9 mm
Sn-A/BL	73–75	49–68		
	74	58	50	41
BD/BL	6–10	3–6		
	8	4	3	4
GD/BL	10–14	7–10		
	12	8	7	8
HL/BL	11–15	5–9		
	13	6	6	9
HW/HL	25–32	22–27		
	28	25	27	26
SnL/HL	32–35	27–37		
	34	32	21	16
ED/HL*	16–21× 18–22	15–17× 16–19		
	19×20	16×17	13×14	11
P_1L/BL	1–3	0.4–2		
	3	1	0.5	1
PdL/BL†		36–56		
	51	45	36	21



99.5 mm

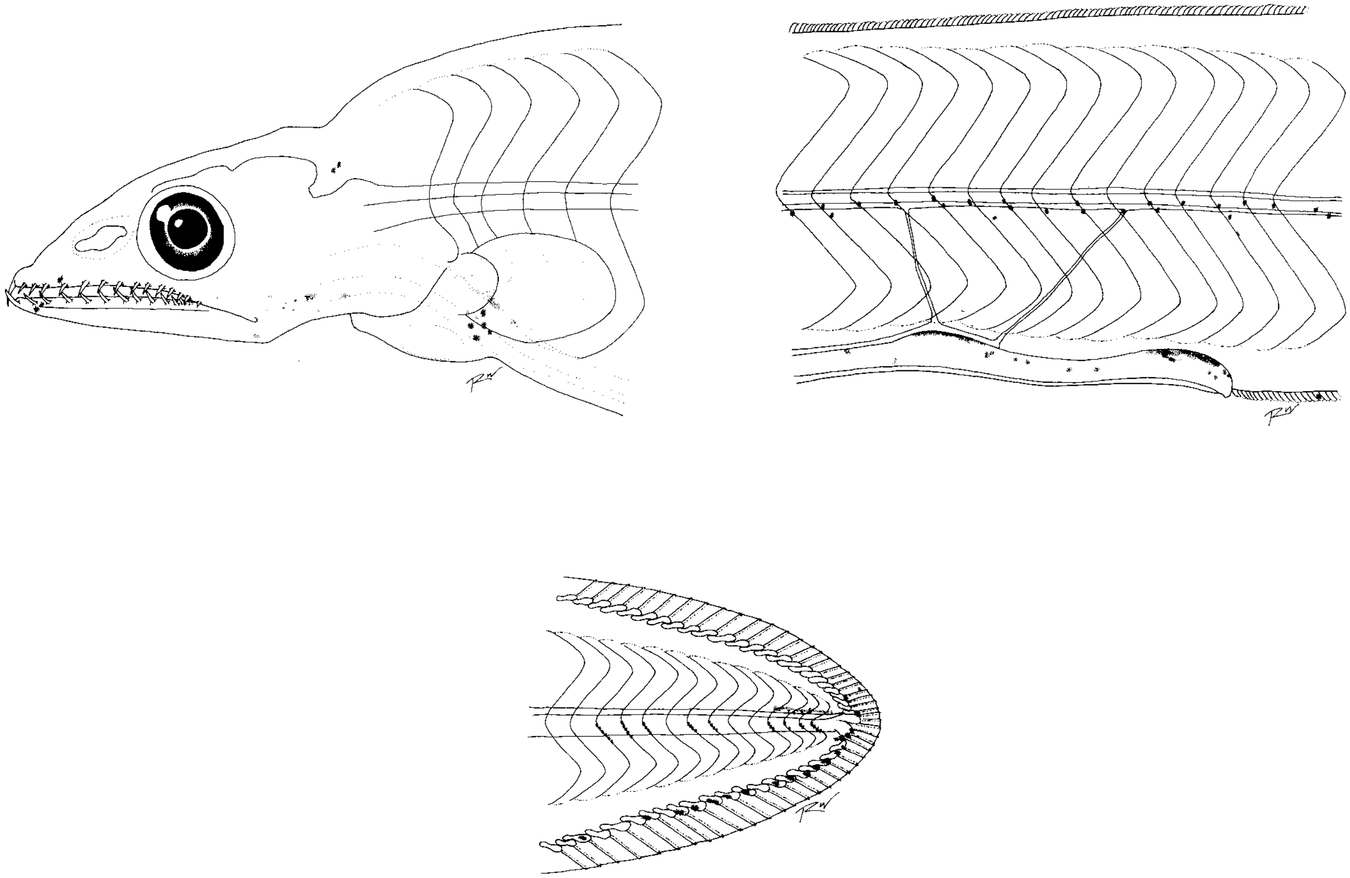


Figure Ophichthidae 2. Larva, 99.5 mm, whole body and sections showing head, nephros, and caudal regions (CalCOFI 5704, station 141G.29).

MERISTICS

	Range	Mode
Vertebrae:		
Total	144–162	154
Precaudal	57–58	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	258	
Anal spines	0	
Anal rays	190	
Pelvic	0	
Pectoral		
Caudal:		
Principal	3+3	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	27	

LIFE HISTORY

Range: Humboldt Bay, California to Peru, including the Gulf of California; uncommon north of Baja California

Habitat: Temperate to subtropical waters; rocky & sandy areas to 64 m; burrows in soft bottoms

Spawning season:

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 82.2 mm (R. C. Walker)
Head, body, & caudal sections of 82.2 mm larva (R. C. Walker)

* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

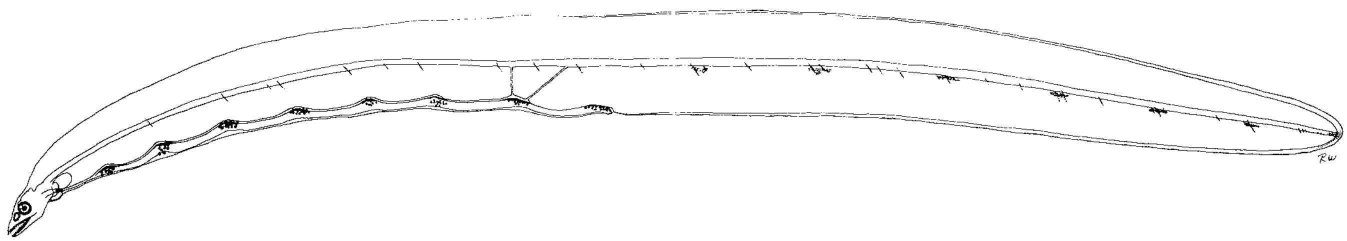
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <7.5 mm
Flexion length:
Transformation length: ≥147.2 mm, shrinking to ≤137.2 mm
Fin development sequence: C, A, D, P_1
Pigmentation: Few on lower jaw; anterior & posterolateral to heart; dorsolaterally on liver lobes & gut loops; on 1–4 hypaxial myosepta; 6 subcutaneous postanal patches ventral to notochord; on most A pterygiophores, patchy at transformation; dorsal & ventral to notocord tip.
Diagnostic features: Nephros at ca. myomere 58 (56–62); total myomeres ca. 157 (146–163); 2 liver lobes; 8 gut loops; 9 loops in larger leptocephali before transformation; pigmentation midlaterally on 1–4 myosepta.

MORPHOMETRICS (range & mean in %)

	7.5–30.6 mm	58.6–147.2 mm	Tr 137.2 mm
Sn-A/BL	66–77 72	46–52 49	46
BD/BL	5–12 7	3–3 3	3
GD/BL	8–14 11	7–8 7	9
HL/BL	8–17 11	4–6 4	5
HW/HL	25–36 30	20–29 24	24
SnL/HL	36–40 38	26–37 30	18
ED/HL*	15–23× 16–27 19×22	14–17× 15–19 16×17	14×15
P_1L/BL	2–2 2	0.3–1 0.7	0.5
PdL/BL	0–0 0	41–49 43	41



82.2 mm

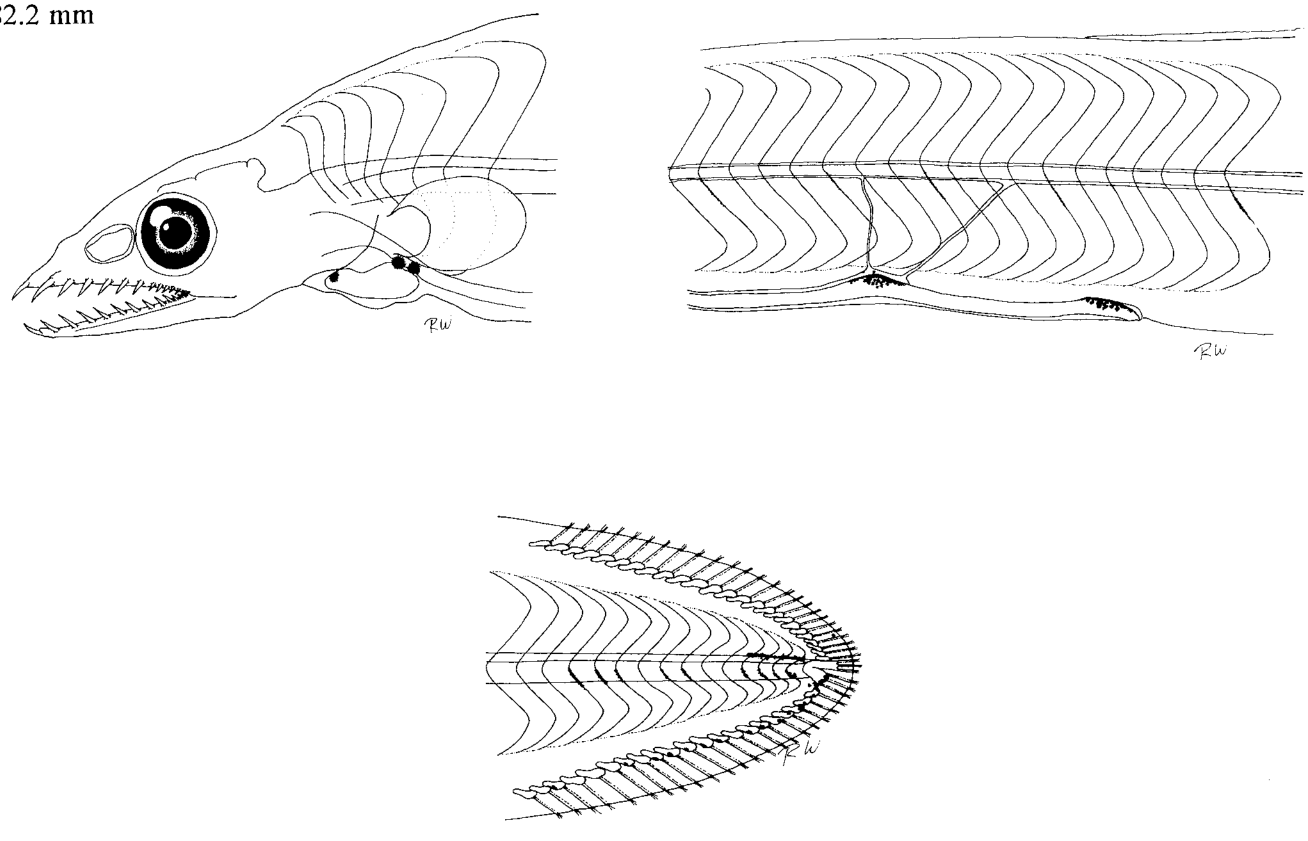


Figure Ophichthidae 3. Larva, 82.2 mm, whole body and sections showing head, nephros, and caudal regions (CalCOFI 5612, station 170.20).

CONGRIDAE: Conger eels

S. R. CHARTER

Congridae is a speciose eel family, with three subfamilies, ca. 17 genera and 103 species (Smith 1989a). Nomenclature (Table Congridae 1) follows Smith (1989a), Smith (1995), and Smith and Lavenberg (in prep.). Five species occur in the California Current region: *Xenomystax atrarius* (British Columbia, Canada to Valparaiso, Chile), *Gnathophis cinctus* (Santa Rosa Island, California to Colombia, including the Gulf of California), *Ariosoma gilberti* and *Gorgasia punctata* (Baja California Sur to Panama), and *Chiloconger obtusus*, (Baja California Sur to Colombia). Three other species (*Bathycongrus macrurus*, *B. varidens*, and *Heteroconger canabus*) have been recorded from the Gulf of California, and *Heteroconger digueti*, *Paraconger californiensis* and *Rhynchoconger nitens* range from the Gulf of California to mainland Mexico, to Peru and to Colombia, respectively. Geographic ranges are difficult to determine for the benthic or fossorial adults.

Leptocephali of seven species occur in the CalCOFI study area; *A. gilberti* is the most abundant and *G. cinctus* the least abundant. Larval *A. gilberti*, *R. nitens*, and *G. cinctus* occur as far south as Ecuador and range northward to the Gulf of California and the outer coast of Baja California. Northern limits for *A. gilberti* and *R. nitens* are Punta Abreojos, Baja California Sur, and Bahía Todos Santos, Baja California, respectively. Larvae of *G. cinctus* have been captured as far north as San Pedro, California. Larval *P. californiensis* and *B. macrurus* range from Cabo San Lucas, Baja California Sur, to Colombia. Larvae of *C. obtusus* range from Point Loma, California, to Colombia. Larval *H. canabus* range from San Jose del Cabo, Baja California Sur to mainland Mexico, including the Gulf of California; *H. digueti* is known only from the Gulf of California.

Adult congrids live in tropical and subtropical oceans; few species range into temperate waters. They lack scales and vary considerably in shape. The snout varies from long and slender to short and stout. The upper lip in some genera and lower lip in most genera are turned up into flanges. The dorsal fin origin is closer to the pectoral fin than to the vent; preanal length is 20–50% BL. The dorsal, caudal and anal fins are confluent, with the dorsal and anal fins commonly edged in black (Smith 1989a). The caudal region ranges from stout and stiff to almost filamentous. Garden eels (Heterocongrinae) are of interest to sport divers.

Congrids are oviparous. Eggs are unknown. Leptocephali are moderate in length to elongate (maximum 300 mm) with a rounded or pointed tail (Smith 1989f). The eye is round to oval; some species have pigment below and above the eye. Midlateral pigment varies from absent to a single row, or an oblique row along the myosepta. The dorsal fin may be long or short (22–99% BL). The gut is a simple straight tube, 71–99% BL.

Meristic (Table Congridae 2) and morphological data were taken from specimens examined in this study (Table Congridae 3). Additional ecological and morphological information was taken from Raju (1985) and Smith (1989f). Specimen lengths from Raju (1985) were calculated from his illustrations. *Chiloconger obtusus* leptocephali were identified from the examination of one transforming specimen, identified by D. G. Smith (SIO 70–362). This specimen retained larval pigmentation, and the nephros terminus myomere count of 49 matched precaudal counts of 46 and 49 from radiographs of two adult specimens. *Heteroconger canabus* and *H. digueti* leptocephali were identified by matching the nephros terminus myomere counts (72–79 and 68–72, respectively) and adult precaudal vertebral counts (70–76 and 66–69, respectively).

Table Congridae 1. Congrid taxonomic names used in this study (following Smith 1989a, 1995; Smith and Lavenberg, in prep.) and synonyms sometimes used in the literature.

This study	Other names
Chiloconger obtusus (Garman 1899)	*Atopichthys dentatus* Garman 1899 *A. obtusus* Garman 1899 *Chiloconger labiatus* Myers & Wade 1941 *Paraconger dentatus* (Garman 1899)
Gnathophis cinctus (Garman 1899)	*Gnathophis catalinensis* (Wade 1946)
Heteroconger canabus (Cowan & Rosenblatt 1974)	*Taenioconger canabus* Cowan & Rosenblatt 1974
H. digueti (Pellegrin 1923)	*T. digueti* Pellegrin 1923
Rhynchoconger nitens (Jordan & Bollman 1890)	*Hildebrandia nitens* (Jordan & Bollman 1890)

Table Congridae 2. Ranges of vertebral counts for adult congrids in the CalCOFI study area and Gulf of California based on Peden 1972, Raju 1985, Seigel 1987, and original counts.

Species	Vertebrae				
	Preanal	Postanal	PrCV	CV	Total
Ariosoma gilberti	47–50	77–89			124–139
Bathycongrus macrurus	30–36	98–107			128–143
B. varidens	38–41	109–115			147–156
Chiloconger obtusus			46–49	70–71	116–120
Gnathophis cinctus			32–36	84–85	127–130
Gorgasia punctata					140–155
Heteroconger canabus			70–76	111–123	185–199
H. digueti			66–69	115–126	184–193
Paraconger californiensis					137–148
Rhynchoconger nitens	30–32	138–150			168–182
Xenomystax atrarius			48–57	107–123	159–177

Table Congridae 3. Number of specimens, size ranges, pigmentation, morphometric, and meristic characters (range above, mean below) for congrid leptocephali in the CalCOFI study area and Gulf of California (Raju 1985 and original data).

Species	No. of specimens	Size range (mm)	Pigmentation		Shape		Myomeres	
			Eye	Midlateral	Eye	Tail	Nephros terminus	Total
Ariosoma gilberti	23 (3 trans.)	16.5–227.2	none	oblique rows	round	rounded	66–71 68	126–138 134
Bathycongrus macrurus	20	36.0–146.7	crescentic patch over and under	single row	oval	pointed	46–50 48	135–148 141
Chiloconger obtusus	14 (1 trans.)	41.4–128.3	none	single row	round	rounded	50–57 52	121–124 123
Gnathophis cinctus	11	20.1–122.5	crescentic patch over and under	none	oval	rounded	42–46 44	126–137 130
Heteroconger canabus	21 (2 trans.)	34.1–122.6	none	single row	off-round	rounded	72–79 75	189–201 196
H. digueti	7	37.3–101.5	none	single row	off-round	rounded	68–72 69	189–196 193
Paraconger californiensis	18	46.3–133.3	none	single row	round	rounded	57–61 59	137–148 143
Rhynchoconger nitens	20	44.8–126.3	crescentic patch below	single row	oval	pointed	46–49 48	169–187 177

MERISTICS

	Range	Mode
Vertebrae:		
Total	124–139	
Preanal	47–50	
Postanal	77–89	
Fins:		
Dorsal spines	0	
Dorsal rays		
Anal spines	0	
Anal rays		
Pelvic	0	
Pectoral		
Caudal:		
Principal	3+3	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Pacific coast of Baja California Sur & Gulf of California to Gulf of Tehuantepec, Mexico

Habitat: Shallow tropical & subtropical waters; fossorial

Spawning season: Larvae collected October–June (mostly May & January); transformation individuals collected January, February, May, June, & November (maximum May)

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: ≥227.2 mm shrinking to ≤139.4 mm
Fin development sequence: C, D, A & P_1
Pigmentation: Oblique series on hypaxial myosepta; preceding D; paired series ventrally along gut; dashes dorsally on gut; on D & A bases.
Diagnostic features: Nephros at ca. myomere 68 (66–71); total myomeres ca. 134 (126–138); lateral pigment in oblique lines along hypaxial myosepta.

MORPHOMETRICS (range & mean in %)

	16.5–19.8 mm	85.3–227.2 mm	Tr 184.1–139.4 mm
Sn-A/BL	93–95 94	97–99 98	94–52 74
BD/BL	6–7 6	2–3 3	2–4 3
GD/BL	13–14 14	7–10 9	8–11 9
HL/BL	7–8 8	1–4 3	1–8 4
HW/HL	36–38 37	28–36 34	27–38 34
SnL/HL	38–40 39	34–41 38	24–41 37
ED/HL	22–23 22	22–26 23	16–20 18
P_1L/BL	2–3 2	0.1–0.4 0.3	0.1–2 1
PdL/BL	0–0 0	96–99 97	95–37 70

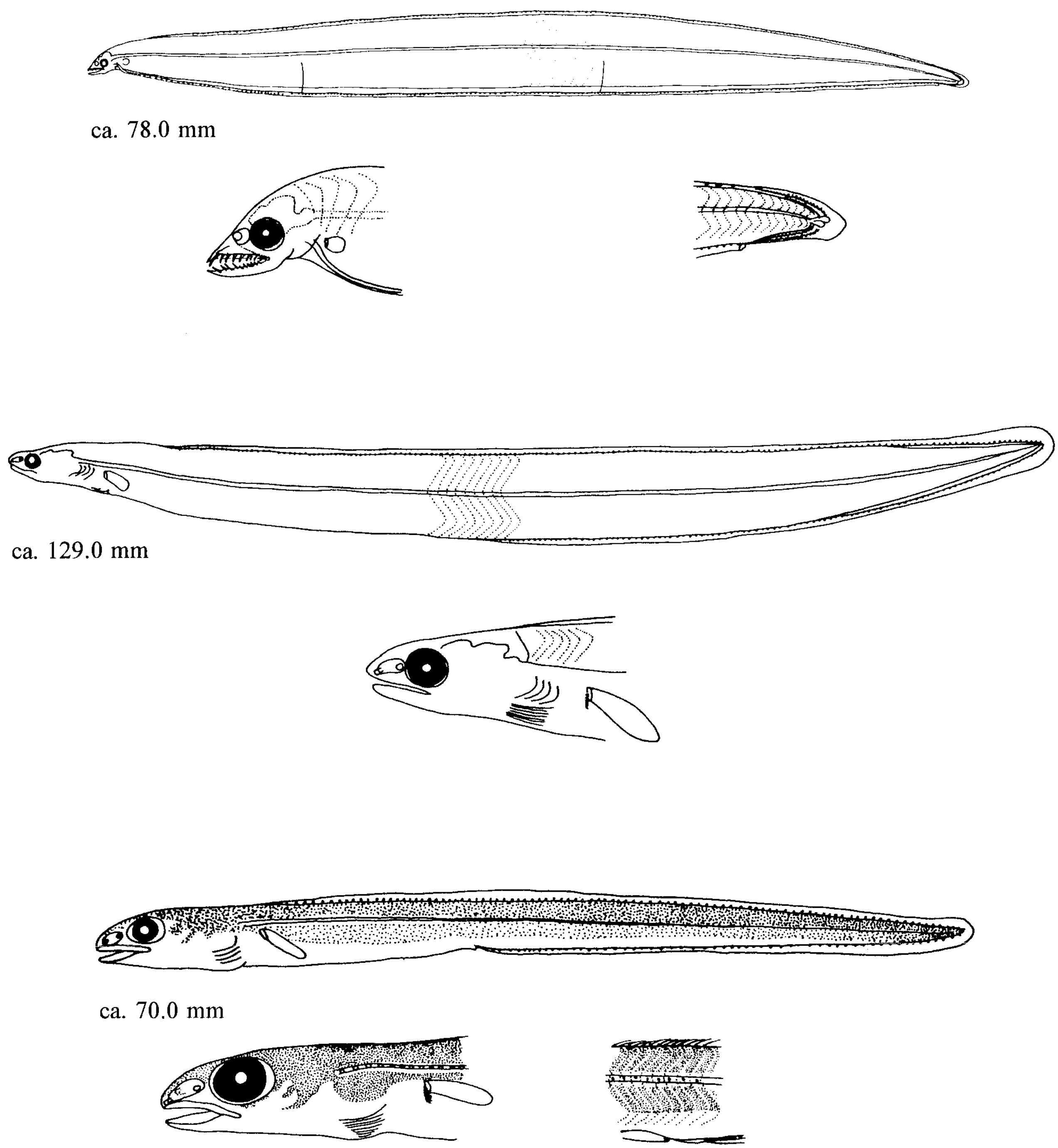


Figure Congridae 1. Larva, ca. 78.0 mm, whole body and sections showing head and caudal regions; late transformation specimen, ca. 129.0 mm, whole body and head; juvenile, ca. 70.0 mm, whole body, head and body section (Raju 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	128–143	
Preanal	30–36	
Postanal	98–107	
Fins:		
Dorsal spines	0	
Dorsal rays		
Anal spines	0	
Anal rays		
Pelvic	0	
Pectoral		
Caudal:		
Principal		
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Gulf of California; larvae recorded from Cabo San Lucas, Baja California Sur

Habitat: Nearshore tropical waters

Spawning season: Larvae collected in February, May, June, August, & October (maximum in June); transformation individuals collected in July; juveniles collected in January

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C, D, A & P_1
Pigmentation: Crescentic patches over & below eye; 1–2 melanophores on operculum; 2 over heart; series midlaterally; paired series ventrally along gut; on D, C, A bases.
Diagnostic features: Nephros at ca. myomere 48 (46–50); total myomeres ca. 141 (135–148); elongate body; crescentic pigment patches over & under eye; pointed tail.

MORPHOMETRICS (range & mean in %)

	36.0–146.7 mm
Sn-A/BL	90–95 92
BD/BL	4–5 5
GD/BL	10–13 12
HL/BL	5–8 6
HW/HL	29–38 35
SnL/HL	28–36 31
ED/HL*	19–24× 22–27 22×25
P_1L/BL	1–2 1
PdL/BL	66–83 71

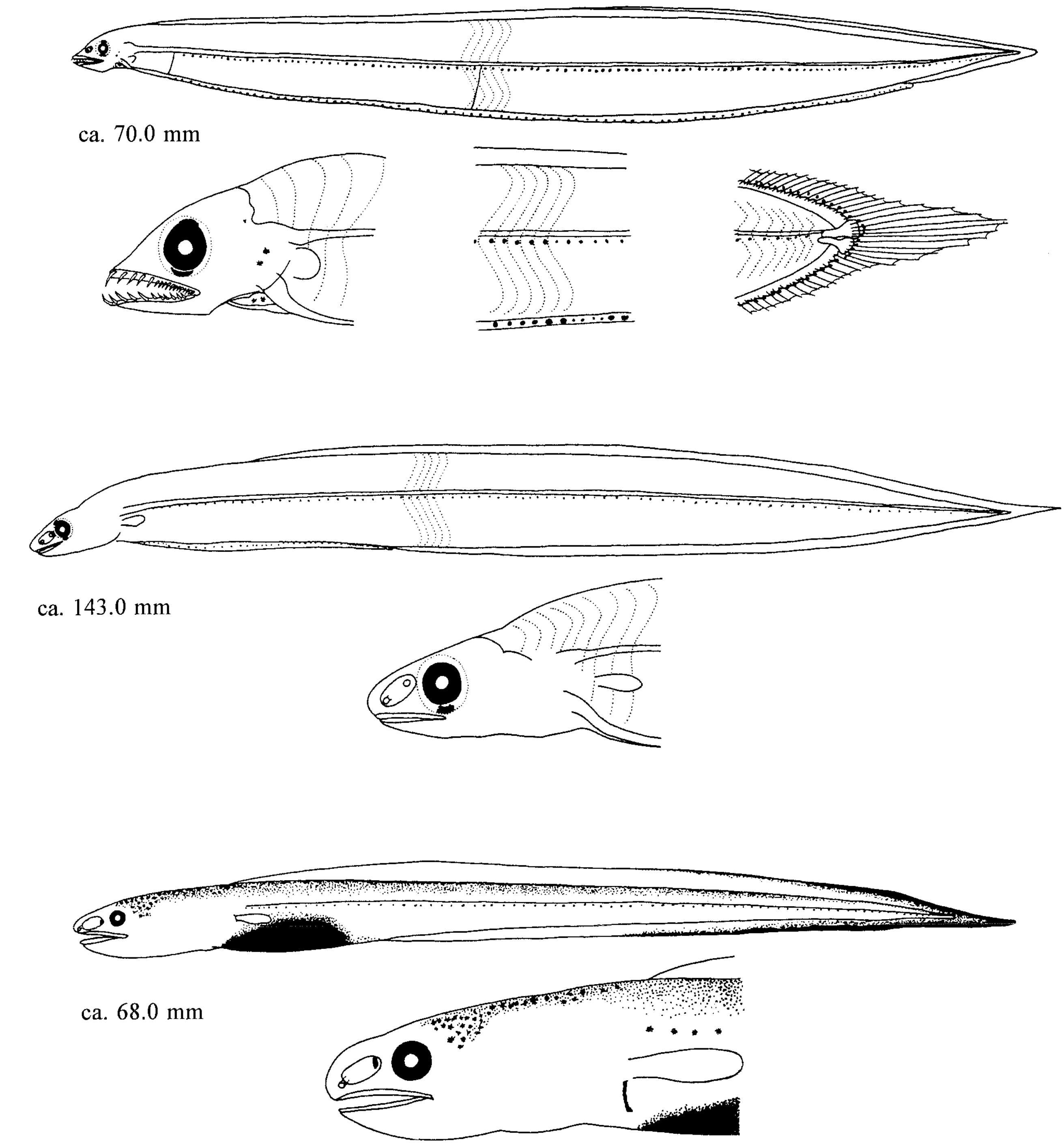


Figure Congridae 2. Larva, ca. 70.0 mm, whole body and sections showing head, midbody and caudal regions; transformation specimen, ca. 143.0 mm, whole body and head; juvenile, ca. 68.0 mm, whole body and head (Raju 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	116–120	
Precaudal	46–49	
Caudal	70–71	
Fins:		
Dorsal spines	0	
Dorsal rays		
Anal spines	0	
Anal rays		
Pelvic	0	
Pectoral		
Caudal:		
Principal	4–5+3	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower	0	
Branchiostegals	0	

LIFE HISTORY

Range: Punta Tosco, Baja California Sur to Colombia

Habitat: Shallow tropical to subtropical waters

Spawning season:

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Garman 1899
Raju 1985

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 94.1 mm (N. Arthur)
Head, body, & caudal sections of 94.1 mm larva (N. Arthur)

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* Eye becomes oval in transformation specimens; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: >128.3 mm shrinking to <110.0 mm
Fin development sequence: C, D, A & P_1
Pigmentation: Evenly spaced series on lateral midline; dorsal & ventral series on gut; 3–4 over heart; 2 on lower jaw; on D, C & A bases.
Diagnostic features: Nephros at ca. myomere 52 (50–57); total myomeres ca. 123 (121–124); laterally compressed teeth; absence of crescentic pigment patch under eye; compared to *Paraconger*—relatively lower myomere count, more regular midlateral pigment, and relatively smaller size (<130.0 mm).

MORPHOMETRICS (range & mean in %)

	41.4–128.3 mm	Tr 110.0 mm
Sn-A/BL	88–91 90	52
BD/BL	5–7 6	6
GD/BL	10–15 12	12
HL/BL	6–8 7	8
HW/HL	26–33 28	32
SnL/HL	27–35 32	16
ED/HL*	16–19 17	15×19
P_1L/BL	1–3 2	2
PdL/BL	59–74 64	24

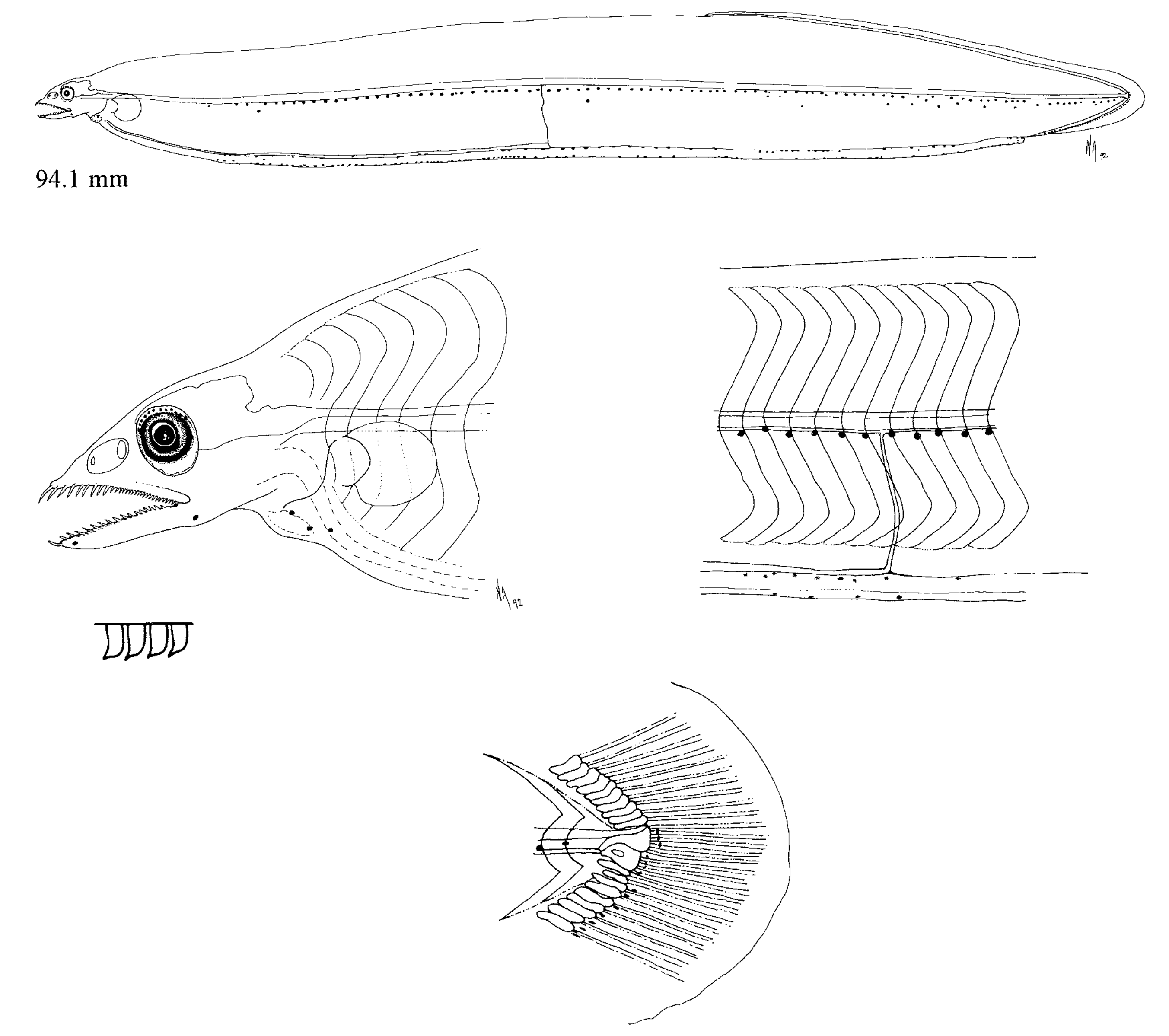


Figure Congridae 3. Larva, 94.1 mm, whole body and sections showing head, nephros and caudal regions (CalCOFI 6001, station 143.55); teeth (below head) from larva ca. 96.0 mm (Raju 1985 as *Paraconger californiensis*).

MERISTICS

	Range	Mode
Vertebrae:		
Total	127–130	128
Precaudal	32–36	32
Caudal	84–85	84–85
Fins:		
Dorsal spines	0	
Dorsal rays	202–207	205
Anal spines	0	
Anal rays	139–162	148
Pelvic	0	
Pectoral		
Caudal:		
Principal	3+3	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Catalina Island, California to Colombia, including Gulf of California & Galápagos Islands

Habitat: Temperate to subtropical shallow water; benthic in sand

Spawning season:

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**

No. of OG: **Diam. of OG:**

Shell surface:

Pigment:

Diagnostic features:

LARVAE

Hatching length:

Flexion length:

Transformation length: ≥123.1 mm shrinking to ≤122.5 mm

Fin development sequence: C, D, A & P_1,

Pigmentation: Crescentic patch above & below eye; patch over heart; series on ventral margin of gut; on A, C & posterior D bases.

Diagnostic features: Nephros at ca. myomere 44 (42–46); total myomeres ca. 130 (126–137); absence of midlateral pigment; blunt tail; crescentic pigment patch above & below eye; transformation individuals develop a blunt, hook-like snout.

MORPHOMETRICS (range & mean in %)

	20.1–123.1 mm	Tr 122.5 mm
Sn-A/BL	90–94 92	75
BD/BL	5–7 6	5
GD/BL	12–16 13	12
HL/BL	6–10 8	7
HW/HL	29–35 32	34
SnL/HL	35–42 38	30
ED/HL*	16–19× 19–25 18×21	19×22
P_1L/BL	0.8–2 1	1
PdL/BL	73–79 76	56

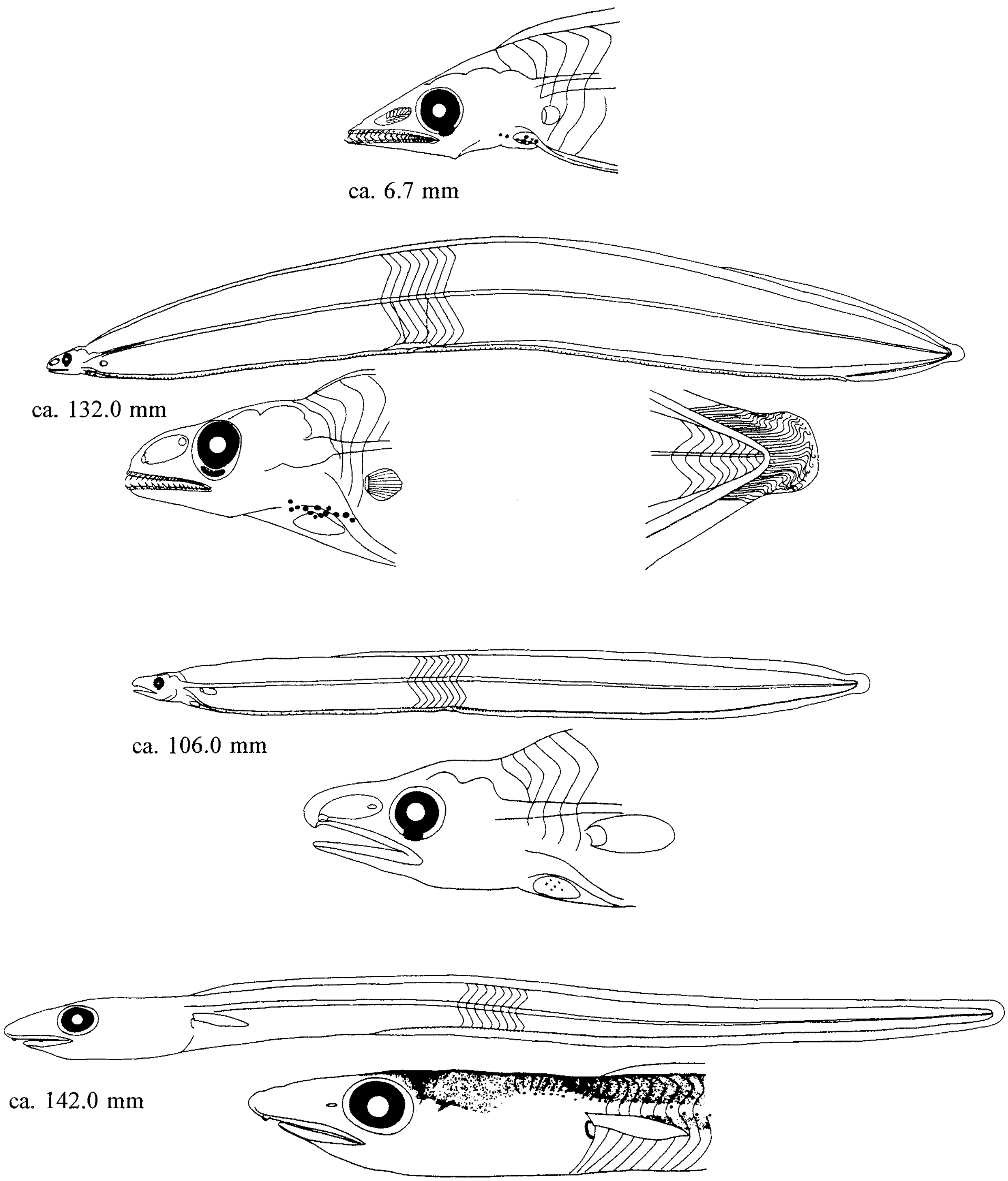


Figure Congridae 4. Head of early larva, head length ca. 6.7 mm; larva, ca. 132.0 mm, whole body, head and caudal regions; transformation specimen, ca. 106.0 mm, whole body and head; juvenile, ca. 142.0 mm, whole body and head (Raju 1985 as *Gnathophis catalinensis*).

MERISTICS

	Range	Mode
Vertebrae:		
Total	185–199	194
Precaudal	70–76	74
Caudal	111–123	
Fins:		
Dorsal spines	0	
Dorsal rays	644	
Anal spines	0	
Anal rays	460	
Pelvic	0	
Pectoral	9–18	13
Caudal:		
Principal	3+3	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Gulf of California; larvae collected off San Jose del Cabo, Baja California Sur

Habitat: Burrows in shallow, sandy bottoms (generally <60 m depth); clear, tropical water in moderate currents

Spawning season: Larvae collected in February & October

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 102.3 mm (R. C. Walker)
Head, body, & caudal sections of 102.3 mm larva (R. C. Walker)

* Eye is oval, becoming round in transformation stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

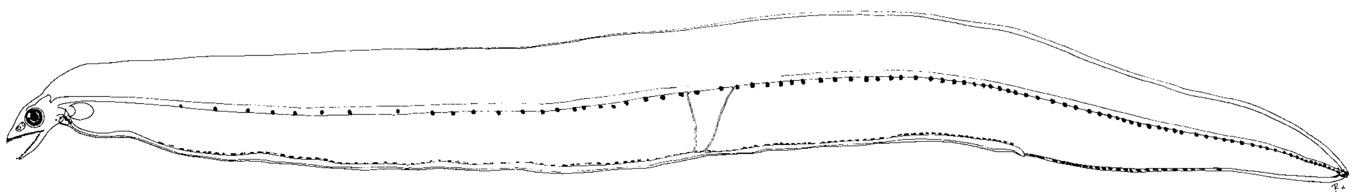
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

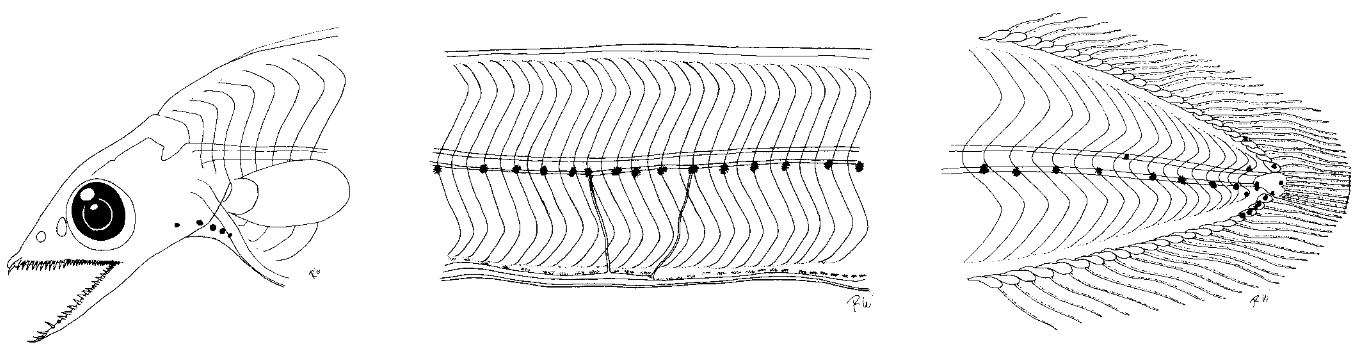
Hatching length:
Flexion length:
Transformation length: >123.0 mm shrinking to ≤ 86.0 mm
Fin development sequence: C, D, A, & P_1
Pigmentation: Several over heart; series on lateral midline; on dorsal surface of gut; series ventrally along gut; on C, A & posterior D bases.
Diagnostic features: Nephros at ca. myomere 75 (72–79); total myomeres ca. 196 (189–201); small conical teeth; rounded tail; compared to *H. digueti*—lack of pigment on maxillary, lateral midline pigment begins at myomere 16–22, relatively longer snout, relatively larger eye, relatively larger head.

MORPHOMETRICS (range & mean in %)

	34.1–122.6 mm	Tr 86.3–95.7 mm
Sn-A/BL	71–85 78	42–46 44
BD/BL	4–6 5	5–5 5
GD/BL	10–14 11	9–10 10
HL/BL	5–10 7	7–7 7
HW/HL	20–36 29	38–41 40
SnL/HL	29–40 36	17–19 18
ED/HL*	17–22× 18–25 19×22	20–23 22
P_1L/BL	0.6–3 2	1–1 1
PdL/BL	24–54 37	13–14 13



102.3 mm



ca. 103.0 mm

Figure Congridae 5. Larva, 102.3 mm, whole body and sections showing head, nephros, and caudal regions (SIO 73–249); early juvenile, ca. 103.0 mm, (Raju 1985 as *Taenioconger canabus*).

MERISTICS

	Range	Mode
Vertebrae:		
Total	184–193	186
Precaudal	66–69	68
Caudal	115–126	
Fins:		
Dorsal spines	0	
Dorsal rays	647	
Anal spines	0	
Anal rays	346	
Pelvic	0	
Pectoral		
Caudal:		
Principal	3+3	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Gulf of California to Bahía de Banderas, Mexico

Habitat: Burrows in shallow, sandy bottoms (generally <60 m); clear, tropical water in moderate currents

Spawning season: Larvae collected in February & October

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 101.5 mm (R. C. Walker)
Head, body, & caudal sections of 101.5 larva (R. C. Walker)

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* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

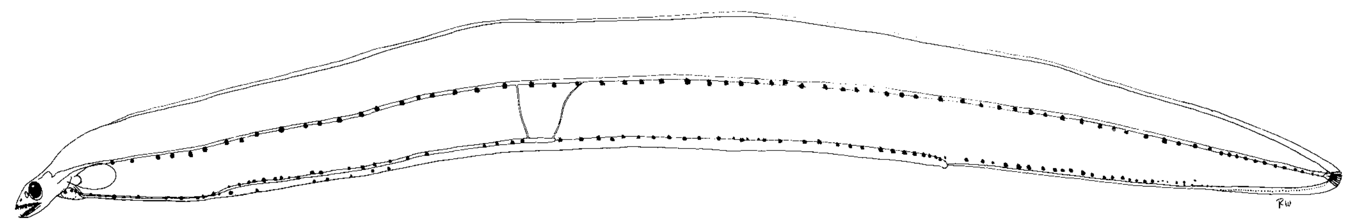
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

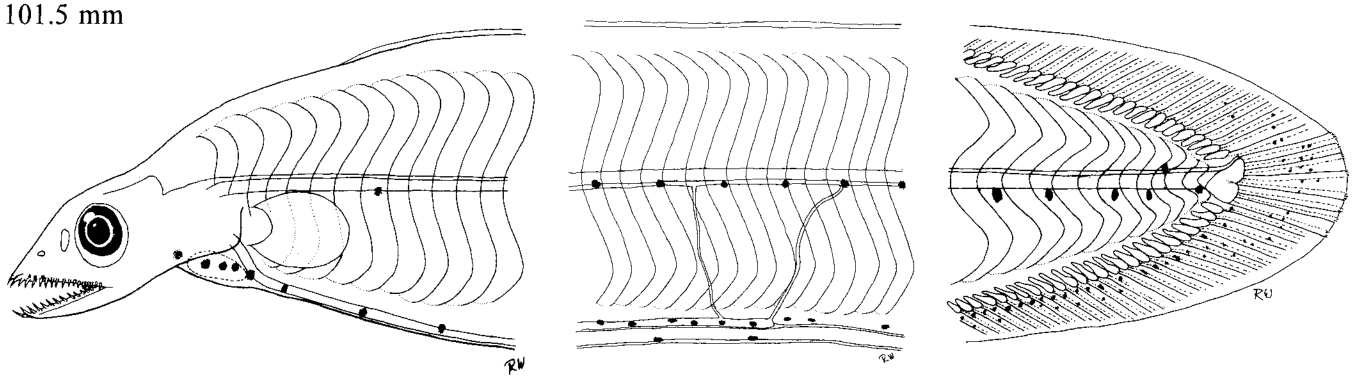
Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C, D, A, & P_1
Pigmentation: Several over heart; 3 on maxillary; series on lateral midline; on dorsal surface of gut; series ventrally along gut; on C, A & posterior D bases.
Diagnostic features: Nephros at ca. myomere 69 (68–72); total myomeres ca. 193 (189–196); small conical teeth; rounded tail; compared to *H. canabus*—pigment on maxillary, lateral midline pigment begins at myomere 11–15, relatively shorter snout, relatively smaller eye, relatively smaller head.

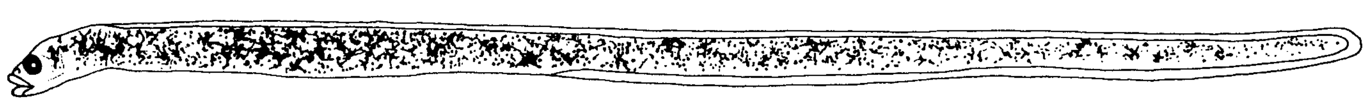
MORPHOMETRICS (range & mean in %)

	37.3–101.5 mm
Sn-A/BL	71–83 77
BD/BL	4–6 5
GD/BL	9–15 11
HL/BL	5–8 6
HW/HL	26–30 28
SnL/HL	31–38 34
ED/HL*	17–20× 20–24 18×21
P_1L/BL	1–2 2
PdL/BL	22–35 27



101.5 mm





ca. 102.0 mm

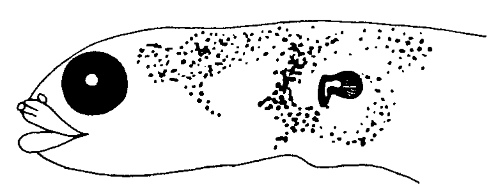


Figure Congridae 6. Larva, 101.5 mm, whole body and sections showing head, nephros, and caudal regions (SIO 73–249); early juvenile, ca. 102.0 mm, whole body and head (Raju 1985 as *Taenioconger digueti*).

MERISTICS

	Range	Mode
Vertebrae:		
Total	137–148	139
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays		
Anal spines	0	
Anal rays		
Pelvic	0	
Pectoral	15–18	16
Caudal:		
Principal	4+3	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Cabo San Lucas, Baja California Sur to Colombia, including southern Gulf of California

Habitat: Shallow tropical & subtropical waters; 33–50 m depth

Spawning season: Larvae collected in all months except August & December (maximum in May); transformation individuals in January & April; juveniles in March

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C, D, A & P_1
Pigmentation: Series on lateral midline; paired series ventrally along gut; on D, C & A bases; 3–4 over heart.
Diagnostic features: Nephros at ca. myomere 59 (57–61); total myomeres ca. 143 (137–148); compressed teeth; absence of crescentic pigment patch under eye; midlateral pigment.

MORPHOMETRICS (range & mean in %)

	46.3–133.3 mm
Sn-A/BL	85–97 93
BD/BL	4–5 4
GD/BL	8–11 10
HL/BL	6–9 7
HW/HL	24–30 27
SnL/HL	29–44 38
ED/HL	13–19 16
P_1L/BL	1–2 1
PdL/BL	76–94 86

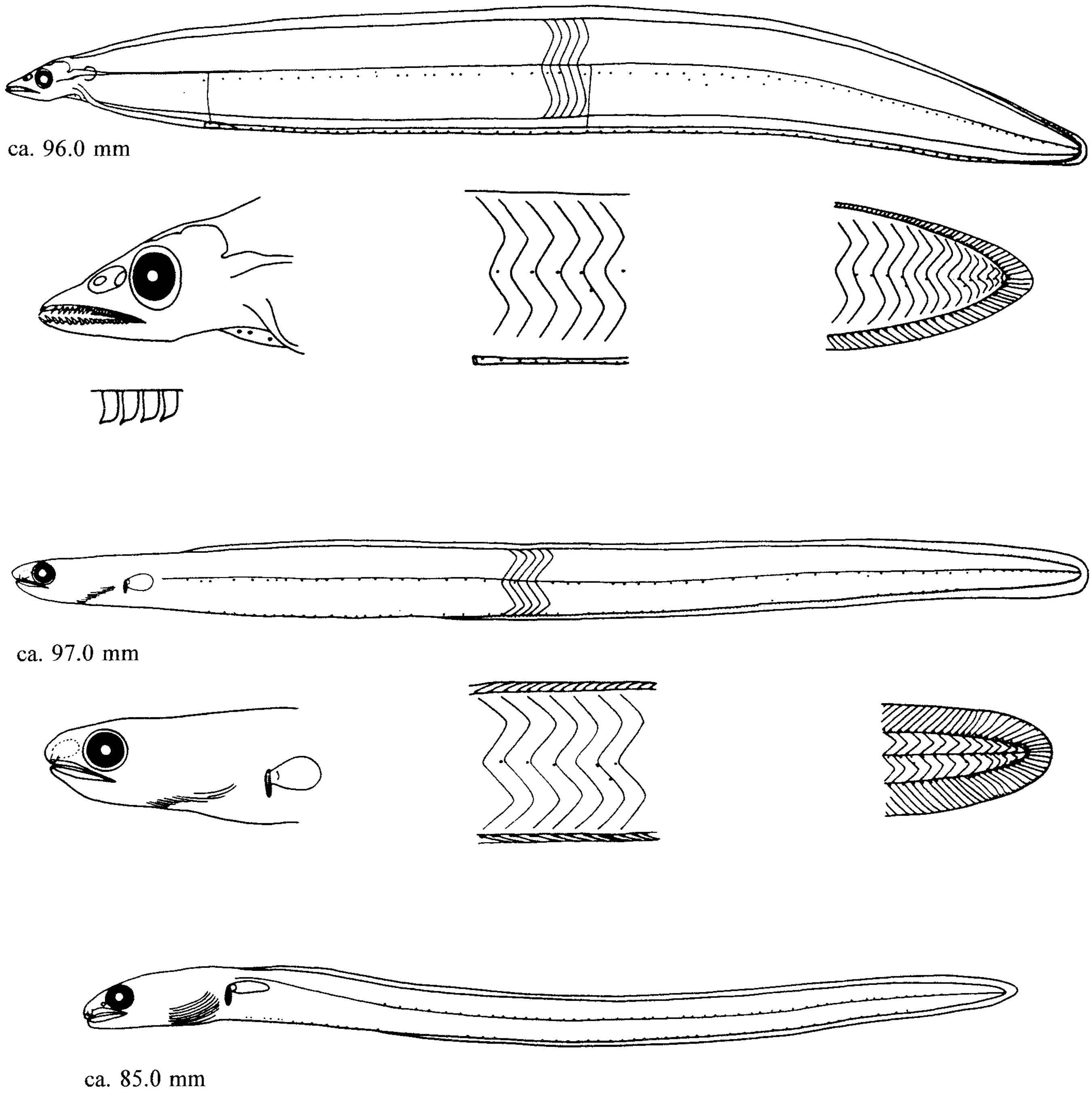


Figure Congridae 7. Larva, ca. 96.0 mm, whole body and sections showing head, midbody, and caudal regions and enlargement of teeth below; early juvenile, ca. 97.0 mm, whole body and sections showing head, midbody, and caudal regions; juvenile, ca. 85.0 mm, whole body (Raju 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	168–182	
Preanal	30–32	
Postanal	138–150	
Fins:		
Dorsal spines	0	
Dorsal rays		
Anal spines	0	
Anal rays		
Pelvic	0	
Pectoral		
Caudal:		
Principal	4+4	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Brauchiostegals		

LIFE HISTORY

Range: Northern Gulf of California to Gulf of Tehuantepec, Mexico; larvae range northward along Pacific coast to Bahía Todos Santos, Baja California

Habitat: Shallow temperate & tropical waters

Spawning season: Larvae collected in all months except December (minimum in October, maximum in May); transformation individuals in October; juveniles in January, March, May, June, & July

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Raju 1985

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C, D, A & P_1
Pigmentation: Crescentic patch below eye; 1–3 on maxilla; 2–3 at jaw articulation; 3–4 over heart; series below lateral midline; paired ventral series from isthmus to vent; on D, A, & C bases.
Diagnostic features: Nephros at ca. myomere 48 (46–49); total myomeres ca. 177 (169–187); elongate body; pointed tail; crescentic eye patch; 1–3 pigment dots on maxilla; midlateral pigment.

MORPHOMETRICS (range & mean in %)

	44.8–126.3 mm
Sn-A/BL	83–93 89
BD/BL	4–6 5
GD/BL	9–12 11
HL/BL	5–8 6
HW/HL	30–41 35
SnL/HL	28–38 34
ED/HL*	18–23× 22–28 20×24
P_1L/BL	1–2 1
PdL/BL	38–51 45

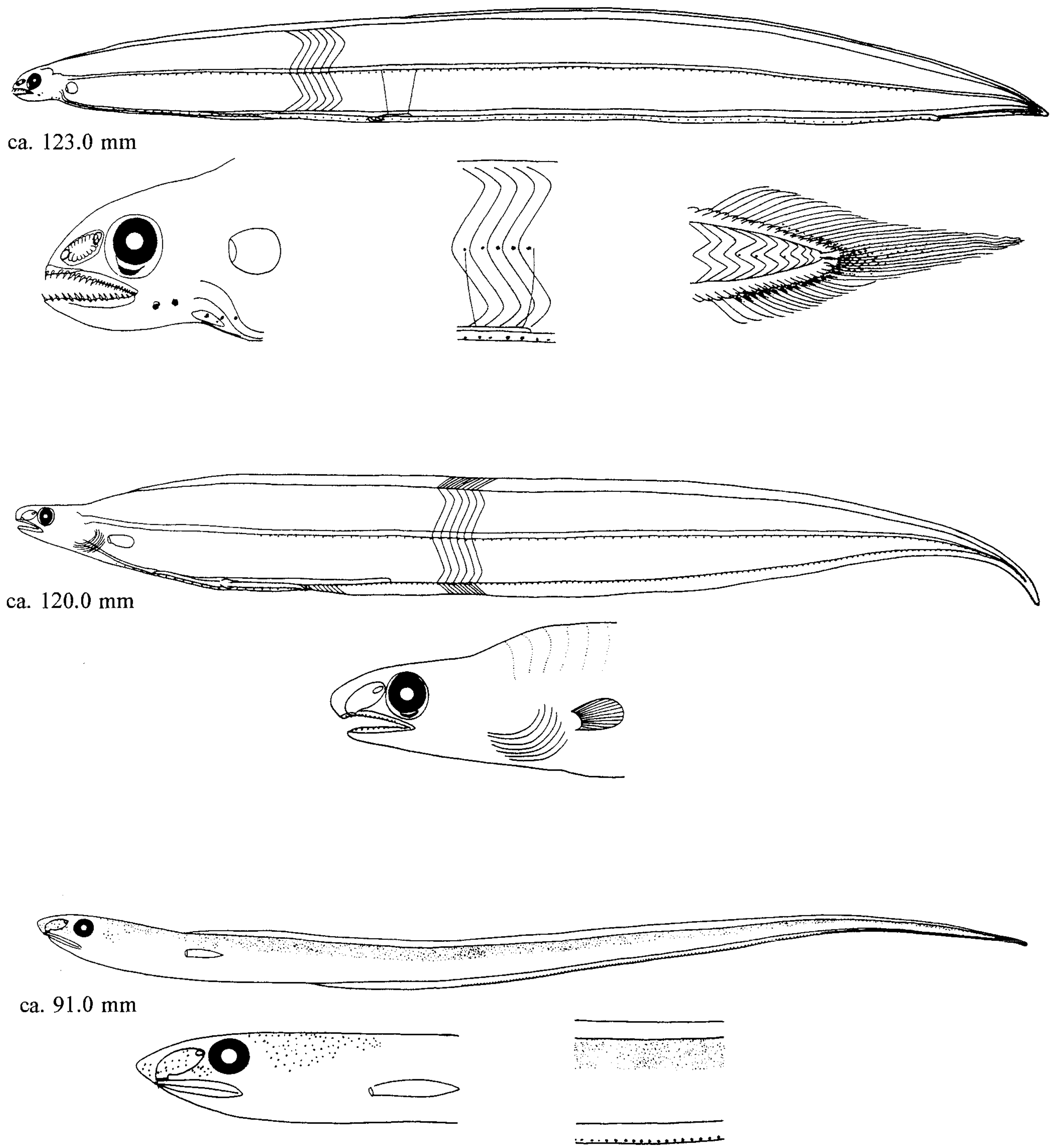


Figure Congridae 8. Larva, ca. 123.0 mm, whole body and sections showing head, nephros, and caudal regions; transformation specimen, ca. 120.0 mm, whole body and head; juvenile, ca. 91.0 mm, whole body and sections showing head and midbody (Raju 1985 as *Hildebrandia nitens*).

DERICHTHYIDAE: Longneck eels

S. R. CHARTER

Derichthyids live throughout the temperate regions of the Atlantic, Pacific, and Indian Oceans in mesopelagic and bathypelagic zones from 457 to 1829 m (Eschmeyer et. al. 1983). Presently, two genera and three species are recognized in this family. Only *Derichthys serpentinus* occurs in the CalCOFI region, ranging from southern California to Chile (Fitch and Lavenberg 1968). The adults are not abundant and larvae have not been collected in the regular CalCOFI ichthyoplankton samples.

Adults are easily recognized by scar-like striations on the head and a constriction in the neck area. The cephalic sensory system has large pores that are sometimes mistaken for nostrils, especially the large, anteriorly directed tubular one on the snout (Castle 1970). The gill slits are nearly horizontal and positioned anteroventrally to the pectoral fins. The vertical fins are contiguous, with the dorsal and anal fins abruptly reduced in the caudal area. The dorsal fin origin is at ca. 20–30% BL. *Derichthys serpentinus* is scaleless. A fresh specimen was tawny olive to mouse gray, while preserved material is dark brown dorsally and light brown on the abdomen (Beebe 1935; Karmovskaya 1986). *D. serpentinus* have an oval, opaque, whitish patch in each web of the dorsal and anal fins, possibly luminescent; this is lost in preservation (Beebe 1935).

Derichthyids are oviparous, with planktonic eggs. Beebe (1935) described *Derichthys serpentinus* ovaries which contained two batches of eggs indicating multiple spawning. Planktonic eggs average 2.33 mm in diameter and have a wide perivitelline space, segmented yolk, and oil globule(s) (Stibane 1983).

Derichthyid leptocephali are small to moderate in length (60–90 mm) and moderately deep-bodied (13–24% BL). The liver is undivided and the gut is a simple straight tube. The tail generally turns dorsad in preserved specimens. The dorsal fin origin is at midbody (43–59% BL), changing during transformation to the adult position (20–30% BL). Pigmentation in *Derichthys serpentinus* leptocephali is limited to minute melanophores on the tail just below the midlateral line. *D. serpentinus* larvae may be distinguished from larval serrivomerids by the position of the nephros terminus, at myomeres 58–65 versus 34–39, respectively.

Egg, larval, and ecological information was taken from the literature (e.g., Beebe 1935; Karmovskaya 1986; Smith 1989h). Morphometrics and meristics of *D. serpentinus* were taken from detailed examination of 16 larval specimens (8.1–43.6 mm) and two transformation specimens (65.1 and 67.0 mm).

MERISTICS

	Range	Mode
Vertebrae:		
Total	126–136	133
Precaudal	53–57	56
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	226–262	244
Anal spines	0	
Anal rays	155–180	159
Pelvic	0	
Pectoral	11–18	13
Caudal:		
Principal	9–11	10
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	6–8	7

LIFE HISTORY

Range: Worldwide in warm & temperate seas; eastern Pacific from southern California to Chile

Habitat: Meso- & bathypelagic, 500–2000 m depth

Spawning season:

ELH pattern: Oviparous; planktonic eggs & leptocephali

LITERATURE

Beebe 1935
Castle 1970
Karmovskaya 1986
Smith 1979, 1989h
Stibane 1983

* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.3 mm **Yolk:** Segmented
No. of OG: Multiple **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features: Large size; wide perivitelline space; segmented yolk.

LARVAE

Hatching length: >5.5 mm
Flexion length:
Transformation length: ca. 55.0 mm
Fin development sequence: D, A, C, P_1
Pigmentation: Similar through all stages; postanal series (minute), just below the lateral midline.
Diagnostic features: Nephros at ca. myomere 62 (58–65); total myomeres ca. 134 (131–137); moderate-sized leptocephali; caudal region curved dorsad in preserved specimens; distinctive pigmentation.

MORPHOMETRICS (range & mean in %)

	8.1–8.8 mm	10.6–43.6 mm	Tr 65.1–67.0 mm
Sn-A/BL	78–78 78	74–83 79	50–58 54
BD/BL	10–12 11	6–12 9	6–8 7
GD/BL	18–19 19	16–24 19	15–16 16
HL/BL	16–16 16	10–15 12	10–10 10
HW/HL	36–38 37	28–38 34	22–31 27
SnL/HL	31–33 32	28–33 30	22–22 22
ED/HL*	27–30× 31–34 28×33	20–26× 21–33 23×28	14–14× 12–16 14×14
P_1L/BL	3–3 3	1–3 2	3–3 3
PdL/BL	45–51 48	43–59 52	21–29 25

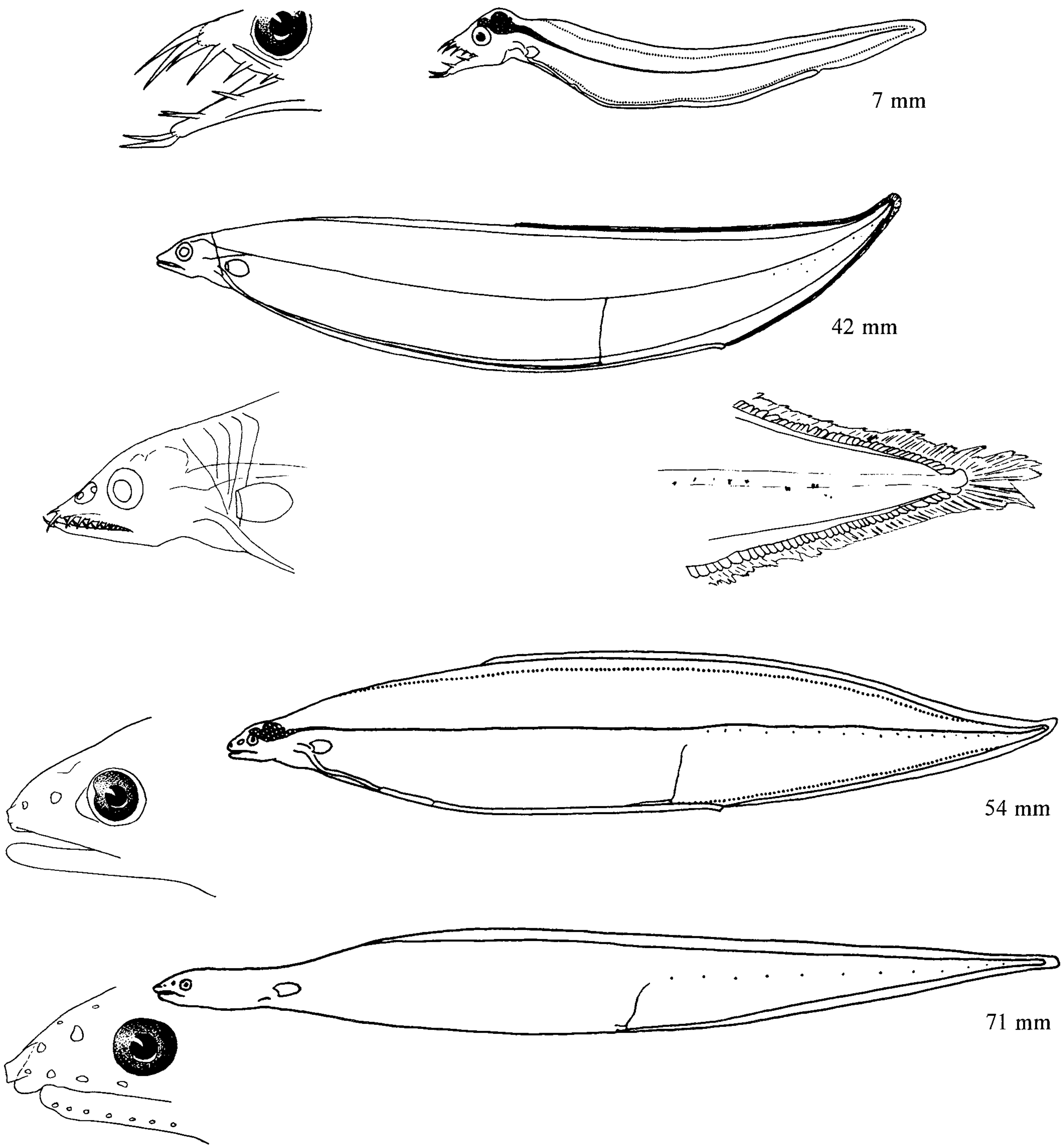


Figure Derichthyidae 1. Early larva, 7 mm, head and whole body (Castle 1970); larva, 42 mm, whole body and sections showing head and caudal region (Smith 1979); transformation specimen, 54 mm, head and whole body; late transformation specimen, 71 mm, head and whole body (Castle 1970).

NEMICHTHYIDAE: Snipe Eels

S. R. CHARTER

Four nemichthyid species occur in the CalCOFI study area (Table Nemichthyidae 1): *Avocettina bowersii*, *A. infans*, *Nemichthys larseni*, and *N. scolopaceus* (Nielsen and Smith 1978). *N. scolopaceus*, the most common species in midwater trawl collections, ranges from British Columbia, Canada, to Peru including the Gulf of California. *A. infans*, the second most common species, occurs from British Columbia, Canada, to central Mexico including the Gulf of California. The distribution of *N. larseni* is similar to that of *A. infans* and *A. bowersii* ranges from San Francisco, California, to Peru.

Adult nemichthyids are mesopelagic eels recognized by scaleless, elongate bodies with upper and lower jaws that curve away from each other. Their bodies are compressed and their anal fins are higher than their dorsal fins. Mature males undergo a transformation, most visibly a shortening of their jaws, and at one time were placed in different genera from conspecific females (Nielsen and Smith 1978). *Nemichthys* species have filamentous tails, a lateral line consisting of three rows of pores, and may have >750 vertebrae. *Avocettina* species have attenuate tails, a lateral line with a single row of pores, and ca. 200 vertebrae. Although usually caught at depths >300 m, *N. scolopaceus* have been caught in surface tows in the Gulf of California (Lavenberg and Fitch 1966).

Adults are oviparous; planktonic eggs are unknown. Leptocephali are long bodied (maximum length 400 mm) and slender with greatest depth 4–11% BL. The liver is undivided and the gut is a simple straight tube 89–96% BL. The caudal region is attenuate or filiform. A characteristic internal series of melanophores lies above the notochord.

Nemichthyid leptocephali in the California Current region may be separated into two groups (Table Nemichthyidae 2): *Nemichthys* has a filiform tail and ca. 300–400 myomeres while *Avocettina* has an attenuate tail and ca. 200 myomeres. *N. larseni* and *N. scolopaceus* are sympatric in the eastern Pacific and have overlapping precaudal vertebral counts (Nielsen and Smith 1978). Ten *Nemichthys* leptocephali (11.0–184.8 mm) examined in this study are identical to those described as *N. scolopaceus* by Castle (1965a) and Smith (1989i). *N. larseni* leptocephali are unknown. *Avocettina bowersii* and *A. infans* have nonoverlapping precaudal vertebral counts (59–66 versus 69–72). *A. bowersii* leptocephali examined in this study had the nephros terminus at ca. myomere 62 (60–64), and lateral pigment patches consisting of 5–12 melanophores at myomeres 24–25, 46–51, and 80–84, whereas *A. infans* had the nephros terminus at ca. myomeres 71 (69–74) and lateral pigment patches consisting of 1–4 melanophores at myomeres 28–31, 59–61, and 97–100. *A. infans* larvae in this study are similar to those described by Smith (1989i). Differences in gut pigmentation and morphometry are noted in the species descriptions.

Table Nemichthyidae 1. Meristic characters for the nemichthyid species in the California Current vicinity (Nielsen and Smith 1978). The caudal filaments are often broken in adult *Nemichthys*; counts for the dorsal and anal fins are the numbers of rays anterior to the 201st vertebra (those counts referred to as D_{200} and A_{200} by Nielsen and Smith, 1978)

Species	Vertebrae			Fin rays	
	PrCV	CV	Total	D	A
Avocettina bowersii	59–66	124–129	177–195	233–333	208–297
A. infans	69–72	116–131	185–203	279–432	240–372
Nemichthys larseni	79–86			164–218	173–222
N. scolopaceus	77–105			170–253	186–273

Table Nemichthyidae 2. Morphology and pigmentation of nemichthyid leptocephali examined in this study. Relative positions of the posterior end of the liver, the nephros terminus, and vent (preanal), are indicated by the corresponding myomere number (range and mean), counting posteriad from head. Also listed for each species are the number of melanophores in the lateral patches and the position of the patches with respect to myomeres.

Species	Myomeres				Pigmentation	
	Liver	Nephros	Preanal	Total	Number	Myomeres
Avocettina bowersii		60–64	123–158	187–191	5–12	24–25, 46–51, & 80–84
	26	62	141	189		
A. infans		69–74	163–167	187–198	1–4	28–31, 59–61, & 97–100
	30	71	165	194		
Nemichthys scolopaceus	39–47	81–88	134–251	275–354	1–5	18–23, 35–44, 69–81, & 103–123
	41	85	210	315		

MERISTICS

	Range	Mode
Vertebrae:		
Total	177–195	
Precaudal	59–66	
Caudal	124–129	
Fins:		
Dorsal spines	0	
Dorsal rays	233–333	
Anal spines	0	
Anal rays	208–297	
Pelvic	0	
Pectoral	15–19	
Caudal:	attenuate	
Principal		
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: Eastern Pacific from San Francisco, California to Peru; offshore to 150° W

Habitat: Mesopelagic in warm temperate & tropical waters; collection depths 92–641 m

Spawning season:

ELH pattern: Oviparous; degenerative changes in males & females suggests semelparity; planktonic leptocephali

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 88.7 mm (N. Arthur)
Head, body, & caudal sections of 88.7 mm larva (N. Arthur)

* One of two available specimens ripped, not usable for BL calculations.

EARLY LIFE HISTORY DESCRIPTION

EGGS

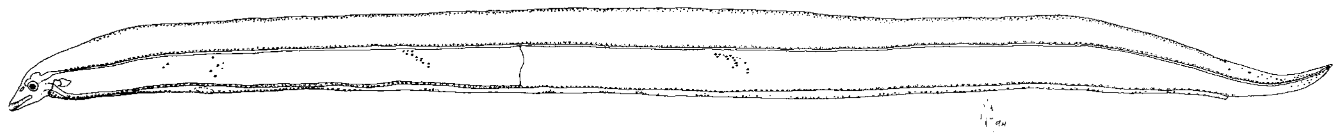
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: D & A & C, P_1
Pigmentation: Dorsally on notochord; three clusters (5–12 each) below lateral midline at myomeres 24–25, 46–51, & 80–84; dorsally on gut, heavier past liver; ventrally on gut, heavier before liver.
Diagnostic features: Liver at ca. myomere 26; nephros at ca. myomere 62 (60–64); total myomeres ca. 189 (187–191); attenuate tail; compared to *A. infans*—relatively smaller eye & longer snout, head less depressed, number (5–12) & position of lateral pigment at myomeres 24–25, 46–51, & 80–84, & dorsal & ventral gut pigment from heart to anus.

MORPHOMETRICS (range & mean in %)

	15.5 mm	88.7 mm*
Sn-A/BL	87	93
BD/BL	8	3
GD/BL	15	7
HL/BL	11	4
HW/HL	34	31–33 32
SnL/HL	44	44–46 45
ED/HL	21	19–20 20
P_1L/BL	3	1
PdL/BL	0	99



88.7 mm

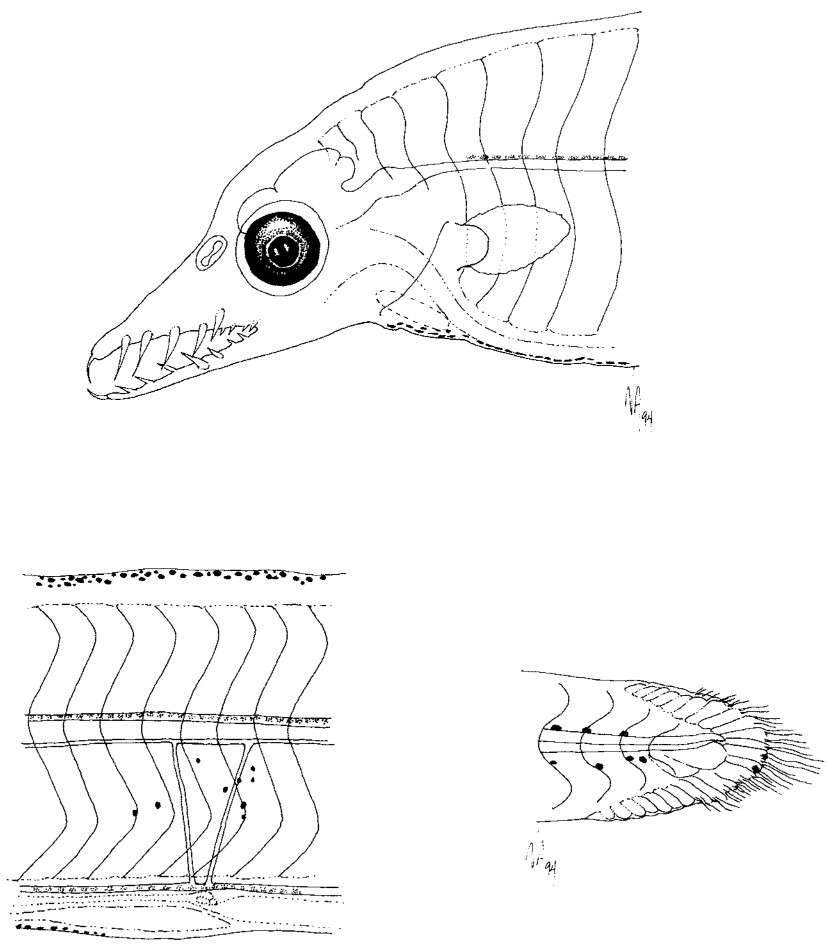


Figure Nemichthyidae 1. Larva, 88.7 mm, whole body and sections showing head, gastric, and caudal regions (EASTROPAC I, station 12.51).

MERISTICS

	Range	Mode
Vertebrae:		
Total	185–203	193
Precaudal	69–72	71
Caudal	116–131	120
Fins:		
Dorsal spines	0	
Dorsal rays	279–432	339
Anal spines	0	
Anal rays	240–372	299
Pelvic	0	
Pectoral	14–18	16
Caudal:	attenuate	
Principal		
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals		

LIFE HISTORY

Range: All oceans north of 20° S; in the eastern Pacific from Queen Charlotte Islands, British Columbia, Canada to central Mexico, including the Gulf of California

Habitat: Surface to 2000 m depth; usually 1200 to 2000 m depth

Spawning season:

ELH pattern: Oviparous; degenerative changes in males & females suggest semelparity; planktonic leptocephali

LITERATURE

Castle 1965a
Nielsen & Smith 1978
Smith 1989i

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

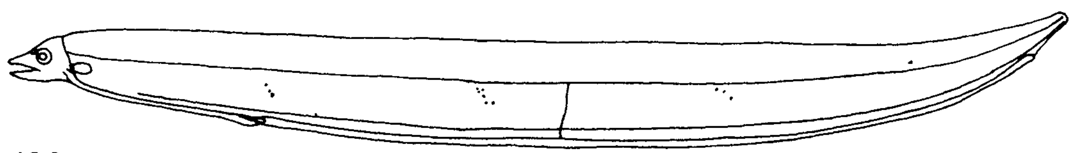
LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: D & A & C, P_1
Pigmentation: Dorsally on notochord; three clusters (1–4 dots each) below lateral midline at myomeres 28–31, 59–61, & 97–100; dorsally along gut from liver; ventrally along gut from heart to liver.
Diagnostic features: Liver at ca. myomere 30; nephros at ca. myomere 71 (69–74); total myomeres ca. 194 (187–198); moderate length (maximum 150 mm); attenuate tail; depressed head; relatively large eye & short snout; number (1–4) & position of lateral pigment at myomeres 28–31, 59–61, & 97–100; dorsal gut pigment starting at liver; ventral gut pigment ending at liver.

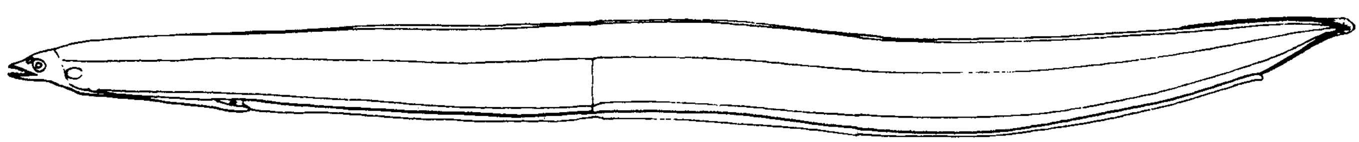
MORPHOMETRICS (range & mean in %)

	46.1–62.9 mm
Sn-A/BL	94–96 95
BD/BL	4–5 5
GD/BL	8–10 9
HL/BL	5–7 6
HW/HL	30–34 32
SnL/HL	40–41 41
ED/HL	23–24 24
P_1L/BL	1–1 1
PdL/BL	90–91 90

20.0 mm



45.0 mm



111.0 mm

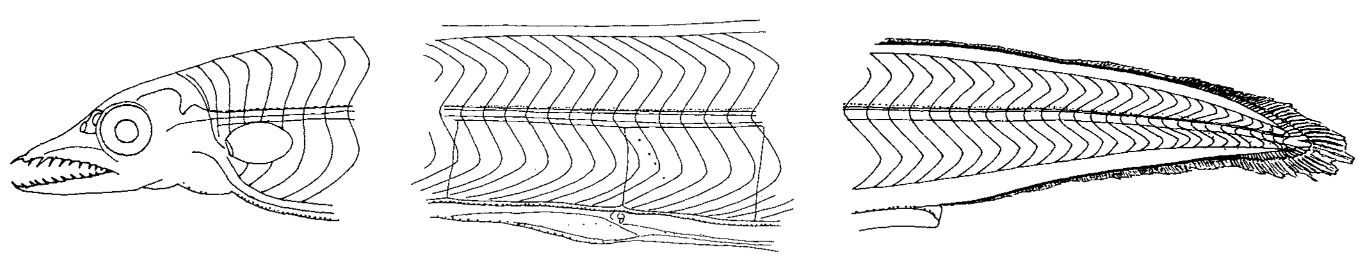


Figure Nemichthyidae 2. Larvae, 20.0 mm, 45.0 mm; larva, 111.0 mm, whole body and sections showing head, gastric, and caudal regions (Smith 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total*		
Precaudal	77–105	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays (D_{200})*	170–253	
Anal spines	0	
Anal rays (A_{200})*	186–273	
Pelvic	0	
Pectoral	10–14	
Caudal*:		
Principal	reduced to filament	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	7–15	

LIFE HISTORY

Range: Cosmopolitan in tropical & temperate seas; in the eastern Pacific from British Columbia, Canada to Peru, including the Gulf of California

Habitat: Mesopelagic; occasionally stranded ashore during storms; eastern Pacific collection depths 24–4337 m, usually <500 m

Spawning season:

ELH pattern: Oviparous; degenerative changes in males & females suggest semelparity; planktonic leptocephali

LITERATURE

Beebe & Crane 1937
Castle 1965a
Nielsen & Smith 1978
Smith 1989i

* See Table Nemichthyidae 1 for explanation.
† Small larvae have slightly oval eyes; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length:
Transformation length:
Fin development sequence: D & A & C, P_1
Pigmentation: Dorsally on notochord; four clusters (1–5 dots each) below lateral midline at myomeres 18–23, 35–44, 69–81, & 103–123; dorsally on gut; D & A fin bases; larvae >120.8 mm have ventral patch posterior to heart.
Diagnostic features: Liver at ca. myomere 41; nephros at ca. myomere 85 (81–88); total myomeres ca. 305 (230–354); number (1–5) & position of lateral pigment at myomeres 18–23, 35–44, 69–81, & 103–123; filamentous tail; maximum body length ca. 260 mm.

MORPHOMETRICS (range & mean in %)

	11.0–32.4 mm	49.6–184.8 mm
Sn-A/BL	79–91 86	86–94 92
BD/BL	5–7 6	2–4 3
GD/BL	9–11 10	4–9 6
HL/BL	7–11 9	3–6 4
HW/HL	33–39 35	28–33 30
SnL/HL	36–43 41	44–50 47
ED/HL†	23–29× 22–25 25×24	19–22 20
P_1L/BL	0.9–2 2	0.2–0.7 0.4
PdL/BL	0–0 0	84–93 90

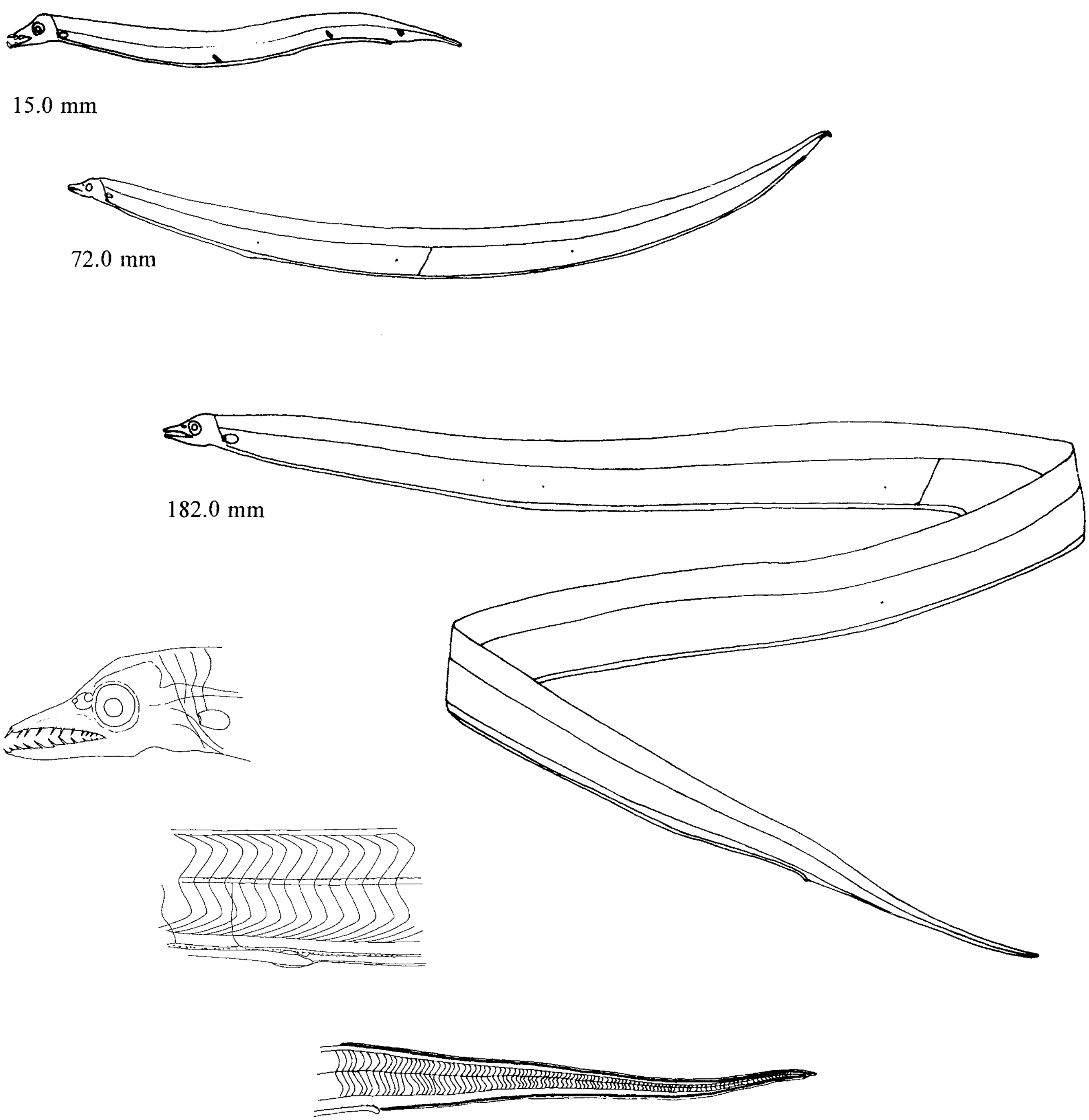


Figure Nemichthyidae 3. Larvae, 15.0 mm, 72.0 mm; larva, 182.0 mm, whole body and sections showing head, gastric region, and caudal region (Smith 1979).

SERRIVOMERIDAE: Sawtooth eels

S. R. CHARTER

Serrivomerids occur in the temperate and tropical regions of nearly all oceans. Tighe (1989a) recognized two genera and 10 species in the family. *Serrivomer sector,* the only species known to occur in the CalCOFI study area, ranges from central California to Chile and usually is collected at depths >1000 m, although specimens have been collected near the surface after sunset (Fitch and Lavenberg 1968). Adults are uncommon in midwater trawl collections and larvae are rare in CalCOFI ichthyoplankton samples. A single *S. jesperseni* specimen collected in the Gulf of California is held by LACM, and Matarese et al. (1989) reported them north of the CalCOFI study area.

Fresh specimens of *Serrivomer* are bronze colored; this pigment may persist in preserved specimens (Tighe 1989a). *S. sector* has moderately attenuate jaws with a dark brown, slender, scaleless body. The dorsal and anal fins are confluent with the caudal fin and the anal fin is more anterior and higher than the dorsal fin. *S. sector* is easily recognized by the large, compressed teeth on the vomer.

S. sector is oviparous; planktonic eggs are unknown. Leptocephali are moderate in size (>63.7 mm before transformation) and relatively deep-bodied (16–24% BL). The liver is undivided, the gut is a simple straight tube, and the tail is pointed. The dorsal fin origin is at ca. 75% (62–81%) BL. An irregular series of minute melanophores is present just below the lateral midline, beginning at ca. 50% BL. Other pigmentation is on the posterior portion of the dorsal fin base, on the anal fin base, and on the eye. *S. sector* may be distinguished from *Derichthys serpentinus* by its more anterior nephros terminus (at myomeres 34–39 vs. 58–65, respectively), a more posterior dorsal fin origin, and the presence of midlateral preanal pigmentation.

Morphometrics and meristics of *S. sector* were obtained from detailed examination of 50 larval specimens (4.7–63.7 mm), largely collected west of the CalCOFI survey area. Additional information on adults was taken from Fitch and Lavenberg (1968).

MERISTICS

	Range	Mode
Vertebrae:		
Total	151–153	153
Precaudal	35–36	36
Caudal	117–118	117
Fins:		
Dorsal spines	0	
Dorsal rays	145–148	
Anal spines	0	
Anal rays	143–152	
Pelvic	0	
Pectoral	reduced	
Caudal:		
Principal	3+3	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	7	

LIFE HISTORY

Range: Central California to Chile

Habitat: Epi- to bathypelagic; usually >305 m depth

Spawning season: Spring & early summer

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Bauchot 1959
Tighe 1989b

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 46.5 mm (M. T. Vona)
Head, body, & caudal sections of 46.5 mm larva (M. T. Vona)

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* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.7 mm
Flexion length:
Transformation length: <63.7 mm
Fin development sequence: C, D & A & P_1
Pigmentation: Minute irregular series just below lateral midline beginning at ca. 50% BL; on posterior portion of D base; on A base; on dorsal surface of eye.
Diagnostic features: Nephros at ca. myomere 37 (34–39); total myomeres ca. 153 (145–161); minute pigment below lateral midline beginning at 50% BL & on D & A bases; compared to *Derichthys serpentinus*—nephros at ca. 33% BL vs. ca. 75% BL; D orgin at ca. 75% BL vs. 50% BL; midlateral pigment before anus.

MORPHOMETRICS (range & mean in %)

	4.7–9.8 mm	10.0–63.7 mm
Sn-A/BL	65–95 82	76–94 87
BD/BL	6–14 11	6–16 9
GD/BL	17–22 19	16–24 21
HL/BL	12–16 15	8–14 11
HW/HL	36–61 44	25–42 33
SnL/HL	28–41 37	33–41 37
ED/HL	26–40× 30–42 32×34	17–30× 17–34 25×27
P_1L/BL	1–4 3	1–4 2
PdL/BL	65–70 67	60–82 69

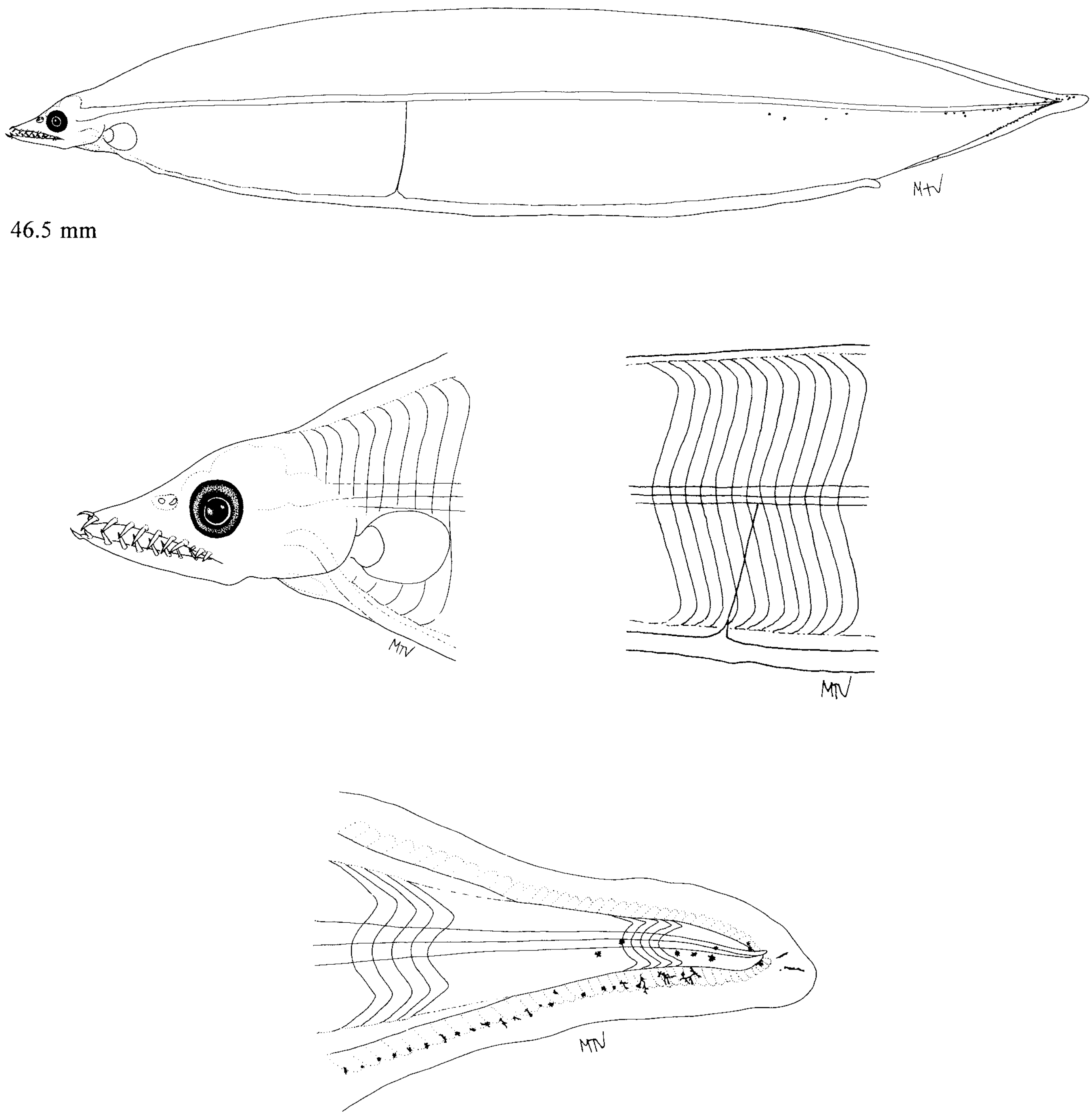


Figure Serrivomeridae 1. Larva, 46.5 mm, whole body and sections showing head, nephros and caudal regions (TC 8406, station 210).

NETTASTOMATIDAE: Duckbill eels

S. R. CHARTER

The family Nettastomatidae contains 6 genera and 25 species, with possibly 10 more undescribed species (Smith and Castle 1982). Only *Facciolella gilbertii* and *Venefica tentaculata* occur commonly in the CalCOFI area (Table Nettastomatidae 1). *F. gilbertii* ranges from Pt. Conception, California, to Panama, while *V. tentaculata* ranges from San Francisco, California, to Chile. *F. gilbertii* leptocephali occur along the Baja California coast, from Bahía Sebastián Vizcaíno to Cabo San Lucas; one early transformation specimen was collected in a midwater trawl off San Diego, California. Smith (1989b and pers. comm.) suggested that *F. gilbertii* may be synonymous with *F. equatorialis*, however, a definitive study of the problem has not been done. Larval *V. tentaculata* are unknown. *Hoplunnis sicarius* (D. G. Smith, pers. comm.) and *Saurenchelys* sp. occur from the Gulf of California south to Ecuador. A single specimen of *H. sicarius* was collected in a CalCOFI ichthyoplankton sample (CalCOFI 6509, station 133.45), off Punta San Juanico, Baja California Sur. Additional specimens were collected south to Ecuador. *Saurenchelys* sp. larvae have been collected from the Gulf of California and south to Ecuador.

Nettastomatid adults are elongate and long-snouted; some have a fleshy proboscis. Vomerine teeth vary from small, granular patches to large and fang-like. Nettastomatids have confluent dorsal, anal, and caudal fins with a slender attenuate tail, which may be regenerated. Only one genus, *Hoplunnis*, retains pectoral fins. Nettastomatids are benthic but not burrowers. Adults have been collected in deep midwater tows from subtropical to tropical latitudes and feed on a variety of small fishes and invertebrates (Smith 1989b).

Nettastomatids are oviparous, presumably with planktonic eggs. One *H. sicarius* female (470 mm) with mature ovaries containing free eggs (ca. 1 mm) was collected off Mazatlan, Mexico (Lane and Stewart 1968). Nettastomatid larvae are slender (GD 3–14% BL) and compressed, with a long-snout (34–49% HL), and attenuate tail. The liver is undivided and the gut is short to moderate (21–57% BL) and may have low undulations (*Facciolella*) or two distinct swellings (*Hoplunnis*). In larger *Facciolella* larvae, the pectoral fins may be resorbed.

Morphometric and meristic information for this study came from detailed examination of 25 larval *Facciolella gilbertii* (7.8–204.1 mm) and 12 *Hoplunnis sicarius* (17.4–155.2 mm). Additional ecological data came from Fitch and Lavenberg (1968) and Smith (1989b).

Table Nettastomatidae 1. Meristic characters for the nettastomatid species in the California Current vicinity and Gulf of California based on Garman 1899 and this study.

	Vertebrae			Fin rays	
Species	PrCV	CV	Total	D	A
Facciolella gilbertii	51–57	172–181	223–238	370	283
Hoplunnis sicarius	ca. 43	ca. 215	252–258	ca. 382	ca. 317
Venefica tentaculata	ca. 61–61	135–172[a]	196–233[a]	397	ca. 285

[a] Large range of counts possibly due to broken and regenerated tails.

MERISTICS

	Range	Mode
Vertebrae:		
Total	223–238	223
Precaudal	51–57	51
Caudal	172–181	172
Fins:		
Dorsal spines	0	
Dorsal rays	370	
Anal spines	0	
Anal rays	283	
Pelvic	0	
Pectoral	0	
Caudal:		
Principal	3–4+3–4 (regenerated 5–7+5–7)	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	12	

LIFE HISTORY

Range: Eastern Pacific from Pt. Conception, California to Panama

Habitat: Benthopelagic

Spawning season: Larvae collected December–July

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Castle 1978
Smith & Castle 1982

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 38.1 mm (M. T. Vona)
Head & body section of 38.1 mm larva (M. T. Vona)

* Eye in yolk-sac larva is slightly oval, becomes round by 11.3 mm; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

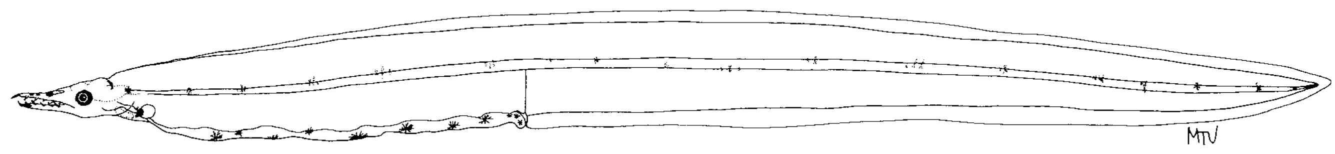
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <7.8 mm
Flexion length:
Transformation length: ca. 204.1 m
Fin development sequence: C, D & A, P_1, P_1 resorbed
Pigmentation: On snout & lower jaw; laterally & posteriorly on braincase; anterior & posterior to heart; on P_1 base; midlateral series (1–several per cluster) arranged vertically in myosepta around notochord; series (stellate) ventrolaterally along gut.
Diagnostic features: Nephros at ca. myomere 57 (52–59); total myomeres ca. 220 (213–229); elongate snout; gut generally <40% BL (1 specimen, 11.3 mm 57% BL); low undulating gut; midlateral series of melanophores arranged vertically in myosepta around notochord; pigmented P_1 base.

MORPHOMETRICS (range & mean in %)

	Y-S 7.8 mm	11.3–23.4 mm	26.1–204.1 mm
Sn-A/BL		49–57	30–46
	34	51	37
BD/BL		5–6	2–5
	9	5	4
GD/BL		8–9	5–10
	9	9	7
HL/BL		11–12	7–11
	4	11	9
HW/HL		22–30	14–23
	106	25	18
SnL/HL		34–44	34–49
	47	42	45
ED/HL*		16–24	9–14
	59×68	18	11
P_1L/BL		1–2	0.7–3
	0	2	1
PdL/BL		0–0	11–21
	0	0	15



38.1 mm

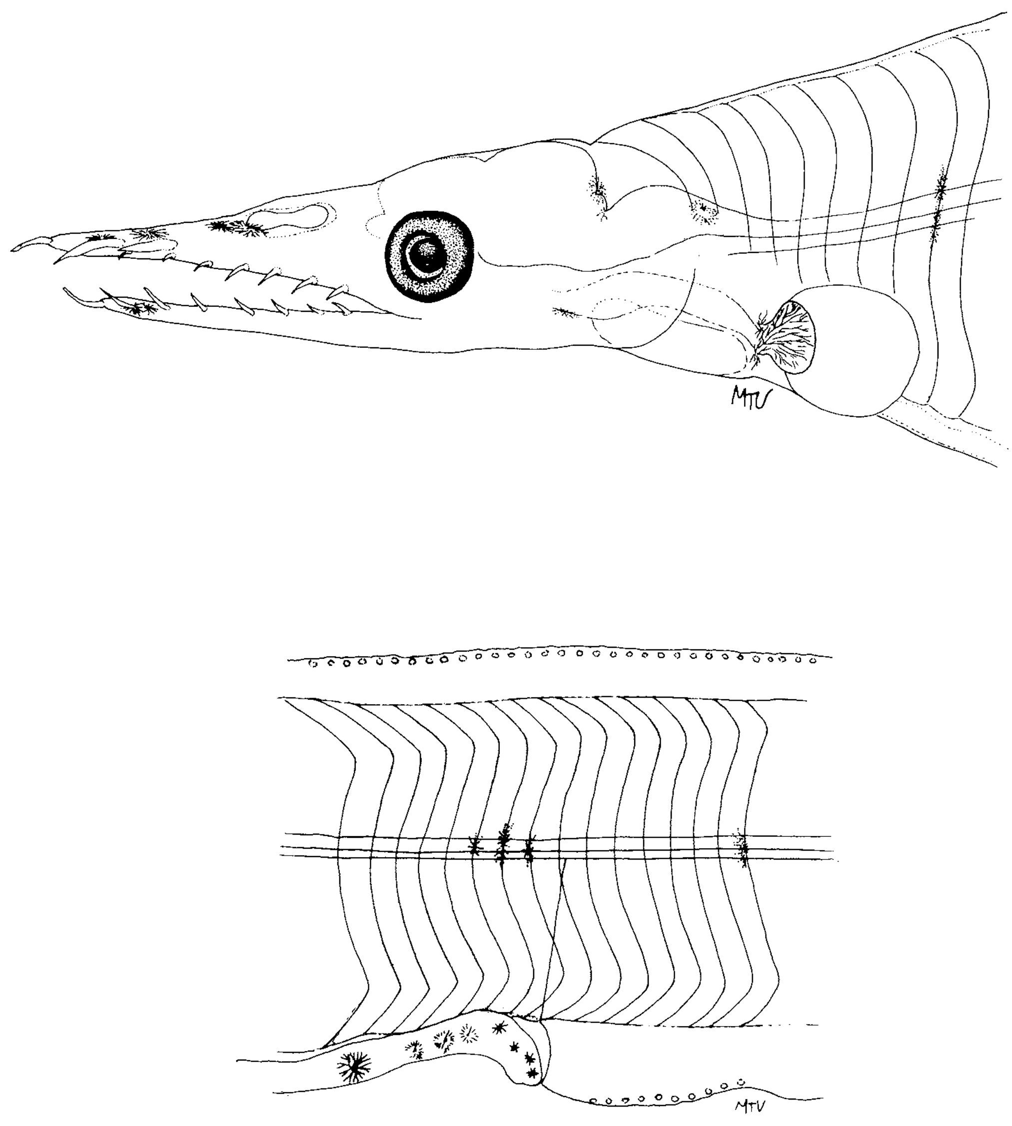


Figure Nettastomatidae 1. Larva, 38.1 mm, whole body and sections showing head and nephros regions (CalCOFI 6501, station 130.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	252–258	
Precaudal	ca. 43	
Caudal	ca. 215	
Fins:		
Dorsal spines	0	
Dorsal rays	ca. 382	
Anal spines	0	
Anal rays	ca. 317	
Pelvic	0	
Pectoral	11	
Caudal:	commonly regenerated	
Principal	3–4+3–4	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper		
Lower		
Branchiostegals	8	

LIFE HISTORY

Range: Eastern Pacific from Mazatlan, Mexico to Panama

Habitat: Benthic but not burrowing

Spawning season:

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Smith & Castle 1982

ORIGINAL ILLUSTRATIONS (Illustrator)

Larva, 107.5 mm (R. C. Walker)
Head, body, & caudal sections of 107.5 mm larva (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

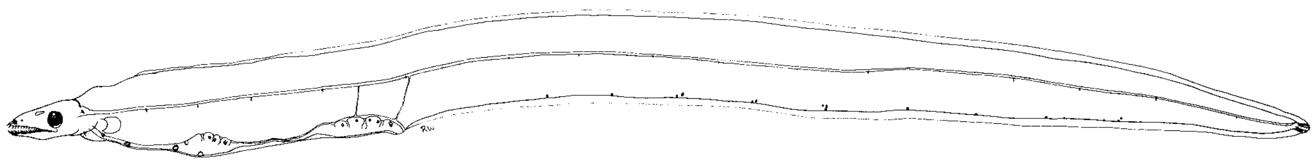
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: >155.2 mm
Fin development sequence: C, D & A, P_1
Pigmentation: Similar through all stages; on tip of snout & lower jaw; laterally & posteriorly on braincase; anterior & posterior to heart; scattered along gut; lateral row along midline to tail; postanally along ventral edge of myomeres.
Diagnostic features: Nephros at ca. myomere 47 (45–48); total myomeres ca. 254 (245–261); gut generally <30% BL with two well developed swellings (2 specimens <54.0 mm, <53% BL); pigment postanally along ventral edge of myomeres.

MORPHOMETRICS (range & mean in %)

	17.4 mm	54.0–155.2 mm
Sn-A/BL	53	21–30 25
BD/BL	7	3–4 3
GD/BL	14	5–7 6
HL/BL	11	6–7 6
HW/HL	23	20–25 22
SnL/HL	38	38–42 40
ED/HL	38	13–16 15
P_1L/BL	1	0.2–1 0.9
PdL/BL	0	7–12 9



107.5 mm

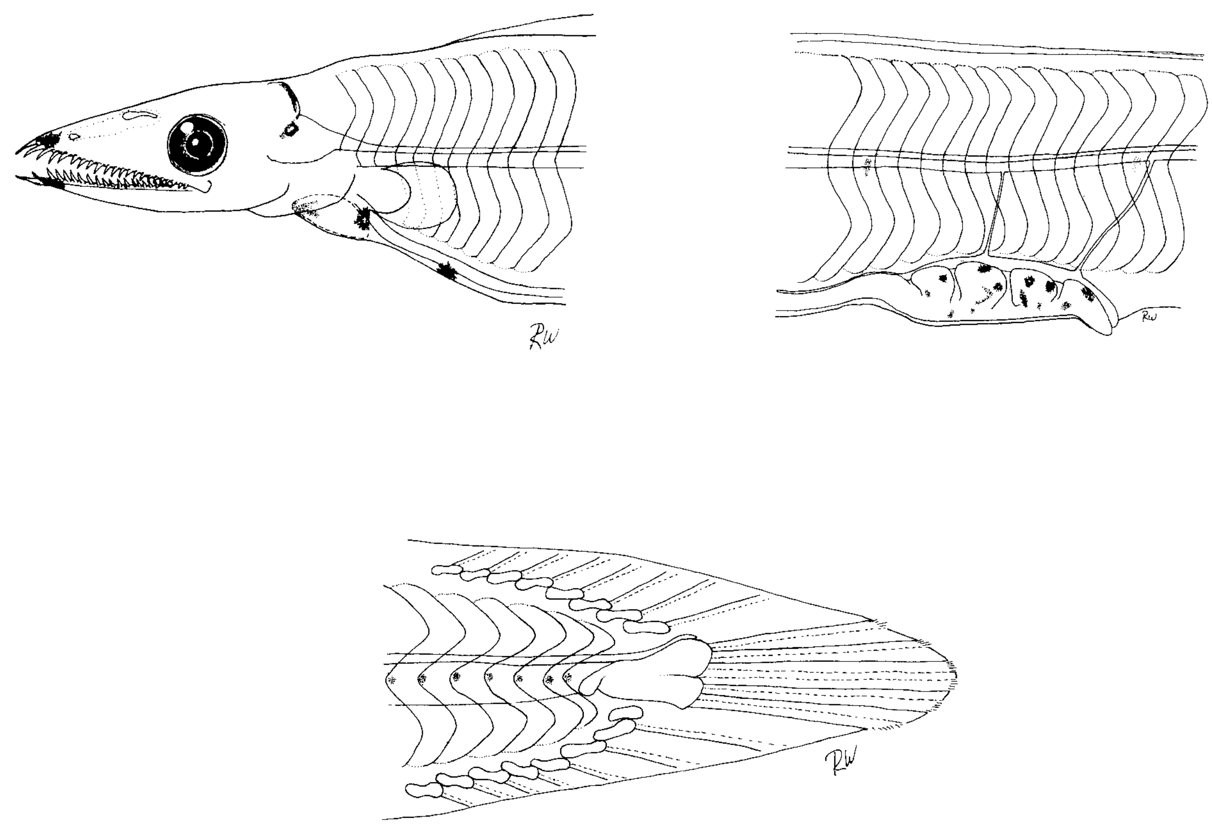


Figure Nettastomatidae 2. Larva, 107.5 mm, whole body and sections showing head, nephros and second intestinal swelling, and caudal regions (Eastropic, station H 43).

INCERTAE SEDIS

S. R. Charter

Thalassenchelys coheni, known only from larval specimens, was originally placed in the Chlopsidae (Castle and Raju 1975). Presently *T. coheni* can not be assigned to a family (Castle and Raju 1975; Lavenberg 1988). In the eastern Pacific, *T. coheni* ranges from Isla de Guadalupe, Baja California to Seattle, Washington, and west to the Hawaiian Islands (Castle and Raju 1975). Aron (1958) collected two leptocephali west of Vancouver Island, British Columbia, Canada.

Leptocephali are large (up to ca. 30 cm), have extremely deep bodies (33–43% BL) with W-shaped myomeres, and an undulating gut (47–54% BL). The snout is pointed and the head is small (4–7% BL). Pigment is lacking. Castle and Raju (1975) described transformation specimens with well defined ova and suggested the species has a short posttransformation life, sufficient only to mature and reproduce.

Morphometric and meristic data were obtained from 11 specimens (137.2–299.2 mm) collected in midwater trawls or MOCNESS samplers at 0–100 m depth, in March and July. Aron (1958) collected leptocephali in September in a midwater trawl (maximum depth of 30 m), and Cohen's (1959) specimens were from a midwater trawl taken in June (27–30 m depth).

MERISTICS

	Range	Mode
Vertebrae:		
Total		
Precaudal		
Caudal		
Fins:		
Dorsal spines		
Dorsal rays		
Anal spines		
Anal rays		
Pelvic		
Pectoral		
Caudal:		
Principal		
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Not well known; larvae from Isla de Guadalupe, Baja California to Vancouver Island, British Columbia & Hawaii

Habitat: Epipelagic

Spawning season:

ELH pattern:

LITERATURE

Castle & Raju 1975
Lavenberg 1988

* Adult unknown
† Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C, D, A & P_1
Pigmentation: None
Diagnostic features: Nephros at ca. myomere 63 (58–66); total myomeres ca. 158 (154–161); relatively moderate length, extremely deep-bodied leptocephali; lacks pigment.

MORPHOMETRICS (range & mean in %)

	137.2–299.2 mm
Sn-A/BL	47–54 50
BD/BL	5–7 6
GD/BL	33–43 37
HL/BL	4–7 5
HW/HL	28–41 33
SnL/HL	35–44 39
ED/HL†	13–19× 15–22 16×18
P_1L/BL	0.4–1 0.9
PdL/BL	45–51 49

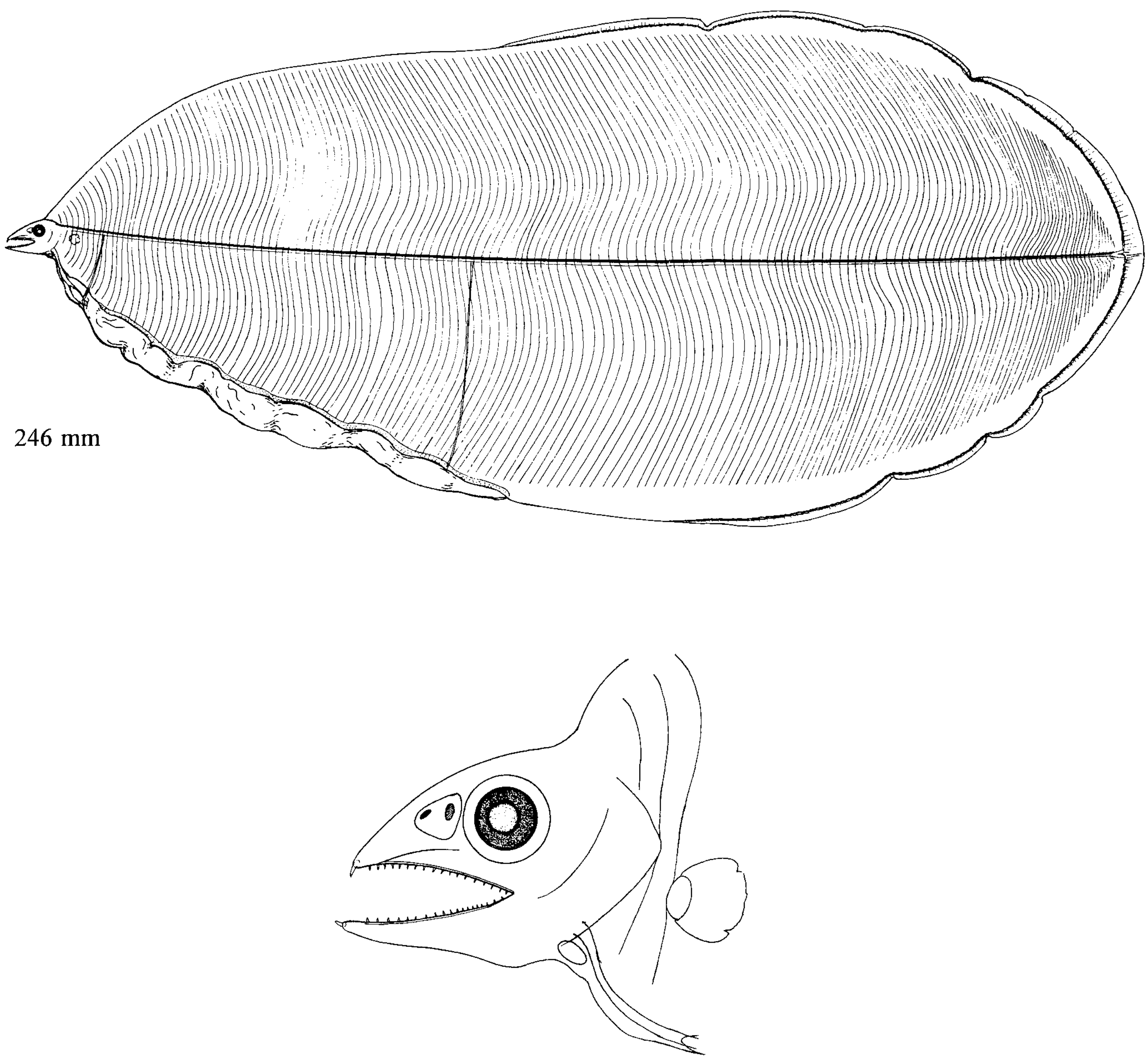


Figure Incertae sedis 1. Larva, 246 mm, whole body and head (Castle & Raju 1975).

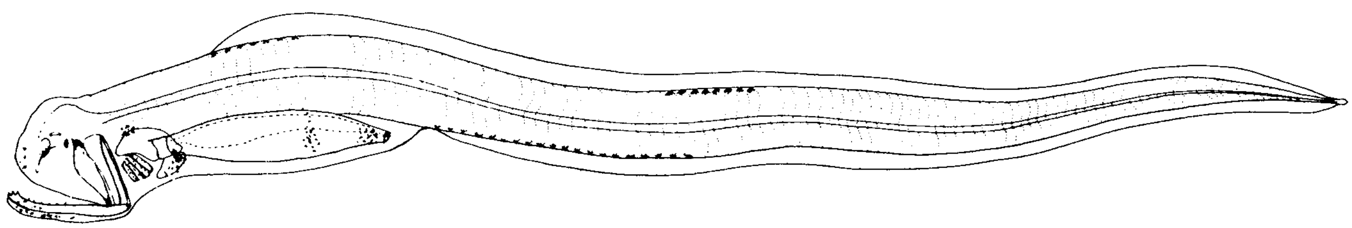
SACCOPHARYNGIFORMES

S. R. CHARTER

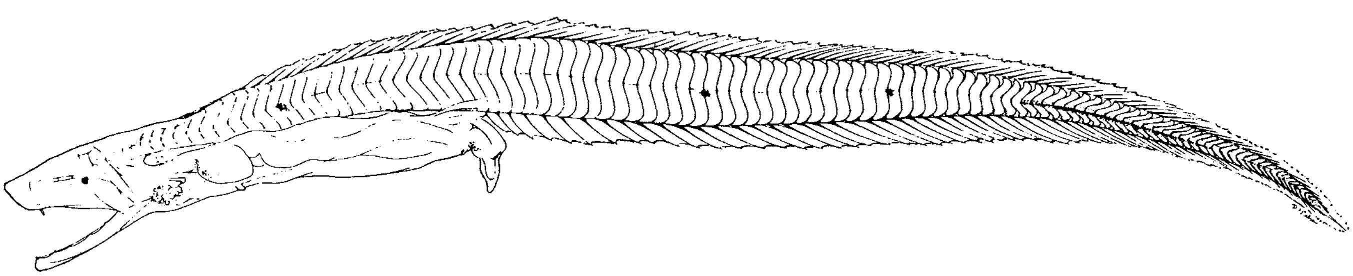
The relationships of the order Saccopharyngiformes are unresolved. Smith (1984) considered gulpers to be highly modified midwater eels, whereas Robins (1989) considered them to be an independent derivative of a separate elopomorph stock. Robins (1989) listed 12 specialized characters that distinguish Saccopharyngiformes (Cyematidae, Saccopharyngidae, Eurypharyngidae, and Monognathidae) from Anguilliformes; most apparent is the huge mouth and the elongate, posteriorly projecting suspensorium.

Saccopharyngiformes are slender meso- to abyssopelagic fishes with greatly reduced skeletons (e.g., no branchiostegal rays or opercular bones, and a relatively small neurocranium). Larvae are known for all families except the Monognathidae. A single damaged *Monognathus* specimen, ca. 40 mm, may represent a larval stage (Bertelsen and Nielsen 1987). Representatives of this family in the CalCOFI study area (*M. ahlstromi* and *M. rosenblatti*) are shown in Figure Saccopharyngiformes 1. An undescribed *Monognathus* has been collected in the CalCOFI Current region (R. Rosenblatt, pers. comm.).

Families included: Cyematidae
Eurypharyngidae
Saccopharyngidae



48.5 mm



60.0 mm

Figure Saccopharyngiformes 1. Representatives of the Monognathidae: *Monognathus ahlstromi*, 48.5 mm (Raju 1974); *Monognathus rosenblatti*, 60 mm (Bertelsen & Nielsen 1987).

CYEMATIDAE: Bobtail eels

S. R. Charter

Cyematids are highly modified midwater eels, widely distributed in all tropical and temperate oceans (Fitch and Lavenberg 1968; Eschmeyer et. al. 1983; Smith 1989c). Historically allied with nemichthyids in Anguilliformes, presently they are recognized as Saccopharyngiformes (Smith 1989c; Eschmeyer 1990). In the eastern Pacific, *Cyema atrum* ranges from Oregon to Panama, is relatively rare, and usually is caught in midwater trawls at depths >610 m (Fitch and Lavenberg 1968; Eschmeyer et. al. 1983). Larval *C. atrum* are collected throughout the CalCOFI study area from northern California to Baja California Sur, Mexico. Another cyematid, *Leptocephalus holti*, ranges from northern to southern California in the CalCOFI area to the central north Pacific. *L. holti* may be the larva of *Neocyema erythrosoma* (Smith 1989j), which is known from two specimens collected from 2000 m in the south Atlantic (Castle 1977).

Adult *C. atrum* have elongate jaws, small eyes and scaleless short, stubby, compressed bodies. The dorsal and anal fins originate at midbody and are confluent with the reduced caudal fin. The elongate jaws and reduced caudal fin create a dart-like profile (Fitch and Lavenberg 1968; Eschmeyer, et al. 1983; Smith 1989c).

Cyematids are oviparous; planktonic eggs are unknown. The distinctive cyematid leptocephali are moderate in size (maximum ca. 70 mm, Smith 1989j) and deep-bodied (16–53% BL). They have fewer myomeres than any other eels. Other leptocephali, *Elops affinis* and *Albula* sp., also have low myomere counts (77–82 and 70–72, respectively), but body depth, gut shape, fin morphology, and pigmentation will easily separate the groups. *C. atrum* and *L. holti* may be distinguished by the number of myomeres (75–83 vs. 95–120, respectively) and lateral pigmentation. Our specimens of *L. holti* showed relatively large variation in nephros terminus and total myomere counts (47–62 and 95–120, respectively) and in pigmentation.

Morphometric and meristic data were obtained from detailed examination of 28 *C. atrum* leptocephali and 9 *L. holti* leptocephali.

MERISTICS

	Range	Mode
Vertebrae:		
Total	70–80	
Precaudal	47	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	85–93	
Anal spines	0	
Anal rays	72–86	
Pelvic	0	
Pectoral	12–15	
Caudal:		
Principal	4	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	0	

LIFE HISTORY

Range: Worldwide; in the eastern Pacific, from Oregon to Panama

Habitat: Midwater in all tropical & temperature oceans; usually >610 m depth

Spawning season: Leptocephali collected in all months except June, September, & December

ELH pattern: Oviparous; planktonic leptocephali

LITERATURE

Bertin 1937
Raju 1974
Smith 1979, 1989j

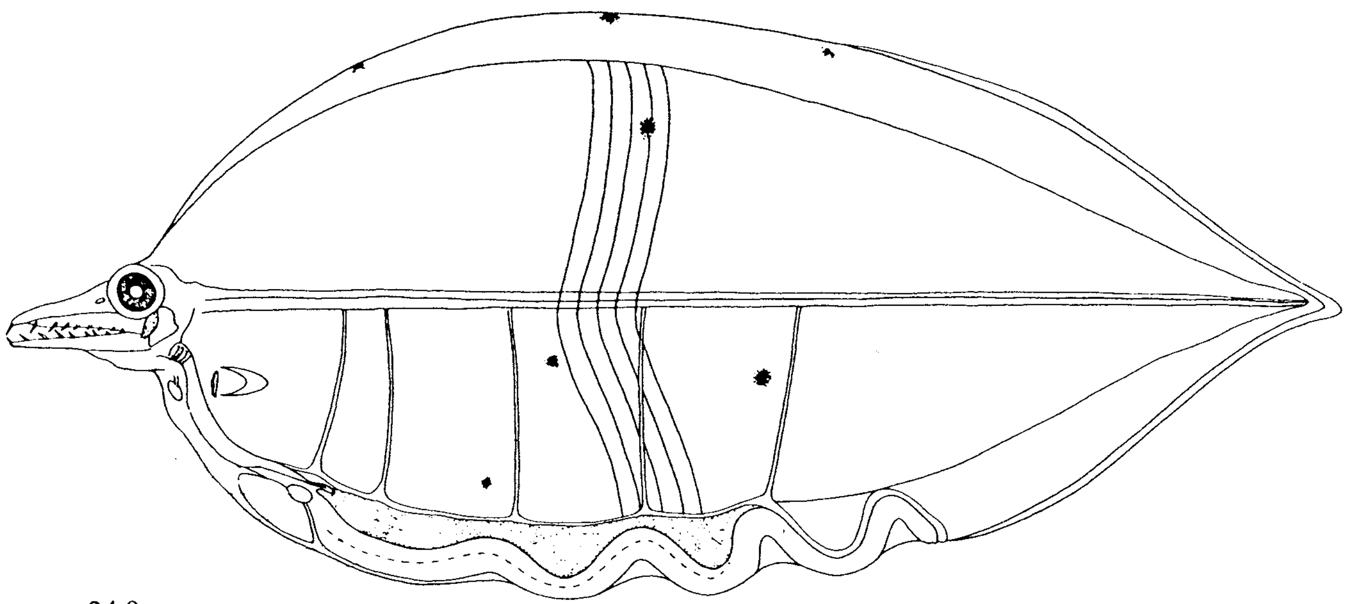
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length:
Transformation length:
Fin development sequence:
Pigmentation: Individual blotches on dorsum; scattered laterally; one on each gut loop peak; irregular ventrally on gut
Diagnostic features: Nephros at ca. myomere 37 (35–40); total myomeres ca. 80 (75–83); compared with *Leptocephalus holti*, greater body depth (23–58% BL), relatively larger eye (13–26% HL), & scattered melanophores laterally.

MORPHOMETRICS (range & mean in %)

	10.2–69.8 mm
Sn-A/BL	63–73 69
BD/BL	18–36 26
GD/BL	23–58 46
HL/BL	13–18 15
HW/HL	19–36 25
SnL/HL	47–63 54
ED/HL	13–26 17
P_1L/BL	3–5 4
PdL/BL	60–68 64



24.9 mm

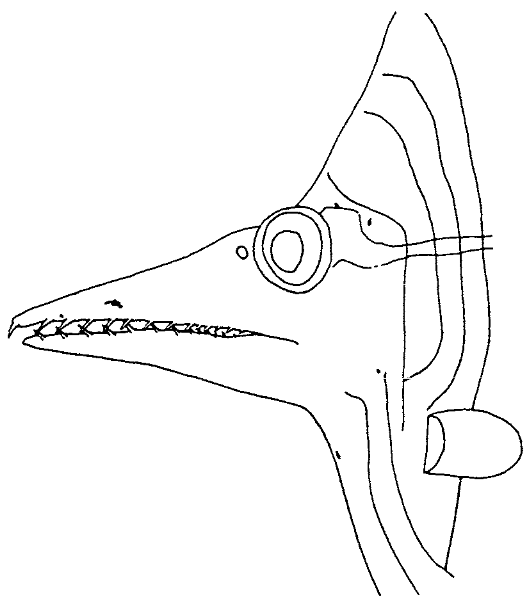


Figure Cyematidae 1. Larva, ca. 24.9 mm (Raju 1974); head of 42.0 mm larva (Smith 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total		
Precaudal		
Caudal		
Fins:		
Dorsal spines		
Dorsal rays		
Anal spines		
Anal rays		
Pelvic		
Pectoral		
Caudal:		
Principal		
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: In the North Pacific, from the California Current region to the central water mass

Habitat:

Spawning season:

ELH pattern:

LITERATURE

Castle 1984
Raju 1974
Schmidt 1909
Smith 1989j

* Adults unknown; possibly more than one species form a *Leptocephalus holti* group (Castle 1984).

EARLY LIFE HISTORY DESCRIPTION

EGGS

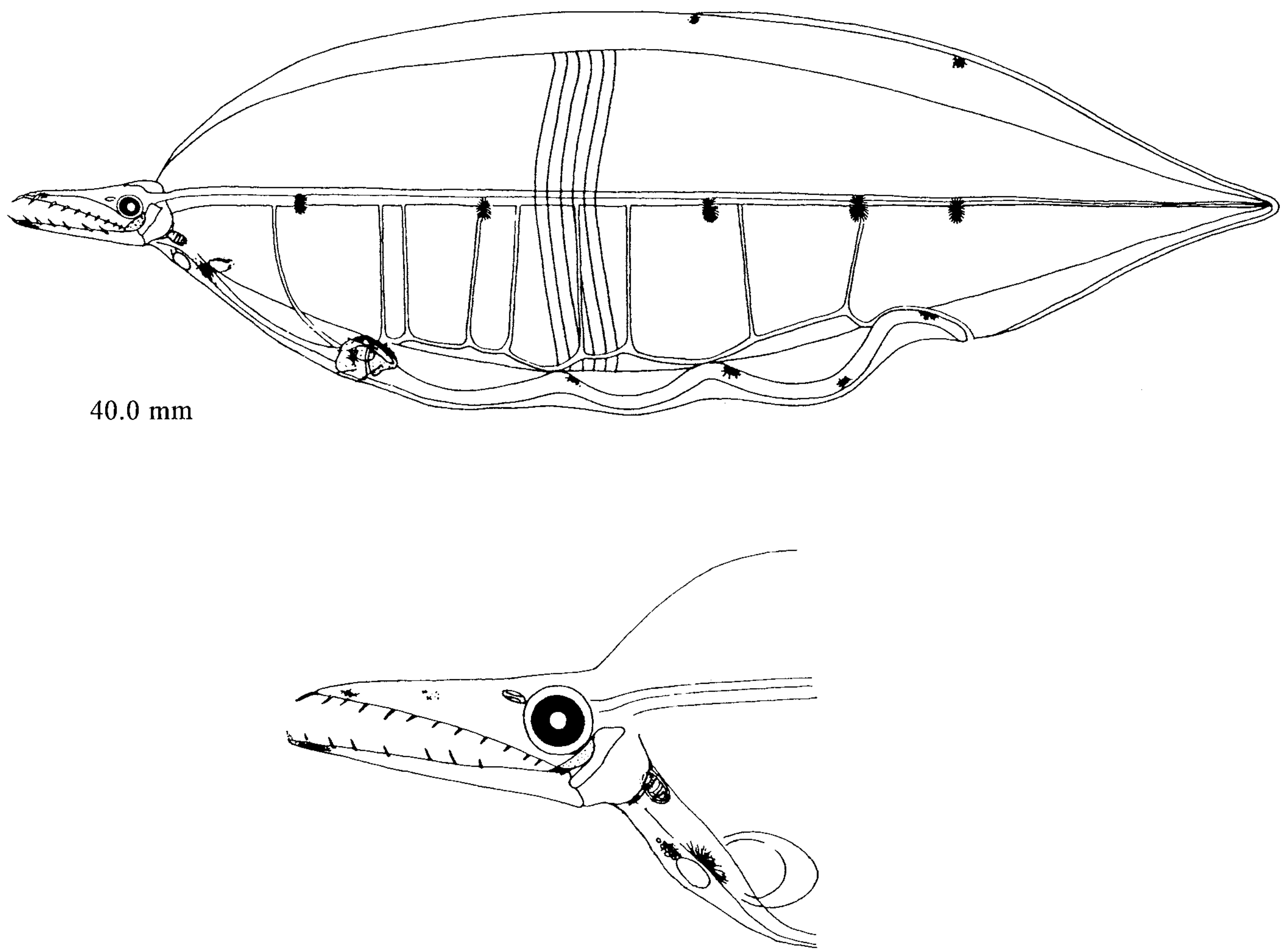
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence:
Pigmentation: Over heart; dorsally & laterally over liver; dorsally on gut loops; most have heavy pigment on lower jaw tip & on two front teeth; on upper jaw, from none to as heavy as on lower jaw; dorsal body surface with 0 or 2 blotches; lateral body with 0, 1 or 5 blotches; laterally on gut on last lower loop (33% of specimens), or on all lower loops (67% of specimens).
Diagnostic features: Nephros at ca. myomere 55 (47–62); total myomeres ca. 108 (95–120); compared with *Cyema atrum*, relatively slender (body depth 16–30% BL), relatively smaller eye (8–15% HL), large melanophores, when present, (usually 1 or 5) along lateral midline.

MORPHOMETRICS (range & mean in %)

	14.3 mm	15.7–48.2 mm
Sn-A/BL	76	70–80 74
BD/BL	11	11–14 13
GD/BL	16	23–30 26
HL/BL	22	17–19 18
HW/HL	25	10–26 21
SnL/HL	51	43–55 48
ED/HL	15	8–15 12
P_1L/BL	3	0.7–4 2
PdL/BL	0	53–76 65



40.0 mm

Figure Cyematidae 2. Larva, 40.0 mm, whole body and head (Raju 1974).

SACCOPHARYNGIDAE: Whiptail gulpers

S. R. Charter

One saccopharyngid occurs in the CalCOFI study area, ranging from northern California to Peru (Fitch and Lavenberg 1968; Nielsen and Bertelsen 1985). It is relatively rare; generally adults are caught in midwater trawls at depths <2400 m, although one was collected alive at the surface. Leptocephali are meso- to bathypelagic, usually collected at depths <1525 m (Nielsen and Bertelsen 1985).

Saccopharyngids are large (total length 1070 mm) highly modified meso- and bathypelagic fishes; most species are cosmopolitan (Nielsen and Bertelsen 1985). Adults are easily identified by a huge mouth, distensible abdomen, and a caudal filament. They are distinguished from eurypharyngids by having relatively shorter jaws, a larger abdomen, a more posterior dorsal fin origin (ca. 20% BL), gill openings closer to the snout than to the anus, large curved teeth, well developed pectoral fins, and dermal filaments (Nelson 1984, 1994; Nielsen and Bertelsen 1985; Bertelsen et al. 1989). *S. lavenbergi* has scaleless, brownish-grey skin that becomes lighter posteriorly, a relatively simple, slender caudal organ, and longitudinal "white lines" that start closer to the snout than to the pectoral fin (Nielsen and Bertelsen 1985).

Saccopharyngids are oviparous; planktonic eggs are unknown (Nielsen and Bertelsen 1985). Their leptocephali are distinguished by an elongate suspensorium which can be seen in yolk-sac larvae as small as 10.4 mm. Leptocephali are small (maximum 43 mm, Schmidt 1909), deep bodied (23–39% BL), with an acute tail. The greater number of total myomeres (210–244 vs. 122–136), more numerous postanal myomeres (168–194 vs. 84–94), and fewer gill slits (4 vs. 6) will separate larval saccopharyngids from eurypharyngids (Orton 1963).

Examination of ten leptocephali provided the morphometric and meristic data for this study. Body depth was measured at the first gill slit and head length measured from the tip of the snout to the top of the first gill slit.

MERISTICS

	Range	Mode
Vertebrae:		
Total	ca. 175–220	
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	224–285	
Anal spines	0	
Anal rays	235–284	
Pelvic	0	
Pectoral	33–36	
Caudal:		
Principal	0	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	0	

LIFE HISTORY

Range: Northern California to Peru

Habitat: Meso- & bathypelagic; primarily 2000–3000 m depth

Spawning season:

ELH pattern: Oviparous; degenerative changes in males & females suggest semelparity; planktonic leptocephali

LITERATURE

Böhlke 1966
Nielsen & Bertelsen 1985
Orton 1963
Raju 1974
Smith 1989k

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 10.4 mm (M. T. Vona)
Head & body section of 10.4 mm yolk-sac larva (M. T. Vona)
Larva, 25.1 mm (M. T. Vona)
Body section of 25.1 mm larva (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <10.4 mm
Flexion length:
Transformation length: >40.4 mm
Fin development sequence:
Pigmentation: Lightly scattered over posterior portion of gut.
Diagnostic features: Nephros at ca. myomere 45 (42–52); total myomeres ca. 225 (210–244); elongate suspensorium; gut with a single pigmented swelling.

MORPHOMETRICS (range & mean in %)

	Y-S 10.4 mm	10.5–15.7 mm	25.1–40.4 mm
Sn-A/BL		53–58	50–57
	52	56	53
BD/BL*		18–23	12–25
	11	20	17
GD/BL		23–36	27–39
	18	29	33
HL/BL†		12–13	9–11
	9	12	10
HW/HL		47–55	37–47
	59	50	41
SnL/HL		24–36	29–41
	4	31	35
ED/HL‡		37–42×	23–33×
		38–46	25–38
	58×53	40×41	27×30
P_1L/BL		2–4	2–2
	2	3	2
PdL/BL§			14–51
	0	19	27

* Body depth at first gill slit.
† Head length from tip of snout to top of gill slit.
‡ Eye is slightly oval; horizontal axis is given first, vertical axis second.
§ Predorsal fin length measured on one small larva.

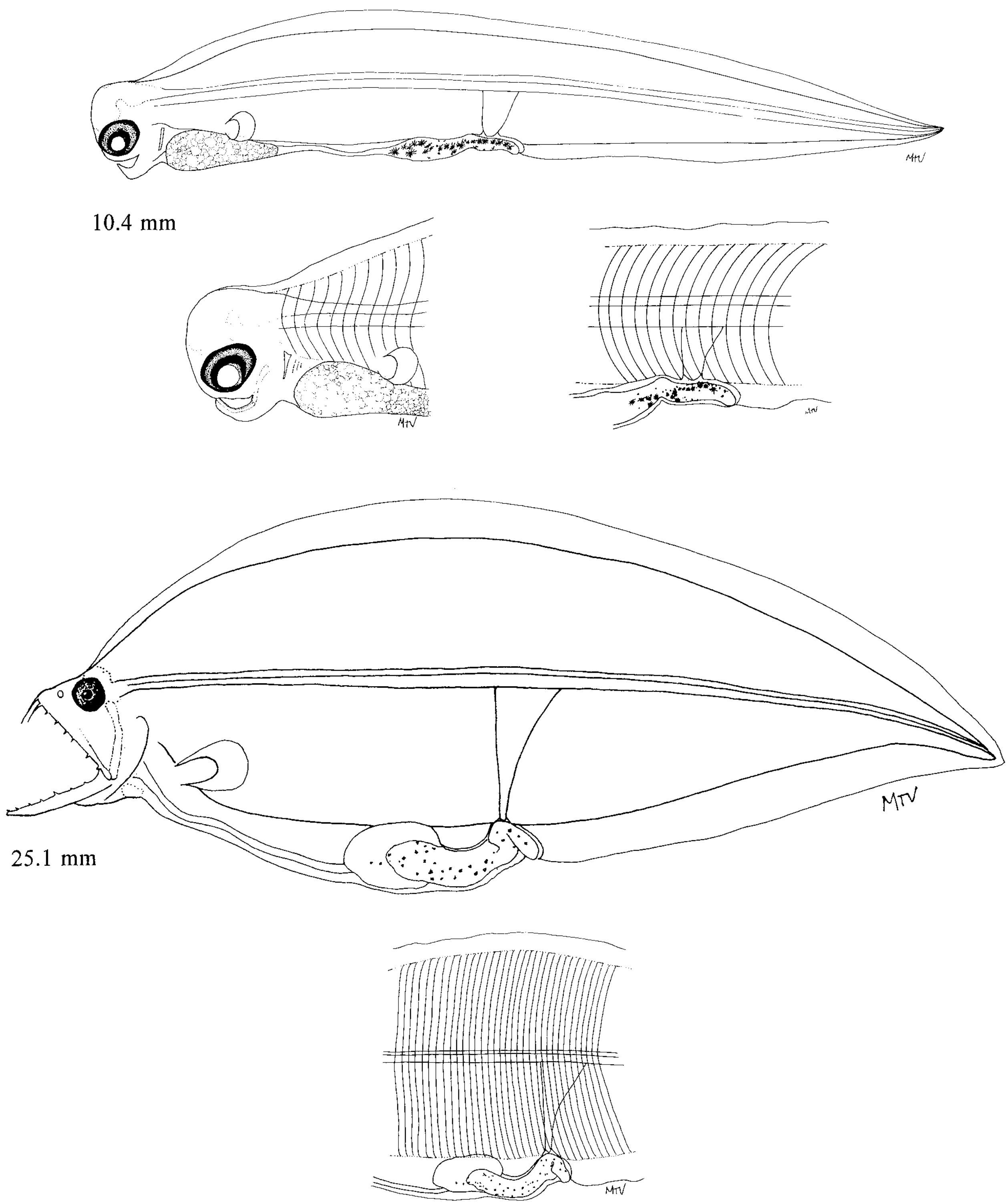


Figure Saccopharyngidae 1. Yolk-sac larva, 10.4 mm, whole body and sections showing head and nephros regions (CFRD 9104, station 73.3.90, MOCNESS); larva, 25.1 mm, whole body and section of nephros region (CalCOFI 6301, station 127.65).

EURYPHARYNGIDAE: Umbrellamouth gulpers

S. R. CHARTER

Eurypharynx pelecanoides, the only known eurypharyngid species, occurs in the meso- and bathypelagic zones of tropical and temperate seas (e.g., Böhlke 1966; Fitch and Lavenberg 1968). In the eastern Pacific, *E. pelecanoides* ranges from northern California to Peru (Fitch and Lavenberg 1968; Matarese et al. 1989). Adults are rare in the CalCOFI study area and larvae have not been collected in the regular survey samples. One of our two larval specimens was collected from the north Pacific gyre and one from a midwater trawl slightly west of the CalCOFI sampling grid.

E. pelecanoides adults are highly modified and, like saccopharyngids, have an enormous mouth, a large distensible abdomen, and a long tapering tail. The black, scaleless body, relatively longer jaw, smaller abdomen, smaller gill openings which are closer to the anus than to the snout, minute teeth and pectoral fins, and more anterior origin of the dorsal fin easily separate them from saccopharyngids. Mature adults undergo a significant transformation. In males, the nasal rosette enlarges so that in dorsal view the head appears notched (Gartner 1983; Nielsen et al. 1989).

Eurypharynx is oviparous: ovarian eggs 1.0–1.3 mm were reported by Nielsen et al. (1989). Planktonic eggs are unknown. Leptocephali are small (maximum 35–40 mm, Smith 1989k), deep bodied (22–36% BL), with an acute tail. *Eurypharynx* has fewer myomeres than saccopharyngids (122–136 vs. 210–244), a greater number of gill slits (6 vs. 4, Orton 1963) and heavier pigment on the gut.

Adult descriptions were taken from Böhlke (1966), Nelson (1984, 1994), Bertelsen et al. (1989), and Nielsen et al. (1989), and meristics were taken from Matarese et al. (1989). Specimen length from Raju (1974) was calculated from his illustration.

MERISTICS

	Range	Mode
Vertebrae:		
Total	97–125	
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	155–196	
Anal spines	0	
Anal rays	118–147	
Pelvic	0	
Pectoral	11	
Caudal:		
Principal	0	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	0	

LIFE HISTORY

Range: Worldwide; in the eastern Pacific, from northern California to Peru

Habitat: Meso- & bathypelagic; 500–3000 m depth

Spawning season: Leptocephali collected in March & May

ELH pattern: Oviparous; degenerative changes in males & females suggests semelparity; planktonic leptocephali

LITERATURE

Nielsen et al. 1989
Orton 1963
Raju 1974
Smith 1979, 1989k
Van Utrecht 1988

* Eyes are slightly oval in small larvae, becoming round in larger larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

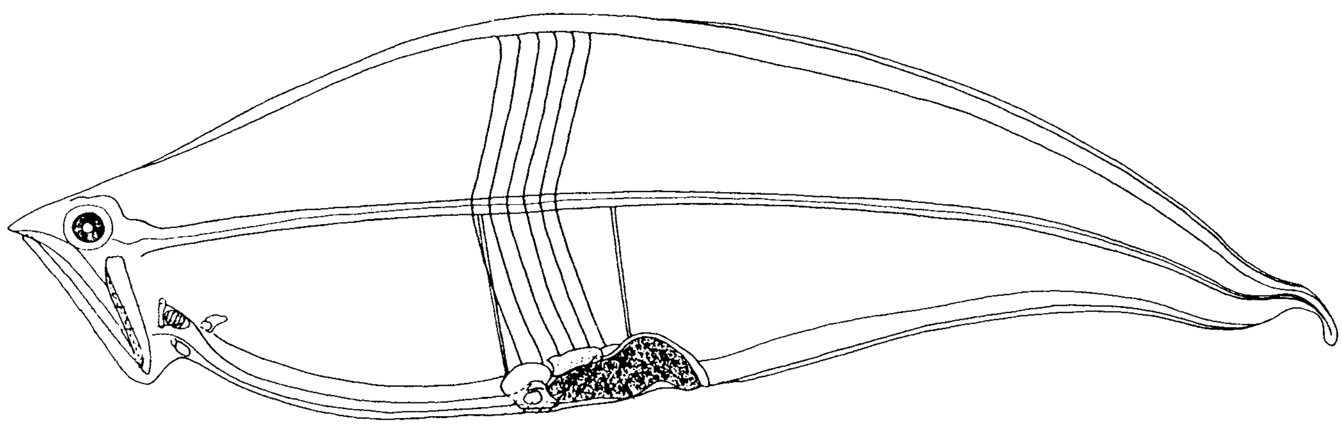
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: ca. 30–40 mm
Fin development sequence:
Pigmentation: Heavily scattered over posterior portion of gut.
Diagnostic features: Nephros at ca. myomere 40 (38–42); total myomeres ca. 129 (122–136); elongate suspensorium; gut with a single pigmented swelling.

MORPHOMETRICS (range & mean in %)

	8.2 mm	22.7 mm
Sn-A/BL	55	56
BD/BL	19	25
GD/BL	22	36
HL/BL	21	12
HW/HL	33	44
SnL/HL	14	37
ED/HL*	27×30	25
P_1L/BL	1	3
PdL/BL	0	41



27.0 mm

Figure Eurypharyngidae 1. Larva, ca. 27.0 mm (Raju 1974 as *Leptocephalus pseudolatissimus*).

CLUPEIFORMES

W. WATSON

Clupeomorpha was a catch-all polyphyletic assemblage of "primitive" teleosts (e.g., Berg 1940) until Greenwood et al. (1966) defined the superorder based on three characters: a unique connection between the gas bladder and ear (the otophysic connection), a unique connection between the preopercular and infraorbital lateral line canals (the recessus lateralis), and an unusual, but not unique, caudal skeleton. Clupeiformes has been further diagnosed as having the parietals separated by the supraoccipital, and as lacking a beryciform foramen in the ceratohyal (Grande 1985). Thus defined, Clupeiformes generally has been accepted as a monophyletic order. The order presently is thought to contain about 356 species of sardines, herrings, and anchovies distributed among 83 genera in four families (Nelson 1984; Whitehead et al. 1988). The taxonomic composition of some of the clupeiform subgroups, and relationships between the subgroups, are unsettled (Nelson 1973b; McGowan and Berry 1984; Grande 1985; Whitehead 1985; Whitehead et al. 1988).

Most clupeiform fishes are small to medium size (ca. 10–30 cm) marine planktivores that school in coastal waters. They are elongate to moderately deep-bodied, slightly to strongly compressed, usually with scutes along the abdomen (only one in round herrings and New World anchovies). There are no spines in the fins, although the first one or two unbranched dorsal and anal fin rays typically are small and spine-like. Clupeiform fishes typically are brown to green or blue dorsally and silvery below. They are key components of coastal ecosystems and are among the most economically important of fishes, annually accounting for about one-quarter of the world's fish catch (e.g., Whitehead 1985; Whitehead et al. 1988).

Families included: Clupeidae
Engraulidae

Clupeiform fishes are oviparous. Most spawn planktonic eggs that range in shape from spherical to strongly elliptical, and in size from ca. 0.6–3.8 mm, with or without oil globules, and with a segmented yolk. Some clupeid species spawn adhesive demersal eggs. Larvae that hatch from planktonic eggs typically are ca. 2–5 mm long, with unpigmented eyes, unformed or partially formed mouth, and large yolk sac. Larvae of species with demersal eggs are larger and better developed at hatching. Clupeiform larvae are characterized by being elongate, with preanal length ranging from ca. 60–90% of body length. The hindgut is marked with prominent annular striations, and through at least the early part of the postflexion stage a characteristic cross-hatched muscle fiber pattern is visible on the myomeres. There are no spines on the head or pectoral girdle. Late in the postflexion stage or during transformation the dorsal fin typically shifts a few myomeres cephalad. The anus also moves a few myomeres cephalad as the gut shortens during completion of anal fin development. Larval pigmentation typically is light and largely restricted to the gut and ventrum through at least the early part of the postflexion stage.

About 18 species of clupeids and engraulids occur in the CalCOFI study area. Among these, larvae of the northern anchovy (*Engraulis mordax*) are by far the most abundant larvae taken in CalCOFI ichthyoplankton collections. The Pacific sardine (*Sardinops sagax*), whose larvae rank eighth in overall abundance, was responsible for establishment of the CalCOFI program by virtue of the collapse of its fishery in the early decades of this century (e.g., Radovich 1982).

CLUPEIDAE: Herrings

W. WATSON AND E. M. SANDKNOP

The family Clupeidae contains about 180–190 species (Nelson 1994; Whitehead 1985), nine of which occur in the CalCOFI study area (Table Clupeidae 1). The precipitous decline (and ultimate demise) of the major commercial fishery for one of these, the Pacific sardine, was the principal basis for establishment of the CalCOFI program in 1947 (the original Cooperative Sardine Research Program was renamed the California Cooperative Oceanic Fisheries Investigations program in 1953).

The composition of the family Clupeidae is not entirely settled (McGowan and Berry 1984). For example, the round herrings are placed in the Clupeidae as the subfamily Dussumieriinae by many authors (e.g., Nelson 1994; Whitehead 1985) while others consider them a separate family (e.g., Eschmeyer et al. 1983). Within the Dussumieriinae, some authors consider *Etrumeus* to consist of a cosmopolitan species, *E. teres*, and an endemic South African species (e.g, Whitehead 1985; Whitehead and Wongratana 1986) while others consider at least some of the *E. teres* populations to be separate species (e.g., Hildebrand 1963b; Eschmeyer et al. 1983). We follow Whitehead's (1985) arrangement of the Clupeidae in this chapter.

Most clupeid larvae taken in CalCOFI ichthyoplankton collections off California and Baja California are *Sardinops sagax*. Larval *Etrumeus teres* are relatively common in summer and fall off southern California and Baja California, while *Opisthonema* larvae have occasionally been taken in summer off southern Baja California (they are common in the Gulf of California). Larval *Clupea pallasii* sometimes are taken in winter and spring at CalCOFI stations from central California northward. A few specimens of *Harengula thrissina* and an unidentified clupeid, probably *Lile stolifera*, have been taken in dip net collections from Bahía Magdalena, Baja California Sur, during CalCOFI surveys. *Alosa sapidissima* and *Dorosoma petenense* are introduced, primarily estuarine, species whose larvae apparently have not been collected during CalCOFI surveys.

Most adult clupeids are small to medium size (typically 10–30 cm) planktivorous fishes that school near the surface in warm coastal waters. A few species occur in cool temperate waters and some species inhabit brackish or fresh water. Clupeids are slightly to strongly compressed, with preanal length about half to three-quarters of body length, and typically with a small terminal mouth. Pectoral fins are inserted low on the sides and the pelvic fins, each with 7–9 rays, are abdominal. The first 2–4 rays in the dorsal and anal fins commonly are unbranched, and the first 1–3 usually are small and spine-like. Clupeids (except round herrings) have a row of scutes along the belly. Pigmentation commonly is green to blue on the dorsum and silvery below, with patterns of dorsolateral stripes or spots in some species. Clupeids are among the most economically important fishes, with several species supporting large commercial fisheries (e.g., Whitehead 1985). Some species are important in sport fisheries as well.

Early life histories are well known for many of the commercially important marine and anadromous species (see review by McGowan and Berry 1984). Clupeids are oviparous. Most spawn spherical planktonic eggs ranging from 0.6–3.8 mm (typically 1–2 mm), with a smooth, often very thin, chorion and a narrow to very wide perivitelline space, a segmented yolk, and usually one (most species) or more oil globules. *Clupea*, *Dorosoma*, and *Spratelloides* species spawn adhesive demersal eggs (McGowan and Berry 1984) ca. 1–2 mm in diameter that are enclosed in thick gelatinous sheathes. Larvae hatch from the planktonic eggs at ca. 3–5 mm with unpigmented eyes, unformed mouth, and large yolk sac. Larvae from demersal eggs typically hatch at ca. 4–7 mm with partially or fully pigmented eyes, partially formed to functional mouth, and small yolk sac. Larvae are elongate, cylindrical to slightly compressed, usually becoming moderately compressed and deeper-bodied during the postflexion or transformation stage. The gut is long (preanal length ca. 75–90% BL, shortening to ca. 70–80% during postflexion or transformation), with prominent annular striations on the hindgut. The typical clupeiform pattern of cross-hatched muscle fibers is clearly visible. The dorsal fin forms above the posterior to middle of the hindgut, and typically shifts forward to a position nearer midbody during transformation. Pigmentation is dorsal in late embryos and newly-hatched larvae, but most or all melanophores migrate ventrad to the gut and ventrum during the yolk-sac stage (e.g., Orton 1953a; O'Toole and King 1974; Matus-Nivón et al. 1989b). Following yolk absorption, dorsal and lateral pigment commonly are lacking, except on the caudal area, until the postflexion stage.

The elongate body with long preanal length, pigmentation largely limited to the gut and ventrum, striated hindgut, and cross-hatched muscle fiber pattern should allow separation of larval clupeids from all other elongate, lightly pigmented larvae in the CalCOFI area except engraulids. Clupeids commonly have a longer preanal length than engraulids have (usually >75% BL versus usually <75%), and when the dorsal fin forms (beginning during the flexion stage) it inserts a few to several myomeres anterior to the anus (or anal fin origin) in clupeids, in contrast to one to a few myomeres posterior to the anus (above or behind the anal fin origin) in engraulids. Identification of the clupeid species requires a combination of meristic characters (e.g., preanal, postanal, and total myomeres, number of myomeres between dorsal fin insertion and anus or anal fin origin, fin ray counts), pigment characters, and geographic location. Larval size and seasonal occurrence may be useful in some cases (e.g., *Clupea* versus *Sardinops*). Not all stages of all species can be distinguished presently; for example, it is unknown how the eggs of *H. thrissina* can be distinguished from those of the *Opisthonema* species, or how larvae of the *Opisthonema* species are distinguished from one another. Houde and Fore (1973) give characters for distinguishing the eggs of *H. jaguana* and *O. oglinum* in the Gulf of Mexico; similar characters might be useful for the eastern Pacific species.

The following descriptions are based on literature and on detailed observations of 4–46 specimens of each species (Table Clupeidae 2). *Alosa sapidissima* and *Dorosoma petenense* are not described; refer to Jones et al. (1978) and Wang (1981) for descriptions and additional references. Meristic data were obtained from Clothier (1950), McHugh (1954), Peterson (1956), Berry and Barrett (1963), McGowan and Berry (1984), and Matus-Nivón et al. (1989b). Dorsal and anal fin-ray counts are totals which include the small spine-like first rays. Ecological information was obtained from Eschmeyer et al. (1983), Whitehead (1985), and Whitehead and Rodriguez-Sánchez (1995a).

Table Clupeidae 1. Meristic characters and geographic ranges for the clupeid species in the CalCOFI study area. All have 10+9 principal caudal fin rays. Northern range limits are followed by southern limits. Abbreviations: Gulf, Gulf of California; CA, California; BC, Baja California; BCS, Baja California Sur.

	Vertebrae			Fin rays						
Species	PrCV	CV	Total	D	A	P_1	P_2	C_2	Gill rakers	Range
Alosa sapidissima	27–29	27–29	55–58	15–19	19–23	13–18	9	7–8+7	14-25+ 28–47	Alaska–Ensenada BC
Clupea pallasii	29–33	19–23	46–58	15–21	13–20	15–20	9	9+8–9	20–21+ 41–50	Bering Sea–BC
Dorosoma petenense	11–13	30–32	40–45	11–15	17–27	12–17	7–8	9+6–7	300-440 total	Humboldt Bay–Long Beach CA
Etrumeus teres	32–36	15–20	48–55	16–22	9–19	14–17	8–9	6–9+ 6–8	12-15+ 28–35	Monterey CA & Gulf–Chile
Harengula thrissina	20–23	19–22	40–43	16–20	14–17	15–16	8–9	7–10+ 5–7	9-18+ 24–34	La Jolla CA & Gulf–Peru
Lile stolifera	21–23	19–21	42–44	15–18	15–23	13–14	8	8–11+ 6–9	13-18+ 32–36	Bahía Ballenas BCS & Gulf–Peru
Opisthonema libertate	22–24		44–48	17–20	19–22	15–18	8–9	6–9+ 6–8	110-149+ 161–224	San Pedro CA & Gulf–Peru
O. medirastre			45–48	17–20	19–23	16–19	8–9	7–8+ 5–6	70-99+ 110–156	Redondo Beach CA & Gulf–Peru
Sardinops sagax	28–30	22–23	48–54	17–20	17–20	16–19	8–9	6–9+ 5–8	21-23+ 44–45	Alaska–Gulf

Table Clupeidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the clupeid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Clupea pallasii	L[a,b]	3 7.4–8.5	6 8.3–12.8	5 15.8–18.5	7 19.5–26.8	3 25.7–29.5	3 53.8–58.4
Etrumeus teres	L[c,d,e]	2 3.8–4.8	5 5.2–9.8	6 10.0–12.1	6 10.7–13.7	3 32.5–35.1	3 63.8–77.4
Harengula thrissina	L[f]	L[f]	5 3.7–6.7	5 7.6–9.3	10 13.0–22.0	3 19.3–25.2	3 29.2–39.4
Opisthonema libertate	L[g]	L[g]	L[g]	L[g]	L[g]	L[g]	4 37.3–49.7
Sardinops sagax	15 1.5–1.7	5 3.7–5.6	8 4.5–10.8	5 11.3–14.7	7 14.0–23.9	3 31.7–38.3	3 36.2–50.4

[a] Matarese et al. 1989
[b] Wang 1981
[c] Watson and Leis 1974
[d] O'Toole and King 1974
[e] Houde and Fore 1973
[f] Matus-Nivón et al. (manuscript; Centro Interdisciplinario de Ciencias Marinas, Apdo. Postal 592, La Paz, BCS, Mexico)
[g] Matus-Nivón et al. 1989b

MERISTICS

	Range	Mode
Vertebrae:		
Total	46–58	51–53
Precaudal	29–33	31
Caudal	19–23	21–22
Fins:		
Dorsal spines	0	0
Dorsal rays	15–21	18–19
Anal spines	0	0
Anal rays	13–20	16–17
Pelvic	9	9
Pectoral	15–20	17
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	9	9
Lower	8–9	8
Gill rakers:		
Upper	20–21	21
Lower	41–50	45–46
Branchiostegals	8–9	

LIFE HISTORY

Range: Northern Baja California to Alaska in the eastern Pacific, southward to Korea in the western Pacific

Habitat: Schools over continental shelf; enters bays & estuaries to spawn

Spawning season: Late fall–spring, primarily December–March in Californian waters

ELH pattern: Oviparous; attached demersal eggs & planktonic larvae

LITERATURE

Matarese et al. 1989
McGowan & Berry 1984
Takita 1988
Uchida et al. 1958b
Wang 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 7.6 mm (R. C. Walker)
Transformation specimen, 29.5 mm (R. C. Walker)

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* Eye initially slightly oval, becoming round by flexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

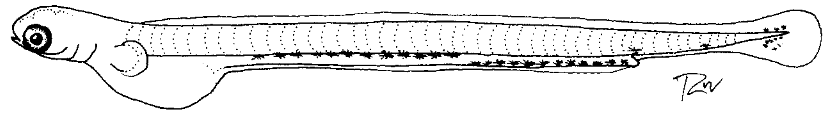
Shell diam.: 1.2–1.7 mm **Yolk:** Segmented
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth
Pigment: Yolk yellowish
Diagnostic features: Attached in large clusters, primarily on seaweed & eelgrass; segmented yolk

LARVAE

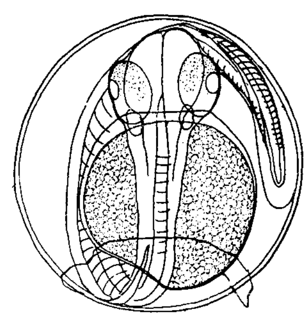
Hatching length: 5.6–7.5 mm
Flexion length: ca. 16–19 mm
Transformation length: 25–27 mm through 35 mm
Fin development sequence: C_1, D, A, P_2 & C_2, P_1
Pigmentation: *Yolk-sac–preflexion*—Dorsolateral row along each side of anterior 40–50% of gut; single row along ventral margin of posterior 50–60% of gut; 1–2 on isthmus by ca. 10 mm; few scattered around notochord tip. *Flexion*—1–2 dorsolaterally on hindbrain by 17 mm, increases; 0–2 over midbrain after 18 mm; internal series over spinal cord beginning posteriorly by ca. 19 mm & spreading cephalad; series on dorsal surface of gut; increasing on isthmus; 1–2 near lower end of cleithrum; proximally on C rays; internally on lower hypurals & parhypural by ca. 18 mm. *Postflexion*—On jaws by 21 mm; on snout & opercle by 25 mm; increasing along cleithrum; spreading ventrad on gut; on D base & midlaterally on caudal peduncle by 21 mm; scattered dorsolaterally beginning posteriorly & spreading cephalad by 25 mm.
Diagnostic features: Myomeres 50–56 (usually 53–55)=40–44+10–14 before transformation; 5–8 myomeres (usually 6–7) between D insertion & A origin through postflexion stage; prominent notochord tip/caudal pigment; large size at hatching & flexion.

MORPHOMETRICS (range & mean in %)

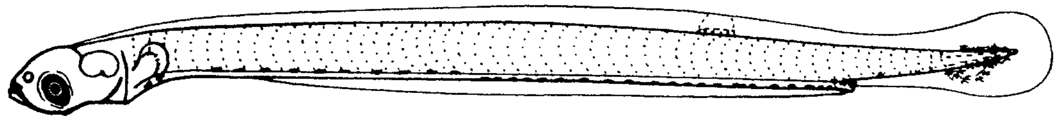
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	80–91 84	83–86 84	84–85 84	80–87 83	75–77 76	75–77 75
BD/BL	3–4 3	5–6 6	7–9 7	8–15 10	15–19 17	19–21 20
HL/BL	12–15 13	12–14 13	16–20 17	19–23 21	26–28 27	26–29 28
HW/HL	52–63 56	54–71 60	44–52 49	38–47 43	33–36 34	30–33 32
SnL/HL	8–19 12	17–24 21	20–28 24	25–29 27	27–29 28	26–31 28
ED/HL*	19–23× 24–27 22×25	17–23× 18–28 21×24	22–28 24	23–25 24	25–25 25	27–30 29
P_1L/BL	0–3 1	2–3 3	2–3 3	3–4 3	5–9 7	14–15 15
P_2L/BL	0–0 0	0–0 0	0–0 0	1–6 3	8–9 8	9–10 10



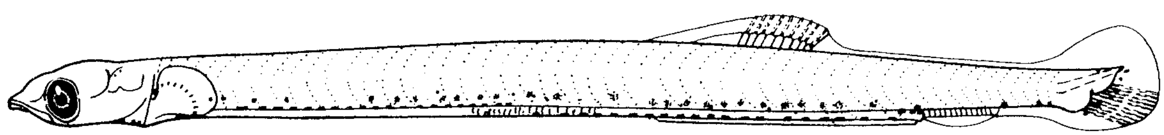
7.6 mm



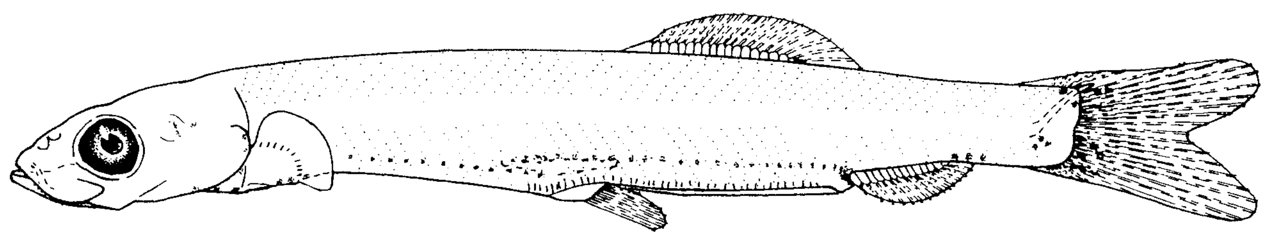
1.4 mm



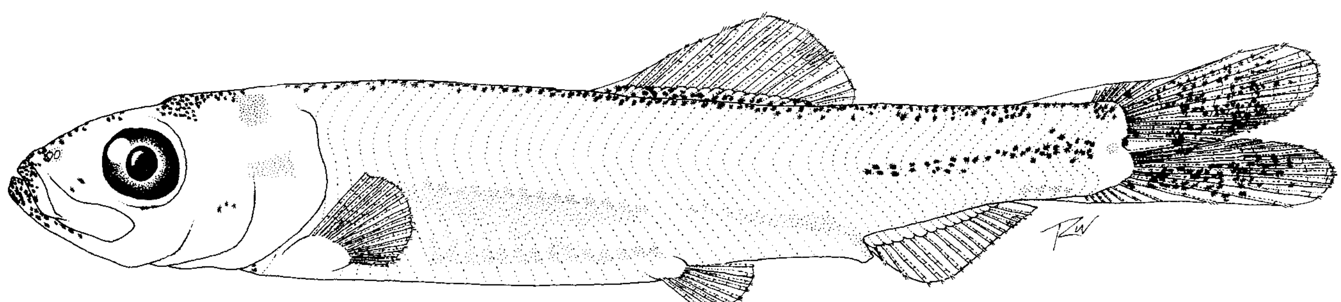
10.4 mm



19.0 mm



23.8 mm



29.5 mm

Figure Clupeidae 1. Egg, 1.4 mm (Uchida et al. 1958b); yolk-sac larva, 7.6 mm (CFRD Ref. Coll., OSU 247C, Buoy 15, Yaquina Bay, Oregon); preflexion larva, 10.4 mm; flexion larva, 19.0 mm; postflexion larva, 23.8 mm (Matarese et al. 1989); transformation specimen, 29.5 mm (CFRD Ref. Coll., San Francisco Bay, California, May 15, 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–55	54
Precaudal	32–36	35
Caudal	15–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	16–22	19–21
Anal spines	0	0
Anal rays	9–19	11–12
Pelvic	8–9	8
Pectoral	14–17	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–9	7
Lower	6–8	6
Gill rakers:		
Upper	12–15	
Lower	28–35	
Branchiostegals	14–16	

LIFE HISTORY

Range: Worldwide; in eastern Pacific from Monterey Bay, California, to Chile

Habitat: Schools over continental shelf, may enter bays

Spawning season: Summer–fall in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1980
Houde & Fore 1973
Jones et al. 1978
Miller et al. 1979
Mito 1961a
O'Toole & King 1974
Takita 1988
Watson & Leis 1974

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 12.1 mm (R. C. Walker)
Transformation specimen, 27.1 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.2–1.5 mm **Yolk:** Segmented; 1.0–1.3 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth
Pigment: Yolk colorless to pale yellow; melanophores on dorsum & near terminus of gut of late stage embryos
Diagnostic features: Diameter; lack of OG; narrow perivitelline space; segmented yolk

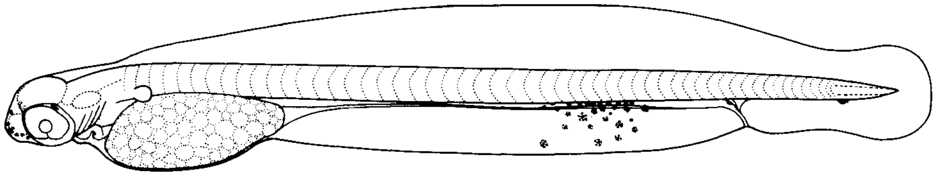
LARVAE

Hatching length: 3.8–4.8 mm
Flexion length: ca. 10–10.5 mm through ca. 12–13 mm
Transformation length: ca. 32–35 mm
Fin development sequence: C_1, D, A, C_2, P_1, P_2
Pigmentation: *Yolk-sac*—Scattered dorsally over midbrain & snout, decreasing in number & disappearing by end of stage; series initially on dorsum from nape to last myomere, migrating to ventrum by end of stage; patch posteriorly on intestine, may extend onto preanal finfold. *Preflexion-postflexion*—None on dorsum or laterally; ventrolateral series along each side of gut; series along ventral margins of isthmus, hindgut, & tail; few on proximal 25% of outer principal caudal fin rays in postflexion stage. *Transformation*—Dorsally & laterally on head; on dorsum, spreading caudad; dorsolateral, spreading caudad; increasing on C & caudal peduncle.
Diagnostic features: Myomeres 40–45+11–15=51–58 (usually 41–42+13); 3–4 myomeres between D insertion & A origin; long, wedge-shaped snout (SnL=27–40% HL); patch of melanophores posteriorly on hindgut in yolk-sac & early preflexion stage; no dorsal or lateral trunk or tail melanophores from preflexion through late postflexion stage.

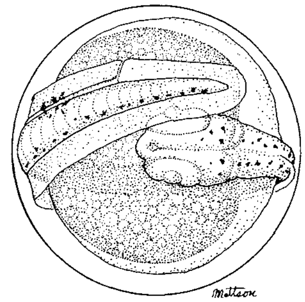
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	76–84 80	78–82 80	84–87 85	84–87 85	80–83 81	80–82 81
BD/BL	8–8 8	7–9 8	7–9 8	7–10 8	14–16 15	16–17 17
HL/BL	19–23 21	17–19 18	18–20 19	20–21 20	26–29 27	28–30 28
HW/HL	46–59 52	45–59 53	50–56 53	45–50 49	30–32 31	35–43 39
SnL/HL	7–9 8	27–33 31	33–40 36	35–40 37	31–33 32	28–29 29
ED/HL*	36–48× 22–23 42×22	17–32× 23–24 23×24	17–22× 21–28 20×24	18–20× 17–21 19×20	21–25 24	28–31 31
P_1L/BL	0–0 0	3–4 4	2–5 3	2–4 3	7–11 10	13–14 14
P_2L/BL	0–0 0	0–0 0	0–0 0	0–0 0	8–10 8	7–8 8

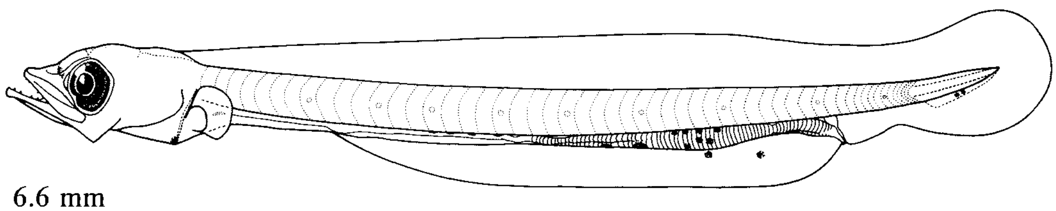
* Eye initially oval, becoming round by transformation; horizontal axis is given first, vertical axis second.



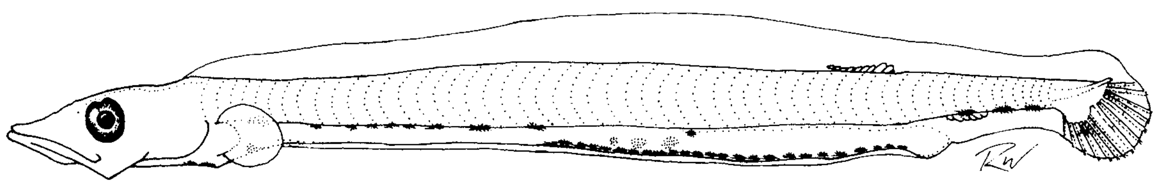
5.7 mm



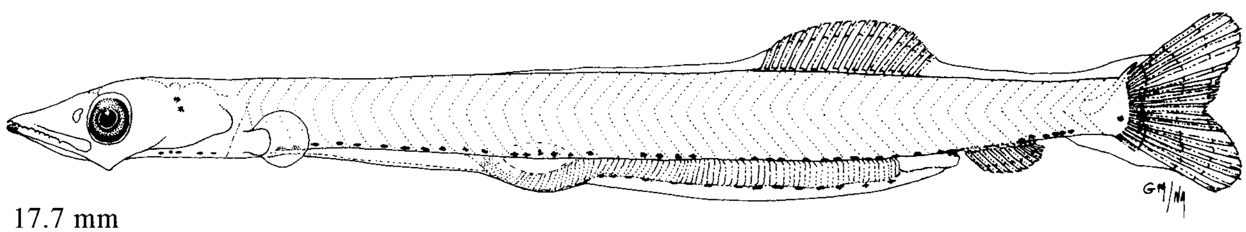
1.4 mm



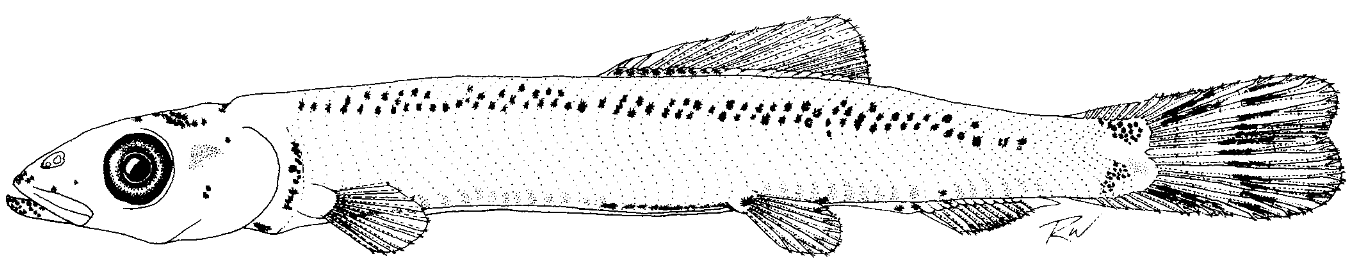
6.6 mm



12.1 mm



17.7 mm



27.1 mm

Figure Clupeidae 2. Egg, 1.4 mm (Ahlstrom and Moser 1980); yolk-sac larva, 5.7 mm; preflexion larva, 6.6 mm (Miller et al. 1979); flexion larva, 12.1 mm (CFRD 7203AH, station 22/3 No. 7); postflexion larva, 17.7 mm (CFRD Ref. Coll.); transformation specimen, 27.1 mm (SIO 85–176; scales developing posteriorly along the lateral midline are not shown).

MERISTICS

	Range	Mode
Vertebrae:		
Total	40–43	41
Precaudal	20–23	
Caudal	19–22	
Fins:		
Dorsal spines	0	0
Dorsal rays	16–20	18–19
Anal spines	0	0
Anal rays	14–17	16
Pelvic	8–9	8
Pectoral	15–16	15–16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–10	7
Lower	5–7	6
Gill rakers:		
Upper	9–18	
Lower	24–34	
Branchiostegals		

LIFE HISTORY

Rauge: La Jolla, California, to Callao, Peru, including Gulf of California; rare north of Baja California Sur

Habitat: Schools in coastal waters

Spawning season: Larvae collected April–October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Matus-Nivón et al. (manuscript; Centro Interdisciplinario de Ciencias Marinas, Apdo. Postal 592, La Paz, BCS, Mexico)

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.7 mm (E. Matus-Nivón)
Yolk-sac larva, 3.7 mm (E. Matus-Nivón)
Preflexion larva, 6.6 mm (E. Matus-Nivón)
Flexion larva, 9.0 mm (E. Matus-Nivón)
Postflexion larva, 18.5 mm (E. Matus-Nivón)
Transformation specimen, 20.8 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.7 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.09 mm
Shell surface: Smooth
Pigment:
Diagnostic features: Large egg with wide perivitelline space; segmented yolk; small OG

LARVAE

Hatching length: ca. 3.7 mm
Flexion length: 6.6–8 mm through 9.5 mm
Transformation length: ca. 19.5 mm
Fin development sequence: C_1, D, C_2, A, P_2, P_1
Pigmentation: *Yolk-sac*—On dorsum initially, moving to gut by end of stage except remaining around notochord tip. *Preflexion*—Dorsally & ventrally on notochord tip; on cleithrum at P_1 base; on isthmus; dorsolaterally along sides of gut; over gas bladder; on ventral margin of gut posteriorly from gas bladder except none on last 10–20%. *Flexion–postflexion*—At nape by 6.6 mm, extending caudad along dorsal margin, becoming deeply internal & reaching urostyle by 14 mm; externally over midbrain by 8 mm, on mandible & opercle by 14 mm; pair under brain by 6.6 mm; in otic capsule by 9.5 mm; increasing on isthmus & cleithrum after 9.5 mm; over foregut by 9 mm; posteriorly on lateral midline by 14 mm, extending cephalad; on ventral margin of tail by 14 mm; on D base by 14 mm; proximally on C rays; internally on urostyle & hypurals.
Diagnostic features: Myomeres 40–43 (33–35+7–8 through flexion, shifting to 28–31+11–14 by late postflexion stage); 4–6 myomeres between D insertion & A origin; moderate to heavy pigment over notochord tip through early postflexion stage; pigment dorsally on head & dorsal margin beginning early in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		85–87 86	84–87 85	75–84 79	74–76 75	73–75 74
BD/BL		7–10 8	8–9 9	8–16 13	18–23 20	23–24 24
HL/BL		17–19 18	17–19 18	21–26 23	27–28 28	27–28 28
HW/HL		43–48 47	46–53 51	34–42 37	32–37 34	36–36 36
SnL/HL		17–22 20	19–25 22	25–29 27	24–32 28	27–30 28
ED/HL		29–30 30	23–27 25	23–28 25	27–31 29	28–32 30
P_1L/BL		0–2 1	1–2 2	2–7 4	12–20 17	16–18 17
P_2L/BL		0–0 0	0–0 0	2–11 7	12–15 13	11–13 12

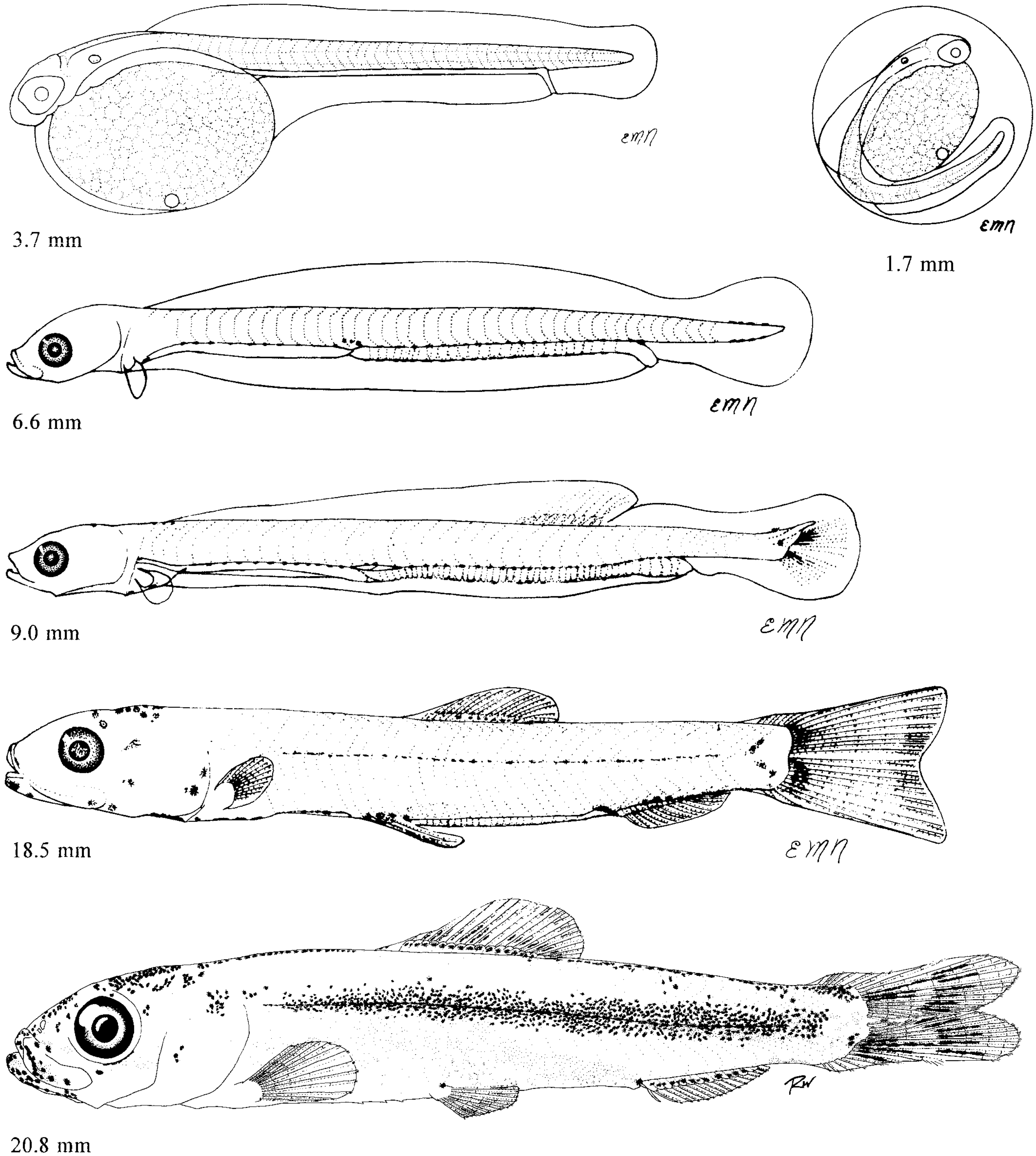


Figure Clupeidae 3. Egg, 1.7 mm; yolk-sac larva, 3.7 mm; preflexion larva, 6.6 mm; flexion larva, 9.0 mm; postflexion larva, 18.5 mm (Matus-Nivón et al., unpublished manuscript); transformation specimen, 20.8 mm (SIO 70–139; scales are not shown; damaged dorsal, anal and caudal fins on this specimen were modified in the illustration based on fins of a 19.3 mm specimen from the same lot).

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–48	46
Precaudal	22–24	23
Caudal		23
Fins:		
Dorsal spines	0	0
Dorsal rays	17–20	19
Anal spiues	0	0
Anal rays	19–22	20
Pelvic	8–9	8
Pectoral	15–18	16–17
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–9	7
Lower	6–8	6
Gill rakers:		
Upper	110–149	
Lower	161–224	
Brauchiostegals		

LIFE HISTORY

Range: Eastern Pacific from San Pedro, California to Peru & throughout Gulf of California; rare on outer coast north of Baja California Sur.

Habitat: Schools in coastal waters

Spawning season: Spring–fall, principally July–September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Funes-Rodríguez & Esquivel-Herrera 1988
Matus-Nivón et al. 1989b
McGowan & Berry 1984

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.3–1.9 mm
Yolk: Segmented; 0.4–0.9 mm diam.
No. of OG: 1
Diam. of OG: 0.08–0.17 mm
Shell surface: Smooth
Pigment: Melanophores on dorsum of embryo beginning soon after blastopore closure
Diagnostic features: Large egg with thin, fragile chorion; wide perivitelline space; segmented yolk; small OG

LARVAE

Hatching length: 2.3–2.6 mm
Flexion length: 6.5–8 mm
Transformation length: 19.4–32.2 mm
Fin development sequence: D, C_1, A, C_2, P_1 & P_2
Pigmentation: *Yolk-sac*—Initially two rows along dorsum, migrating ventrad to gut & ventral margin by end of stage. *Preflexion*—On isthmus adjacent to cleithra; dorsolateral row along each side to near middle of gut, double row along ventral margin of gut posteriorly; dorsally on gut near anus; dorsal series spreading forward along hindgut after 4 mm. *Postflexion*—Internal dorsolateral pair on hindbrain by 12 mm; over mid- & hindbrain; below eye, & on opercle by 19 mm; in otic capsule by 12 mm; on lower part of cleithrum by 12 mm; on dorsal margin of caudal peduncle, on hypurals, & along C rays by 12 mm; internal series along lateral midline by 19 mm; on D & A bases by 19 mm.
Diagnostic features: Myomeres 32–40+5–13=45–48 (usually 37–40+5–10 in larvae <16 mm); 5–9 myomeres (usually 6–8) between D insertion & A origin; pair of dorsolateral melanophores on hindbrain & external melanophore(s) on dorsal margin of caudal peduncle early in postflexion stage.

MORPHOMETRICS (range & mean iu %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		84–87	86–96	79–89	79–84	74–85
	86	85	88	87	82	78
BD/BL		7–10	6–10	7–9	9–14	25–27
	16	8	9	8	12	26
HL/BL		15–18	15–21	15–19	19–25	26–31
	16	16	17	16	21	28
HW/HL						31–39
						35
SnL/HL		13–18	16–22	21–27	24–28	25–28
	18	17	19	23	26	27
ED/HL		34–42	25–35	26–31	23–27	28–34
	39	36	30	28	25	31
P_1L/BL						15–17
						16
P_2L/BL						10–10
						10

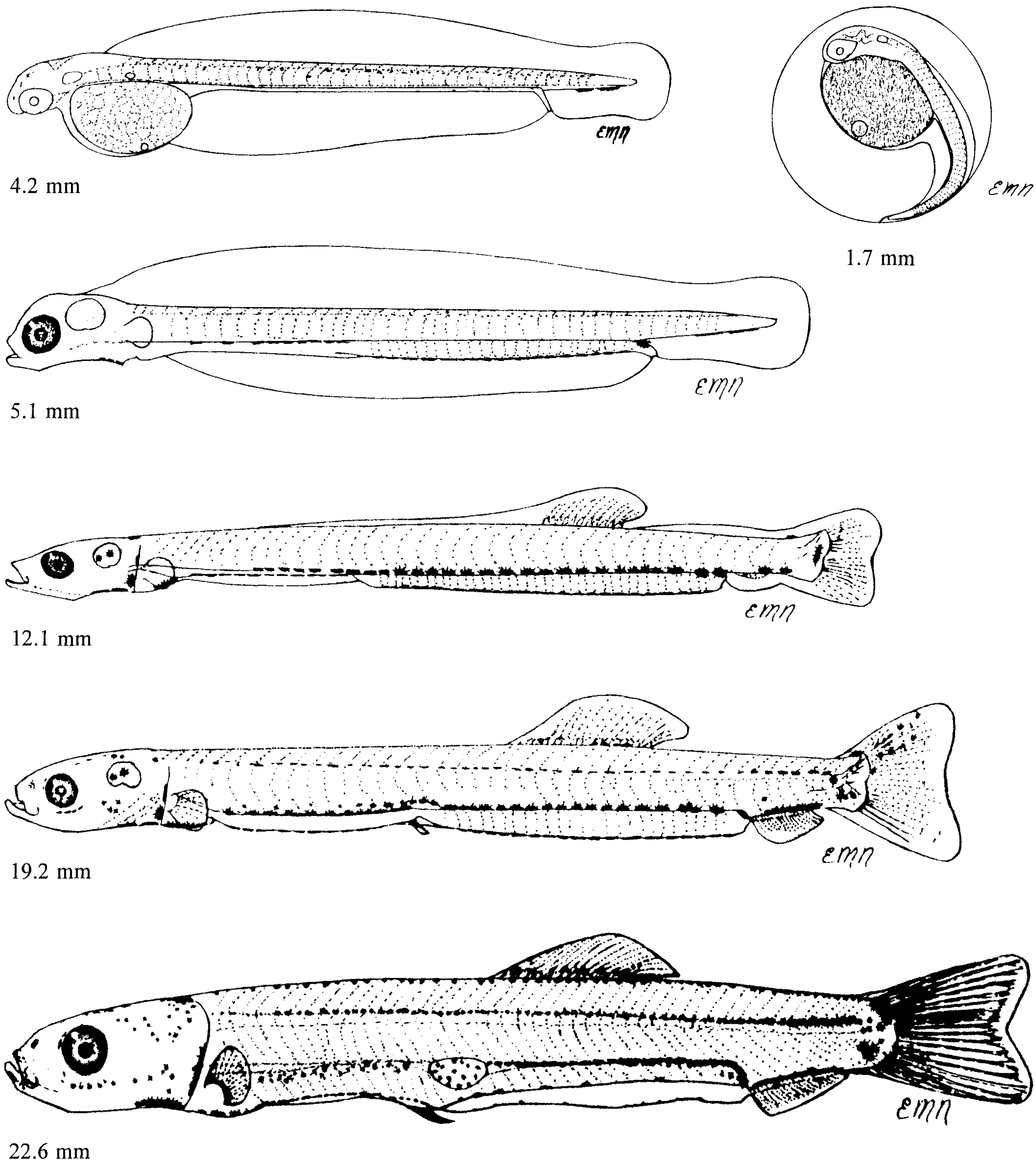


Figure Clupeidae 4. Egg, 1.7 mm; yolk-sac larva, 4.2 mm; preflexion larva, 5.1 mm; late flexion larva, 12.1 mm; postflexion larva, 19.2 mm; transformation specimen, 22.6 mm (Matus-Nivón et al. 1989b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–54	51
Precaudal	28–30	29
Caudal	22–23	22
Fins:		
Dorsal spines	0	0
Dorsal rays	17–20	19
Anal spines	0	0
Anal rays	17–20	18–19
Pelvic	8–9	8
Pectoral	16–19	18–19
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–9	6–7
Lower	5–8	5–6
Gill rakers:		
Upper	21–23	
Lower	44–45	
Branchiostegals	6–10	

LIFE HISTORY

Range: Kamchatka to Alaska & along eastern Pacific coast to Cabo San Lucas, Baja California Sur; in Gulf of California north to Guaymas, Sonora, Mexico

Habitat: Schools over continental shelf, often near shore

Spawning season: Throughout the year with peaks in spring & summer, minimum in fall & winter off California

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1959, 1960, 1966
Kramer 1970
Matarese & Sandknop 1984
Matarese et al. 1989
McGowan & Berry 1984
Scofield 1934

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.3–2.1 mm
Yolk: Segmented; 0.9–1.4 mm diam.
No. of OG: 1 (occasionally 0 in northern part of range)
Diam. of OG: 0.12–0.19 mm
Shell surface: Smooth
Pigment: Melanophores form along dorsum of embryo soon after blastopore closure
Diagnostic features: Large egg with thin, fragile chorion & wide perivitelline space; segmented yolk with small OG

LARVAE

Hatching length: 3.5–3.8 mm
Flexion length: 9–10.5 mm through 13–14.7 mm
Transformation length: 25 mm through 35–40 mm
Fin development sequence: C_1, D, A, P_2 & C_2, P_1
Pigmentation: *Yolk-sac*—Initially on dorsum, migrating ventrad to gut & ventral margin by end of stage. *Preflexion–flexion*—Usually none on dorsum; 1–2 on isthmus; 1 on cleithrum just above P_1 origin, 1 below P_1 insertion after ca. 13 mm; dorsolateral row on each side of gut, shifting dorsally posteriorly from gas bladder; irregular single to double row on ventral margin of gut posteriorly from gas bladder; few on ventral margin of tail; on hypurals & C rays, usually 1 prominent spot distally between middle hypurals. *Postflexion*—1–2 anteriorly over hindbrain by 13–14 mm, posteriorly over midbrain by 16 mm; in otic capsule by 15 mm; on snout & jaws by end of stage; internal series along spinal cord beginning anteriorly by ca. 15 mm & spreading caudad.
Diagnostic features: Myomeres 38–42+10–14=50–54; 5–8 myomeres (usually 6) between D insertion & A origin; often a prominent melanophore at distal margin between middle hypurals.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	79–81 80	82–86 84	82–86 84	80–85 83	76–77 76	76–78 77
BD/BL	4–6 5	6–8 7	6–7 7	7–11 8	14–15 15	16–17 17
HL/BL	13–15 14	13–15 14	13–15 15	15–21 18	24–25 24	26–27 27
HW/HL	51–72 60	52–70 57	47–57 52	38–48 43	28–31 30	28–31 30
SnL/HL	8–14 11	15–30 23	24–29 27	26–30 29	30–30 30	28–31 30
ED/HL	31–39 36	23–33 28	21–25 23	21–28 23	24–28 26	25–27 26
P_1L/BL	0–0 0	1–3 2	3–3 3	1–3 3	8–12 10	13–15 14
P_2L/BL	0–0 0	0–0 0	0–0 0	0–4 1	9–10 9	9–10 10

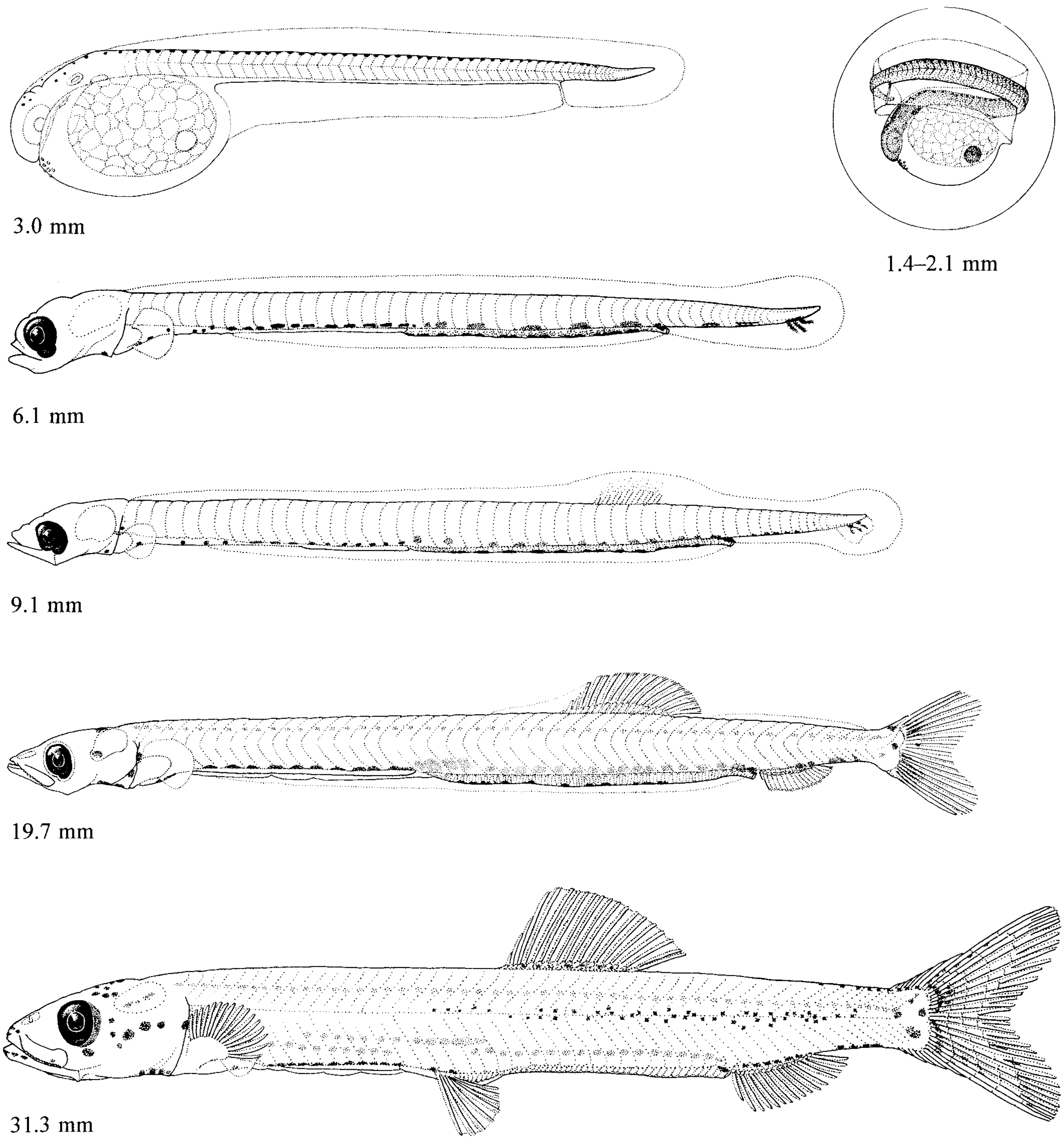


Figure Clupeidae 5. Egg, 1.4–2.1 mm (Matarese and Sandknop 1984); yolk-sac larva, 3.0 mm; preflexion larva, 6.1 mm; flexion larva, 9.1 mm; postflexion larva, 19.7 mm; transformation specimen, 31.3 mm (modified from Kramer 1970).

ENGRAULIDAE: Anchovies

W. Watson and E. M. Sandknop

Nine to eleven of the approximately 139 engraulid species occur in the CalCOFI study area (Table Engraulidae 1). Although the anchovies are widely accepted as a monophyletic group, the composition and relationships of the genera within the family are not fully resolved (McGowan and Berry 1984; Whitehead et al. 1988). The Engraulinae may be polyphyletic (Grande 1985) and there are both undescribed anchovy species and species that may be split (Whitehead et al. 1988). Nelson (1984) suggested that *Cetengraulis* be included as a subgenus in *Engraulis* based primarily on intestinal coiling and a gill arch synapomorphy shared with the New World *Engraulis* species. However, larval characters, for example the order of initial fin ray formation, which is the same in *Anchoa* and *Cetengraulis* but different in both from the eastern Pacific *Engraulis* (e.g., Orellana and Balbontín 1983; Caddell 1988; this study), suggest the possibility of other affinities.

Nearly all anchovy eggs and larvae collected in CalCOFI ichthyoplankton samples are *Engraulis mordax*, the most abundant fish species collected during CalCOFI surveys. *Anchoa* larvae apparently are largely restricted to bays, harbors, and estuaries. Larvae tentatively identified as *Cetengraulis mysticetus* have been taken in the Gulf of California.

Anchovies are small (most <20 cm; range ca. 2–37 cm), primarily planktivorous fishes that school in coastal waters. Some species live in fresh water. Adults are slightly to strongly compressed, with preanal length about half to two-thirds of body length, and with a large mouth, elongate snout, and inferior lower jaw. There are no spines in the fins, although the first one or two dorsal and anal fin rays are small and spine-like. Anchovies are brown to green (occasionally blue) dorsally and silvery below; some species have a prominent midlateral silver stripe. Anchovies are among the most economically important fishes, supporting some of the world's largest fisheries (Whitehead 1985; Whitehead et al. 1988). They are used primarily in reduction and bait fisheries, although some species are prepared in various ways for direct human consumption.

Early life histories are well known for a number of species (see review by McGowan and Berry 1984). All are oviparous, spawning small to moderately large (largest dimension 0.7–2.3 mm) planktonic eggs that vary in shape from spherical to strongly elliptical, with a knob at one pole in some species. Most genera lack oil globules; all have a segmented yolk. Larvae ca. 2–3.5 mm long hatch with unpigmented eyes, a partially formed mouth, a large yolk sac, and little or no pigment on the body. Larvae are elongate, with preanal length ca. 60–80% of body length. The hindgut is strongly marked with annular striations. The gas bladder, which first inflates between mid-preflexion and early flexion stage, is near midbody. The typical clupeoid cross-hatched muscle fiber pattern is visible during much of larval development. The dorsal fin typically inserts at postanal myomere 1–4, overlapping the anal fin origin by one to several rays. During the latter part of the postflexion stage and transformation, the dorsal fin and anus typically shift a few myomeres forward. Larval pigmentation is light and largely limited to the gut, the dorsal surface of the gas bladder, the ventrum, and the caudal fin through the late postflexion stage.

In the CalCOFI study area, larval engraulids are most likely to be confused with larval clupeids. The engraulids commonly have fewer myomeres than the clupeids (overall range 38–47, most species with ≤43 vs. 40–58, ≥43) and a shorter preanal length (usually <75% BL vs. usually >75% BL). The dorsal fin inserts after the last preanal myomere in the engraulids and before the last preanal myomere in the clupeids. Identification of the engraulid species larvae is more problematic. Presently, no known characters allow certain discrimination of the *Anchoa* species from one another, or *Cetengraulis* from *Anchoa*, before mid- to late postflexion stage. Geographic location, together with myomere and fin-ray counts (e.g., Table Engraulidae 1) may allow species identification in some cases, but more commonly will only reduce the number of potential identifications to two or three species. Larval *E. mordax* are relatively easily distinguished from *Anchoa* and *Cetengraulis* on the basis of several characters, for example *E. mordax* typically is more elongate and slender, and is more heavily pigmented than the other two genera. Most useful is the dorsal hindgut pigment, which nearly always is present after yolk absorption in *E. mordax*, but nearly always is absent before the late postflexion stage in *C. mysticetus* and before transformation in *Anchoa*. The principal caudal fin rays begin to form before the dorsal and anal fin rays in *E. mordax*, while the opposite is true for *Anchoa* and *Cetengraulis*.

The following descriptions are based on literature and on detailed examinations of 8–33 specimens of each species (Table Engraulidae 2). The larval and juvenile *C. mysticetus* described here are from the Gulf of Panama, and from the Gulf of Nicoya, Costa Rica. Larvae tentatively identified as *C. mysticetus* from the Gulf of California are somewhat more heavily pigmented in the mid-preflexion through mid-postflexion stages than the Central American specimens (in Gulf of California specimens all early preflexion stage pigmentation apparently is retained and perhaps augmented while in the Panamanian specimens much of the early gut pigment is lost by the early part of the postflexion stage). Meristic data were obtained from the literature (McHugh 1951; Howard 1954; Peterson 1956; Nelson 1983, 1984, 1986; McGowan and Berry 1984; Whitehead and Rodriguez-Sánchez 1995c) and from counts made during this study. Dorsal and anal fin ray counts include both the branched rays and the first 1–4 (usually 2 or 3) unbranched rays (sometimes counted separately and indicated with lower case roman numerals, or not counted at all, in the literature). Ecological information is from Peterson (1956), Eschmeyer et al. (1983), and Whitehead and Rodriguez-Sánchez (1995c). Peterson (1956) gave the northern range limits of *Anchoa curta* and *A. exigua* as Bahía San Juanico, Baja California Sur, while Whitehead and Rodriguez-Sánchez (1995c) show both ranging only to the mainland coast of the lower Gulf of California.

Table Engraulidae 1. Meristic characters and geographic ranges for the engraulid species in the California Current vicinity. All species have 10+9 principal caudal fin rays. Abbreviations: BC, Baja California; BCS, Baja California Sur; CA, California; Gulf, Gulf of California.

	Vertebrae			Fin rays						
Species	PrCV	CV	Total	D	A	P_1	P_2	C_2	Gill rakers	Range
Anchoa compressa	18–19	20–23	39–41	12–14	29–33	13–16	7–8	8–9+ 6–8	19–22+ 24–27	Morro Bay CA–Bahía Todos Santos BC
A. curta	19–22	19–22	39–42	14–16	21–27	13–14	6–8	8–10+ 8–10	16–20+ 22–26	Bahía San Juanico BCS–Ecuador
A. delicatissima	19–21	19–21	39–41	13–16	23–27	12–14	6–8	8–9+ 7–9	18–21+ 26–32	Long Beach CA–Bahía Magdalena BCS
A. exigua	22–24	20–23	43–46	14–15	18–23	12–15	7	9+9	17–23+ 22–28	Bahía San Juanico BCS–Panama
A. ischana	22–24	19–21	41–45	14–15	17–22	16–17	6–8	6–9+8	14–19+ 17–23	Bahía Magdalena BCS & Gulf–Costa Rica
A. lucida	17–20	19–22	38–42	13–15	26–32	14–15	6–7	8–10+ 7–8	16–20+ 18–22	Bahía Magdalena & Gulf–Peru
A. nasus	19–21	19–22	39–42	14–16	22–28	14–16	6–7	8–10+ 8–10	17–24+ 20–28	Bahía San Juanico BCS–Peru
A. walkeri	18–20	16–24	40–42	13–14	30–35	13	7	9–11+ 7–9	17–22 lower	Cabo San Lucas & Gulf–Panama
Anchovia macrolepidota	19–21	19–22	40–41	14–16	28–32	13–14	6–7	8–10+ 7–8	70–135 total	Bahía Magdalena & Gulf–Peru
Cetengraulis mysticetus	21–23	19–20	39–43	13–17	18–26	15–17	6–7	9–10+ 7–11	63–145 total	Los Angeles CA–Peru
Engraulis mordax	24–26	19–21	43–47	14–19	19–26	13–20	6–8	7–10+ 7–10	28–41+ 37–45	British Columbia–Gulf

Table Engraulidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the engraulid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Anchoa compressa	L[a]	5 2.5–3.2	L[a]	L[a]	L[a]	0	3 28.5–38.2
A. delicatissima	L[a]	5 2.4–3.0	L[a]	L[a]	L[a]	0	5 44.7–62.3
Cetengraulis mysticetus	L[b]	L[b]	3 6.1–6.4	7 6.5–9.3	9 12.0–23.8	5 23.7–28.6	3 32.3–34.0
Engraulis mordax	L[c]	5 2.7–3.2	9 2.8–8.1	6 7.6–12.0	6 13.7–26.2	3 28.5–36.7	4 49.1–64.3

[a] Caddell 1988
[b] Simpson 1959
[c] Bolin 1936

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	40
Precaudal	18–19	19
Caudal	20–23	21
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13–14
Anal spines	0	0
Anal rays	29–33	31
Pelvic	7–8	7
Pectoral	13–16	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	8–9
Lower	6–8	6–7
Gill rakers:		
Upper	19–22	
Lower	24–27	24–25
Branchiostegals	10–13	12

LIFE HISTORY

Range: Morro Bay, California, to Bahía Magdalena, Baja California Sur

Habitat: Schools in shallow coastal waters, commonly in bays & estuaries

Spawning season: Summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Caddell 1988
Eigenmann 1892

* Values calculated from Caddell (1988: Appendix 1) using larval length classes that exclusively represent each stage: preflexion, 4.00–4.99; flexion, 7.00–8.99 mm; postflexion, 11.00–19.99 mm.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.63–0.90 mm **Yolk:** Segmented
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth
Pigment: None
Diagnostic features: Round to slightly elliptical; segmented yolk; no OG

LARVAE

Hatching length: 1.5–2.5 mm
Flexion length: 5.5–6.5 mm through 10.0–10.5 mm
Transformation length: >20 mm, <28 mm
Fin development sequence: D, A, C_1, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Little dorsolaterally along gut & on ventral margin of tail. *Preflexion–flexion*—On isthmus; 1–6 dorsolaterally along gut anterior to gas bladder; on gas bladder beginning at ca. 7 mm; few on ventral margin of hindgut, decreasing in number during flexion stage; rarely 1 or 2 anteriorly over hindgut; rarely 1 or 2 over end of hindgut; on ventral margin of tail; under notochord tip, becoming aligned along developing C rays. *Postflexion*—Internally on brain after 15 mm; along cleithrum after 11 mm; internally on urostyle & lower hypurals; along vertebral column posteriorly after 16.5 mm; increasing on C.
Diagnostic features: Myomeres 38–41 (20–26 preanal through postflexion stage); D insertion above A ray 5–7 (postanal myomere 2 or 3) through postflexion stage; high A ray count; little or no pigment (usually none) over hindgut; compared with *Engraulis mordax*—relatively deeper body, shorter preanal length, smaller size at given developmental stage, & more lightly pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF*	F*	PoF*	Tr	Juv
Sn-A/BL	70–75 72	69–72 71	70–76 73	61–72 68		52–54 53
BD/BL	6–7 6	4–5 4	5–10 7	7–15 10		17–19 19
HL/BL	17–23 19	14–18 15	16–22 18	16–27 20		25–26 25
HW/HL	46–59 51					33–38 36
SnL/HL	7–15 12					13–15 14
ED/HL	33–43 38	23–30 26	21–27 24	21–29 26		25–27 26
P_1L/BL	0–0 0					14–16 15
P_2L/BL	0–0 0					9–10 9

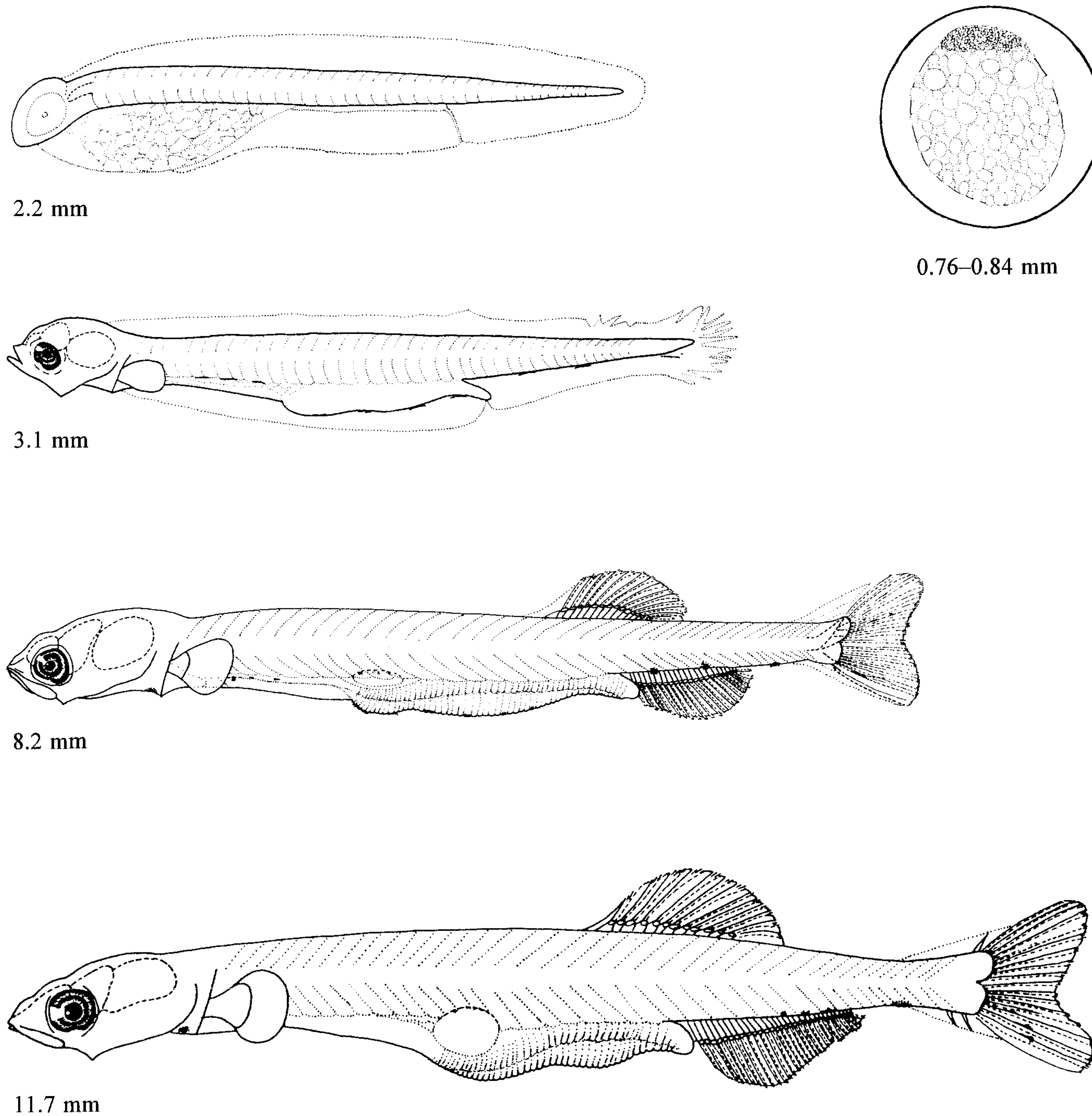


Figure Engraulidae 1. Egg, 0.76–0.84 mm; *Anchoa* sp. yolk-sac larva, 2.2 mm; *Anchoa* sp. preflexion larva, 3.1 mm; *Anchoa* sp. late flexion larva, 8.2 mm; *A. compressa* postflexion larva, 11.7 mm (Caddell 1988).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	40
Precaudal	19–21	20
Caudal	19–21	20
Fins:		
Dorsal spines	0	0
Dorsal rays	13–16	15
Anal spines	0	0
Anal rays	23–27	25
Pelvic	6–8	7
Pectoral	12–14	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	8–9
Lower	7–9	8
Gill rakers:		
Upper	18–21	
Lower	26–32	
Branchiostegals	11–12	11

LIFE HISTORY

Range: Long Beach Harbor, California, to Bahía Magdalena, Baja California Sur

Habitat: Coastal waters; schools primarily in bays, harbors & estuaries, occasionally near shore along open coast

Spawning season: Summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Caddell 1988
Eigenmann 1892

* Values calculated from Caddell (1988: Appendix 2) using larval length classes that exclusively represent each stage: preflexion, 3.00–5.99 mm; flexion, 7.00–8.99 mm; postflexion, 12.00–19.99 mm.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.81–1.07 × 0.48–0.63 mm **Yolk:** Segmented
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth
Pigment: None
Diagnostic features: Elliptical, average 0.91× 0.57 mm; segmented yolk; unpigmented

LARVAE

Hatching length: 2.0–2.5 mm
Flexion length: 6–7 mm through 9.5–11 mm
Transformation length:
Fin development sequence: D, A, C_1, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Few dorsolaterally along gut; few on ventral margin of tail. *Preflexion–flexion*—2–4 on isthmus; few dorsolaterally along foregut; dorsally on gas bladder; few on ventral margin of hindgut, decreasing during flexion stage; few on ventral margin of tail; little ventrally on caudal finfold & along developing C rays. *Postflexion*—Internally on mid- & hindbrain after 15 mm; on cleithrum after 11 mm; increasing on gas bladder, ventral margin of tail, & C; none on ventral margin of hindgut; internally over caudal vertebrae after 16.5 mm; internally on urostyle & lower hypurals.
Diagnostic features: Myomeres 20–26+14–18=38–42 (usually 24–25+14–16 through early postflexion stage); D insertion at postanal myomere 2–3, above A rays 6–8 through postflexion stage; little or no pigment (usually none) dorsally on hindgut; A rays 23–27; compared with *Engraulis mordax*—deeper-bodied, greater overlap between D insertion & A origin, D & A ray formation begins before C_1 ray formation, & more lightly pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF*	F*	PoF*	Tr	Juv
Sn-A/BL	69–74 72	66–76 71	71–75 74	59–72 67		53–55 54
BD/BL	5–7 6	3–6 4	5–10 7	7–15 11		18–20 19
HL/BL	16–21 19	11–18 14	16–23 19	17–23 20		23–26 25
HW/HL	42–58 49					32–44 39
SnL/HL	7–11 8					18–21 19
ED/HL	32–38 34	23–36 30	19–32 26	21–30 24		30–31 30
P_1L/BL	0–3 1					9–15 12
P_2L/BL	0–0 0					8–9 9

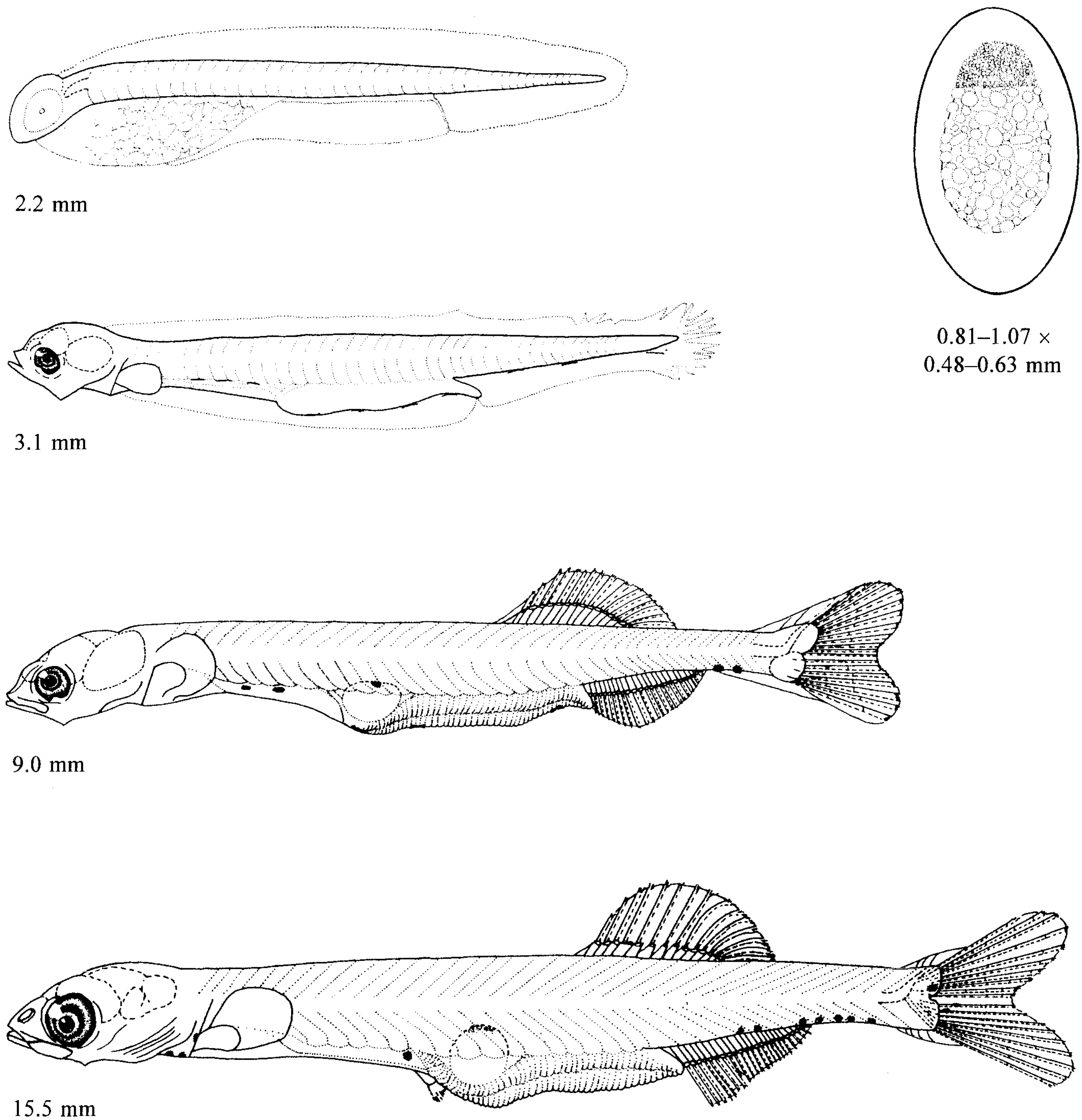


Figure Engraulidae 2. Egg, 0.81–1.07 × 0.48–0.63 mm; *Anchoa* sp. yolk-sac larva, 2.2 mm; *Anchoa* sp. preflexion larva, 3.1 mm; *A. delicatissima* late flexion larva, 9.0 mm; *A. delicatissima* postflexion larva, 15.5 mm (Caddell 1988).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–43	41–42
Precaudal	21–23	
Caudal	19–20	
Fins:		
Dorsal spines	0	0
Dorsal rays	13–17	15
Anal spines	0	0
Anal rays	18–26	21–23
Pelvic	6–7	6
Pectoral	15–17	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	9–10	9
Lower	7–11	9
Gill rakers:		
Total*	63–145	
Upper		
Lower	25–60	
Branchiostegals	7–9	8

LIFE HISTORY

Range: Los Angeles, California, to Peru, including Gulf of California

Habitat: Coastal waters; schools in bays, estuaries, & along open coast, often well offshore

Spawning season: Fall–winter with December peak (Panama)

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Simpson 1959

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 6.1 mm (R. C. Walker)
Flexion larva, 7.8 mm (R. C. Walker)
Postflexion larvae, 14.0 mm, 21.7 mm (R. C. Walker)
Transformation specimen, 28.6 mm (R. C. Walker)

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* The number of gill rakers increases with increasing adult length.
† The eye is oval, becoming round or nearly so by postflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.99–1.4 mm × 0.49–0.66 mm **Yolk:** Segmented
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth
Pigment: None
Diagnostic features: Elliptical, average 1.2 × 0.56 mm; segmented yolk; unpigmented

LARVAE

Hatching length: ca. 2 mm
Flexion length: 6.5–7.5 mm
Transformation length: ca. 23–30 mm
Fin development sequence: D & A, C_1, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Few dorsolaterally on foregut & ventrally on hindgut & tail near end of stage. *Preflexion–flexion*—1–3 on isthmus; 0–1 on cleithrum; 1–4 dorsolaterally on foregut; pair posterodorsally on gas bladder; 4–6 each on ventral margins of hindgut & tail; little ventrally on caudal region. *Postflexion*—External dorsally on head at ca. 21 mm; on opercle at 18 mm; internally on brain by 21 mm; increasing on isthmus, cleithrum, gas bladder, ventral margin of tail, & C after 18 mm; decreasing to 0–2 ventrally on gut by 14 mm; increasing dorsally & dorsolaterally on gut after ca. 19 mm; internally in caudal peduncle after 18 mm; on dorsal margin beginning posteriorly after 21 mm. *Transformation*—On snout & increasing on head at 23 mm; heavy on gut; spreading cephalad on dorsal margin; laterally on trunk & tail.
Diagnostic features: Myomeres 40–43 (23–25+15–18 through early postflexion stage, shifting to 20–23+19–22 by transformation); D inserts at postanal myomere 2–4 (above A rays 5–8) through postflexion stage; hindgut coils & snout becomes elongate & pointed during transformation; no dorsal hindgut pigment before 18 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		73–75 74	73–77 75	64–72 68	63–65 64	61–63 62
BD/BL		7–9 8	8–9 8	9–13 11	16–20 18	22–23 23
HL/BL		16–18 17	18–20 19	20–24 22	27–31 30	33–35 34
HW/HL		54–66 59	46–57 52	36–46 40	32–34 33	25–28 26
SnL/HL		18–19 18	21–29 24	16–23 19	16–17 16	17–17 17
ED/HL†		27–30× 22–26 29×24	22–27× 17–26 24×23	19–23× 18–22 22×21	20–22× 22–23 21×22	18–21× 20–22 20×21
P_1L/BL		2–3 2	3–4 3	2–4 3	6–11 8	12–12 12
P_2L/BL		0–0 0	0–0 0	0–8 5	8–9 9	9–9 9

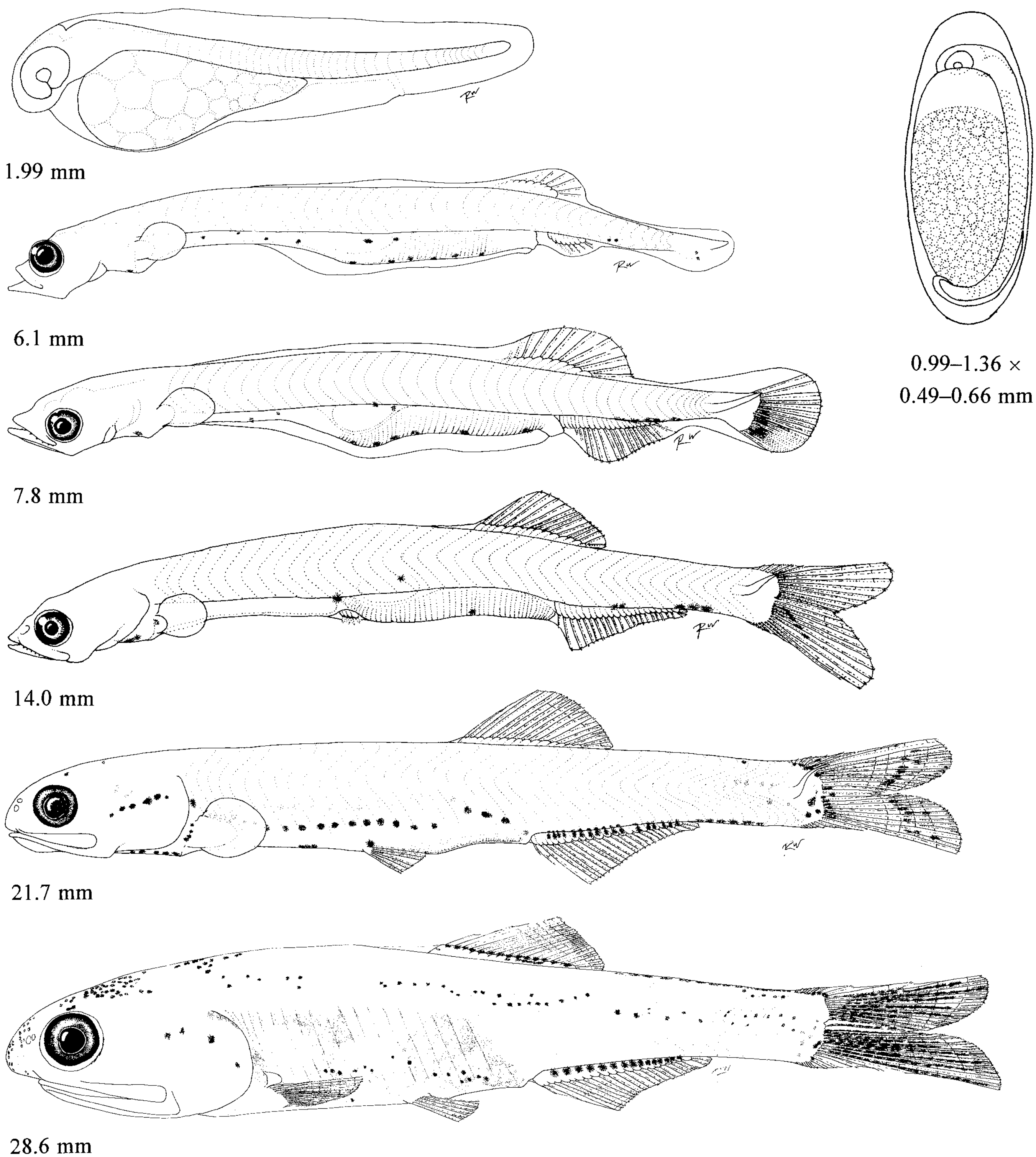

Figure Engraulidae 3. Egg, 0.99–1.36 × 0.49–0.66 mm; yolk-sac larva, 1.99 mm (redrawn from Simpson 1959); preflexion larva, 6.1 mm; flexion larva, 7.8 mm (IATTC, Gulf of Panama 1721L); postflexion larvae, 14.0 mm (IATTC, Gulf of Panama 1687L), 21.7 mm (IATTC, Gulf of Panama 1721L); transformation specimen, 28.6 mm (IATTC, Gulf of Panama 1687L; developing scales are not shown).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–47	45–46
Precaudal	24–26	25
Caudal	19–21	20–21
Fins:		
Dorsal spines	0	0
Dorsal rays	14–19	16–17
Anal spines	0	0
Anal rays	19–26	22–23
Pelvic	6–8	6–7
Pectoral	13–20	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–10	9
Lower	7–10	9
Gill rakers:		
Upper	28–41	38–40
Lower	37–45	41–43
Branchiostegals	11–14	14

LIFE HISTORY

Range: Queen Charlotte Island, British Columbia, to Cabo San Lucas, Baja California Sur, & lower Gulf of California

Habitat: Schools in coastal waters

Spawning season: Throughout the year with late winter–spring peak, late summer–fall minimum

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965, 1966
Bolin 1936
Caddell 1988
Kramer & Ahlstrom 1968
Matarese & Sandknop 1984
Matarese et al. 1989
McGowan & Berry 1984
Moser & Ahlstrom 1985
Wang 1981

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.23–1.55 × 0.65–0.82 mm
Yolk: Segmented
No. of OG: 0
Diam. of OG:
Shell surface: Smooth
Pigment: None
Diagnostic features: Ellipsoidal shape; size

LARVAE

Hatching length: 2.5–3 mm
Flexion length: 6.5–10 mm through 10.5–13.5 mm
Transformation length: ca. 35–40 mm
Fin development sequence: C_1, D & A, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Few form dorsolaterally on gut & on ventral margin of tail mid-way through stage. *Preflexion–flexion*—1–few on isthmus; on cleithrum near P_1 origin by 11 mm; few dorsolaterally along gut to level of gas bladder, becoming dorsal over hindgut; on ventral margin of hindgut; on ventral margin of tail; under notochord tip, becoming proximal along developing C rays. *Postflexion*—Dorsally over mid- & hindbrain & on opercle after 18 mm; on hindbrain after 16 mm; increasing on isthmus, cleithrum, gut, ventral margin of tail, & C; internally on hypurals by 16 mm; midlaterally on body beginning posteriorly by ca. 18 mm. *Transformation*—On dorsum beginning posteriorly, extending full length of body by ca. 37 mm; on snout & mandible by 37 mm; increasing generally, especially on dorsum, midlaterally on body, & on gut.
Diagnostic features: Myomeres 43–47 (26–30+13–18 to late postflexion stage); D insertion above A ray 2–4 (at postanal myomere 1 or 2) through postflexion stage; dorsal pigment on hindgut; more elongate, larger at given stage, & more pigment than *Anchoa*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	60–71 68	70–77 74	74–79 76	65–76 72	64–67 65	64–66 66
BD/BL	7–9 8	8–11 9	8–9 8	8–10 9	12–14 13	16–18 17
HL/BL	15–19 17	14–17 16	16–18 17	18–22 19	22–26 24	30–32 31
HW/HL	40–69 59	49–67 59	45–56 49	34–44 40	33–36 35	24–29 27
SnL/HL	4–10 8	16–28 21	21–29 25	19–27 23	17–19 17	18–20 19
ED/HL	37–43 40	22–33 27	21–26 23	20–24 21	24–26 25	21–26 25
P_1L/BL	0–0 0	2–4 3	2–4 3	3–4 3	4–6 5	13–14 14
P_2L/BL	0–0 0	0–0 0	0–0 0	0–5 2	7–9 8	9–10 9

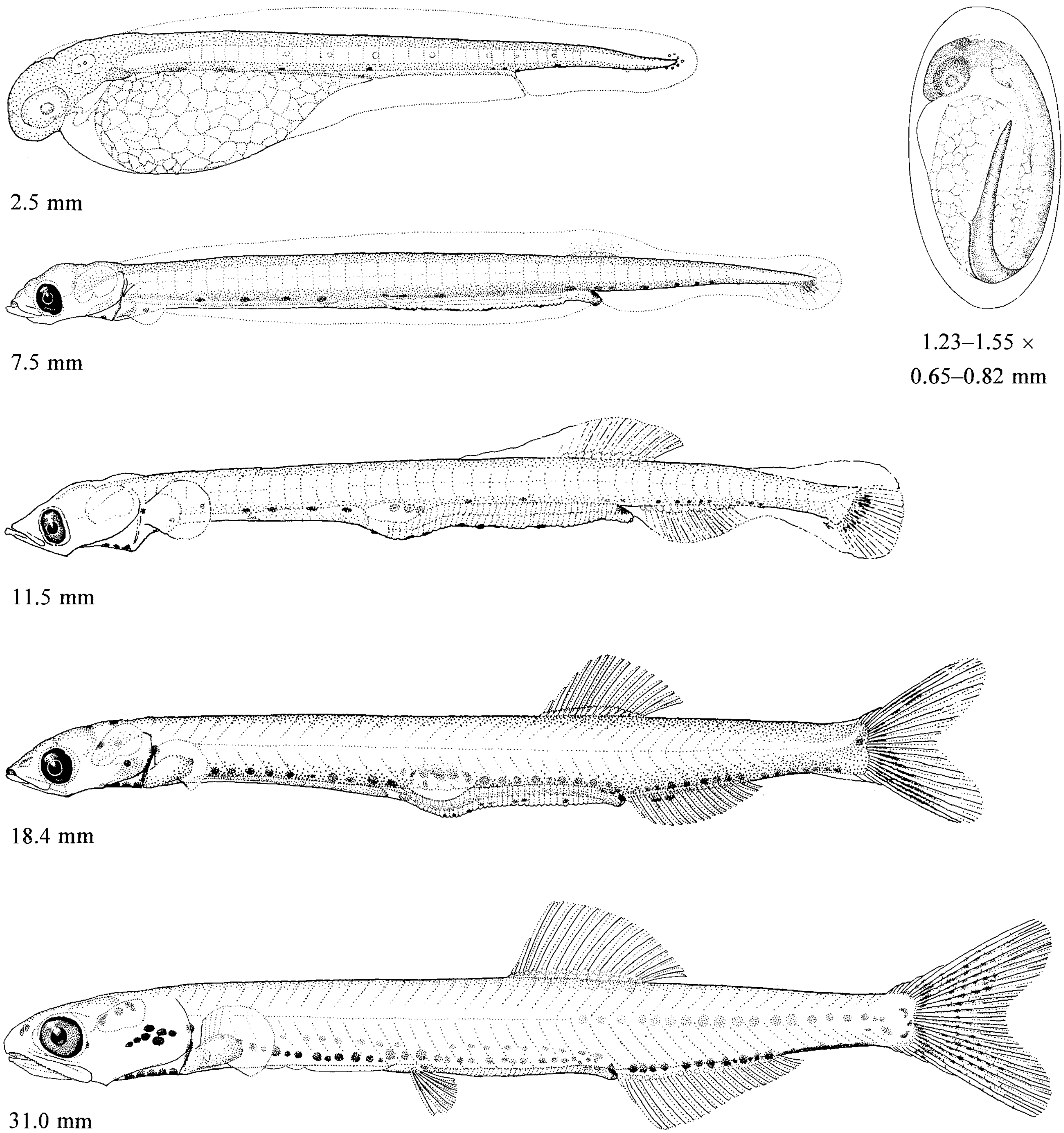

Figure Engraulidae 4. Egg, 1.23–1.55 × 0.65–0.82 mm (Moser and Ahlstrom 1985); yolk-sac larva, 2.5 mm; preflexion larva, 7.5 mm; flexion larva, 11.5 mm; postflexion larvae, 18.4 mm, 31.0 mm (Kramer and Ahlstrom 1968). Most stippling on the Kramer and Ahlstrom (1968) illustrations is not pigment (especially along the dorsal and ventral margins and on the head), but is shading which was intended to convey shape.

SALMONIFORMES

H. G. MOSER

Greenwood et al. (1966) hypothesized a taxonomically complex order consisting of 8 suborders and 37 families. Use of cladistic methods by subsequent workers resolved some ambiguities concerning the relationships of these fishes and brought into question the monophyly of the order (Rosen 1974; Fink and Weitzman 1982; Lauder and Leim 1983). Fink (1984) and Begle (1991) suggested that Salmoniformes (sensu Greenwood et al. 1966) is no longer useful, since evaluation of salmoniform characters has left no monophyletic group larger than Salmonidae. Begle (1991, 1992) proposed the taxon Osmerae for the non-salmonid members of the order, Argentinoidei plus Osmeroidei, based on several characters (e.g., fusion of rudimentary neural arches to ural centra, presence of a cartilaginous vane on the anterior basibranchials, and loss of nuptual tubercles). Within the osmeroids, the Osmeridae were defined by numerous characters including the presence of an anchor membrane on the egg, the pattern of fusion in the caudal skeleton, and the shape of the palatine.

Monophyly of the two principal clades in Argentinoidei, the superfamilies Argentinoidea and Alepocephaloidea, is based on the presence of a crumenal organ, a unique branchial outpocketing with specialized structural elements (Rosen and Greenwood 1971; Begle 1992). Monophyly of the Alepocephaloidea is based on: 1) a dorsally reduced opercle, 2) a specialized spine on the dorsal margin of the opercle, 3) specialization of the basibranchial, and 4) teeth on the gill rakers (Begle 1992). Ahlstrom et al. (1984b) used four synapomorphies to define Argentinoidea: 1) initial development of dorsal and anal fins in the finfold, 2) ornamentation of the inner surface of the egg shell, 3) a unique rete mirabile in the swim bladder, and 4) the tendency for the vomer and palatines to assume the function of the premaxillary and maxillary. Begle (1991, 1992) dismissed the fourth of these characters and added three others (a small terminal mouth, an anterior extension of the vomer, and the presence of supraneural lamellae in the caudal complex). Ahlstrom et al. (1984b) defined four distinct lineages (Argentinidae, Microstomatidae, Bathylagidae, and Opisthoproctidae) within the Argentinoidea, based on ontogenetic and adult characters.

Despite the great interest in the systematics of these fishes, their phylogenetic relationships and those of primitive euteleostean fishes in general have not been fully resolved. Hence, we follow Eschmeyer's (1990) classification of Salmoniformes that includes the suborders Esocoidei, Argentinoidei, Lepidogalaxioidei, and Salmonoidei.

Early life history stages of the Salmonoidei and Argentinoidei are present in the California region. Some species of osmerid smelts spawn intertidally, attaching their eggs to coarse sand grains, while other species are reported to spawn offshore. Osmerid larvae are taken occasionally in nearshore CalCOFI stations. They superficially resemble clupeoids but lack the transverse muscle layer found in clupeoids and differ in the structure and pigment of the gut. Eggs and larvae of all argentinoid families occur in the CalCOFI region. ELH stages of the Alepocephalidae and Platytroctidae are found relatively deep in the water column and, consequently, are rare in CalCOFI samples. Their eggs are large, and yolk-sac individuals develop directly into juveniles. Eggs and larvae of Bathylagidae, Argentinidae, and Microstomatidae are well represented in CalCOFI ichthyoplankton collections and those of Bathylagidae are particularly abundant. The highly distinctive ELH stages of these three families can be identified by a large array of characters described in detail below. The spookfishes (Opisthoproctidae) are relatively rare midwater fishes whose larvae are rare in CalCOFI samples.

Suborders and families included:

- Argentinoidei
  - Argentinidae
  - Bathylagidae
  - Microstomatidae
  - Opisthoproctidae
- Alepocephaloidei
  - Alepocephalidae
  - Platytroctidae
- Salmonoidei
  - Osmeridae

ARGENTINIDAE: Argentines

H. G. Moser

The family Argentinidae includes two genera and about 19 species distributed in coastal regions of the Atlantic, Pacific, and Indian oceans. The single argentine species in the CalCOFI area, *Argentina sialis,* ranges from the mouth of the Columbia River south to Cabo San Lucas, Baja California Sur and into the Gulf of California. The distributional range for larvae is from Pt. Arena, California, to Southern Baja California, with highest abundance off central Baja California. Larvae are relatively rare in the Gulf of California.

Adult argentines are medium-size (<22 cm) silvery, flat-sided fishes with a wedge-like head, large eyes, and a small mouth (Cohen 1964b). The jaws are toothless but teeth are present on the tongue. The dorsal fin is just forward of the pelvic fin origin at midbody and the anal fin is far posteriad with an adipose fin above it. The pectoral fins are ventrolateral. Adults are benthopelagic over the outer shelf and continental slope. Little is known of their behavior. There are commercial fisheries for them in the Atlantic and off Japan.

The planktonic eggs of argentines are relatively large (1.3–1.85 mm), with a moderately large perivitelline space, segmented yolk, a large oil globule, and pustules (visible in early stages) on the inner surface of the shell. Yolk-sac larvae hatch at ca. 3.5–5.0 mm with characteristic ventral pigmentation that forms on late-stage embryos. The larvae are elongate with an elongate gut and a distinct ventrolateral series of blotches. At the end of the preflexion stage a series of lateral bars begins to overlay the ventrolateral blotches. One or two postanal ventral median blotches also have associated pigment bars. This pigmentation, along with the characteristic embedded pigment in the snout and opercular region, make the larvae unmistakable.

The following description of *Argentina sialis* is based on detailed examination of 23 larvae (4 yolk-sac, 5.2–6.8 mm; 5 preflexion, 7.2–10.0 mm; 4 flexion, 10.6–14.7 mm; 7 postflexion, 16.6–27.2 mm) from CalCOFI collections off southern California to central Baja California; also, 3 juveniles (37.0–47.9 mm) from bottom-trawl collections (SIO) were examined in detail. Meristic information was derived from the literature (Cohen 1964b; Ahlstrom et al. 1984b) and from original counts made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–49	48
Precaudal	28–30	29
Caudal	18–21	19
Fins:		
Dorsal spines	0	0
Dorsal rays	10–13	11
Anal spines	0	0
Anal rays	11–15	12
Pelvic	10–12	11
Pectoral	15–19	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–13	12
Lower	10–12	12
Gill rakers:		
Upper	7–9	
Lower	14–20	
Branchiostegals	5–5	5–5

LIFE HISTORY

Range: Mouth of Columbia River, Oregon, to Cabo San Lucas, Baja California Sur, & into Gulf of California

Habitat: On or near bottom at depths to 274 m

Spawning season: Larvae present year-round in CalCOFI samples with peak abundance in January-March

ELH pattern: Oviparous; planktonic eggs & larvae; demersal at ca. 35 mm SL

LITERATURE

Ahlstrom et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.5 mm (G. Mattson/N. Arthur)
Yolk-sac larva, 5.8 mm (G. Mattson/N. Arthur)

* Eye trapezoidal to oval, becoming round by postflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.3–1.7 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.27–0.46 mm
Shell surface: Faint pustulation on inner surface
Pigment: Nape; anterior trunk; gut terminus; tip of tail of embryo
Diagnostic features: Large shell & OG diameter; faintly pustulate inner shell surface; characteristic pigment pattern on embryo

LARVAE

Hatching length: 3.5–4.0 mm
Flexion length: 10.5–15.0 mm
Transformation length: ca. 35 mm
Fin development sequence: C_1, D & A & P_1, C_2, P_2
Pigmentation: *Yolk-sac*—Blotch above terminal gut region; 2 ventrolateral pairs widely spaced along gut/trunk juncture; above & below tail tip; ventral to anterior region of yolk sac; internally above roof of mouth. *Preflexion*—4 blotches added above gut, series becoming median & embedded; postanal ventral blotch; tail-tip blotch enlarged; embedded opercular streak; trunk bars beginning to form above blotches. *Flexion–postflexion*—8 embedded gut blotches, maximum of 8 trunk & 3 postanal bars, including caudal; P_1 base; anteriorly & posteriorly on brain; opercle; ventrally along lower jaw; on P_2 & on D base just before transformation. *Juvenile*—Bars coalesce, become saddles.
Diagnostic features: Elongate body; gut elongate & straight; series of embedded blotches above gut associated with later-developing trunk bars; embedded pigment above roof of mouth & in opercular region; large caudal blotch; slight fleshy protuberance on snout in flexion & postflexion stage larvae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	72–73 73	75–79 77	78–82 80	80–85 82		77–78 78
BD/BL	9–18 12	8–10 9	9–10 10	10–12 11		15–16 15
HL/BL	15–19 17	16–19 18	20–22 21	20–28 24		29–30 30
HW/HL	37–58 47	42–50 45	39–41 40	33–39 36		31–34 32
SnL/HL	11–20 15	20–31 24	26–29 27	26–30 29		32–35 34
ED/HL*	28–33× 23–30 31×26	25–32× 26–32 28×29	22–26× 22–28 24×25	20–27× 20–27 24×24		23–27× 23–27 26×26
P_1L/BL	0–2 0.4	2–4 3	4–6 5	4–10 7		11–14 12
P_2L/BL	0–0 0	0–0 0	0–0 0	0–6 2		11–12 11

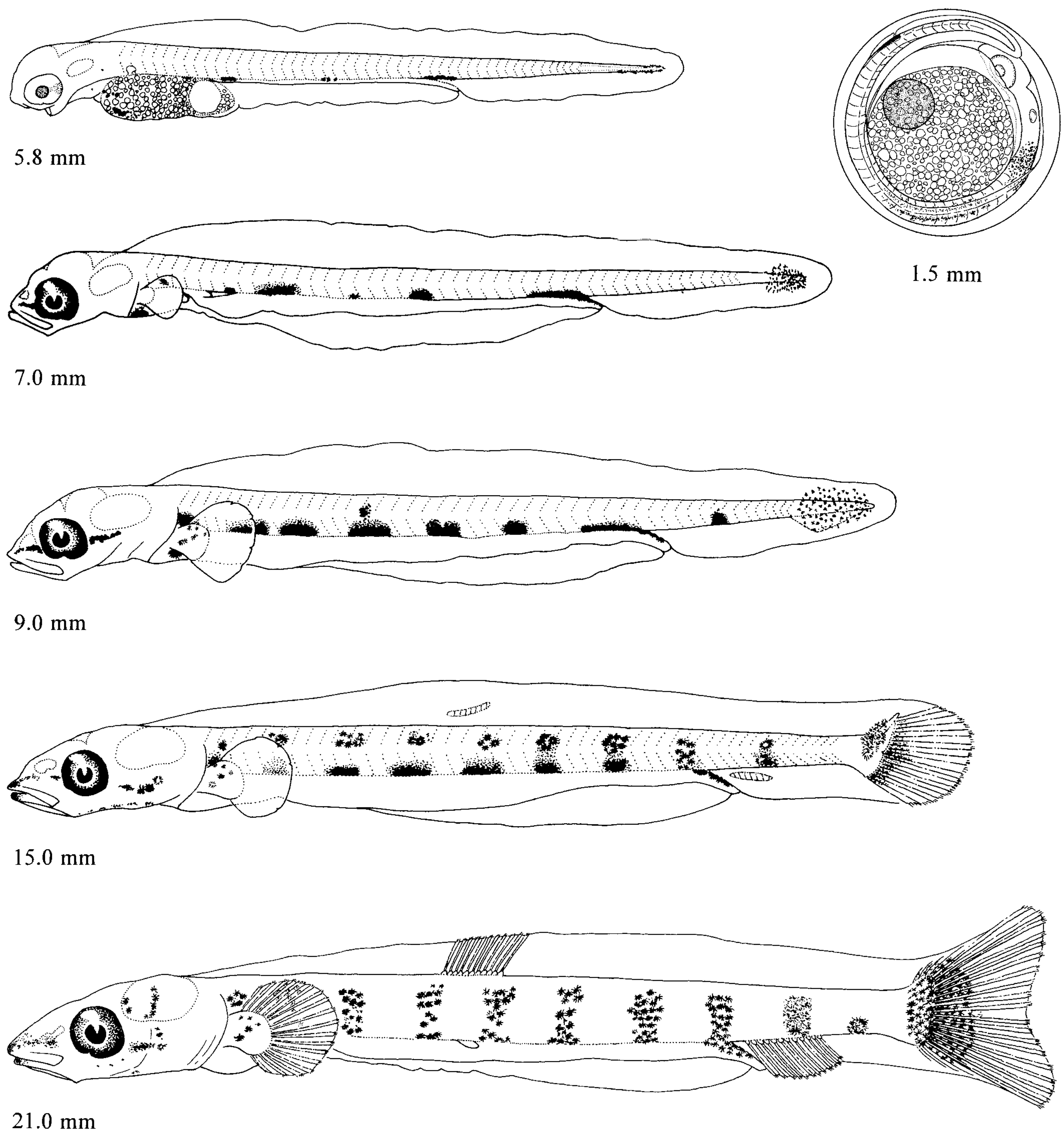

Figure Argentinidae 1. Egg, 1.5 mm; yolk-sac larva, 5.8 mm (CalCOFI 5103, station 117.40); preflexion larvae, 7.0 mm, 9.0 mm; postflexion larvae, 15.0 mm, 21.0 mm (Ahlstrom et al. 1984b).

BATHYLAGIDAE: Blacksmelts and smoothtongues

H. G. MOSER AND E. H. AHLSTROM[1]

Ten species of bathylagids occur in the California Current and adjacent regions (Table Bathylagidae 1). Larvae of three of these, *Leuroglossus stilbius*, *Bathylagus wesethi*, and *B. ochotensis*, are among the most abundant species in the CalCOFI time series, ranking 5th, 12th, and 13th in overall abundance. The distributions of *L. stilbius* and *B. wesethi* are essentially confined to the California Current, while *B. ochotensis* occurs in the subarctic-transitional zone westward to Japan. Larvae of three other subarctic-transitional species, *B. pacificus*, *B. milleri*, and *L. schmidti*, are much less abundant in CalCOFI samples. *B. bericoides* and *B. longirostris* apparently are widely distributed in tropical and subtropical seas and their larvae are rare in CalCOFI samples at the western margin of the survey pattern. Adults and larvae of *B. nigrigenys*, an eastern tropical Pacific species, occur at the southern extreme of the CalCOFI pattern (Ahlstrom 1971). Another eastern tropical Pacific species, *L. urotranus*, does not occur in the CalCOFI region (Bussing 1965).

Adult bathylagids are medium-size (most species <20 cm) fishes that inhabit epi- to bathypelagic zones of all oceans. Some species have a deep body and a deep caudal peduncle, some are robust with a narrow caudal peduncle, while others are slender (Cohen 1964b). They have small mouths, short snouts, and relatively large eyes. The dorsal fin origin is at about midbody, the anal fin origin is at the posterior third of the body, and the pectorals are ventrolateral. Some species are dark colored with narrow gill openings and others are comparatively paler with gill slits extending halfway up the body (Kobylyanskiy 1985). Most species have an adipose fin. Little is known of their behavior and there is no fishery for them.

Bathylagids are oviparous with planktonic eggs and larvae. Ontogenetic stages of bathylagids are highly evolved. Eggs of all known species have a pustulate inner chorion, segmented yolk, and multiple oil globules (Ahlstrom et al. 1984b). Moreover, the oil globules of some species undergo remarkable patterns of migration and coalescence from their initial position at the vegetal pole of the egg (Ahlstrom 1969b). In *Leuroglossus stilbius* the globules first migrate to a position under the blastodisc, coalesce to a smaller number, divide into two groups and migrate to polar positions with respect to the embryonic axis (considered to be in the equatorial plane), then coalesce to single globules, migrate to a position below the embryo and, finally, coalesce further to a single globule before hatching (Ahlstrom 1969b). In species of *Bathylagus* whose embryogenesis has been documented, the cluster of globules migrates initially to the periphery of the blastodisc, then divides into two groups that migrate to each pole. They remain there during the remainder of the egg stage, undergoing partial coalescence in some species (Ahlstrom 1969b).

Bathylagid larvae are elongate and have large finfolds in which the dorsal and anal fins develop. Development of all fins except the caudal is delayed until late in the larval period; ray formation in the pectoral and pelvic fins occurs at metamorphosis. The gut is straight with a valve separating the relatively long foregut from the hindgut and another valve separating the hindgut from the shorter terminal gut section. Larval development is diverse with some species developing stalked eyes and complex patterns of pigmentation (Ahlstrom et al. 1984b). *Leuroglossus* has short eye stalks in early larvae whereas *B. ochotensis* has stalks of moderate length throughout larval development. Eye stalks are longer in *B. pacificus* and extremely long in *B. bericoides* and *B. longirostris*. *Bathylagus wesethi* and *B. nigrigenys* have small eyes without stalks whereas *B. milleri* has moderately large sessile eyes. Larval pigmentation varies markedly. *Bathylagus bericoides* is sparsely pigmented with a series of inconspicuous melanophores along the gut. *Leuroglossus*, *B. pacificus*, and *B. milleri* have relatively large isolated melanophores or blotches whereas the other species in the region have serial gut and trunk melanophores and extensive head pigmentation. This pattern reaches maximum development in *B. wesethi* and *B. nigrigenys*, which also are remarkable in having a voluminous foregut with transverse rugae.

[1] Formerly, at La Jolla Laboratory, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Ahlstrom et al. (1984b) summarized knowledge of bathylagid ontogeny and presented single illustrations and summary descriptions of the known eggs and larvae of the species discussed above. Matarese et al. (1989) presented additional information on larvae of *B. bericoides*, *B. milleri*, *B. ochotensis*, *B. pacificus*, *B. wesethi*, *L. schmidti*, and *L. stilbius*. The following descriptions are based on literature and on examination of 6–28 larvae and juveniles of each species (Table Bathylagidae 2). Eggs of *L. urotranus* are similar to those of *L. stilbius* (Ahlstrom 1969b) as are their larvae; since neither eggs nor larvae of *L. urotranus* occur in CalCOFI samples their development is not described in this guide.

Table Bathylagidae 1. Meristic characters for the bathylagid species in the California Current vicinity. All species have 10+9 principal caudal fin rays and 2 pairs of branchiostegal rays.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	P_2	C_2
Bathylagus bericoides	29–31	22–24	52–54	9–11	17–22	8–12	8–10	12–15+13–17
B. longirostris	28–31	18–23	48–53	9–12	18–21	9–13	9–10	11–14+10–13
B. milleri	18–21	28–34	49–55	6–9	20–28	9–16	6–9	14–18+13–17
B. nigrigenys	21–26	17–21	41–45	10–14	14–18	9–11	8–10	11–15+11–14
B. ochotensis	25–27	21–23	47–49	9–13	12–17	8–12	9–11	12–15+13–16
B. pacificus	18–25	21–32	44–51	8–13	15–25	7–11	7–10	13–15+12–15
B. wesethi	23–26	19–23	43–47	10–14	13–17	9–12	8–11	13–16+13–16
Leuroglossus schmidti	22–29	25–27	47–52	10–11	11–14	8–9	8–10	10–17+11–15
L. stilbius	20–21	18–21	39–42	9–12	11–15	8–11	8–10	11–16+9–15
L. urotranus	19–20	20–23	40–42	9	10–11	9	8	

Table Bathylagidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the bathylagid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Bathylagus bericoides	0	0	2 5.9–7.5	2 14.2–15.2	2 16.4–23.0	0	0
B. longirostris	0	1 4.7	6 4.7–10.8	4 11.2–15.6	3 16.4–21.0	3 23.8–34.7	3 31.3–37.3
B. milleri	0	1 7.8	7 8.5–16.1	4 19.3–24.0	3 22.5–28.6	2 26.0–28.7	3 35.6–43.8
B. nigrigenys	L[a]	3 3.3–3.6	7 5.0–9.1	3 9.4–11.3	9 12.0–21.2	0	3 22.5–28.0
B. ochotensis	L[a]	2 4.8–5.0	7 5.0–11.3	3 12.7–16.2	6 16.4–26.6	2 26.0–27.6	2 24.9–26.4
B. pacificus	20 1.4–1.6	3 5.6–5.8	7 6.4–14.7	3 16.1–19.3	3 19.1–22.6	2 20.9–24.2	0
B. wesethi	L[a]	3 3.7–4.2	9 4.5–9.6	4 10.4–12.8	8 14.0–23.7	0	3 22.4–28.2
Leuroglossus schmidti	L[a,b]	0	L[b]	L[b]	L[b]	0	L[b]
L. stilbius	L[a]	3 4.2–4.3	8 6.2–10.0	4 10.5–14.7	7 15.4–27.4	3 27.2–30.3	3 28.8–36.4

[a] Ahlstrom et al. 1984b
[b] Dunn 1983

MERISTICS

	Range	Mode
Vertebrae:		
Total	52–54	53
Precaudal	29–31	30
Caudal	22–24	23
Fins:		
Dorsal spines	0	0
Dorsal rays	9–11	9
Anal spines	0	0
Anal rays	17–22	20
Pelvic	8–10	9
Pectoral	8–12	8
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–15	14
Lower	13–17	15
Gill rakers:		
Upper		
Lower		
Branchiostegals	2	2

LIFE HISTORY

Range: Widely distributed in tropical & subtropical Atlantic, Pacific, & Indian Oceans

Habitat: Epi- & bathypelagic

Spawning season: Larvae collected in summer & autumn

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984b
Matarese et al. 1989
Olivar & Fortuño 1991

ORIGINAL ILLUSTRATIONS (Illustrator)

Head of 6.4 mm preflexion larva (H. M. Orr)
Preflexion larva, 7.3 mm (H. M. Orr)
Flexion larva, 14.5 mm (H. M. Orr)

* Eye elliptical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 14 mm
Transformation length: >23 mm
Fin development sequence: C_1, A, D & P_1 & P_2 & C_2
Pigmentation: *Preflexion–postflexion*—Lateral to liver; dorsally on terminal section of gut; series of up to 11 along lateral gut surface; in some late postflexion larvae, on lower jaw, isthmus, opercle, P_1 base, & lateral region of caudal peduncle.
Diagnostic features: Extremely long eye stalks, ca. 50% HL in preflexion stage, maximum of ca. 70% at flexion stage; sparse pigmentation, limited to gut region in available specimens; extremely long gut, especially in postflexion stage; differs from Atlantic larvae of the same species in having relatively longer eye stalks & in brain shape (width of optic lobe region slightly greater than length, versus width equals 80% of its length in Atlantic larvae); differs from *B. longirostris* in having less pigment & relatively longer eye stalks.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		71–83 77	82–83 83	90–91 90		
BD/BL		9–9 9	8–8 8	8–10 9		
HL/BL		22–23 22	25–25 25	24–27 26		
HW/HL		35–41 38	36–36 36	39–40 39		
SnL/HL		11–13 12	22–22 22	24–27 25		
ED/HL*		18–19× 27–31 18×29	12–14× 24–24 13×25	10–10× 19–20 10×19		
P_1L/BL		2–5 4	3–3 3	4–6 5		
P_2L/BL		0–0 0	0–0 0	0		

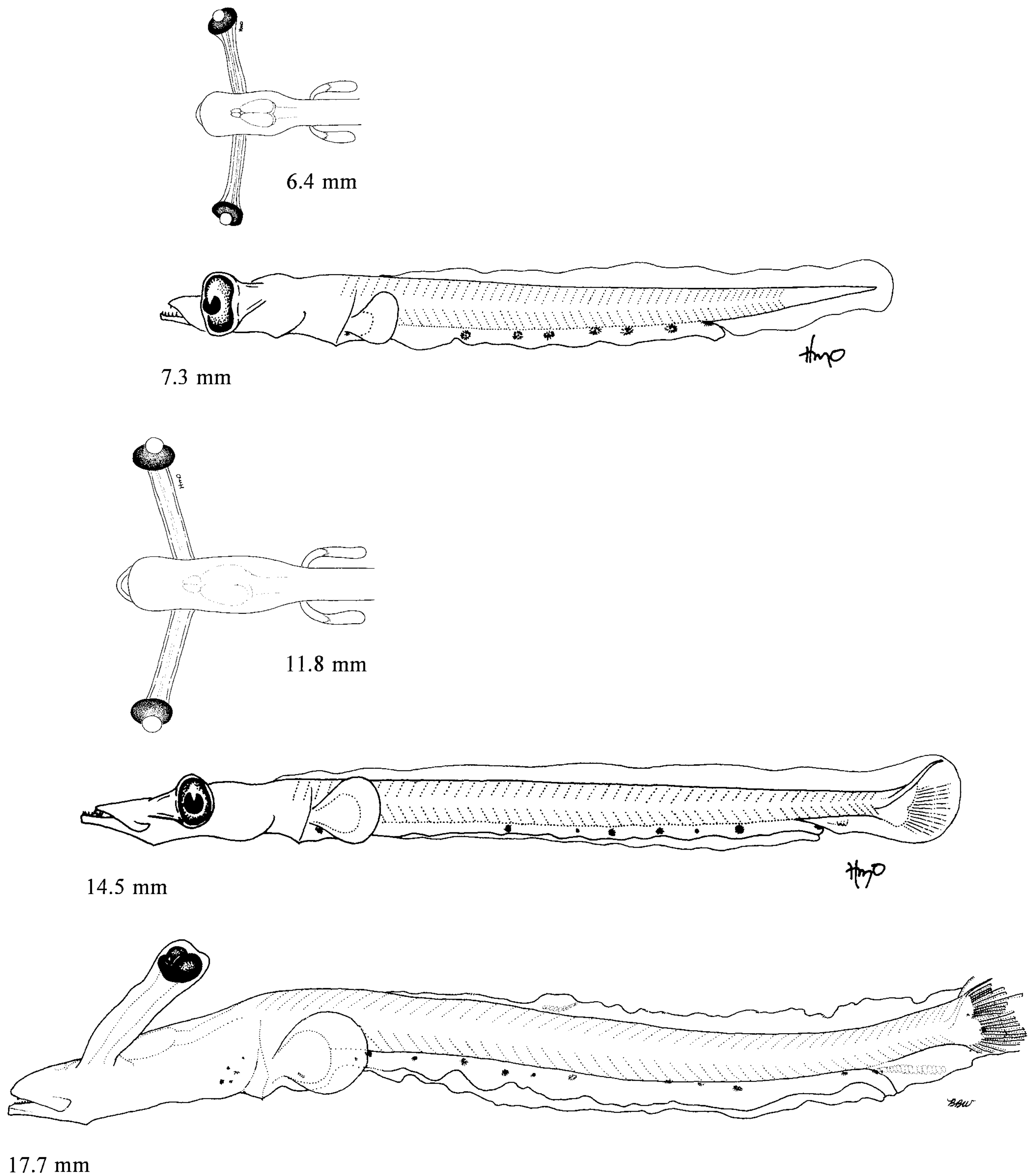

Figure Bathylagidae 1. Head of 6.4 mm preflexion larva, dorsal view; preflexion larva, 7.3 mm (CalCOFI); head of 11.8 mm preflexion larva, dorsal view (Ahlstrom et al. 1984b); flexion larva, 14.5 mm (CalCOFI 7210, station 39.137); postflexion larva, 17.7 mm (from tropical eastern Atlantic, Ahlstrom et al. 1984b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–53	51
Precaudal	28–31	29
Caudal	18–23	22
Fins:		
Dorsal spines	0	0
Dorsal rays	9–12	10
Anal spines	0	0
Anal rays	18–21	19
Pelvic	9–10	10
Pectoral	9–13	11–12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	11–14	11
Lower	10–13	11
Gill rakers:		
Upper	8–9	8
Lower	13–18	14
Branchiostegals	2	2

LIFE HISTORY

Range: Widely distributed in tropical & subtropical Atlantic, Pacific, & Indian Oceans

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured from April–October in CalCOFI surveys

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Late preflexion larva, 9.1 mm (H. M. Orr)

* Eye elliptical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: 11–16 mm
Transformation length: 24–35 mm
Fin development sequence: C_1, A, C_2, P_1, D & P_2
Pigmentation: *Yolk-sac*—Series of 12–14 laterally on gut; ca. 7 in postanal ventral midline series. *Preflexion*—Lateral gut series becomes subdivided (series of 4–5 on terminal section, 8–12 on hindgut, up to ca. 12 on foregut); patch on opercle; series of 3 lateral to liver; series of 3 embedded at isthmus; on lower jaw; subocular, from jaw to opercle; series on hypaxial myomeres from P_1 to C; below tip of notochord. *Flexion–postflexion*—Hind- & foregut series increase to 12–15; series on hypaxial myomeres along entire body in late postflexion stage; on snout; on anterior surface of P_1 base. *Transformation*—Several per myomere in epaxial & hypaxial series.
Diagnostic features: Extremely long eye stalks, average 53% HL in preflexion & flexion stages, decreasing in postflexion stage; heavy pigment series on gut & myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		79–87	88–91	91–94	81–82	74–75
	79	83	89	92	82	74
BD/BL		7–9	8–10	9–12	11–14	15–16
	6	9	9	10	12	15
HL/BL		21–26	24–26	26–28	22–25	24–27
	17	25	25	27	24	26
HW/HL		30–42	36–48	40–43	44–51	42–52
	40	37	41	41	47	48
SnL/HL		13–15	13–15	16–22	28–33	27–29
	8	14	14	19	30	28
ED/HL*		12–22× 19–32	11–14× 16–20	13–14× 17–19	15–17× 17–20	21–26× 25–31
	25×35	15×24	13×19	13×18	16×19	24×28
P_1L/BL		2–4	2–4		4–6	7–11
	0	3	3	3	5	9
P_2L/BL		0–0	0–0	0–0	2–4	5–7
	0	0	0	0	3	6

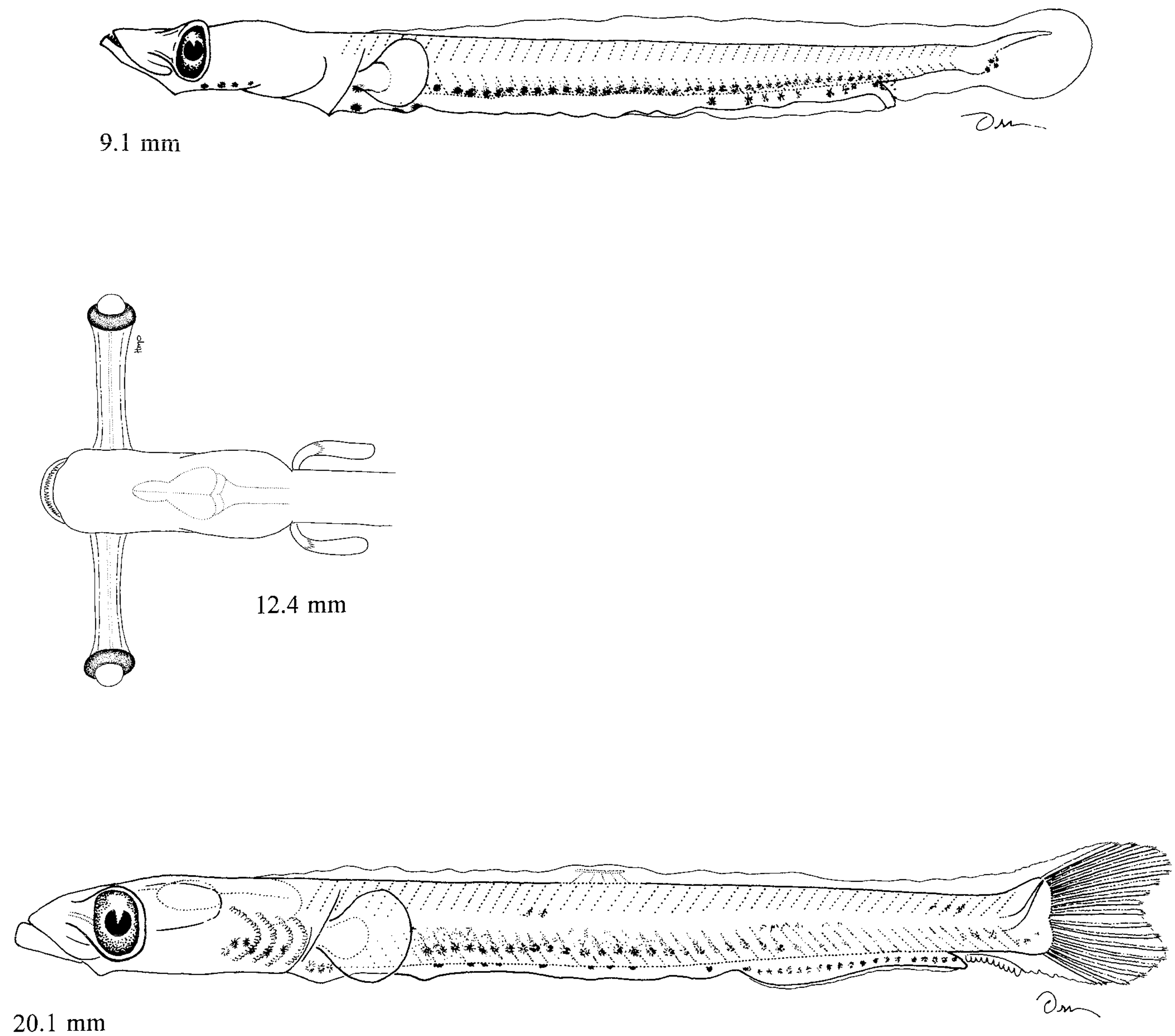

Figure Bathylagidae 2. Late preflexion larva, 9.1 mm (CalCOFI 7210, station 31.143); head of 12.4 mm flexion larva, dorsal view; postflexion larva, 20.1 mm (Ahlstrom et al. 1984b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	49–55	52
Precaudal	18–21	19
Caudal	28–34	31
Fins:		
Dorsal spines	0	0
Dorsal rays	6–9	7
Anal spines	0	0
Anal rays	20–28	23
Pelvic	6–9	7–8
Pectoral	9–16	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	14–18	14
Lower	13–17	15
Gill rakers:		
Upper		
Lower	15–20	16–18
Branchiostegals	2	2

LIFE HISTORY

Range: Southern California to Bering Sea & west to Japan

Habitat: Epi- to mesopelagic

Spawning season: Larvae most abundant in CalCOFI surveys in December–February

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Head of 23.1 mm flexion larva (H. M. Orr)

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* Eye oval; horizontal axis is given first, vertical axis second.
† Fin rays broken in juvenile specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

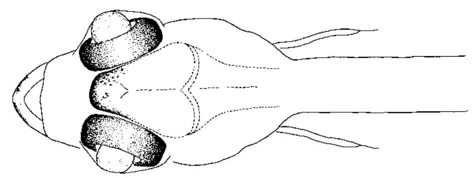
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

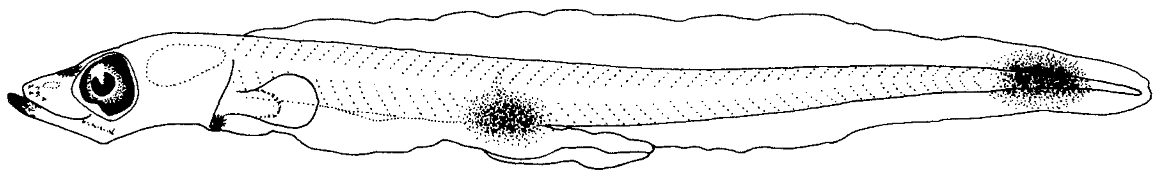
Hatching length: ca. 5 mm
Flexion length: 19–24 mm
Transformation length: 26–29 mm
Fin development sequence: C_1, A & C_2, P_1, D & P_2
Pigmentation: *Yolk-sac*—Blotch anterior to notochord tip. *Preflexion*—Large pair at juncture of gut & trunk where terminal gut section begins; below P_1 base (lateral to liver, then moves anterior to liver); lower jaw; forebrain; 1 above midgut; embedded at hindbrain; on opercle, postorbital; on lateral surface of P_1 base. *Flexion–postflexion*—On upper jaw; at nares; lower region of head posterior to jaws; 1 at dorsal margin & at ventral margin (at Ad & A fin bases); 1 at dorsal margin above anus; 1 on postanal ventral margin; on ventral surface of terminal gut section; blotch over hypural region.
Diagnostic features: Relatively short gut; large unstalked eyes, nearly round, developing slight dorsolateral orientation; large isolated melanophores & clumps in distinct pattern; large size at hatching, notochord flexion, & transformation; larval pigment visible in juveniles up to ca. 50 mm SL; low preanal myomere count (ca. 24–25), high postanal myomere count (ca. 27–28), & high total count (49–53); low D ray count (6–9); high A ray count (20–28).

MORPHOMETRICS (range & mean in %)

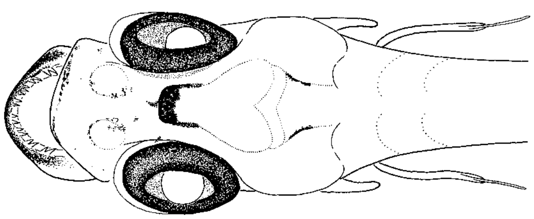
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		58–60	54–63	60–62	59–61	63–65
	56	59	60	61	60	64
BD/BL		8–11	8–10	11–14	12–13	20–20
	5	9	10	12	12	20
HL/BL		18–20	18–20	20–25	23–25	24–27
	14	18	19	22	24	25
HW/HL		53–59	52–54	49–59	49–50	61–65
	40	56	53	53	49	63
SnL/HL		9–28	27–38	27–28	27–31	16–20
	15	21	32	28	29	18
ED/HL*		25–32× 29–35	24–25× 26–30	20–24× 24–28	20–22× 22–24	33–38× 36–38
	35×29	29×33	24×28	23×26	21×23	36×37
P_1L/BL		0.4–1	1–2	1–3	3–4	†
	0	1	1	2	4	
P_2L/BL		0–0	0–0	0–0.8		†
	0	0	0	0.3	1	



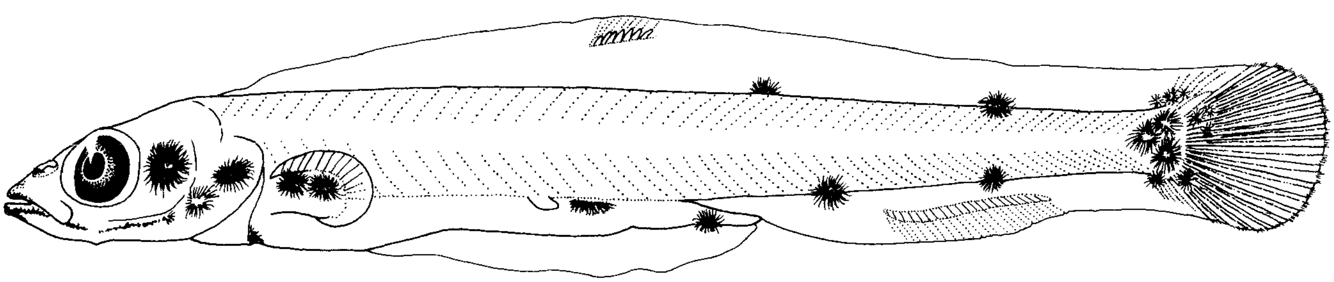
9.5 mm



10.6 mm



23.1 mm



27.5 mm

Figure Bathylagidae 3. Head of 9.5 mm preflexion larva, dorsal view; preflexion larva, 10.6 mm (Moser 1981); head of 23.1 mm flexion larva, dorsal view (CalCOFI); postflexion larva, 27.5 mm (Moser 1981).

MERISTICS

	Range	Mode
Vertebrae:		
Total	41–45	43
Precaudal	21–26	23
Caudal	17–21	19
Fins:		
Dorsal spines	0	0
Dorsal rays	10–14	12
Anal spines	0	0
Anal rays	14–18	15–16
Pelvic	8–10	9
Pectoral	9–11	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	11–15	12–13
Lower	11–14	12–13
Gill rakers:		
Upper	6–10	7–9
Lower	14–19	15–16
Branchiostegals	2	2

LIFE HISTORY

Range: Eastern tropical Pacific

Habitat: Epi- to mesopelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984b
Castillo 1979
Pertseva-Ostroumova & Rass 1973

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.96 mm (G. Mattson)
Yolk-sac larva, 2.8 mm (G. Mattson/N. Arthur)
Preflexion larva, 4.5 mm (G. Mattson/N. Arthur)
Head of 21.8 mm postflexion larva (G. Mattson/N. Arthur)
Juvenile, 27.0 mm (G. Mattson/N. Arthur)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.83–1.09 mm **Yolk:** Segmented
No. of OG: 12–20 **Diam. of OG:** Various
Shell surface: Pustulate inner surface
Pigment: On dorsum of embryo; heavy on nape; migrates ventrad in late-stage embryos, some to adjacent yolk sac; light on finfold
Diagnostic features: Pustulate shell; multiple oil globules clumped at poles; some dorsal pigment migrates to yolk sac; heavy nape pigment

LARVAE

Hatching length: ca. 3 mm
Flexion length: ca. 9–12 mm
Transformation length: ca. 22 mm
Fin development sequence: C_1, A, C_2, & D, P_1 & P_2
Pigmentation: *Yolk-sac*—Coalescing ventrally into 8–10 pairs dorsolateral to gut, from above P_1 base to anus; cluster above & below notochord tip. *Early preflexion*—8–11 pairs dorsolateral to gut; on ventral surface of each optic lobe; 1 at ventral notochord tip; at cleithral symphysis; on branchiostegal membrane; postorbital; on snout. *Mid- & late preflexion*—On upper & lower jaws; on ventrolateral margin of head; ventral notochord patch over hypural region & base of C rays; irregular hypaxial series begins; peppering on ventral finfold & adjacent area; on inner & lateral surface of P_1 base; 1 or more on postanal ventral midline; patch at cleithral symphysis. *Flexion*—Up to 12 dorsolaterally on gut; 1 or more above brain; on dorsal finfold. *Postflexion*—Irregular epaxial series; laterally on hindbrain; dorsally on peduncle.
Diagnostic features: Early migration of dorsal pigment; complex & unique pigment pattern; voluminous & rugose foregut; more pairs of ventrolateral gut pigment (8–10) than in *B. wesethi* (6–8); ventral notochord tip pigment versus dorsal & ventral in *B. wesethi*; optic lobe pigment; trunk series sparser & more irregular than in *B. wesethi*; fewer total vertebrae than *B. wesethi* (41–45 vs. 43–47).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	70–77 74	79–88 82	86–91 89	91–96 94		75–77 76
BD/BL	6–8 7	11–15 13	14–16 15	15–18 17		21–23 22
HL/BL	14–16 15	19–26 23	27–29 28	24–29 27		29–31 30
HW/HL	52–60 55	57–68 64	55–60 57	44–58 51		42–49 45
SnL/HL	7–16 12	19–28 26	26–30 28	26–32 28		20–24 22
ED/HL*	40–48× 32–35	17–24× 17–26	14–16× 17–18	11–17× 12–19		23–27× 24–31
	43×33	20×21	15×18	15×16		25×27
P_1L/BL	0–0 0	1–5 3	2–4 3	2–6 4		8–10 9
P_2L/BL	0–0 0	0–0 0	0–0 0	0–0.3 0.04		 7

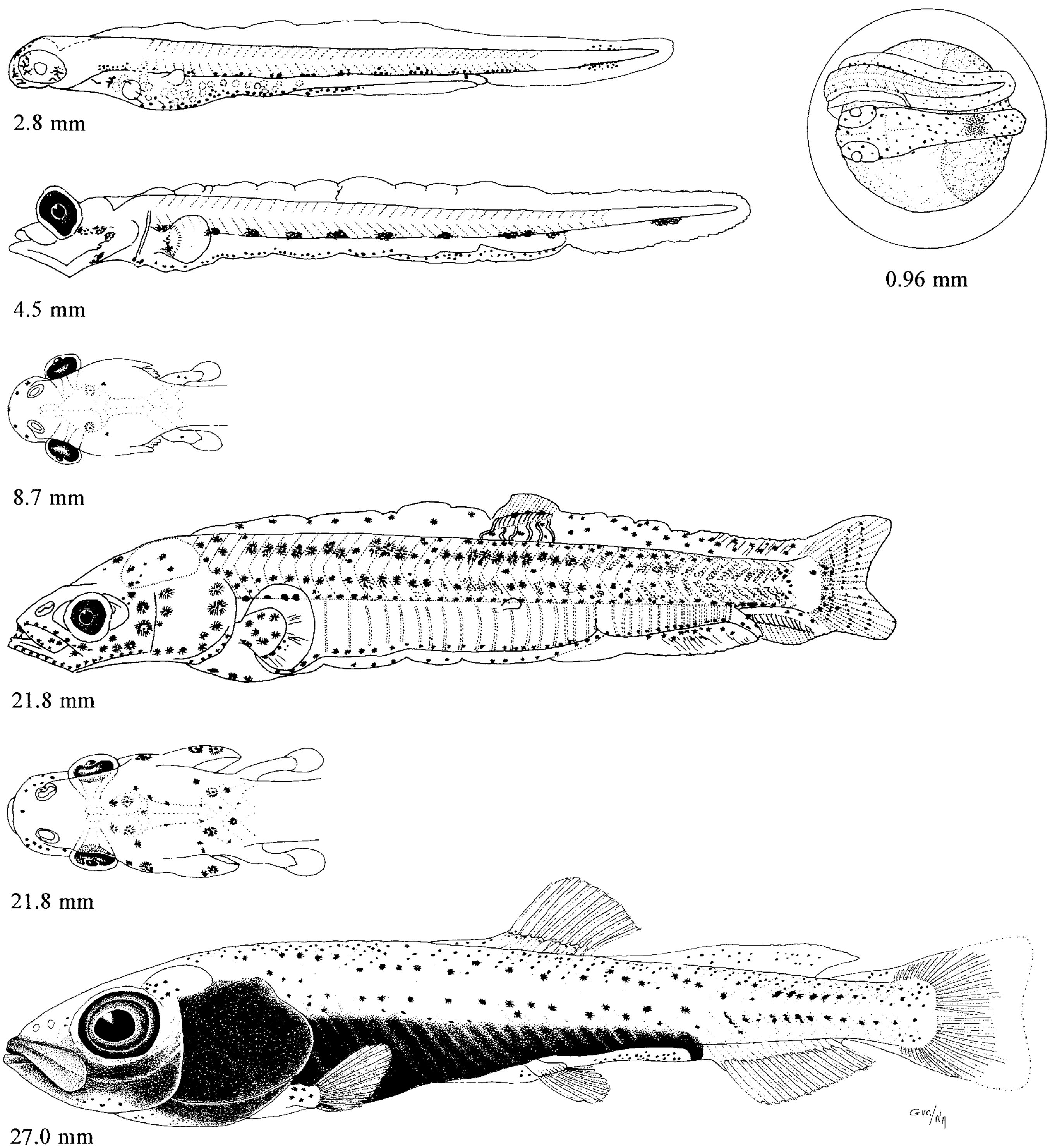


Figure Bathylagidae 4. Egg, 0.96 mm (Shellback, station 19); yolk-sac larva, 2.8 mm (Shellback, station 28); preflexion larva, 4.5 mm (Shellback, station 86); head of 8.7 mm preflexion larva, dorsal view; postflexion larva, 21.8 mm (Ahlstrom et al. 1984b); head of 21.8 mm postflexion larva, dorsal view (Shellback, station 92); juvenile, 27.0 mm (CalCOFI 5106, station 157.10).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–49	48
Precaudal	25–27	26
Caudal	21–23	22
Fins:		
Dorsal spines	0	0
Dorsal rays	9–13	11–12
Anal spines	0	
Anal rays	12–17	14–15
Pelvic	9–11	10
Pectoral	8–12	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–15	14
Lower	13–16	14
Gill rakers:		
Upper	8–9	8
Lower	13–20	16
Branchiostegals	2	2

LIFE HISTORY

Range: Central Baja California north to Gulf of Alaska, Bering Sea, & westward to Japan

Habitat: Epi- & mesopelagic; ca 50–900 m depth

Spawning season: CalCOFI larval abundance highest in winter–spring with peak in February–March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1972a
Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.1 mm (G. Mattson)
Head of 21.5 mm postflexion larva (G. Mattson/N. Arthur)

* Eye elliptical to oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.92–1.1 mm **Yolk:** Segmented
No. of OG: >10, coalesce to ca. 2 **Diam. of OG:** Various
Shell surface: Pustulate inner surface
Pigment:
Diagnostic features: Size; pustulate shell; lack of pigment; OG coalescence

LARVAE

Hatching length: ca. 3 mm
Flexion length: ca. 12–16 mm
Transformation length: ca. 26 mm
Fin development sequence: C_1, A, C_2, D, P_1 & P_2
Pigmentation: *Yolk-sac*—On notochord tip. *Preflexion*—Below P_1 base lateral to liver; on terminal gut section; series of ca. 5 on lower trunk, increasing to ca. 12 at end of stage; pair on terminal gut increases to series extending forward to entire hindgut; internal series on isthmus; series on expaxial myomeres above hindgut. *Flexion-postflexion*—Hypaxial series increases to ca. 1 per myomere from P_1 base to C; on hypural; on opercle; on upper & lower jaws; laterally on brain; postorbital & otic regions.
Diagnostic features: Stalked eyes with stalk length increasing to ca. 20% HL at ca. 9 mm, decreasing to ca. 12% at flexion stage & to 2–4% in postflexion stage; notochord tip pigment in early preflexion stage; hypaxial pigment series along entire body, epaxial series on posterior 33% of body; pigment series along hindgut.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	71–76 73	78–84 81	84–91 88	87–92 90	78–78 78	76–78 77
BD/BL	7–8 8	7–9 8	9–11 10	11–14 12	15–15 15	16–16 16
HL/BL	12–17 14	18–22 20	21–22 22	21–23 21	25–25 25	25–27 26
HW/HL	38–53 45	37–53 48	47–50 49	46–48 47	41–45 43	42–45 44
SnL/HL	13–13 13	11–22 19	18–25 22	24–36 29	26–26 26	24–27 26
ED/HL*	38–43× 28–33 40×30	13–19× 22–33 16×28	13–15× 21–23 14×22	14–20× 20–22 16×20	21–25× 24–26 23×25	27–30× 31–31 29×31
P_1L/BL	0–0 0	1–5 4	3–5 5	4–5 5	7–8 7	8–10 9
P_2L/BL	0–0 0	0–0 0	0–0 0	0–3 0.8	5–6 6	8–9 8

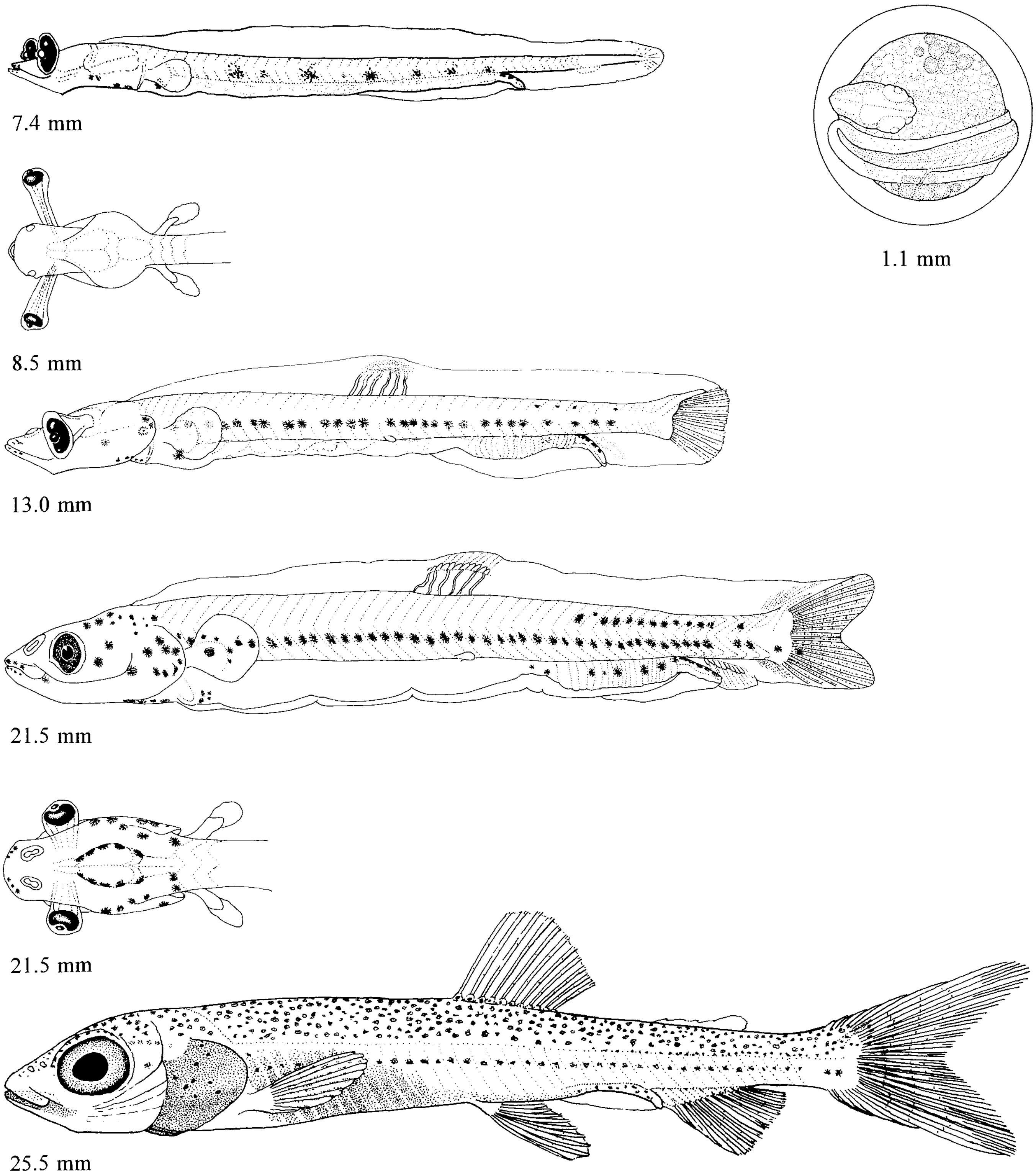


Figure Bathylagidae 5. Egg, 1.1 mm (CalCOFI 5002, station 60.90); preflexion larva, 7.4 mm (Ahlstrom 1972a); head of 8.5 mm preflexion larva, dorsal view (Moser 1981); flexion larva, 13.0 mm (Ahlstrom 1972a); postflexion larva, 21.5 mm (Ahlstrom et al. 1984b); head of 21.5 mm postflexion larva, dorsal view (CalCOFI); juvenile, 25.5 mm (Ahlstrom 1972a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–51	45
Precaudal	18–25	18
Caudal	21–32	27
Fins:		
Dorsal spines	0	0
Dorsal rays	8–13	8–10
Anal spines	0	0
Anal rays	15–25	20
Pelvic	7–10	8
Pectoral	7–11	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–15	14
Lower	12–15	13
Gill rakers:		
Upper		
Lower	13–20	17–19
Branchiostegals	2	2

LIFE HISTORY

Range: Gulf of Alaska & Bering Sea to northern Baja California; westward between 54°–66° N to Japan

Habitat: Epi- & mesopelagic at ca. 149–1,000 m depth

Spawning season: In CalCOFI surveys, larvae most abundant in winter-spring with peak in February-March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.6 mm (N. Arthur)
Preflexion larva, 7.1 mm (G. Mattson/N. Arthur)
Flexion larva, 16.0 mm (G. Mattson/N. Arthur)

* Eye elliptical to oval, becoming round by transformation; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.4–1.6 mm **Yolk:** Segmented
No. of OG: Many (>50), condensing to ca. 10–15
Diam. of OG: Various, 0.02–0.2 mm
Shell surface: Outer surface covered with small contiguous bumps
Pigment:
Diagnostic features: Pebbled shell surface; large diameter; numerous oil globules of varied size clumped at vegetal pole, coalescing & forming 2 polar groups in late-stage eggs

LARVAE

Hatching length: 3.5–4.0 mm
Flexion length: 16–19 mm
Transformation length: 20–24 mm
Fin development sequence: C_1, A, D & P_1 & P_2 & C_2
Pigmentation: *Yolk-sac*—At notochord tip; in late yolk-sac larvae 2 (large) laterally at juncture of gut & trunk, 1 at midbody & the other at posterior region of hindgut. *Preflexion*—Lateral to liver, 1 added to gut ca. midway between original 2; on terminal gut section; on opercle; on lower jaw. *Late preflexion–postflexion*—In some specimens 1 or 2 between original ones & 1 or 2 anterior to original one at midbody; on upper jaw; embedded, lateral to hindbrain.
Diagnostic features: Stalked eyes with stalk length averaging 28% HL in preflexion stage & 33% in flexion stage, decreasing to 7–11% in late postflexion & transformation stages; 2 large blotch-like lateral melanophores with 1–2 smaller ones on gut between; low D ray count (8–13) & relatively high A ray count (15–25).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	72–78 74	75–82 78	81–84 83	83–85 84	77–82 80	
BD/BL	7–9 8	8–10 9	9–11 10	11–13 12	13–13 13	
HL/BL	16–19 17	19–25 22	22–24 23	24–25 24	26–26 26	
HW/HL	40–46 42	36–50 42	42–47 44	46–50 48	48–50 49	
SnL/HL	11–19 14	20–28 24	26–30 29	27–32 29	24–32 28	
ED/HL	36–37× 26–33 36×28	17–23× 23–35 19×30	15–18× 22–24 17×23	15–16× 20–23 15×22	18–18× 21–21 18×21	
P_1L/BL	0–0 0	1–5 3	2–2 2	3–3 3	3–4 4	
P_2L/BL	0–0 0	0–0 0	0–0 0	0–0 0	0.05–2 1	

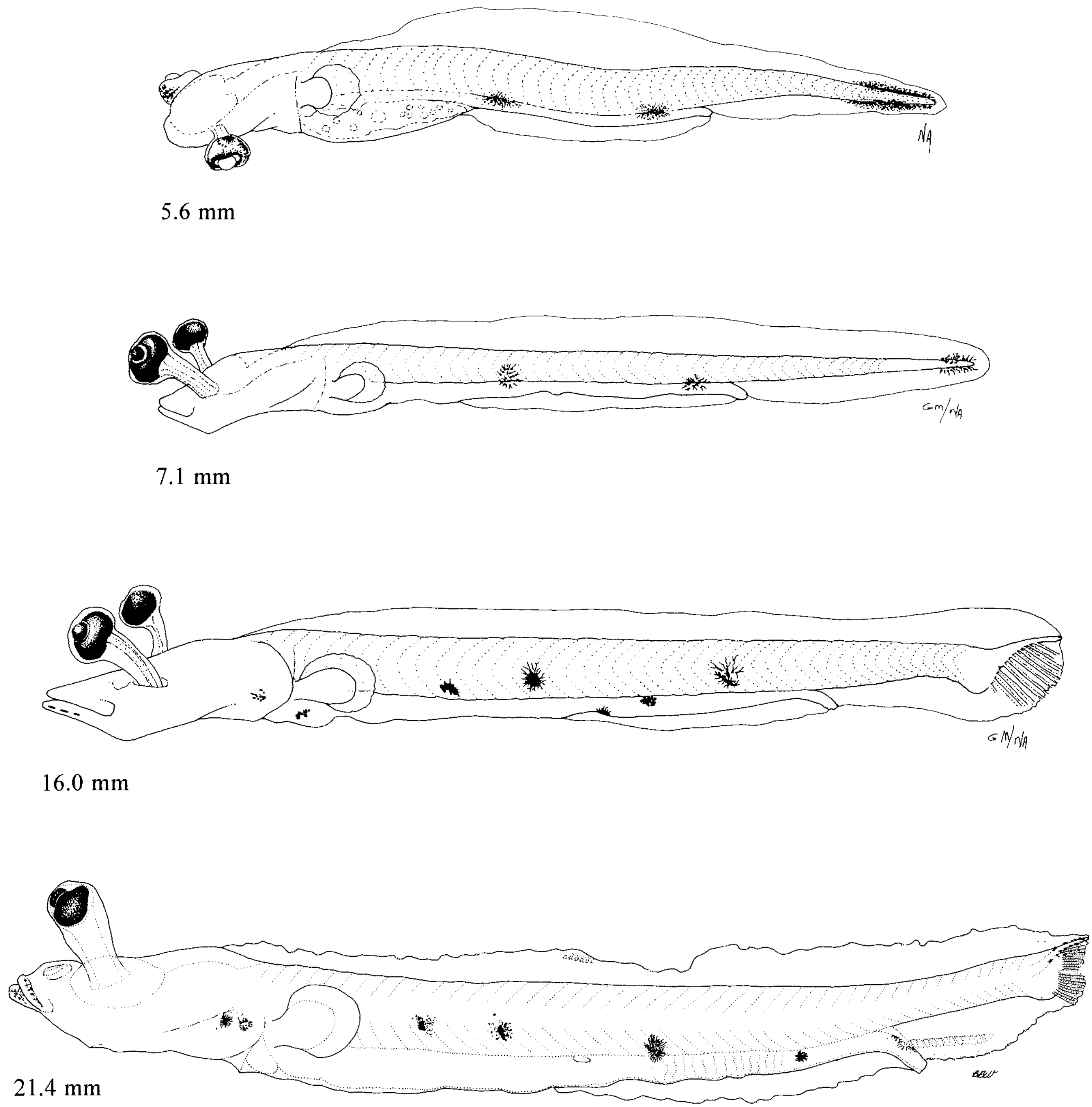


Figure Bathylagidae 6. Yolk-sac larva, 5.6 mm (CalCOFI 8803, station 74.9.54.6); preflexion larva, 7.1 mm (CalCOFI 5204, station 70.55); flexion larva, 16.0 mm (CalCOFI 5204, station 87.50); postflexion larva, 21.4 mm (Ahlstrom et al. 1984b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–47	44
Precaudal	23–26	24
Caudal	19–23	21
Fins:		
Dorsal spines	0	0
Dorsal rays	10–14	11–12
Anal spines	0	0
Anal rays	13–17	16
Pelvic	8–11	9
Pectoral	9–12	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–16	14
Lower	13–16	14
Gill rakers:		
Upper	8–10	9
Lower	14–19	16–17
Branchiostegals	2	2

LIFE HISTORY

Range: California Current from Oregon to southern Baja California

Habitat: Epi- to mesopelagic

Spawning season: Spring–summer with some spawning year-round; highest larval abundance in CalCOFI surveys in May–August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965, 1969b, 1972a
Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Head of 20.5 mm postflexion larva (G. Mattson/N. Arthur)
Juvenile, 27.0 mm (G. Mattson/N. Arthur)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.90–1.1 mm **Yolk:** Segmented
No. of OG: 12–20 mm **Diam. of OG:** Various
Shell surface: Pustulate inner surface
Pigment: On dorsum of late embryo, less dense on head; on ventral finfold
Diagnostic features: Pustulate shell; differs from *B. nigrigenys* in lack of heavy nape pigment patch & in having no migration of pigment to yolk sac

LARVAE

Hatching length: ca. 3 mm
Flexion length: 10–14 mm
Transformation length: 22–24 mm
Fin development sequence: C_1, A, C_2 & D, P_1 & P_2
Pigmentation: *Yolk-sac*—Peppering over entire body, migrating ventrad & coalescing. *Preflexion*—At cleithral junction; 6–8 pairs dorsolateral to gut from above P_1 base to terminal gut region; on anterior surface & lower margin of P_1 base; opposing pair anterior to notochord tip; on lower opercular region; postorbital; on upper & lower jaws; branchiostegal membrane; embedded lateral to cerebellum; ventrolaterally on head from jaws to opercle; series along postanal ventral midline; peppering along ventral & lateral gut surface & associated finfold. *Flexion*—8–10 dorsolateral gut pairs; hypaxial series from head to hindgut; on C rays. *Postflexion–transformation*—Hypaxial & epaxial series along entire body, then 2 or more per myomere.
Diagnostic features: Eyes not stalked; complex & unique pigment pattern; voluminous rugose foregut; fewer pairs of ventrolateral gut melanophores (6–8) than in *B. nigrigenys* (8–10); dorsal & ventral pigment at notochord tip vs. only ventrally in *B. nigrigenys*; trunk series heavier & more regular than in *B. nigrigenys*; more total vertebrae than *B. nigrigenys* (43–47 vs. 41–45).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	76–76 76	77–86 82	86–91 88	92–98 94		77–78 77
BD/BL	7–9 8	8–14 11	13–14 14	13–18 15		17–18 17
HL/BL	16–19 17	16–24 20	24–26 25	23–27 25		27–29 29
HW/HL	46–50 49	55–65 61	55–57 56	49–55 52		45–49 46
SnL/HL	16–18 17	20–31 25	29–34 32	25–30 27		20–25 23
ED/HL*	31–34× 23–27	16–25× 19–32	14–15× 16–18	11–14× 13–16		28–33× 30–35
	33×25	20×25	15×17	13×14		30×32
P_1L/BL	0–0 0	4–6 5	5–6 6	4–7 6		8–10 9
P_2L/BL	0–0 0	0–0 0	0–0 0	0.6–1 0.9		6–10 8

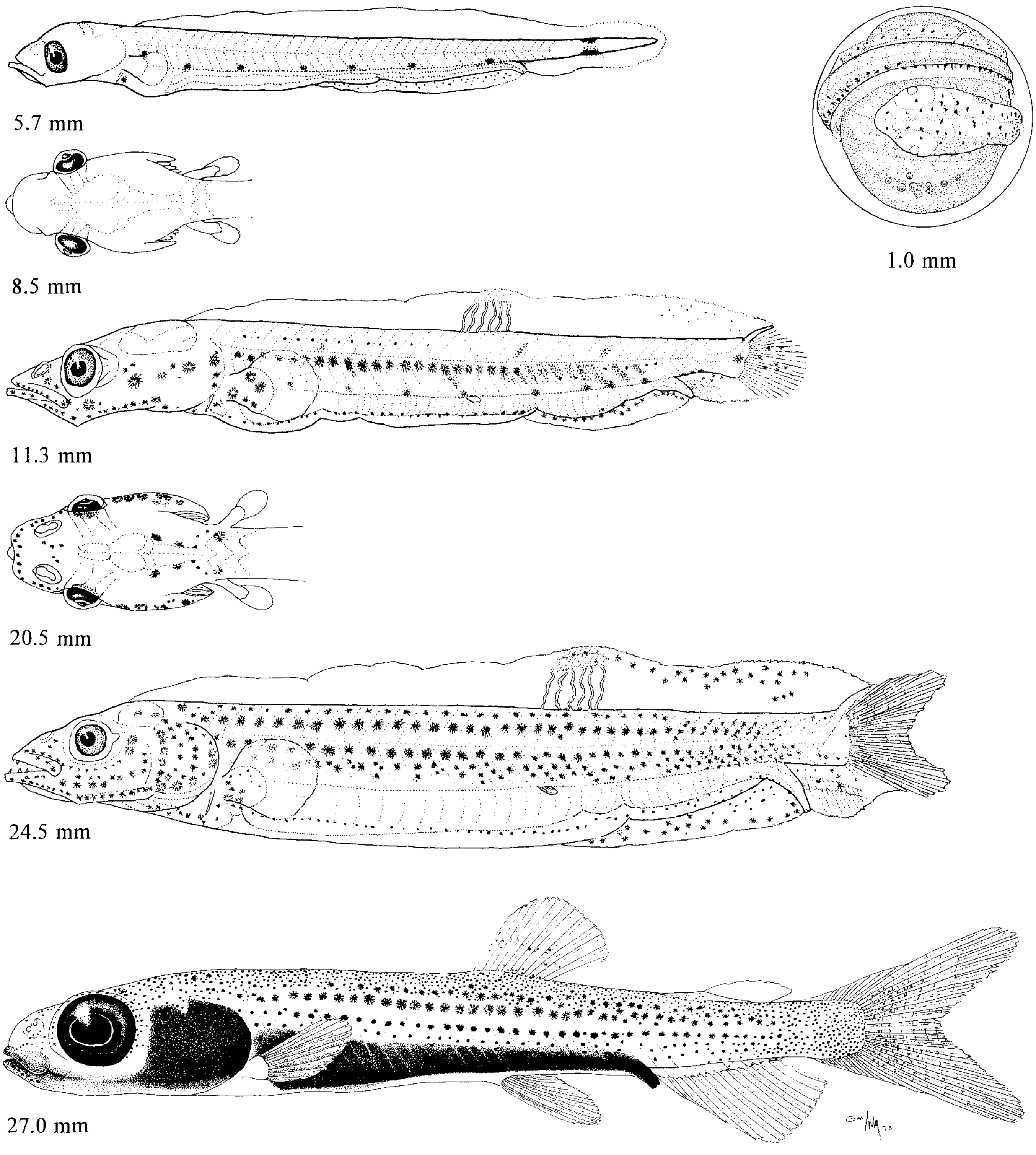


Figure Bathylagidae 7. Egg, 1.0 mm (Ahlstrom 1969); preflexion larva, 5.7 mm (Ahlstrom 1972a); head of 8.5 mm preflexion larva, dorsal view (Moser 1981); flexion larva, 11.3 mm (Ahlstrom 1972a); head of 20.5 mm postflexion larva, dorsal view (CalCOFI); postflexion larva, 24.5 mm (Ahlstrom 1972a); juvenile, 27.0 mm (CalCOFI 4903, station 92.117).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–52	49
Precaudal	22–29	24
Caudal	25–27	25
Fins:		
Dorsal spines	0	0
Dorsal rays	10–11	10
Anal spines	0	0
Anal rays	11–14	12–13
Pelvic	8–10	9–10
Pectoral	8–9	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–17	12–13
Lower	11–15	12
Gill rakers:		
Upper	8–9	
Lower	17–19	
Branchiostegals	2	2

LIFE HISTORY

Range: Southern British Columbia to the Bering & Okhotsk Seas; eggs & larvae south to 46° N in eastern Pacific

Habitat: Epi- & mesopelagic

Spawning season: Summer–winter

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1969b
Ahlstrom et al. 1984b
Dunn 1983
Matarese et. al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 8.4 mm (G. Mattson/N. Arthur)
Flexion larva, 20.5 mm (G. Mattson/N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.65–1.90 mm
Yolk: Segmented
No. of OG: 1–9, coalescing to 1
Diam. of OG: 0.35–0.40 mm before fusing
Shell surface: Pustulate inner surface
Pigment: On notochord tip & OG
Diagnostic features: Pustulate inner shell surface; coalescence & migration of oil globules; shell diameter larger than in *L. stilbius.*

LARVAE

Hatching length: 4–5 mm
Flexion length: 13–18 mm
Transformation length: 31–35 mm
Fin development sequence: C_1, A, D, C_2, P_1, P_2
Pigmentation: *Yolk-sac*—Around notochord tip; on OG. *Preflexion*—Blotch on trunk above midgut, extends to midgut when expanded; blotch on hindgut, extends dorsad to trunk when expanded. *Flexion–postflexion*—Series of 2–8 (large) on trunk; series of 3–6 on hindgut; 1–4 on opercle; at tip of lower jaw; 1–2 on caudal peduncle; on base of C rays in late postflexion.
Diagnostic features: Slightly stalked eyes in early preflexion stage; more lateral body pigment & higher total vertebral count than in *L. stilbius* (47–52 vs. 39–42); large blotch-like melanophores on gut & body.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		64–80 72	67–81 76	74–81 78		71–77 74
BD/BL		4–9 7	7–9 8	8–13 10		12–17 14
HL/BL		7–20 16	17–23 19	17–28 23		28–30 29
HW/HL						
SnL/HL		11–39 24	15–32 26	24–46 32		26–30 27
ED/HL†		23–63× 26–78 30×39	15–24× 22–32 20×26	11–33× 18–31 20×25		26–32× 24–31 29×28
P_1L/BL						
P_2L/BL						

* Data from Dunn (1983).
† Eye slightly oval; horizontal axis is given first, vertical axis second.

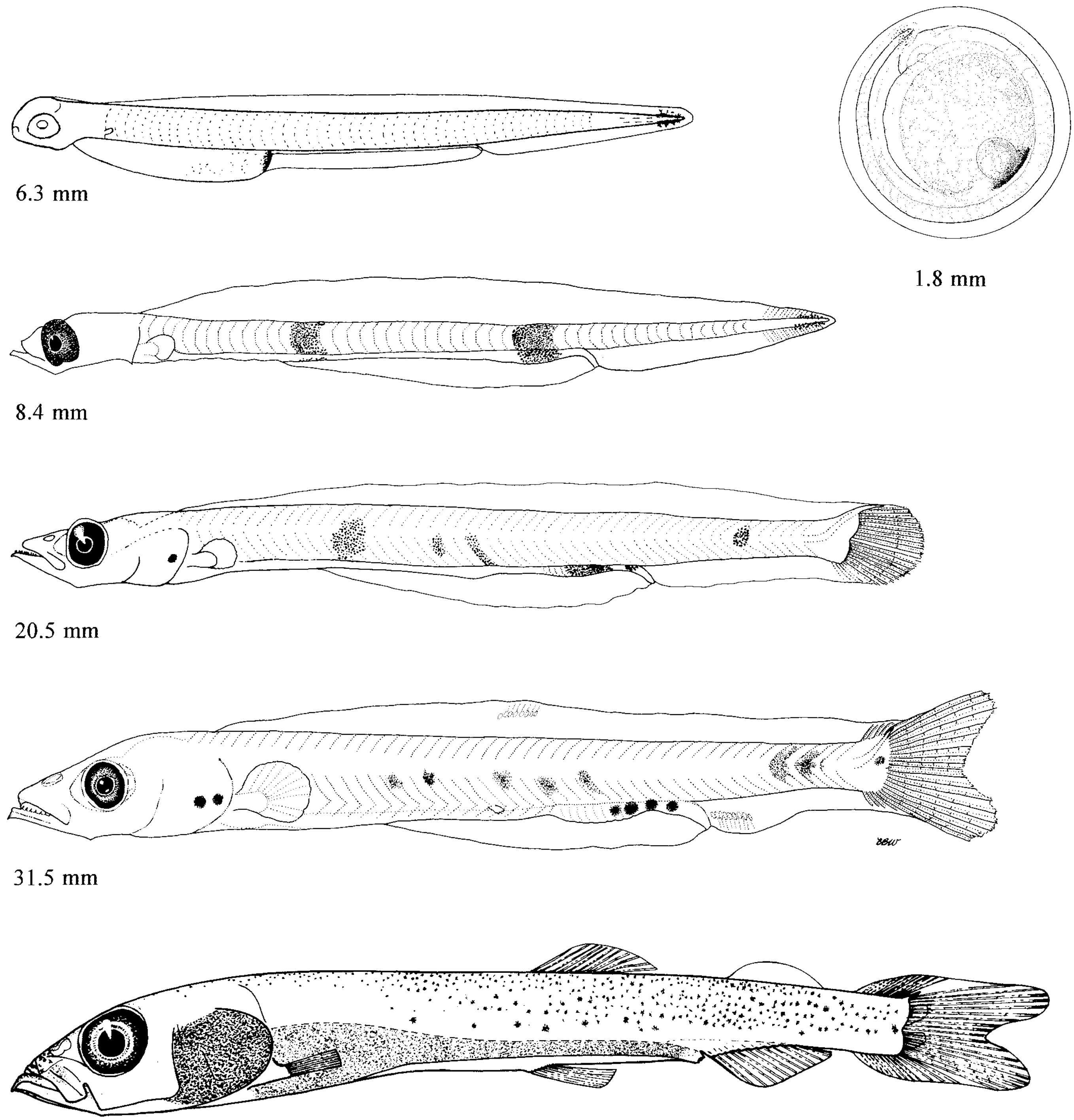


Figure Bathylagidae 8. Egg, 1.8 mm (Ahlstrom 1969); yolk-sac larva, 6.3 mm (Dunn 1983); preflexion larva, 8.4 mm (Northern Holiday, station 47); flexion larva, 20.5 mm (Northern Holiday, station 29); postflexion larva, 31.5 mm (Ahlstrom et al. 1984b); juvenile 33.1 mm (Dunn 1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–42	40
Precaudal	20–21	21
Caudal	18–21	20
Fins:		
Dorsal spines	0	0
Dorsal rays	9–12	10
Anal spines	0	0
Anal rays	11–15	12
Pelvic	8–10	8
Pectoral	8–11	8
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	11–16	13
Lower	9–15	13
Gill rakers:		
Upper	7–9	
Lower	17–20	
Branchiostegals	2	2

LIFE HISTORY

Range: Oregon to Gulf of California

Habitat: Epi- & mesopelagic

Spawning season: Winter–spring; highest larval abundance in January–April in CalCOFI surveys

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965, 1969b, 1972a
Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.1 mm (G. Mattson)
Yolk-sac larva, 3.9 mm (G. Mattson/N. Arthur)
Head of 5.4 mm preflexion larva (G. Mattson/N. Arthur)
Preflexion larva, 9.0 mm (G. Mattson/N. Arthur)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.0–1.2 mm
Yolk: Segmented
No. of OG: 15–25 initially, coalescing to 2, & finally 1
Diam. of OG: Pustulate inner surface
Shell surface:
Pigment: Around notochord tip, on OG
Diagnostic features: Pustulate inner surface of shell; coalescence & migration of oil globules; pigmentation

LARVAE

Hatching length: ca. 3 mm
Flexion length: 3.5–15 mm
Transformation length: 24–29 mm
Fin development sequence: C_1, C_2, D & A, P_1, P_2
Pigmentation: *Yolk-sac*—Around notochord tip; on OG. *Preflexion*—Oil globule melanophores migrate dorsally to either right or left side of trunk; diminishes from notochord & disappears by flexion stage; 1 (large) on hindgut, then others appear to form a series; pair below P_1 base in half the specimens (ca. 10% have 1 on one side & 40% have none); on lower & upper jaws. *Flexion–postflexion*—Hindgut series increases to 5–6; opercular patch; on isthmus; over brain & nape; on pectoral girdle.
Diagnostic features: Slightly stalked eyes in early preflexion stage; sparse pigmentation; distinctive hindgut pigment series; 0–1 ventrolateral melanophores on trunk vs. 2–5 in *L. schmidti*; caudal peduncle lacks pigment; lower total vertebral count than in *L. schmidti* (39–42 vs. 47–52).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	67–70	73–77	75–78	78–82	72–76	76–76
	69	74	76	79	74	76
BD/BL	8–15	7–10	10–11	11–14	15–16	15–15
	11	9	10	12	16	15
HL/BL	14–15	17–22	20–22	23–26	28–30	30–31
	15	20	22	24	29	31
HW/HL	33–60	52–67	52–54	43–50	38–42	36–41
	49	58	53	47	40	39
SnL/HL	13–17	17–26	26–33	26–31	25–30	24–27
	15	22	29	29	28	26
ED/HL*	36–50×	18–24×	18–19×	15–21×	21–25×	24–29×
	27–33	26–39	24–27	20–23	22–26	27–29
	43×31	20×30	19×25	17×21	23×24	27×28
P_1L/BL	0–0	2–5	5–6	3–6	7–10	11–11
	0	3	6	4	8	11
P_2L/BL	0–0	0–0	0–0	0–1	5–9	9–9
	0	0	0	0.4	7	9

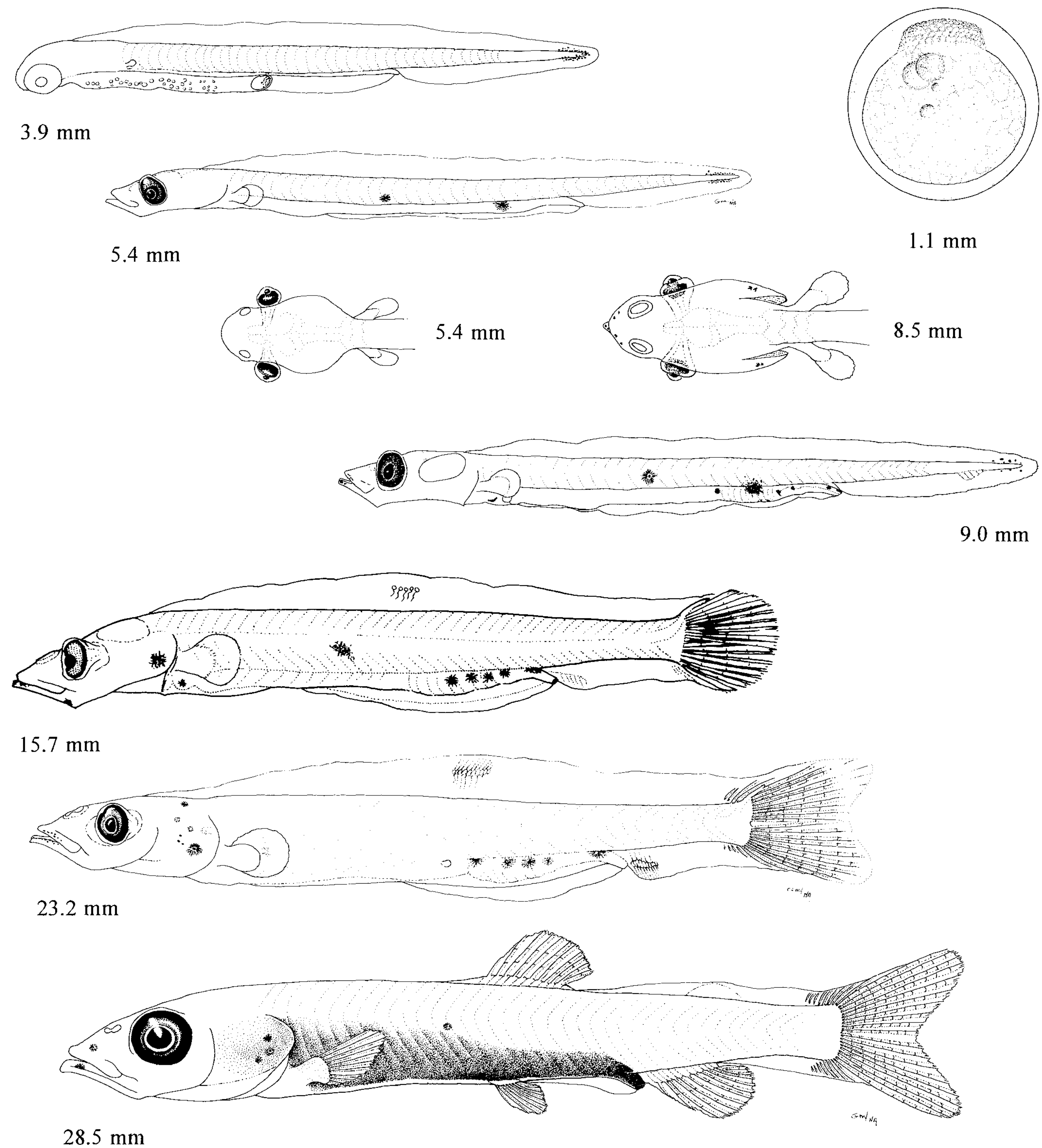


Figure Bathylagidae 9. Egg, 1.1 mm (CalCOFI); yolk-sac larva, 3.9 mm (CalCOFI 5103, station 112.65); preflexion larva, 5.4 mm (Ahlstrom 1972a); head of 5.4 mm preflexion larva, dorsal view (CalCOFI 5101, station 93.40); head of 8.5 mm preflexion larva, dorsal view (Ahlstrom et al. 1984b); preflexion larva, 9.0 mm (CalCOFI 5104, station 70.90); postflexion larvae, 15.7 mm (Ahlstrom 1972a), 23.2 mm (Ahlstrom et al. 1984b); juvenile, 28.5 mm (Ahlstrom 1972a).

MICROSTOMATIDAE: Argentines and pencilfishes

H. G. MOSER AND J. L. BUTLER[1]

The family Microstomatidae includes three genera and about 17 species and is found worldwide from equatorial to boreal waters. Two of the three genera occur in the CalCOFI region: there are at least five species of *Nansenia* whereas *Microstoma* is represented by a single undescribed species (Table Microstomatidae 1). Species distributions are delimited by water mass boundaries. *Nansenia candida* occurs in the California Current from the Gulf of Alaska to northern Baja California and *N. crassa* has a subtropical distribution that extends northward off Baja California and overlaps that of *N. candida* off southern California (Kawaguchi and Butler 1984). Larval abundances of these two species are low near the coast and peak offshore in the core of the California Current. *Nansenia ahlstromi*, *N. pelagica*, and *N. longicauda* occur primarily in the eastern tropical Pacific. Of these, only the larvae of *N. pelagica* have been identified in offshore CalCOFI samples. Ahlstrom et al. (1984b) listed adult and ontogenetic characters that distinguish the eastern Pacific species of *Microstoma* from *M. microstoma* of the north Atlantic. Larvae of *Microstoma* sp. occur in CalCOFI samples from central California to southern Baja California with a more seaward abundance peak compared with *N. candida* and *N. crassa* larvae.

Adult microstomatids are medium-size (usually <20 cm), slender, silvery, midwater fishes. They occur primarily in epi- and mesopelagic waters but some species may also be benthopelagic where they encounter the continental slope. The lateral line is well developed with distinct scales that extend posteriad onto the caudal fin. Pectoral fins are on the sides of the body and the dorsal fin is either at midbody (*Nansenia*) or well posterior (*Microstoma*). The snout is short and blunt (Cohen 1964b; Kawaguchi and Butler 1984).

Microstomatids are oviparous, with relatively large planktonic eggs characterized by a pustulate inner surface of the chorion, segmented yolk, and a single large oil globule (Ahlstrom et al. 1984b). Larvae are slender and develop an unusual fold in the foregut that often has associated pigmentation. The head is rounded with a blunt anterior profile; in some species the head is bent downward from the longitudinal axis. The eye is elliptical in most species, becoming round at the end of the larval period. Pectoral fin rays are the first to form in most species. Pigmentation is heavy or at least characteristic in most species. A common feature is the presence of a longitudinal series of melanophores or blotches above the gut, extending posteriad onto the tail and, in some species, anteriad into the head region.

Ahlstrom et al. (1984b) summarized information on eggs and larvae of *N. candida*, *N. crassa*, and *Microstoma* sp. with single illustrations of eggs and flexion larvae of these species. Complete developmental series of these three species presented here are based primarily on detailed examination of 29 *N. candida*, 23 *N. crassa*, and 19 *Microstoma* sp. (Table Microstomatidae 2). Primary sources for adult meristic and distributional information were Cohen (1964b), Kawaguchi and Butler (1984), and Ahlstrom et al. (1984b). Larvae of *Nansenia pelagica* in CalCOFI samples are rare and in poor condition and are not included in the species descriptions. They are easily distinguished by a deep body (body depth averages 22% BL in postflexion) and diagnostic pigmentation. Heavy pigment blotches develop on the dorsal, pelvic, caudal, and adipose fin bases and in the gular region. In late postflexion larvae the blotches on the dorsal and pelvic fin bases extend onto the basal regions of the rays.

[1] La Jolla Laboratory, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Table Microstomatidae 1. Meristic characters for the microstomatid species in the California Current vicinity. All species have 10+9 principal caudal rays.

	Vertebrae			Fin rays					
Species	PrCV	CV	Total	D	A	P_1	P_2	C_2	BrR
Microstoma sp.	32–35	15–17	49–50	9–11	7–8	11	9	10–12+ 10–11	4
Nansenia ahlstromi			35–36	8–11	7–8	12	9–11		3
N. candida	27–29	16–19	44–47	9–10	8–9	9–11	9–11	9–10+ 8–9	3
N. crassa	29	17	43–46	9–10	8–9	11–13	10–11	10+10	4
N. longicauda			47–50	10–11	10–11	11–14	9–11		4
N. pelagica			38–39	9–10	8–9	9–11	10–11		4

Table Microstomatidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the microstomatid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Microstoma sp.	L[a]	3 6.7–7.9	4 7.8–9.0	3 9.5–12.7	3 13.8–16.0	3 18.6–21.2	2 25.6–28.9
Nansenia candida	L[a]	3 4.4–5.3	6 5.2–7.0	8 7.1–9.8	6 10.5–15.0	4 17.2–23.3	2 24.3–25.9
N. crassa	L[a]	3 3.9–4.8	6 4.9–7.1	4 7.5–9.5	8 10.0–14.2	2 18.4–20.4	0

[a] Ahlstrom et al. 1984b

MERISTICS

	Range	Mode
Vertebrae:		
Total	49–50	50
Precaudal	32–35	34
Caudal	15–17	16
Fins:		
Dorsal spines	0	0
Dorsal rays	9–11	11
Anal spines	0	0
Anal rays	7–8	7
Pelvic	9	9
Pectoral	11	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–12	
Lower	10–11	
Gill rakers:		
Upper	9	
Lower	15	
Branchiostegals	4	4

LIFE HISTORY

Range: Subarctic-transitional eastern Pacific, south to central Baja California

Habitat: Mesopelagic

Spawning season: Larvae present year-round in CalCOFI samples with peak abundance in August

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

Ahlstrom et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 4.3 mm (G. Mattson/N. Arthur)
Preflexion larva, 8.6 mm (G. Mattson/N. Arthur)
Juvenile, 28.3 mm (G. Mattson/N. Arthur)

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* Eye slightly oval, long axis typically inclined from vertical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.1–2.4 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.49–0.82 mm
Shell surface: Pustulate inner surface
Pigment: Along ventral surface of trunk above gut, extending onto head & tail region; on yolk sac
Diagnostic features: Large shell & oil globule diameter; pustulate inner shell surface; pigment pattern on embryo

LARVAE

Hatching length: 5–6 mm
Flexion length: 9–13 mm
Transformation length: 18–25 mm
Fin development sequence: P_1, C_1, D & A, P_2, C_2
Pigmentation: *Yolk-sac*—Paired ventral trunk series extends posteriad on tail to hypural region & anteriad through branchial region to snout; on yolk sac; concentrated on ventral midline from isthmus to anus. *Preflexion*—Heavy on gut fold; at angle of gill arches. *Flexion*—Paired embedded series above notochord between D & C; on C ray bases & on finfolds in caudal region. *Postflexion*—On lateral surface between D & C. *Transformation*—Over entire surface, heaviest posterior to D.
Diagnostic features: Long gut with fold appearing in late yolk-sac stage; heavy paired ventral pigment continuous from snout to C; rays form early in P_1; D, A, & P_2 far back on body; no Ad; embedded pigment above notochord between D & C; silvery guanine layer developed at transformation; higher total vertebral count (49–50) than in *Nansenia candida* (44–47) or *N. crassa* (43–46).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	73–75 74	74–78 76	72–79 76	79–81 80	79–81 80	81–82 81
BD/BL	10–13 11	8–10 9	9–10 9	9–10 10	10–11 11	10–11 11
HL/BL	13–15 14	16–18 17	17–20 19	18–19 18	17–18 17	18–19 18
HW/HL	54–62 57	56–63 59	50–56 53	39–50 46	39–42 41	37–39 38
SnL/HL	8–18 12	21–25 23	17–27 23	22–25 24	18–22 20	19–19 19
ED/HL*	33–42× 33–40 39×36	28–30× 33–40 28×37	26–32× 33–39 29×35	25–30× 29–33 28×30	29–30× 30–32 30×31	26–26× 26–30 26×28
P_1L/BL	0–3 3	3–5 4	2–6 4	6–9 8	10–10 10	14–14 14
P_2L/BL	0–0 0	0–0 0	0–0 0	2–3 2	4–7 6	7–12 9

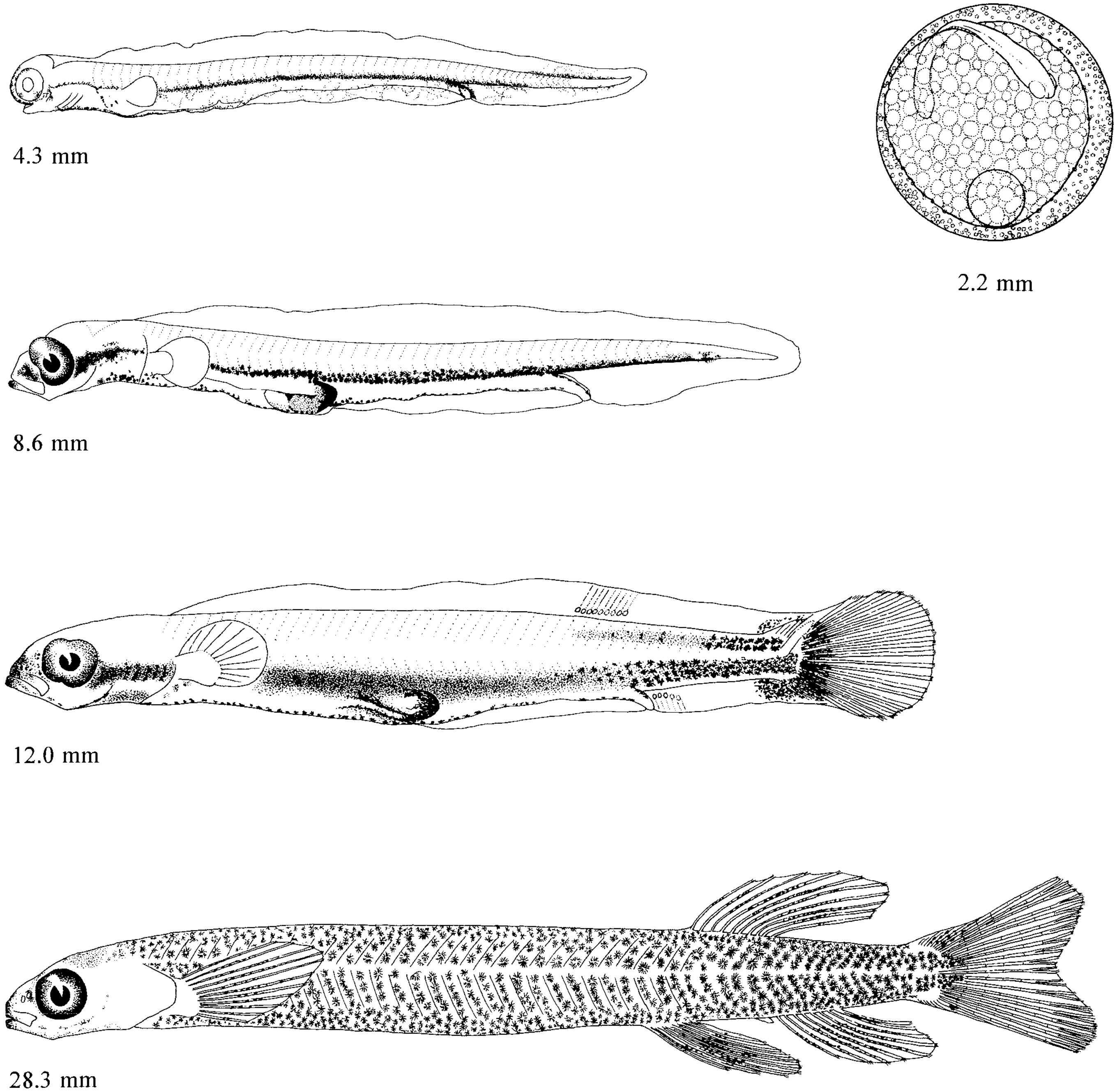


Figure Microstomatidae 1. Egg, 2.2 mm (Ahlstrom et al. 1984b); yolk-sac larva, 4.3 mm (CalCOFI 5104, station 90.120); preflexion larva, 8.6 mm (CalCOFI 5104, station 90.120); flexion larva, 12.0 mm (Ahlstrom et al. 1984b); juvenile, 28.3 mm (CalCOFI 5101, station 97.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–47	46
Precaudal	27–29	27–29
Caudal	16–19	17–19
Fins:		
Dorsal spines	0	0
Dorsal rays	9–10	10
Anal spines	0	0
Anal rays	8–9	9
Pelvic	9–11	
Pectoral	9–11	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	9–10	
Lower	8–9	
Gill rakers:		
Upper	8–11	
Lower	18–21	
Branchiostegals	3	3

LIFE HISTORY

Range: Subarctic-transitional eastern Pacific from 30° to 55° N

Habitat: Mesopelagic

Spawning season: Larvae present year-round in CalCOFI samples with peak abundance in February

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.4 mm (G. Mattson)
Preflexion larva, 7.0 mm (G. Mattson/N. Arthur)
Postflexion larva, 14.0 mm (G. Mattson/N. Arthur)
Juvenile, 20.0 mm (G. Mattson/N. Arthur)

* Eye slightly oval, long axis typically inclined from vertical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

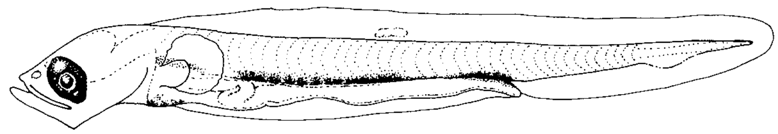
Shell diam.: 1.4–1.6 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.41–0.49 mm
Shell surface: Pustulate inner surface
Pigment: Between trunk & gut; on yolk sac
Diagnostic features: Moderately large shell & OG diameter; pustulate inner shell surface; embryonic pigment

LARVAE

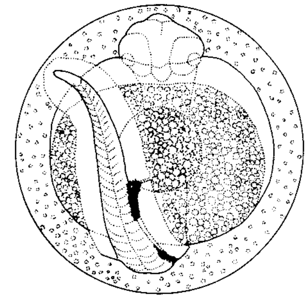
Hatching length: 3.5–4.0 mm
Flexion length: 7.0–10.0 mm
Transformation length: ca. 17 mm
Fin development sequence: P_1, C_1, D & A, P_2, C_2
Pigmentation: *Yolk-sac*—Paired series between trunk & gut from P_1 base to midgut; above terminal section of gut; on anterior region of yolk sac. *Preflexion*—Ventral midline patch below liver. *Flexion*—Paired series forming above hindgut; ventral midline patch extends posteriad to hindgut; on hypural region. *Postflexion*—Hypural blotch expanded; above A base; on body surface, heaviest on myosepta. *Transformation*—Covering entire body surface, heaviest at hypural region.
Diagnostic features: Moderately long gut with lateral fold developing at preflexion stage; gut fold unpigmented; paired melanophore series between trunk & gut; hypural pigment; D & P_2 origins slightly posterior to midbody; rays form early in P_1; guanine layer developing in late postflexion stage.

MORPHOMETRICS (range & mean in %)

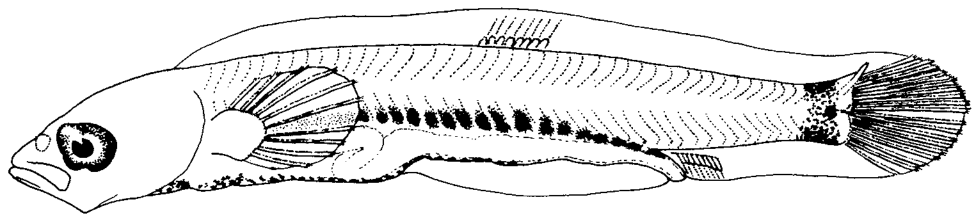
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	68–76 72	72–80 75	74–80 76	78–83 80	80–85 82	82–84 83
BD/BL	13–14 13	10–14 12	13–15 14	15–17 15	13–15 14	14–15 14
HL/BL	7–9 9	19–24 22	24–26 25	24–27 25	24–26 25	24–26 25
HW/HL	96–118 105	49–57 54	50–59 53	42–48 45	38–47 43	41–45 43
SnL/HL	29–56 44	21–34 27	23–27 25	21–25 22	20–23 21	19–20 19
ED/HL*	72–86× 56–76 80×67	25–29× 32–38 27×35	23–27× 27–33 26×29	25–29× 26–30 27×28	25–29× 28–33 28×31	27–29× 29–31 28×30
P_1L/BL	0–0 0	2–6 4	6–12 9	9–15 11	12–15 14	15–16 15
P_2L/BL	0–0 0	0–0 0	0–1 0.3	1–7 4	8–8 8	9–9 9



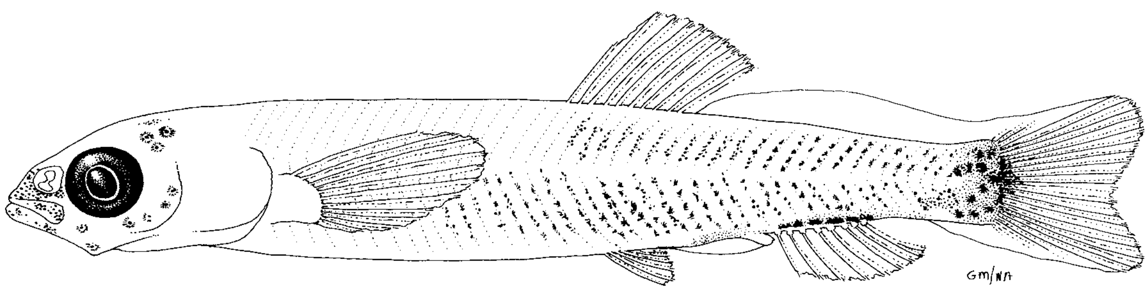
7.0 mm



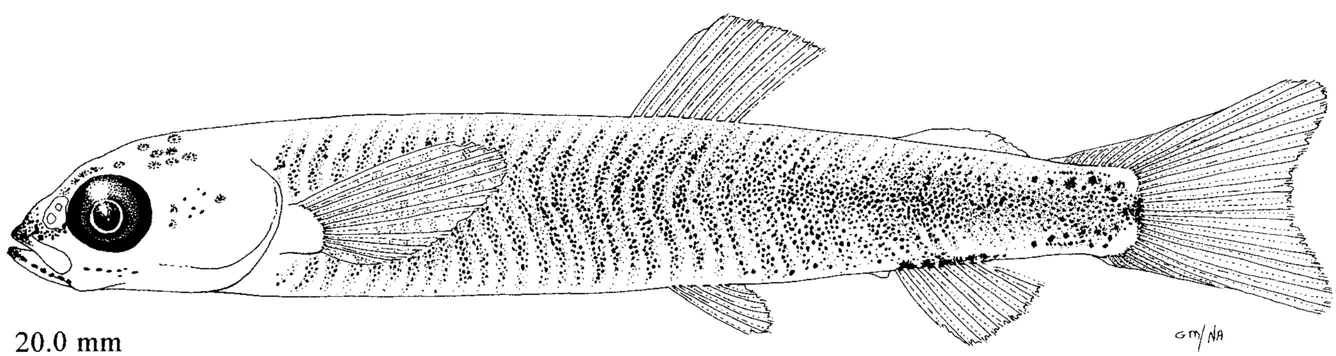
1.4 mm



8.4 mm



14.0 mm



20.0 mm

Figure Microstomatidae 2. Egg, 1.4 mm (CalCOFI); preflexion larva, 7.0 mm (CalCOFI 5003, station 40.100); flexion larva, 8.4 mm (Ahlstrom et al. 1984b); postflexion larva, 14.0 mm (CalCOFI 5004, station 50.100); juvenile, 20.0 mm (CalCOFI 5005, station 40.110).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–46	
Precaudal	29	
Caudal	17	
Fins:		
Dorsal spines	0	0
Dorsal rays	9–10	
Anal spines	0	0
Anal rays	8–9	
Pelvic	10–11	
Pectoral	11–13	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10	
Lower	10	
Gill rakers:		
Upper	12–14	
Lower	23–24	
Branchiostegals	4	4

LIFE HISTORY

Range: Subtropical; southern region of California Current south of 35° N

Habitat: Mesopelagic; adults benthopelagic in continental slope regions

Spawning season: Larvae present year-round in CalCOFI samples with peak abundance in January–March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.6 mm (G. Mattson/N. Arthur)
Preflexion larva, 6.0 mm (G. Mattson/N. Arthur)
Postflexion larva, 14.5 mm (G. Mattson/N. Arthur)
Transformation specimen, 18.8 mm (G. Mattson/N. Arthur)

* Eye slightly oval, long axis inclined from vertical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.1–1.3 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.30–0.35 mm
Shell surface: Pustulate inner surface
Pigment: Paired series between trunk & gut; on yolk sac
Diagnostic features: Large shell & OG diameter

LARVAE

Hatching length: ca. 3 mm
Flexion length: 7.5–9.5 mm
Transformation length: >18 mm
Fin development sequence: P_1 & C_1 & D, A, P_2, C_2
Pigmentation: *Yolk-sac–early preflexion*—Paired series between trunk & midgut & hindgut; elongate patch on ventral midline from isthmus to liver. *Late preflexion–early flexion*—6–7 blotches on dorsum anterior to anus; on posterior surface of gut fold. *Late flexion–early postflexion*—On hypural region; median blotches above & below caudal peduncle. *Late postflexion*—On lower jaw; snout. *Transformation*—Body surface covered anterior to A origin; heavy on Ad, D, & P_2 bases & above anus.
Diagnostic features: Gut fold forms in preflexion stage, pigmented on posterior surface; heavy embedded blotches along dorsum; heavy ventral midline pigment below isthmus & liver; heavy hypural & caudal peduncle blotches; large P_1 with early-forming rays.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	56–71 65	71–77 74	74–79 76	75–83 79	80–80 80	
BD/BL	10–11 10	9–12 10	11–13 13	14–17 15	14–15 14	
HL/BL	13–17 16	20–25 22	24–27 25	26–29 27	27–30 28	
HW/HL	54–68 60	53–60 55	48–56 52	42–46 44	38–43 40	
SnL/HL	16–23 21	12–25 20	22–26 24	21–25 23	20–21 21	
ED/HL*	43–50× 31–35	25–29× 31–40	23–25× 27–33	19–26× 24–29	21–25× 25–27	
	45×33	27×36	24×30	22×27	23×26	
P_1L/BL	0–3 0.8	4–6 5	5–7 6	6–20 14	15–16 16	
P_2L/BL	0–0 0	0–0 0	0–0 0	1–8 5	10	

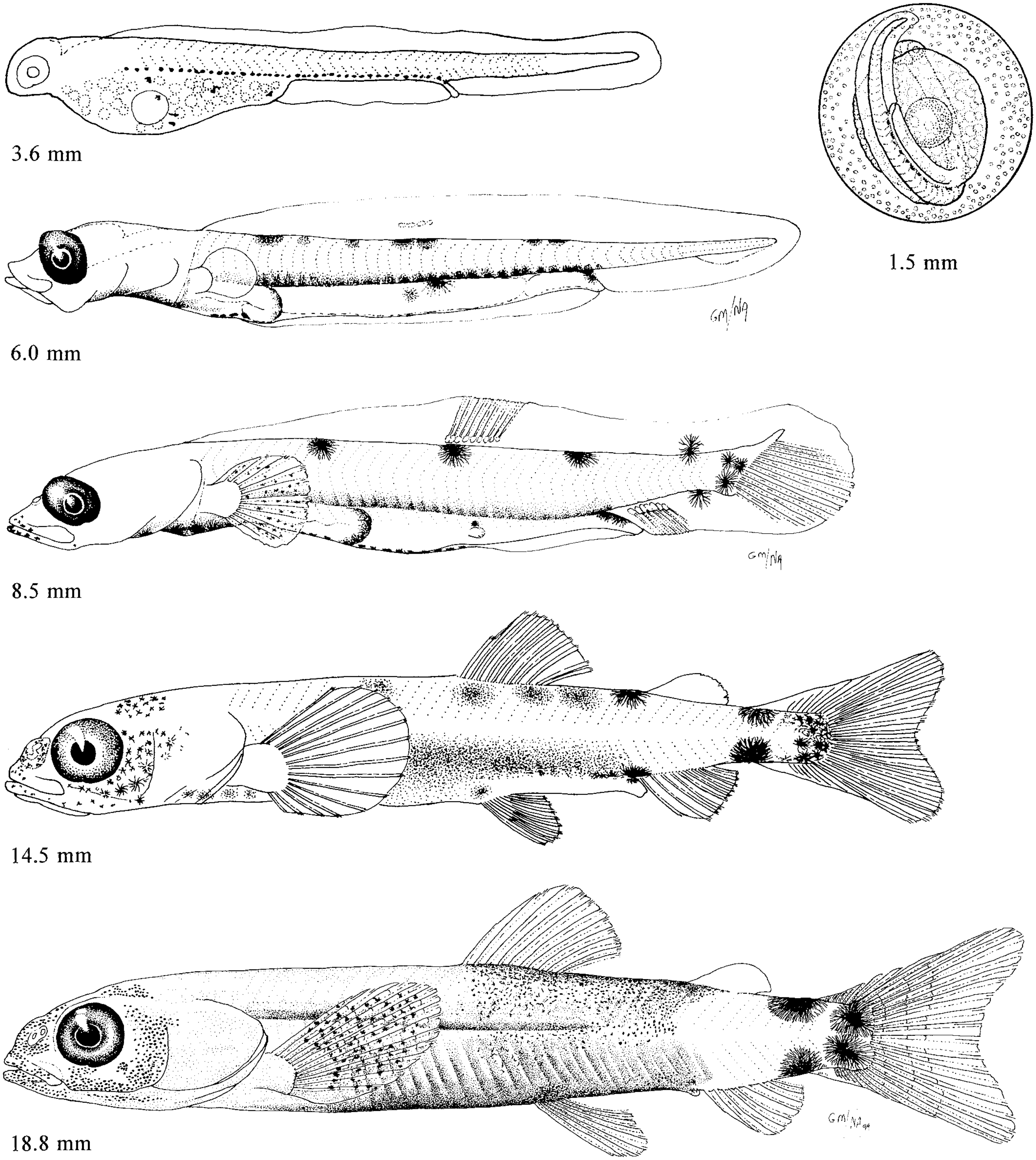


Figure Microstomatidae 3. Egg, 1.5 mm (Ahlstrom et al. 1984b); yolk-sac larva, 3.6 mm (CalCOFI 5103, station 133.40); preflexion larva, 6.0 mm (CalCOFI 5102, station 137.35); flexion larva, 8.5 mm (Ahlstrom et al. 1984b); postflexion larva, 14.5 mm (CalCOFI 5103, station 120.45); transformation specimen, 18.8 mm (CalCOFI 5106, station 127.40).

OPISTHOPROCTIDAE: Spookfishes

H. G. MOSER

The Opisthoproctidae is a small family of relatively rare fishes found worldwide in oceanic midwaters. The family includes six genera and about 10 species; the taxonomy of the group is somewhat unsettled due to their rarity and to the existence of numerous undescribed species (Cohen 1964b; Badcock 1988). Six opisthoproctid species in three genera occur in the California Current (Table Opisthoproctidae 1). Larvae of three species, *Dolichopteryx longipes*, *Bathylychnops exilis*, and *Macropinna microstoma*, occur in CalCOFI ichthyoplankton samples. *D. longipes* apparently has a worldwide tropical to temperate distribution while *B. exilis* and *M. microstoma* occur in eastern Pacific transitional waters. A few specimens of *M. microstoma* have been collected in the tropical central Pacific. *D. binocularis* and *B. brachyrhynchus*, primarily known from the Atlantic, and an undescribed *Dolichopteryx* species are known from a few juvenile or adult specimens collected in the CalCOFI sampling region.

Opisthoproctids are among the most highly specialized teleosts. *Bathylychnops* has round dorsally-directed eyes and all other genera have tubular eyes that are directed either dorsad (*Dolichopteryx*, *Macropinna*, *Opisthoproctus*, *Rhynchohyalus*) or rostrad (*Winteria*). All species have retinal diverticulae that extend the field of vision and, in *Bathylychnops*, the diverticulum is a secondary eye with separate lens and cornea (Pearcy et al. 1965; Munk 1966; Lockett 1977; Stein and Bond 1985). Two body morphs occur in the family: an elongate form (*Dolichopteryx* and *Bathylychnops*) and a foreshortened, laterally compressed form (e.g., *Macropinna*). Opisthoproctids have small mouths, numerous modifications of the head bones associated with eye and jaw specializations, and enlarged pectoral or pelvic fins that are high on the body in some species (Cohen 1964b). Species of *Dolichopteryx* differ in fin position and ray length (Table Opisthoproctidae 1). In *D. binocularis* the dorsal, anal, and pelvic fins are near the caudal fin and the pectoral fin rays extend beyond the caudal fin base. In *D. longipes* the dorsal, anal, and pelvic fins are more anterior and the pelvic fin rays are longer than the pectoral rays. In *Dolichopteryx* sp., pelvic fin origin is relatively more anterior than in *D. longipes* and the head is relatively larger (Table Opisthoproctidae 1). The general tendency for delayed metamorphosis and paedomorphosis in the group culminates in *Dolichopteryx*, which has a gelatinous sheath and larvoid appearance.

Planktonic eggs of opisthoproctids have not been identified and may reside below usual sampling depths. Beebe (1933a) reported large ovarian eggs in an 85 mm *D. longipes* and Stein and Bond (1985) reported ripe ovarian eggs (2.2–2.6 mm diameter) in a 464 mm *B. exilis*. Large eggs and large size at hatching may be typical of opisthoproctids. This may explain, in part, the absence of small preflexion larvae in ichthyoplankton samples. The smallest known larvae (flexion stage) of *D. longipes* and *M. microstoma* are easily recognized by their well-developed tubular eyes, prominent abdominal pelvic fins, and relatively long gut; flexion stage *B. exilis* have a unique alternating arrangement of dorsal and ventral pigment blotches.

The following descriptions of *D. longipes*, *B. exilis*, and *M. microstoma* are based on detailed examinations of 19 specimens (Table Opisthoproctidae 2). Counts and morphometric information were obtained from Cohen (1960, 1964b), Ahlstrom et al. (1984b), Stein and Bond (1985), and Badcock (1988) and from counts and measurements taken in this study.

Table Opisthoproctidae 1. Morphometric characters and fin ray and vertebral counts of Opisthoproctidae species that occur in the California Current region based on juvenile or adult specimens. All species have 10+9 principal caudal fin rays.

	Morphometric characters				Fin rays				
Species	Sn-D/SL	Sn-P_2/SL	Sn-A/SL	HL/SL	D	A	P_1	P_2	Total vertebrae
Bathylychnops brachyrhynchus[a]	73	64	82	25	10	11	13	8	58
B. exilis	71–73	70	82–85	16–21	13–16	10–14	10–13	7–8	78–84
Dolichopteryx binocularis[b]	82	86	88	25	13	11	14	7	57
D. longipes	74–77	69–70	77–79	31–34	10–11	8–10	11–13	8–11	41
Dolichopteryx sp.[c]	80	63	84	37	9	8	14–15	11	45
Macropinna microstoma	70–76	59–61	61–66	45–46	11–12	10–14	17–19	9–10	34–37

[a] SIO 72–58, 106.5 mm
[b] SIO 75–51, 121.7 mm
[c] SIO 93–246, 73.4 mm

Table Opisthoproctidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the opisthoproctid species descriptions.

Species	Flexion	Postflexion	Transformation	Juvenile
Bathylychnops exilis	2 14.2–16.7	2 25.4–60.3	1 99.9	0
Dolichopteryx longipes	2 13.0–13.4	2 20.8–29.7	0	2 70.7–101.9
Macropinna microstoma	1 11.8	4 12.2–20.2	2 21.5–23.7	2 26.1–29.5

MERISTICS

	Range	Mode
Vertebrae:		
Total	78–84	81
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	0
Dorsal rays	13–16	14
Anal spines	0	0
Anal rays	10–14	12
Pelvic	7–8	7
Pectoral	10–13	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12	12
Lower	12	12
Gill rakers:		
Upper		
Lower		
Branchiostegals	2	2

LIFE HISTORY

Range: Central California to British Columbia

Habitat: Epi- & mesopelagic

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Ahlstrom et al. 1984b
Badcock 1988
Cohen 1960, 1964b
Matarese et al. 1989
Stein & Bond 1985

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 25.4 mm (N. Arthur)

* P_2 rays broken in transforming specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS

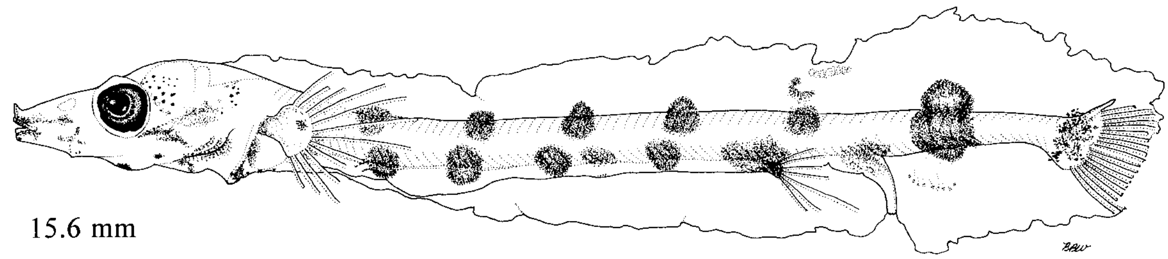
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

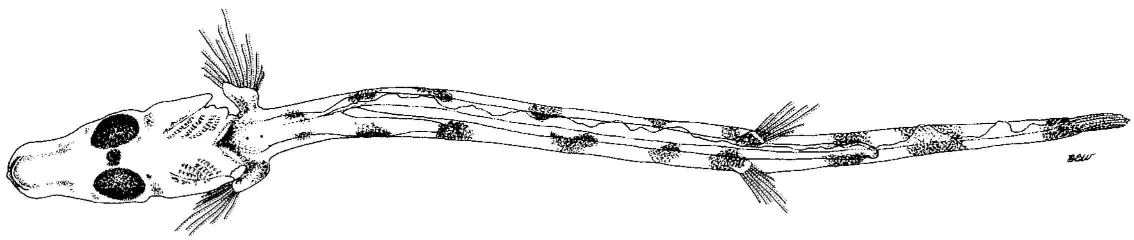
Hatching length:
Flexion length: 14–16 mm
Transformation length: Up to ca. 120 mm
Fin development sequence: C_1 & P_1, P_2, D, A, C_2
Pigmentation: *Flexion–postflexion*—On upper & lower jaws; internal elongate patches in snout; ventrally & laterally on brain; on filaments of lower limbs of gill arches; internally posteroventral to eye; paired in gular & basibranchial region; internally at P_1 base & cleithrum; at cleithral symphysis; 6–7 paired blotches along gut at trunk/gut juncture extending ventrad over gut; postanal bar; heavy on hypural region; 5 median dorsal blotches alternating with ventrolateral blotches; on P_1 & P_2 bases. *Transformation*—Same as above but also on D & A bases.
Diagnostic features: Elongate gut; eyes round, dorsolateral orientation; fleshy snout protuberance; early forming P_1 & P_2; unique head pigment; alternating median dorso- & ventrolateral blotches; stomach forms early on right side; dorsal longitudinal septum open; high total vertebral count (78–84).

MORPHOMETRICS (range & mean in %)

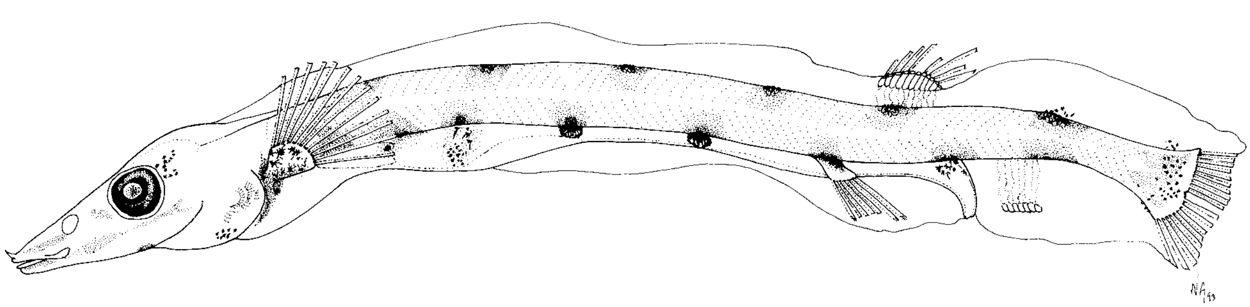
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			79–80 79	83–83 83	85	
BD/BL			6–8 7	7–9 8	6	
HL/BL			18–21 19	21–22 22	21	
HW/HL			40–44 42	31–37 34	33	
SnL/HL			26–34 30	37–43 40	47	
ED/HL			21×22	17–19 18	20	
P_1L/BL			4–10 7	8	5	
P_2L/BL			0–7 4	7	*	



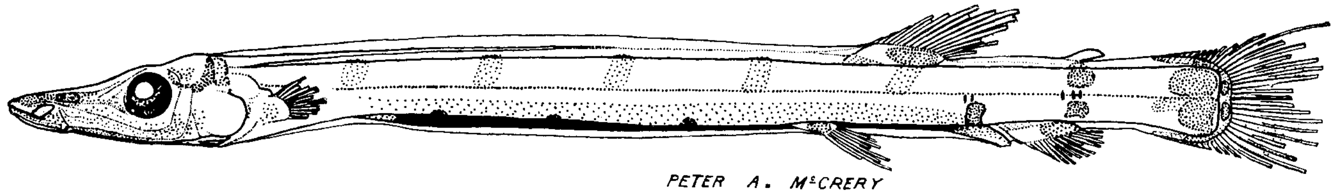
15.6 mm



15.6 mm



25.4 mm



112.5 mm

Figure Opisthoproctidae 1. Flexion larva, 15.6 mm, lateral and ventral views (Ahlstrom et al. 1984b); postflexion larva, 25.4 mm (CFRD AO 71, station 43); juvenile, 112.5 mm (Cohen 1960).

MERISTICS

	Range	Mode
Vertebrae:		
Total	41	
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	0
Dorsal rays	10–11	11
Anal spines	0	0
Anal rays	8–10	10
Pelvic	8–11	11
Pectoral	11–13	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–11	10–11
Lower	11–12	11–12
Gill rakers:		
Upper		
Lower		
Branchiostegals	2	2

LIFE HISTORY

Range: Apparently worldwide in temperate & tropical waters

Habitat: Mesopelagic

Spawning season:

ELH pattern: Oviparous; larvae planktonic; paedomorphic

LITERATURE

Ahlstrom et al. 1984b
Cohen 1964b

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 13.4 mm (N. Arthur)
Postflexion larva, 27.8 mm, lateral & ventral views (N. Arthur)

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* Maximum diameter of tubular eye.
† P_1 rays broken in flexion specimen.
‡ P_2 rays broken in flexion specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS

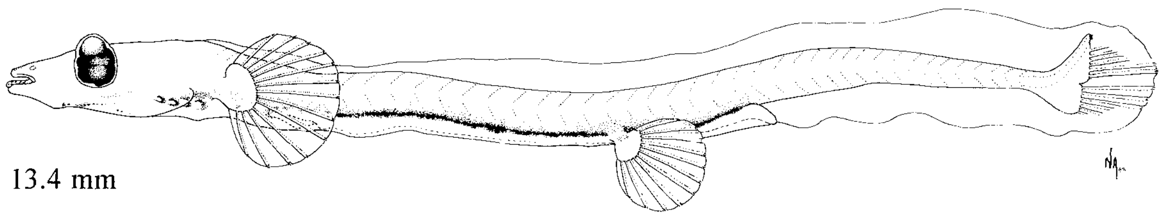
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

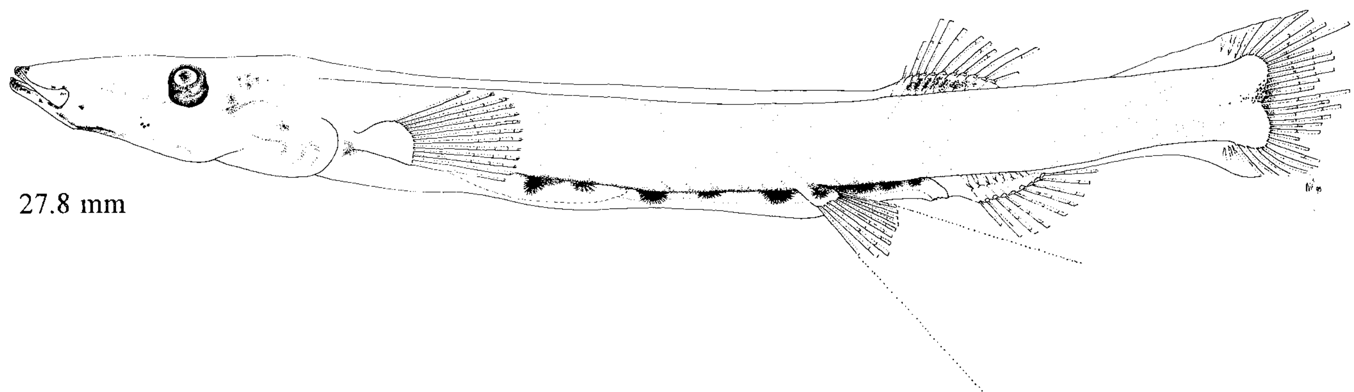
Hatching length:
Flexion length: ca. 13 mm
Transformation length: ca. 30 mm
Fin development sequence: C_1 & P_1 & P_2, D & A & C_2
Pigmentation: *Flexion*—On gill arches & filaments, mostly at angle; series between gut & trunk from P_1 base to terminal section of gut; on P_2 base. *Postflexion*—On upper & lower jaws; lateral series on isthmus; lateral series extending posterior from angle of lower jaw; below & lateral to brain; elongate patch on vomer; on gill arches; series of blotches extending ventrad from above gut; on both surfaces of P_2 bases; on D base; median patch at base of C. *Juvenile–adult*—Similar to above except gut enclosed in sheath; on P_1 base; on hypural region.
Diagnostic features: Dorsally directed tubular eyes; elongate gut; early forming P_1 & P_2 with pedunculate bases; pigment on vomer & gill arches; larvoid juveniles & adults enclosed in gelatinous sheath; stomach forms early on left side; dorsal longitudinal septum open.

MORPHOMETRICS (range & mean in %)

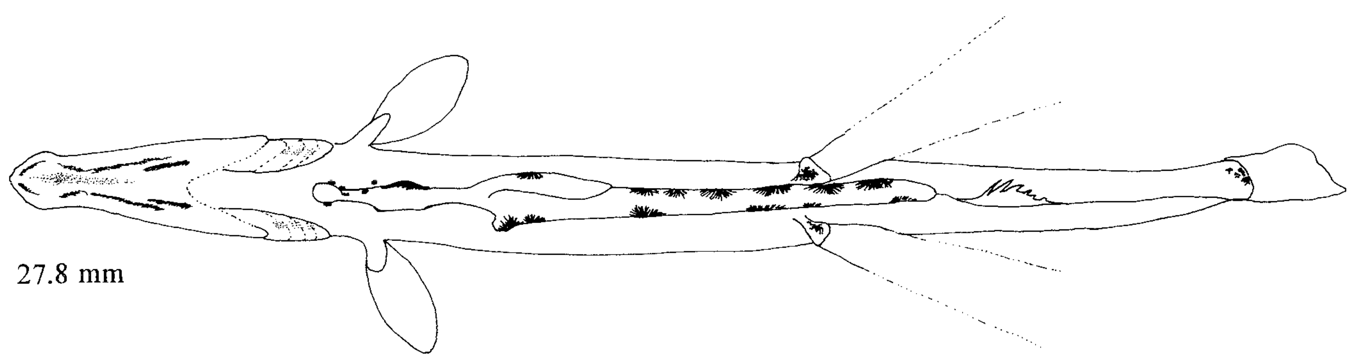
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			70–72 71	74–75 75		77–79 78
BD/BL			6–8 7	7–8 8		12–16 14
HL/BL			21–25 23	24–27 25		31–34 32
HW/HL			41–43 42	28–35 32		30–40 35
SnL/HL			31–36 34	37–43 40		42–44 43
ED/HL*			16–16 16	11–16 14		14–21 17
P_1L/BL			†	 8		9–12 11
P_2L/BL			‡	 8		20–25 23



13.4 mm



27.8 mm



27.8 mm

Figure Opisthoproctidae 2. Flexion larva, 13.4 mm (CalCOFI 7203, station 97.90); postflexion larva, 27.8 mm, lateral and ventral views (CFRD 8701, station 62.0.54.7).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–37	35
Precaudal	15–18	16
Caudal	17–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	11–12	12
Anal spines	0	0
Anal rays	10–14	13
Pelvic	9–10	
Pectoral	17–19	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–11	10
Lower	10–11	
Gill rakers:		
Upper		
Lower		
Branchiostegals	3	3

LIFE HISTORY

Range: Eastern Pacific from Bering Sea to southeast of Isla de Guadalupe, Baja California

Habitat: Epi- & mesopelagic

Spawning season:

ELH pattern: Oviparous; larvae planktonic

LITERATURE

Ahlstrom et al. 1984b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 21.5 mm (N. Arthur)

* Maximum diameter of tubular eye.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <12 mm
Transformation length: 21–24 mm
Fin development sequence: C_1 & P_1 & P_2, D & A, C_2
Pigmentation: *Flexion*—Streak extending posteriad from angle of lower jaw; along cleithra; midventrally at liver; internally dorsal to liver; heavy blotch in P_2 base, extending dorsad over myomeres & ventrad over gut; median hypural blotch; two lower hypural blotches; series of diagonal streaks on hypaxial myomeres; dorsally on terminal section of gut. *Postflexion*—Series on epaxial myomeres increases posteriad, complete at transformation. *Transformation*—Gut enclosed in black sheath; on P_1 & P_2 rays. *Juvenile*—Solid pigmentation except for snout.
Diagnostic features: Large head with occipital hump & dorsally directed tubular eyes; anus slightly posterior to midbody; P_2 origin anterior to midbody; paired fins large, P_2 rays elongate; series on hypaxial myomeres & later on epaxial myomeres; hypural blotch; lower total vertebral count (34–37) compared to other genera in region.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				58–65	60–61	61–66
			64	61	60	64
BD/BL				12–25	30–31	34–36
			14	20	31	35
HL/BL				26–37	41–43	45–46
			27	33	42	46
HW/HL				49–55	51–52	53–54
			47	53	52	54
SnL/HL				40–52	45–48	42–46
			38	46	46	44
ED/HL*				18–21	24–25	28–33
			19	20	24	31
P_1L/BL				12–19	25–26	
			9	15	25	24
P_2L/BL				20–25	47–50	
			16	22	48	47

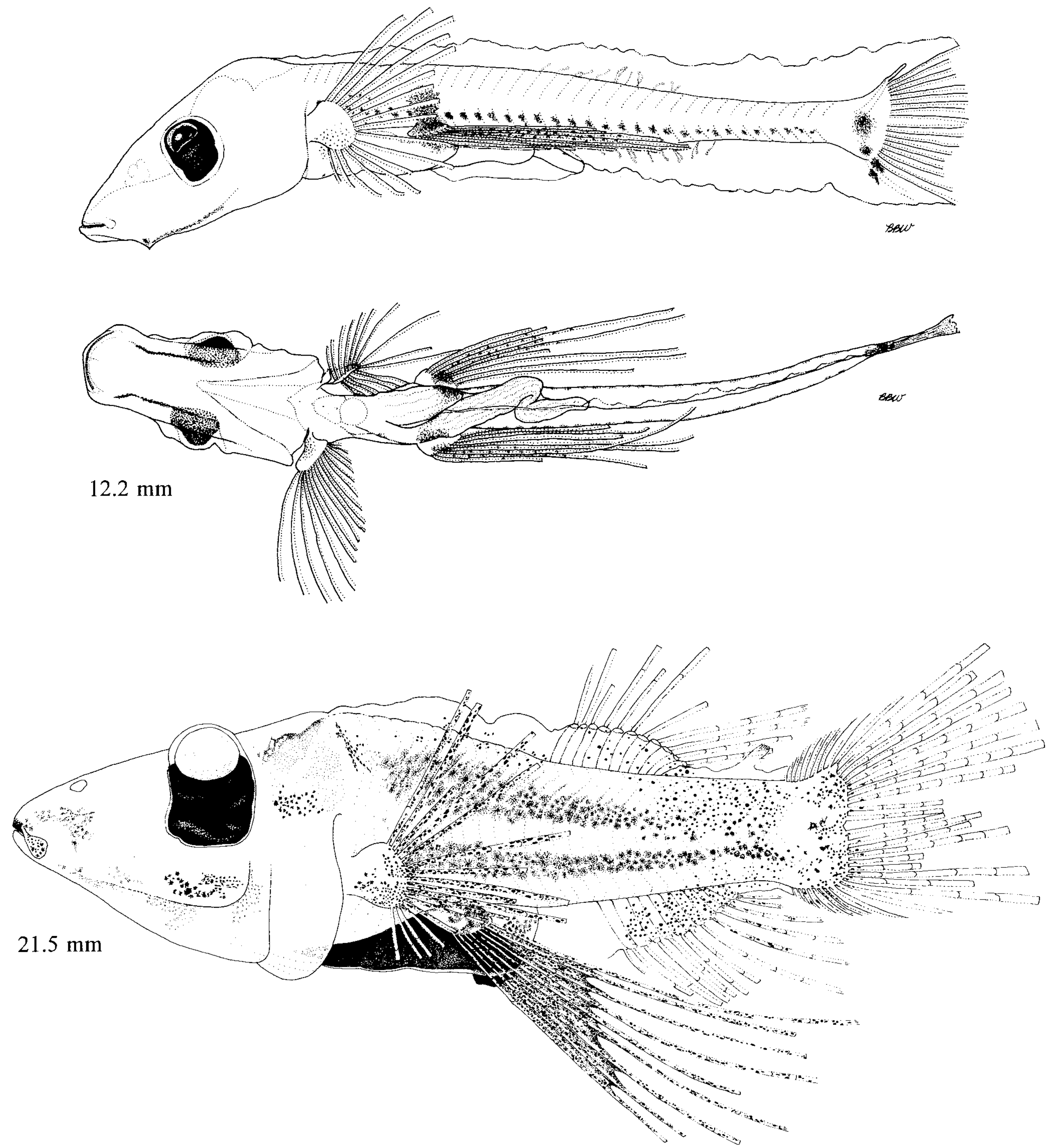


Figure Opisthoproctidae 3. Flexion larva, 12.2 mm, lateral and ventral views (labelled 11.7 mm in Ahlstrom et al. 1984b); postflexion larva, 21.5 mm (CFRD 9203, station 56.7.80.3).

ALEPOCEPHALIDAE: Slickheads

D. A. AMBROSE

Alepocephalidae includes about 24 genera with more than 90 species (Sazonov and Markle 1990; Nelson 1994). Ten species and one closely related leptochilichthyid species may occur in the California Current vicinity (Table Alepocephalidae 1); however, young pelagic stages usually reside below 200 m and are collected rarely on CalCOFI plankton surveys. Only *Alepocephalus tenebrosus*, *Bajacalifornia burragei*, *Bathylaco nigricans*, and *Talismania bifurcata* occur regularly in deep collections from the California Current region.

Slickheads are small to medium-sized (ca. 10–100 cm) demersal, meso- and bathypelagic (45–5500 m, usually >1000 m) residents of all oceans. The leptochilichthyid species, *Leptochilichthys agassizii*, is a rare, poorly known bathypelagic denizen (2000–3000 m) with a higher branchiostegal ray count than the alepocephalids from this area (13 vs. 4–10). The slickheads are osmeriform fishes (Nelson 1994) that have somewhat compressed, moderately deep to elongate bodies, vertical fins on the posterior half of the body, abdominal pelvic fins, and lack shoulder organs, premaxillary tusks, adipose fin, gas bladder, and head scales. Pectoral fins, when present, are low on the uniformly pigmented body. Slickheads are most closely related to platytroctids, which possess a unique tube-shaped postcleithral structure, the shoulder organ (Matsui and Rosenblatt 1987). Begle (1992) suggested that the platytroctids and *Leptochilichthys* be included in the Alepocephalidae. Even though alepocephaloids and argentinoids possess a similar epibranchial organ (crumenal organ), early life history characters suggest that they are not closely related. Alepocephalids have larger eggs than do the argentinoids, undergo direct development (like the platytroctids) in contrast to metamorphosis from a distinct larval to juvenile form in the argentinoids, and they share no specialized ontogenetic characters with argentinoids (Ahlstrom et al. 1984b).

Little is known about this group including its reproduction. Beebe (1933a) found alepocephalids to hatch from large eggs (3–4 mm) and to have direct development. Late-stage intraovarian eggs of *B. nigricans* are 2.7 mm (Nielsen and Larsen 1968) and those of *A. tenebrosus* are >3 mm. The smallest specimens available (*T. bifurcata* and *B. nigricans*, ca. 15 mm; *A. tenebrosus* and *B. burragei*, ca. 18 mm) have the general shape and pigmentation of early juveniles. The dorsal, anal and primary caudal fin ray complements are complete by ca. 30 mm SL, although those of the pectoral fin and procurrent caudal fin are not completed until greater than 60 mm SL. For the four most common species in our study area, the relative proportions of the large head (HL ca. 33–42% SL) and the preanal length (Sn-AL ca. 59–74% SL) change little through the early juvenile stage; however, the body depth increases (BD ca. 11–22% SL). Eyes are horizontally elongate, becoming rounder in early juveniles. Black tissue lines the mouth, branchial cavity, and peritoneum in the smallest specimens examined. The top of the skull is translucent through the early juvenile stage.

Young alepocephalids may be confused with platytroctids and early juvenile bathylagids. Alepocephalids lack the shoulder organ that is present even in yolk-sac platytroctid larvae (Matsui 1991) and they also lack an adipose fin, which is present in early juvenile bathylagids. The meristic counts (Table Alepocephalidae 1) and the position of the anal fin origin relative to the dorsal fin origin help to differentiate the young slickheads in this region. The anal fin origin is well anterior to the dorsal fin origin in *Leptoderma lubricum* and *Conocara salmoneum*; posterior to the dorsal fin origin in *Bajacalifornia burragei*, *Bathylaco nigricans*, *Narcetes stomias*, and *Leptochilichthys agassizii*; and subequal to the dorsal fin origin in *Alepocephalus tenebrosus*, *Asquamiceps velaris*, *Asquamiceps pacificus*, *Photostylus pycnopterus*, and *Talismania bifurcata*. Features useful in separating young of the more common species are the prominent chin projection of *Bajacalifornia burragei*, the relatively large mouth (>60% HL) of *Bathylaco nigricans*, the two produced pectoral fin rays of *Talismania bifurcata* (by ca. 26 mm SL), and the total myomere count (50–54) of *Alepocephalus tenebrosus*.

The following descriptions are based on detailed examinations of 3 postflexion larvae (18.5–24.2 mm) of *Alepocephalus tenebrosus*; 2 postflexion larvae (18.3–26.0 mm), 4 transitional specimens (32.0–56.0), and 1 scaleless early juvenile (66.6 mm) of *Bajacalifornia burragei*; 5 postflexion larvae (14.8–28.8 mm), 1 transitional specimen (31.6 mm), and 1 scaleless early juvenile (76.0 mm) of *Bathylaco nigricans*; and 5 postflexion larvae (14.3–26.6 mm), 3 transition specimens (32.5–48.4 mm), and 2 scaleless early juveniles (58.5–68.2 mm) of *Talismania bifurcata*. Meristic data were obtained from the literature (Beebe 1933a; Nielsen and Larsen 1968; Markle 1976, 1980; Markle and Quéro 1984; Markle and Krefft 1985; Machida and Shiogaki 1988; Matarese et al. 1989; Sazonov and Markle 1990), from unpublished counts made by T. Matsui, and from counts made during this study. Ecological information was obtained from Parr (1954), Berry and Perkins (1966), Nielsen and Larsen (1968), Eschmeyer et al. (1983), Markle and Quéro (1984), Markle and Krefft (1985), and Machida and Shiogaki (1988).

Table Alepocephalidae 1. Meristic characters for the alepocephalid and leptochilichthyid species in the California Current vicinity. All have 10+9 principal caudal rays.

Taxon	Vertebrae			Fin rays					BrR	GR
	PrCV	CV	Total	D	A	P_1	P_2	C_2		
Alepocephalidae										
Alepocephalus tenebrosus	24–26	26–29	51–55	15–18	15–18	10–12	6–7	14–16+14–15	6–7	6–7+17–18
Asquamiceps pacificus	18–21	21–24	42	17–18	16–17	15–17	6	9+9	6	9+16–17
Asquamiceps velaris	16–17	20–21	37	16–17	16–17	13–15	5	10–12+9	5–6	5–6+9–12
Bajacalifornia burragei	26–28	19–22	46–48	14–17	12–14	15–17	7–8	19–20+14–17	7	7–10+24–29
Bathylaco nigricans	25	16–17	41–42	17–22	11–12	6–11	6–9	12–14+11–14	9–10	3–5+8–13
Conocara salmoneum	20–21	31–33	51–53	16–23	25–28	7–12	5–7		6	
Leptoderma lubricum	15–17	48–59	63–74	27–37	42–51	7	4–5		4–6	
Narcetes stomias	25–28	21–23	47–50	17–21	14–17	8–12	7–10		8–9	
Photostylus pycnopterus	26	18	44	12–15	16–19	17–20	6–7		6	
Talismania bifurcata	16–18	26–31	43–50	17–24	17–24	8–13	6–8	14–18+12–16	7–8	5–8+15–19
Leptochilichthyidae										
Leptochilichthys agassizii	27–30	18–24	47–52	11–15	11–13	8–11	8–11	12+9	13	6–11+16–21

MERISTICS

	Range	Mode
Vertebrae:		
Total	51–55	53
Precaudal	24–26	25
Caudal	26–29	29
Fins:		
Dorsal spines	0	0
Dorsal rays	15–18	17
Anal spines	0	0
Anal rays	15–18	17
Pelvic	6–7	7
Pectoral	10–12	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	14–16	15
Lower	14–15	15
Gill rakers:		
Upper	6–7	7
Lower	17–18	18
Branchiostegals	6–7	6

LIFE HISTORY

Range: Bering Sea to at least Isla de Guadalupe, Mexico; also reported from Chile

Habitat: Demersal, 46–1524 m depth

Spawning season:

ELH pattern: Oviparous; larvae meso- & bathypelagic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 24.2 mm (R. C. Walker)

* Eye is oval; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length:
Fin development sequence: C_1, D & A, P_2, C_2, P_1
Pigmentation: *Postflexion*—Black tissue lining digestive tract from mouth & branchial chamber to anus; concentrated at body margin & spreading over entire body; entire top of skull translucent.
Diagnostic features: Total vertebrae 51–55; A rays 15–18; A origin subequal to D origin; P_1 rays not elongate on specimens >ca. 26 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				60–66 63		
BD/BL				13–15 14		
HL/BL				36–38 37		
HW/HL				40–44 41		
SnL/HL				30–31 30		
ED/HL*				21–24× 15–19 22×17		
P_1L/BL				1–2 2		
P_2L/BL				5–6 6		
MxL/HL				32–37 34		

24.2 mm

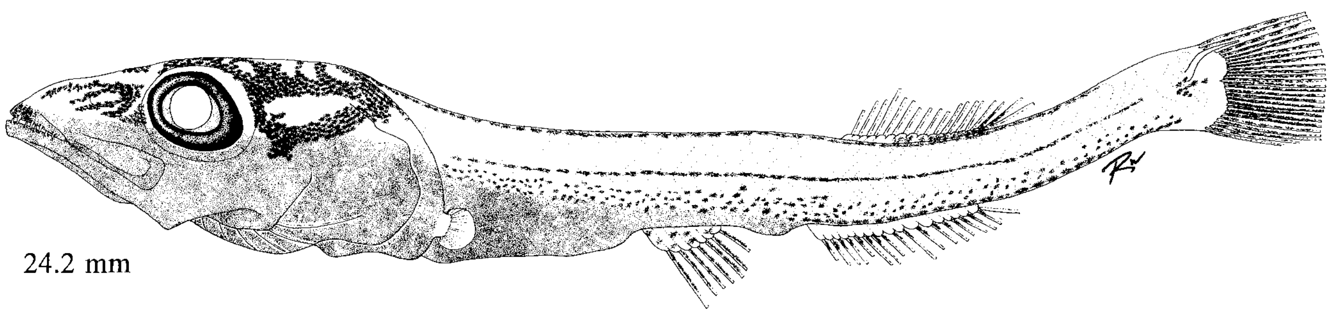


Figure Alepocephalidae 1. Postflexion larva, 24.2 mm (SIO 67–101).

MERISTICS

	Range	Mode
Vertebrae:		
Total	46–48	48
Precaudal	26–28	26
Caudal	19–22	22
Fins:		
Dorsal spines	0	0
Dorsal rays	14–17	15
Anal spines	0	0
Anal rays	12–14	13
Pelvic	7–8	8
Pectoral	15–17	17
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	19–20	
Lower	14–17	
Gill rakers:		
Upper	7–10	8
Lower	24–29	28
Branchiostegals	7	7

LIFE HISTORY

Range: Southern California (ca. 34° N), the Gulf of California, & Chile (ca. 21° S)

Habitat: Mesopelagic, but also probably associated with the bottom

Spawning season:

ELH pattern: Oviparous; larvae mesopelagic or deeper

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 18.3 mm (R. C. Walker)

* Eye is oval; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: By ca. 32 mm, rays forming in all fins
Fin development sequence: C_1, D & A, C_2, P_1
Pigmentation: *Postflexion-juvenile*—Black tissue lining digestive tract from mouth & branchial chamber to anus; concentrated at body margins & spreading over entire body; top of skull translucent.
Diagnostic features: Total vertebrae 46–48; A rays 12–14; A origin well posterior to D origin; prominent chin projection.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				67–72 70	66–70 68	65
BD/BL				13–17 15	13–15 14	16
HL/BL				39–40 39	34–39 36	33
HW/HL				40–45 42	40–41 40	40
SnL/HL				27–38 32	32–38 34	28
ED/HL*				23–27× 17–20 25×19	22–29× 18–23 25×20	28×21
P_1L/BL				3–4 4	4–5 4	4
P_2L/BL				5–9 7	5–7 6	7
MxL/HL				35–44 39	41–46 43	46

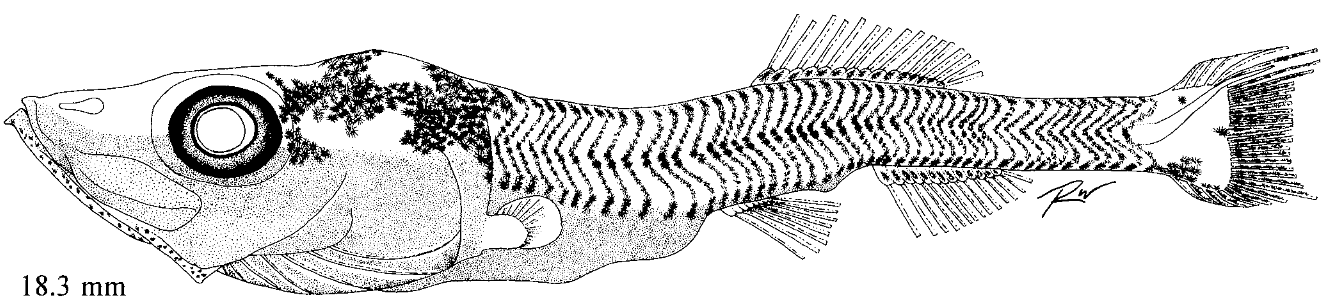


Figure Alepocephalidae 2. Postflexion larva, 18.3 mm (SIO 70–19).

MERISTICS

	Range	Mode
Vertebrae:		
Total	41–42	41–42
Precaudal	25	25
Caudal	16–17	16–17
Fins:		
Dorsal spines	0	0
Dorsal rays	17–22	18–19
Anal spines	0	0
Anal rays	11–12	12
Pelvic	6–9	7
Pectoral	6–11	7
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–14	14
Lower	11–14	11–13
Gill rakers:		
Upper	3–5	4
Lower	8–13	10
Branchiostegals	9–10	10

LIFE HISTORY

Range: Circumglobal between 40° N & 40° S

Habitat: Meso- & bathypelagic

Spawning season:

ELH pattern: Oviparous; larvae mesopelagic or deeper

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 16.3 mm (R. C. Walker)

* Eye is oval; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: Largest ovarian eggs ca. 2.7 mm (Nielsen & Larsen 1968)

Yolk:

No. of OG:

Diam. of OG:

Shell surface:

Pigment:

Diagnostic features:

LARVAE

Hatching length:

Flexion length:

Transformation length: By ca. 36 mm, rays forming in all fins

Fin development sequence: C_1, D & A, P_2, C_2, P_1

Pigmentation: *Postflexion–juvenile*—Black tissue lining digestive tract from mouth & branchial chamber to anus; concentrated at body margins & spreading over entire body; tip of skull translucent.

Diagnostic features: Total vertebrae ca. 41–42; A rays 11–12; maxilla >50% of HL, extending well posterior to orbit; P_1 small, low on body; A origin well posterior to D origin.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				59–74 69	71	72
BD/BL				11–15 14	15	21
HL/BL				33–37 35	33	37
HW/HL				38–47 43	43	33
SnL/HL				19–22 21	21	23
ED/HL*				26–30× 19–23 28×20	22×19	23×23
P_1L/BL				0.5–2 1	0.8	3
P_2L/BL				6–9 7	7	9
MxL/HL				59–66 62	58	70

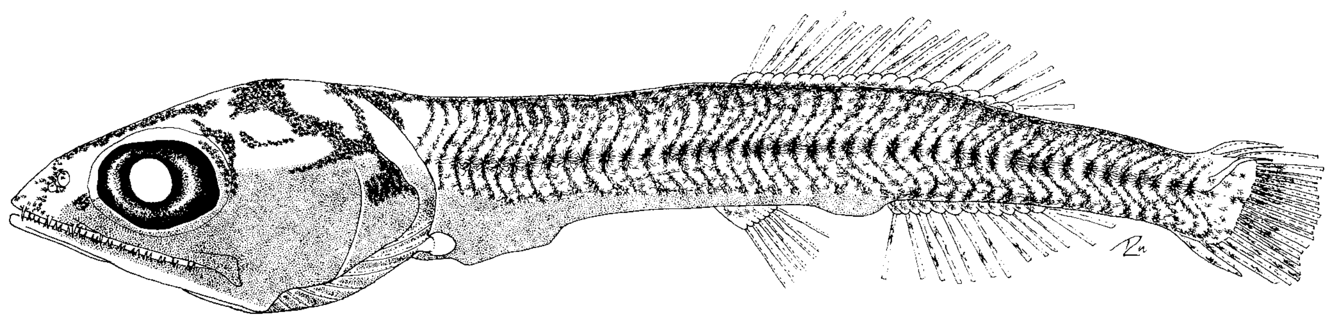


Figure Alepocephalidae 3. Postflexion larva, 16.3 mm (CFRD 9107NH, station 64.5.85.6).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–50	48
Precaudal	16–18	17–18
Caudal	26–31	30–31
Fins:		
Dorsal spines	0	0
Dorsal rays	17–24	21
Anal spines	0	0
Anal rays	17–24	21–22
Pelvic	6–8	6
Pectoral	8–13	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	14–18	17
Lower	12–16	15
Gill rakers:		
Upper	5–8	7
Lower	15–19	18
Branchiostegals	7–8	7

LIFE HISTORY

Range: British Columbia, Canada to Peru

Habitat: Demersal, usually between 300–2000 m depth

Spawning season:

ELH pattern: Oviparous; eggs & larvae mesopelagic or deeper

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 14.3 mm (R. C. Walker)

* Eye is oval; horizontal axis is given first, vertical second.

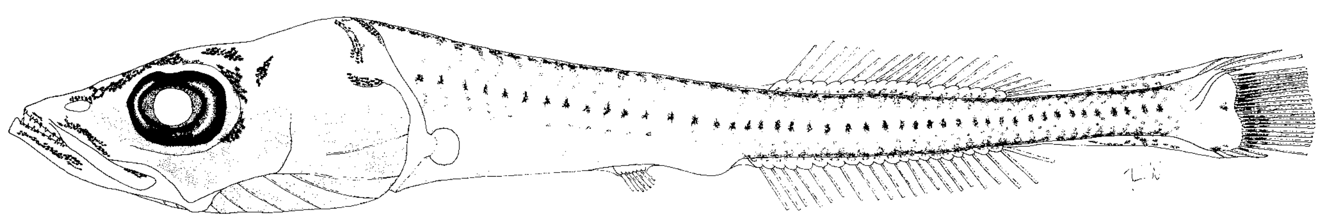
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length:
Transformation length: By ca. 32 mm, rays forming in all fins
Fin development sequence: C_1, D & A, P_2, C_2, P_1
Pigmentation: *Postflexion-juvenile*—Black tissue lining digestive tract from mouth & branchial chamber to anus; concentrated at body margins & spreading over entire body; top of skull translucent.
Diagnostic features: Total vertebrae 43–50; A rays 17–24; A origin subequal to D origin; elongated first & second P_1 rays evident by ca. 26 mm SL; dark spot on P_2; D & A present by ca. 32 mm SL.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				61–66 63	60–62 61	63–64 63
BD/BL				12–18 15	18–19 19	21–22 22
HL/BL				33–42 38	39–42 41	41–42 42
HW/HL				40–49 45	38–42 40	41–42 41
SnL/HL				26–30 28	24–28 26	27–28 28
ED/HL*				23–29× 10–24 25×19	24–26× 21–24 25×22	22–23× 19–20 23×20
P_1L/BL				2–4 3	4–26 12	60–85 72
P_2L/BL				3–7 5	5–7 6	7–10 9
MxL/HL				38–42 40	35–43 40	44–48 46



14.3 mm

Figure Alepocephalidae 4. Postflexion larva, 14.3 mm (SIO 66–41).

PLATYTROCTIDAE: Tubeshoulders

D. A. AMBROSE

Platytroctidae includes 13 genera and 37 species; 5 species occur in the California Current region (Table Platytroctidae 1; Matsui and Rosenblatt 1987). Begle (1992) placed the tubeshoulders in the Alepocephalidae. The young stages have not been collected in CalCOFI plankton surveys. *Holtbyrnia latifrons* and *Sagamichthys abei* range throughout the study area and commonly occur in midwater tows from 300–800 m deep. *Pellisolus eubranchus* and *Mirorictus taningi* generally reside below 900 m depth and are less common, with *P. eubranchus* ranging from central California (ca. 35° N) to central Mexico (ca. 17° N) and *M. taningi* to Chile (12° S). *Maulisia agripalla* is collected uncommonly in the Pacific from off central California, Baja California, and Chile, usually at depths below 900 m.

Platytroctids are medium-sized (ca. 12–30 cm) meso- and bathypelagic residents (usually 200–2000 m depth) of eutrophic waters near continents, islands, ocean ridges, and seamounts in all oceans. Tubeshoulders derive their name from a tubular papilla located just below the lateral line and posterior to the shoulder girdle through which a luminous blue-green fluid can be discharged. Platytroctids are moderately elongate and somewhat compressed, with dorsal and anal fins to the rear of the body, with small pectoral fins low on the body, with abdominal pelvic fins, and a forked tail. Light organs when present are directed horizontally in the young and ventrally in adults. Lacking are head scales, radii on the scales, an adipose fin, and fin spines. Body pigmentation is uniform dorsally and ventrally.

Little is known of the reproduction characteristics of these oviparous fishes (Parr 1960). The only published descriptions of larval platytroctids are those of Murray and Hjort (1912), Beebe (1933a) and Matsui (1991). They are elongate and fairly slender (BD ca. 12% BL in yolk-sac larvae increasing to ca. 20% BL in juveniles). The preanal length is ca. 64–70% of body length throughout development. The least developed platytroctid larva available (10 mm, SIO 78–160) is an early flexion specimen with a large yolk sac extending from the cleithrum to about halfway to the anus, and dorsal, anal, and caudal fin anlagen. Pigment is forming in the eyes, at the margins of the shoulder organ, dorsally on the yolk, and laterally on the body behind the shoulder organ. In later yolk-sac larvae, pigment lines the mouth, branchial cavity, yolk, and peritoneum to the anus, rays are forming in dorsal and anal fins, and the full complement of principal caudal rays (10+9) is present. The head length increases from ca. 15–18% BL in the least developed yolk-sac specimens to ca. 30% BL by the time the yolk is absorbed, even though the body length changes little (10–16 mm). The eye is horizontally elongate, becoming more round in juveniles. Once the yolk sac is absorbed, development is direct. The top of the skull remains translucent through the early juvenile stage.

Young platytroctids resemble alepocephalids, which undergo similar larval development, and transitional and juvenile stages of some bathylagids, although both of these taxa lack the posteriorly directed shoulder tubule that is present even in early yolk-sac larval platytroctids. Matsui (1991) presented a key to the young platytroctids off California. The presence of a gular photophore (GO_2) separates the two most common species (*Holtbyrnia latifrons* and *Sagamichthys abei*) from all other species in our study area. *S. abei* has a light organ on the anterior dorsal margin of the eye (OO); this photophore is lacking on *H. latifrons*. *Maulisia argipalla* has a small photophore between the bases of the pelvic fin (IVO). *Pellisolus eubranchus* has its nasal sac nearly bordering the maxilla; whereas, on *Mirorictus taningi* the nasal sac is at the midlength of the snout; neither species has photophores.

In this study the yolk-sac stage is considered to last until the yolk sac is absorbed completely (ca. 13–15 mm), the postflexion stage persists until most pectoral fin rays have formed (ca. 30 mm), and the transitional stage persists until the full complement of fin rays is complete or until the beginning of scale formation, (ca. 50 mm). The following descriptions are based on detailed examinations of 4 yolk-sac larvae (12.2–13.5 mm), 6 postflexion larvae (13.0–26.2 mm), 3 transitional specimens (29.0–39.4 mm), and 3 juveniles (49.1–65.6 mm) of *Holtbyrnia latifrons*, and 5 yolk-sac larvae (14.8–16.0 mm), 6 postflexion larvae (16.0–27.0 mm), 3 transitional specimens (30.2–38.0 mm), and 3 juveniles (54.1–81.0 mm) of *Sagamichthys abei*. The comparative morphometry of young of the less common platytroctid species in our study area are presented in Table Platytroctidae 2. Meristic and ecological data were obtained primarily from Matsui and Rosenblatt (1987) and Matsui (1991).

Table Platytroctidae 1. Meristic characters for the platytroctid species in the California Current vicinity. All species have 10+9 principal caudal rays and 12–15+11–13 procurrent caudal rays.

	Vertebrae			Fin rays					
Species	Precaudal	Caudal	Total	Dorsal	Anal	P_1	P_2	Gill rakers	BrR
Holtbyrnia latifrons	26–29	20–21	46–50	17–20	14–16	16–20	8–9	7–9+18–21	8–9
Maulisia agripalla	25–27	19–22	46–47	17–20	15–17	18–19	7–8	7–8+16–18	8–9
Mirorictus taningi	22–26	19–22	43–46	15–20	14–17	16–20	7–9	4–6+12–15	6–7
Pellisolus eubranchus	20–23	20–22	42–44	17–19	15–16	18–21	6–8	5–6+17–18	6–8
Sagamichthys abei	30–31	19–21	50–52	16–18	14–16	14–18	9–10	7–8+16–18	8

Table Platytroctidae 2. Comparative morphometry of young of the less common platytrocids in the California Current region. Proportions are in percent with the range above the mean. The number of specimens examined are listed in parentheses.

Species	SL (mm)	Sn-A/BL	BD/BL	HL/BL	HW/HL	SnL/HL	ED/HL (horizontal)	ED/HL (vertical)	MaxL/HL	Developmental stage
Maulisia	20.0–28.0	67–69	15–15	35–36	43–46	24–27	25–27	19–19	40–50	postflexion (2)
agripalla	24.0	68	15	36	44	26	26	19	45	
	38.0	66	17	36	43	26	24	20	52	transitional (1)
	51.2	64	23	43	42	27	27	19	58	juvenile (1)
Mirorictus	20.0–28.5	64–65	16–17	33–39	48–50	23–28	27–31	19–22	40–49	postflexion (3)
taningi	24.8	64	17	36	49	25	29	21	44	
	40.0–43.0	62–64	18–19	33–35	45–48	21–21	28–28	22–22	35–38	transitional (2)
	41.5	63	19	34	46	21	28	22	37	
	52.0	63	21	36	51	21	31	24	40	juvenile (1)
Pellisolus	29.2–46.0	67–69	16–20	37–39	48–51	24–25	26–32	21–26	42–48	transitional (2)
eubranchus	37.6	68	18	38	50	24	29	23	45	
	58.4–71.0	61–63	19–19	32–35	45–48	21–23	30–33	26–27	41–43	juvenile (2)
	64.7	62	19	34	46	22	31	26	42	

MERISTICS

	Range	Mode
Vertebrae:		
Total	46–50	
Precaudal	26–29	
Caudal	20–21	
Fins:		
Dorsal spines	0	0
Dorsal rays	17–20	
Anal spines	0	0
Anal rays	14–16	
Pelvic	8–9	9
Pectoral	16–20	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–15	
Lower	11–13	
Gill rakers:		
Upper	7–9	
Lower	18–21	
Branchiostegals	8–9	8

LIFE HISTORY

Range: Coastal eastern Pacific from Washington (48° N) to Chile (23° S)

Habitat: Mesopelagic, 300–1000 m depth

Spawning season: Year-round

ELH pattern: Oviparous; large mesopelagic larvae

LITERATURE

Matsui 1991

* Eye elongate (horizontally); horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <ca. 12 mm
Flexion length: <ca. 12 mm
Transformation length: Adult counts on all fin by ca. 45 mm
Fin development sequence: C_1, D & A, P_2, C_2, P_1
Pigmentation: *Yolk-sac*—On eyes; shoulder organ; at site of posterior gular organ; posterior margin of opercle; dorsally on yolk sac; specks dorsally & ventrally on body margins. *Postflexion*—Heaviest along lateral midline of body & at base of D & A fins but lightly scattered over entire body; proximally on C. *Transition–juvenile*—Body dark brown.
Diagnostic features: Photophore or round melanophore in gular region; orbital organ (anteriodorsal eye photophore) & subopercular organ (photophore) absent; intraventral organ (photophore between pelvic fin bases) present near end of yolk-sac stage; opercular opening extending dorsally to top of eye.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	64–67 66			65–69 68	68–68 68	66–70 68
BD/BL	12–16 14			15–18 17	18–19 19	18–21 19
HL/BL	25–31 28			36–39 37	37–40 38	40–41 41
HW/HL	46–55 51			37–48 41	33–43 38	37–43 39
SnL/HL	24–28 27			23–27 25	23–27 25	21–24 23
ED/HL*	20–25× 13–18			24–26× 15–19	23–26× 19–21	22–23× 19–20
	23×15			24×17	25×20	23×20
P_1L/BL	1–2 2			2–4 3	4–4 4	4–6 5
P_2L/BL	0–2 0.8			0–7 5	6–8 7	8–13 11
MaxL/HL	33–45 39			36–43 39	45–49 47	49–50 50

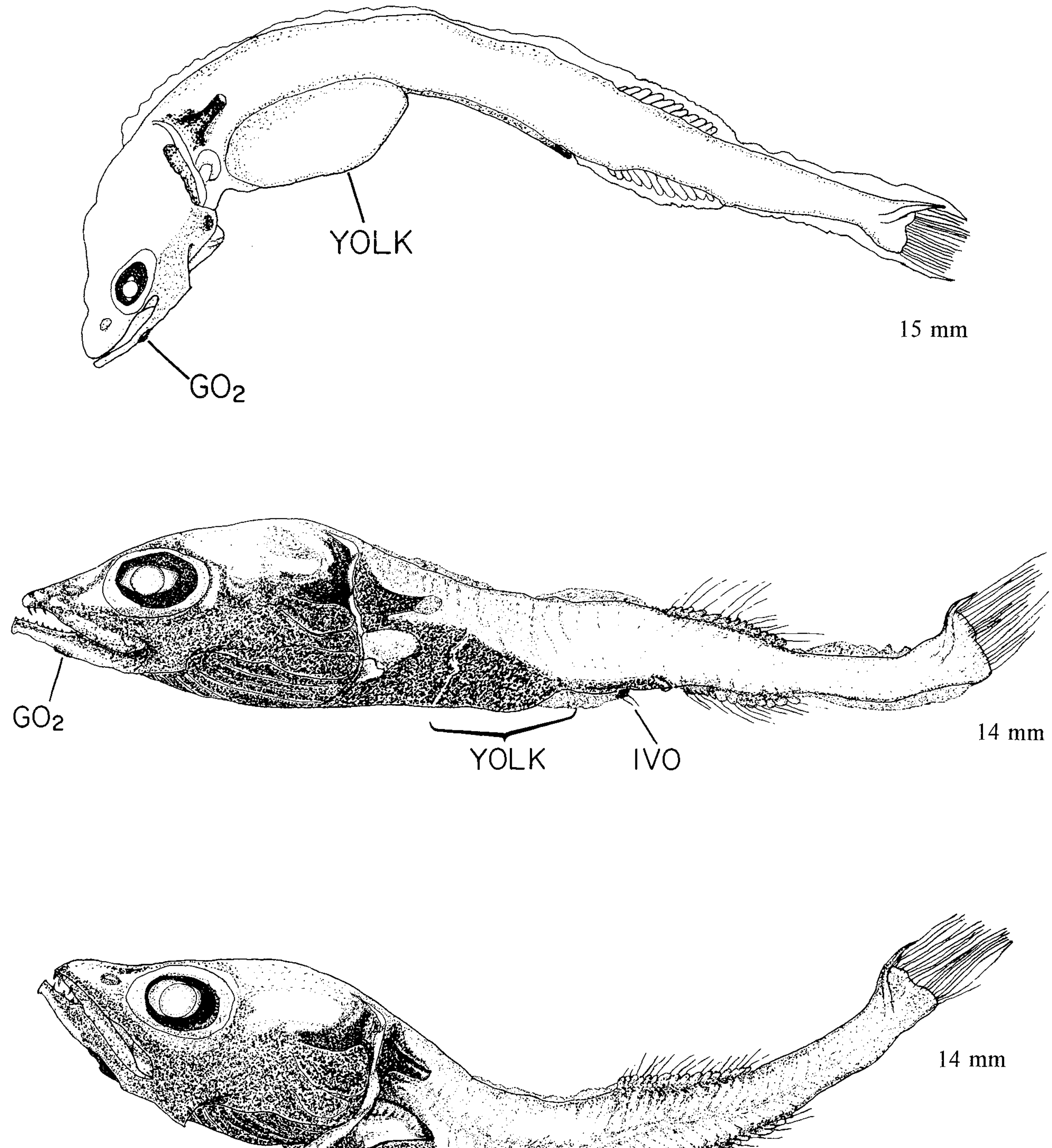


Figure Platytroctidae 1. Yolk-sac larvae, 15 mm, 14 mm; postflexion larva, 14 mm (Matsui 1991). GO_2 = posterior gular organ; IVO = intraventral organ.

MERISTICS

	Range	Mode
Vertebrae:		
Total	50–52	51
Precaudal	30–31	30
Caudal	19–21	21
Fins:		
Dorsal spines	0	0
Dorsal rays	16–18	17
Anal spines	0	0
Anal rays	14–16	15
Pelvic	9–10	9
Pectoral	14–18	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–15	
Lower	11–13	
Gill rakers:		
Upper	7–8	7
Lower	16–18	16
Branchiostegals	8	8

LIFE HISTORY

Range: Japan; in eastern Pacific coastally from British Columbia, Canada (ca. 52° N) to Baja California (ca. 27° N) & Peru (ca. 16° S) to Chile (ca. 39° S)

Habitat: Mesopelagic, 300–900 m depth

Spawning season: Year-round

ELH pattern: Oviparous; large mesopelagic larvae

LITERATURE

Matsui 1991

* Eye elongate (horizontally); horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <ca. 12 mm
Flexion length: <ca. 12 mm
Transformation length: Adult counts on all fins by ca. 32 mm
Fin development sequence: C_1, D & A, P_2, C_2, P_1
Pigmentation: *Yolk-sac*—On eye, shoulder organ, subopercular photophore, gular photophore, intraventral organ, dorsally on yolk sac, & in mouth & gill chamber; increasing internally on peritoneum & gut. *Postflexion*—On nostrils & lower jaw; dashed line along lateral midline between D & A, spreads laterally; internally between D & A, spreading anteriorly & later posteriorly. *Transition–juvenile*—Patch on hypurals & A base; body whitish blue.
Diagnostic features: *Yolk-sac to juvenile*—Photophore or melanophore in shape of photophore in gular region (GO_2); photophore & silvery reflector on anterior dorsal margin of eye (OO) & on subopercle (SBO); intraventral photophore (IVO) present; opercle opening extending dorsally to about mid-eye; body coloration whitish blue.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	65–68 67			66–69 68	67–71 69	66–70 68
BD/BL	13–16 14			13–18 15	15–17 16	18–19 18
HL/BL	24–29 27			27–34 32	33–37 35	34–37 36
HW/HL	46–52 49			38–48 44	39–42 41	42–43 42
SnL/HL	21–24 22			20–25 23	21–23 22	17–21 19
ED/HL*	26–34× 21–26 30×24			26–31× 22–25 28×24	26–31× 22–25 28×24	25–26× 24–25 26×25
P_1L/BL	2–5 3			1–4 2	4–4 4	4–6 5
P_2L/BL	1–3 2			2–7 5	6–9 7	7–9 8
MaxL/HL	34–46 39			36–43 41	44–50 47	48–54 51

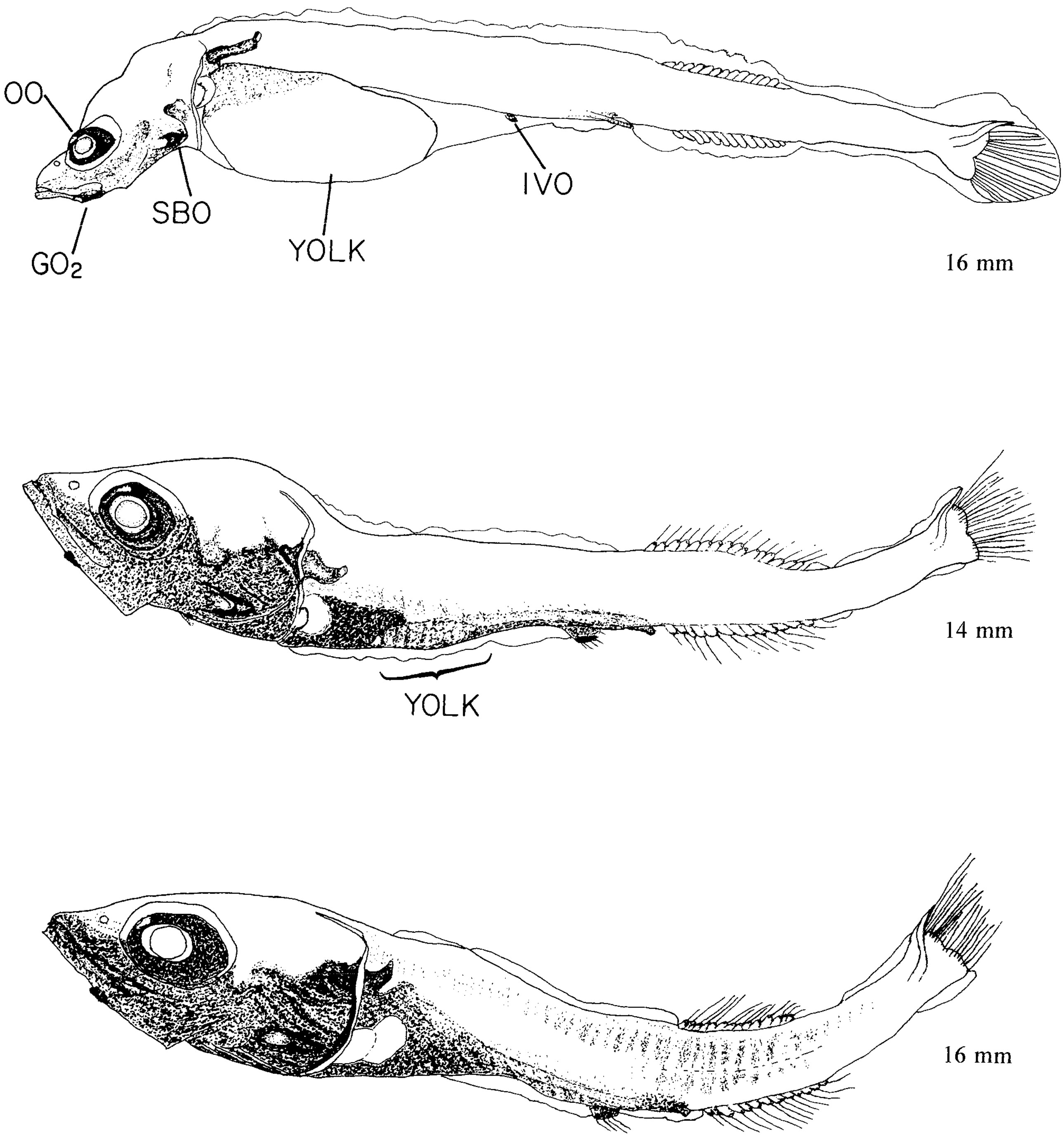


Figure Platytroctidae 2. Yolk-sac larvae, 16 mm, 14 mm; postflexion larva, 16 mm (Matsui 1991). OO = orbital organ; GO_2 = posterior gular organ; SBO = suborpercular organ; IVO = intraventral organ.

OSMERIDAE: Smelts

H. G. Moser

Osmerid smelts occur in shallow subarctic and temperate waters of the Northern Hemisphere, mostly in marine habitats, although some species are anadromous or landlocked in fresh water; a total of 13 species in 7 genera are recognized (Eschmeyer et al. 1983; Nelson 1994). Six species in four genera are reported from California (Miller and Lea 1972); however, three of these (*Hypomesus transpacificus*, *Thaleichthys pacificus*, *Spirinchus thaleichthys*) are anadromous and it is unlikely that their early larvae would occur in plankton samples from the CalCOFI sampling region. The marine species, *Hypomesus pretiosus*, *Spirinchus starksi*, and *Allosmerus elongatus*, range as far south as southern California but do not spawn south of central California.

Adults are medium-size (<40 cm), silvery fishes that usually school in shallow water. They have a short dorsal fin located at midbody, an adipose fin, and abdominal pelvic fins. Some species are highly regarded food fishes and provide recreational and commercial fisheries during spawning runs.

Hypomesus pretiosus, the surf smelt, spawns in the upper intertidal zone during the day. Eggs are attached to coarse sand grains and the species appears to select spawning beaches on the basis of sand grain size (Yapchiongo 1949; Hearne 1983). *Spirinchus starksi*, the night smelt, spawns nocturnally in the surf, and apparently selects beaches composed of coarse sand (Fitch and Lavenberg 1971; Hearne 1983). *Allosmerus elongatus*, the whitebait smelt is believed to be an ocean spawner. Osmerid eggs are 0.8–1.1 mm in diameter, adhesive, and have a characteristic double chorion and numerous oil globules (Hearne 1983, 1984; Matarese et al. 1989).

Osmerid larvae are slender, have an elongate gut, a depressed head, and a single series of melanophores along the ventral midline of the gut (Hearne 1983, 1984). Their larvae superficially resemble those of clupeoids but are easily distinguished on the basis of their body musculature, gut morphology, and ventral pigmentation. The myotomes of clupeoid larvae have a characteristic cross-hatched appearance caused by two layers of fibers that are aligned obliquely in opposite directions (O'Connell 1981), in contrast to the near-horizontal alignment in most other teleosts, including osmerids. The clupeoid hindgut has a much larger diameter than the foregut and has conspicuous transverse folds, while in osmerids the hindgut has only a slightly larger diameter than the foregut and inconspicuous transverse folds. In clupeoid larvae, the ventral midline melanophore series is limited to the hindgut region and consists of elongate dashes, often irregularly paired. In osmerids, the series consists of large single melanophores that often are located in the finfold below the foregut and hindgut.

There have been only 13 occurrences of osmerid larvae in CalCOFI ichthyoplankton surveys from 1981 to 1984; all but one were at nearshore stations between Pt. Reyes and Monterey Bay, California. The larvae (5.2–15.2 mm) appear to represent a single species. The total myomere count (71) of the largest specimen indicates that the series is *Hypomesus pretiosus*, since vertebral counts are lower in the other two species whose early larvae might occur at this distance from shore (Table Osmeridae 1). However, the melanophore pattern differs somewhat from that of *H. pretiosus* larvae described by Hearne (1983). His larvae have 13–21 preanal and 4–8 postanal ventral midline melanophores while CalCOFI larvae have 8–11 and 1–4, respectively. Also, about one-third of the CalCOFI specimens have one or two postanal dorsal midline melanophores, while Hearne (1983, 1984) stated that the lack of these melanophores is a diagnostic feature of osmerid larvae. Without a transformation series it is not possible to determine whether these differences are due to individual variation or to incorrect identification.

The following description of a partial larval series (yolk-sac through notochord flexion stages), tentatively identified as *Hypomesus pretiosus*, is based on detailed examination of 12 larvae (1 yolk-sac, 5.2 mm; 8 preflexion, 6.8–11.7 mm; 3 flexion, 13.0–15.2 mm) from the CalCOFI surveys. Meristic data were obtained from the literature (Miller and Lea 1972, Hearne 1983, Matarese et al. 1989) and from counts made during this study.

Table Osmeridae 1. Distributional ranges and meristic characters of the marine osmerid species that may be encountered in CalCOFI samples off Central California. All species have 10+9 principal caudal fin rays.

		Vertebrae			Fin rays			
Species	Range	PrCV	CV	Total	D	A	P_1	P_2
Allosmerus elongatus	Brit. Col.–S. Calif.	40–44	23–27	65–67	9–11	14–17	12–14	8
Hypomesus pretiosus	Bering Sea–S. Calif.	42–44	22–24	62–70	8–12	12–17	14–17	8
Spirinchus starksi	SE Alaska–S. Calif.	33–36	25–29	60–65	8–11	15–21	10–11	8

MERISTICS

	Range	Mode
Vertebrae:		
Total	62–70	66
Precaudal	42–44	43
Caudal	22–24	23
Fins:		
Dorsal spines	0	0
Dorsal rays	8–12	10
Anal spines	0	0
Anal rays	12–17	14
Pelvic	8	8–9
Pectoral	14–17	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–13	12
Lower	10–11	11
Gill rakers:		
Upper	10–13	
Lower	20–25	
Branchiostegals	7–8	

LIFE HISTORY

Range: Prince William Sound, Alaska, to Long Beach, California

Habitat: Marine, nearshore; sometimes entering freshwater

Spawning season: January–October; larvae occur in CalCOFI samples from January to May

ELH pattern: Oviparous with demersal eggs attached to coarse sand grains in upper intertidal zone; larvae are planktonic

LITERATURE

Hearne 1983, 1984
Matarese et al. 1989
Saruwatari & Okiyama 1988
Yapchiongo 1949

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.2 mm (N. Arthur)
Preflexion larvae, 8.3 mm, 11.2 mm (N. Arthur)
Flexion larva, 15.2 mm (N. Arthur)

* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

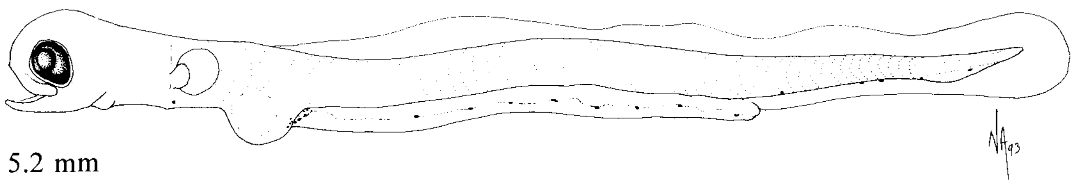
Shell diam.: 1.1 mm **Yolk:** Segmented
No. of OG: Numerous **Diam. of OG:**
Shell surface: Smooth
Pigment: Numerous melanophores on ventral region of yolk
Diagnostic features: Attachment disc; double chorion; multiple oil globules

LARVAE

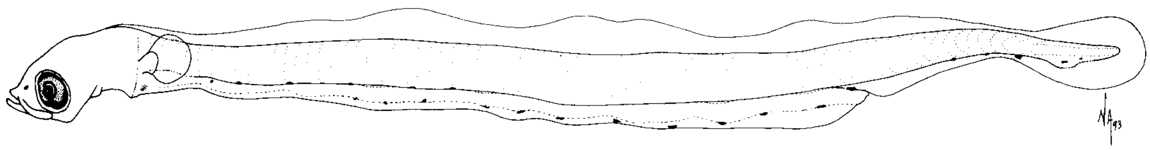
Hatching length: 3–4 mm
Flexion length: 13–15 mm
Transformation length: ca. 40 mm
Fin development sequence: C_1, A & D, P_1 & P_2
Pigmentation: *Yolk-sac*—Cluster on posterior surface of yolk sac; 9 on ventral midline below gut, some entering finfold; 4 on postanal ventral midline; 1 below notochord tip; lateral pair below P_1 base. *Preflexion–flexion*—8 to 11 on preanal ventral midline; 2–4 on postanal ventral midline; 1–4 below notochord tip; ca. one-third of larvae have 1–2 on postanal dorsal midline; lateral pairs between gut & trunk musculature increasing to 15–16 at end of flexion stage; lateral pair on terminal section of gut.
Diagnostic features: High total myomere count (65–68); number & arrangement of preanal ventral midline melanophores (lacking in clupeoid larvae); absence of diagonal muscle layers that are present in clupeoids.

MORPHOMETRICS (range & mean in %)

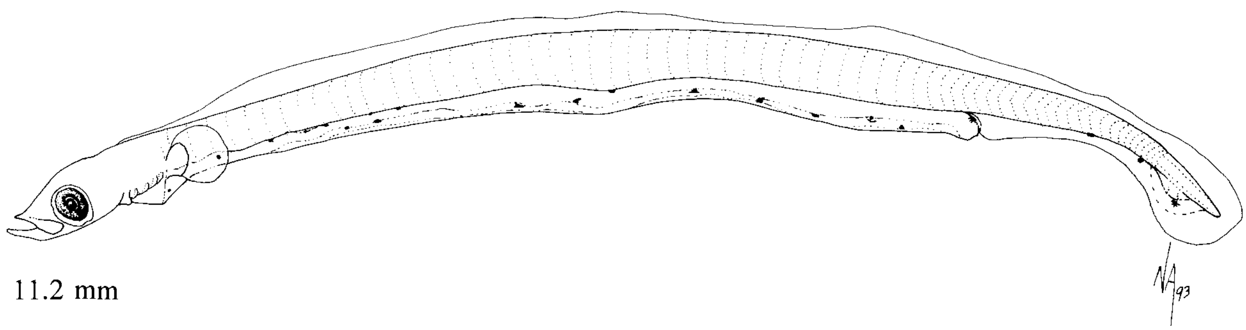
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		69–81	78–81			
	75	77	80			
BD/BL		5–6	6–6			
	8	6	6			
HL/BL		12–15	13–13			
	15	13	13			
HW/HL		53–63	55–59			
	63	60	57			
SnL/HL		14–23	20–22			
	20	18	21			
ED/HL*		17–23× 24–29	18–20× 23–34			
	28×30	20×27	19×27			
P_1L/BL		2–4	2–3			
	2	3	2			
P_2L/BL		0–0	0–0			
	0	0	0			



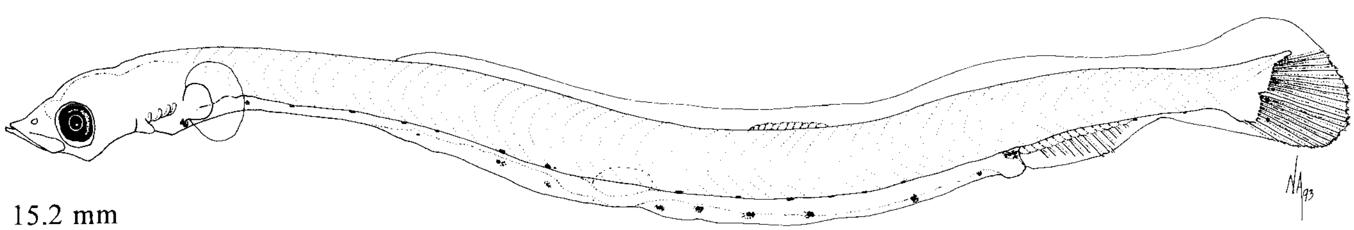
5.2 mm



8.3 mm



11.2 mm



15.2 mm

Figure Osmeridae 1. Yolk-sac larva, 5.2 mm (CalCOFI 6304, station 60.52); preflexion larvae, 8.3 mm, 11.2 mm; flexion larva, 15.2 mm (CalCOFI 7203, station 60.52).

STOMIIFORMES

H. G. Moser and W. Watson

Stomiiforms are small to medium-size fishes that inhabit the epi- to bathypelagic zones of all oceans. They are diverse (ca. 50 genera, >300 species), abundant, and constitute a major part of the oceanic ichthyofauna. Species of the genera *Cylothone* and *Vinciguerria* may be the most numerous vertebrates. Because of their morphological and phylogenetic richness and ecological importance they are one of the most extensively studied of all teleost groups. Monophyly of the order is based on unique photophore morphology, type of tooth attachment, specialization of the adductor mandibulae muscle, a posterior location of the rete mirabila on the swim bladder, a unique ligament connecting the ethmoid and the premaxilla, and several osteological specializations of the branchial region (Fink and Weitzman 1982).

Traditionally, stomiiforms were thought to consist of the lightfishes (Gonostomatidae), the hatchetfishes (Sternoptychidae), and the stomioid fishes, a group of larger midwater predators (dragonfishes, viperfishes, snaggletooths, and loosejaws) segregated into six families. Subsequent phylogenetic studies have altered traditional views of stomiiform relationships and have identified systematic problems at all taxonomic levels within the order. A stable classification has yet to be achieved (Weitzman 1967a, 1974; Fink and Weitzman 1982; Ahlstrom et al. 1984c; Fink 1984, 1985; Nelson 1994). Weitzman (1974) reduced the number of gonostomatid genera to six by placing some genera in the Sternoptychidae and some in a separate family, the Phosichthyidae. Fink (1984, 1985) based monophyly of stomioids on numerous characters including presence of a single infraorbital bone, lack of gill rakers in adults, presence of a mental barbel associated with the hyoid apparatus, a portion of the adductor mandibulae muscle inserting on the postorbital photophore and a divided geniohyoideus muscle. Since he could not demonstrate monophyly for the six traditional component families he combined them into a single family, the Stomiidae (Fink 1985). Eschmeyer (1990) retained the traditional arrangement of six stomioid families and we follow his classification in this guide.

Photophore arrangements are a valuable diagnostic tool in stomiiform identification. The nomenclature of photophores differs somewhat between the traditional lightfish, hatchetfish, and stomioid groups. These are shown in Figure Stomiiformes 1, and defined in Table Stomiiformes 1.

Families included:
- Gonostomatidae
- Sternoptychidae
- Phosichthyidae
- Chauliodontidae
- Stomiidae
- Astronesthidae
- Melanostomiidae
- Malacosteidae
- Idiacanthidae

Table Stomiiformes 1. Definitions of symbols used for designating photophore groups in stomiiform fishes (Ahlstrom et al. 1984c).

Deep bodied sternoptychids		Other stomiiforms	
Code	Definition	Code	Definition
SO	Subopercle photophore which is equivalent to posteriormost photophore in opercular series of gonostomatids.	SO	Symphyseal photophores (organs) located at tip of lower jaw.
PO	Photophore located anterior (pre) to orbit.	Orb	Photophores associated with the eye located anterior and posterior of orbit.
PTO	Photophore located posterior to orbit, may be equivalent to upper photophore of opercular series of gonostomatids.	Op	Photophores of opercle series, generally three coded as follows: 1/(1+1).
PRO	Preopercular photophore.	Br (BRP)	Photophores located on the branchiostegal membranes.
Br	Same as gonostomatid definition.	Is (I)	Photophores located on the isthmus.
Is	Same as gonostomatid definition.	IP	Photophores of the ventral series found from the isthmus to the base of the pectoral fin.
AB	Photophores of ventral series located abdominally between pectoral fin base and pelvic fin base and equivalent to PV in gonostomatids, plus a few posterior photophores of the IP series.	PV	Photophores of the ventral series found from the pectoral fin base to the pelvic (ventral) fin base.
PAN	Photophores found anterior (pre) to anal fin and may be equivalent to VAV or VA in gonostomatids.	VAV	Photophores of the ventral series found from the pelvic (ventral) fin base to the anal fin base.
AN	Photophores found above anal fin.	AC	Photophores of the ventral series found from the anal fin base to caudal fin base.
SC	Photophores found on lower (sub) caudal peduncle. Together with AN group may be equivalent to AC in gonostomatids.	IC	Summary of photophores of the ventral series from the isthmus to caudal fin base (IP+PV+VAV+AC).
SAB	Photophores located above (supra) to the abdominal series and may be equivalent to VAL in gonostomatids (SAB lacking in *Sternoptyx*).	IV	Summary of photophores of the ventral series from isthmus to pelvic (ventral) fin base (IP+PV).
SP	Photophores located above (supra) the pectoral fin and may be equivalent to OV in gonostomatids.	OV	Photophores of the lateral series from the opercle to pelvic (ventral) fin base.
L	Photophores located laterally above PAN (found only in *Polyipnus*).	VAL (VALA)	Photophores of the lateral series from the pelvic (ventral) fin base to the anal fin base.
		OA (OAA,OAB)	Summary of lateral photophores from the opercle to anal fin base (OV+VA).
		OAC (OC)	Entire lateral series on body just dorsal to ventral series and extending from opercular border, or just medial to it, over anal fin to caudal fin base.
		ODM	Photophores (organs) found dorsal to the lateral midline (found only in *Gonostoma gracile*).

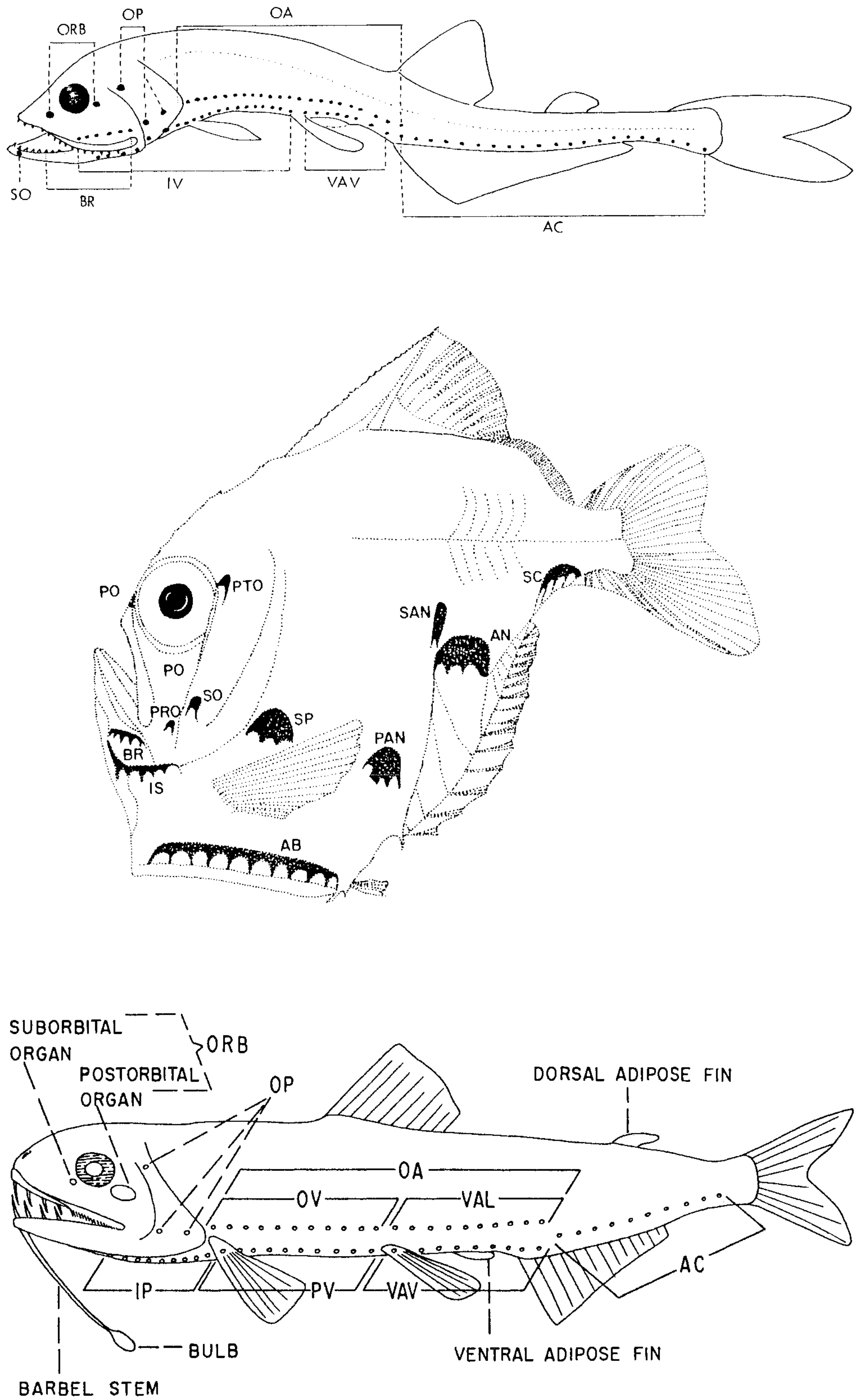


Figure Stomiiformes 1. Generalized photophore patterns and their terminologies for lightfishes (top; Fahay 1983), hatchetfishes (middle; modified from Badcock and Baird 1980), and stomioids (bottom; Morrow 1964a). The photophore groups are defined in Table Stomiiformes 1.

GONOSTOMATIDAE: Bristlemouths

W. WATSON

Eleven gonostomatid species occur in the CalCOFI area (Table Gonostomatidae 1), but only four (*Cyclothone acclinidens, C. signata, Diplophos taenia, Gonostoma atlanticum*) occur with any regularity in CalCOFI ichthyoplankton samples. Four others (*Cyclothone pseudopallida, Diplophos proximus, Gonostoma ebelingi, G. elongatum*) occur principally at southern, offshore CalCOFI stations; their distributions apparently are largely outside the CalCOFI area. Larval *Cyclothone alba, C. atraria* and *C. pallida* have not been recognized in CalCOFI ichthyoplankton samples, although small juveniles of the last two occasionally are taken.

Adult gonostomatids are small (usually ≤20 cm), elongate, moderately compressed, bioluminescent fishes that occur in the epi-, meso-, and bathypelagic zones. They closely resemble phosichthyids; the taxonomic status of these two families has not yet been entirely resolved.

Gonostomatids are oviparous (some are protandrous hermaphrodites, e.g., Fisher 1983; Miya and Nemoto 1985), with planktonic eggs and larvae; eggs have been described for *Gonostoma denudatum* (Sanzo 1931a), and planktonic larvae are known for six of the seven genera (e.g., Ahlstrom et al. 1984c; Ozawa and Oda 1986b). *Diplophos* hatches with unpigmented eyes, an elongate yolk sac, and without a functional mouth; presumably the other gonostomatid species hatch at a similar stage of development. Larvae of all species are elongate and slender, with a moderate to long preanal length (ca. 40–70% BL, depending on species). The gut trails only slightly, or more commonly, not at all. Eyes are slightly to strongly oval, depending on species, but become round, or nearly so, by transformation in most species. Larval pigment is absent or light; when present it occurs principally on the ventrum, swimbladder, and gut, except in *Diplophos* and *Manducus*, which display prominent dorsal melanophore series during part or all of larval development (e.g., Ahlstrom et al. 1984c; Ozawa and Oda 1986b; Smith et al. 1991). Photophores develop during transformation. These originate as "white photophores," with most or all of the photophores within each ventral series forming simultaneously. In *Cyclothone* the BR and VAV series form first, while in *Gonostoma* and *Diplophos* the OP_3 photophore is first (Table Gonostomatidae 2).

Although a good deal of literature exists concerning larval stages of the gonostomatids, especially *Cyclothone* and *Diplophos* (e.g., Mukhacheva 1964; Gorbunova 1982; Ahlstrom et al. 1984c; Ozawa and Oda 1986a,b), larval identities are not well known. *Cyclothone* species, especially, have been confused in the literature. The following species accounts are based on the literature (*Cyclothone atraria*) and on detailed examinations of 40 specimens of *C. acclinidens*, 10 *C. atraria*, 24 *C. pseudopallida*, 36 *C. signata*, 36 *Diplophos proximus*, 35 *D. taenia*, 37 *Gonostoma atlanticum*, 24 *G. ebelingi*, and 30 *G. elongatum* (Table Gonostomatidae 3). Ozawa and Oda (1986a) described and illustrated larvae which they identified as *C. alba* and *C. pallida*; those descriptions are not reproduced here. Meristic data were obtained from Kobayashi (1973), Fujii (1984a), Schaefer et al. (1986), Ozawa et al. (1990), Miya (1994), and counts made during this study. Myomere counts given under "Diagnostic features" in the following descriptions refer to counts made on the specimens examined in this study and may not reflect the full range for each species. Ecological information was obtained from a variety of literature sources including Grey (1964), DeWitt (1972), Kobayashi (1973), Clarke (1974), Miya and Nemoto (1985, 1991), and Ozawa et al. (1990).

Table Gonostomatidae 1. Selected meristic characters for the gonostomatid species that occur in the CalCOFI region. All species have 10+9 principal caudal fin rays.

Species	Vertebrae			Fin rays					GR
	PrCV	CV	Total	D	A	P_1	P_2	C_2	
Cyclothone acclinidens	13–14	17–19	30–32	13–15	18–20	8–10	6–7	6–7+5–6	6–9+12–17
C. alba	13	18–19	31–32	12–15	17–20	9–10	6–7	6+5–7	4+10–11
C. atraria	12–14	17–20	31–33	12–15	17–20	9–11	6–7	5–7+5–8	7–10+13–18
C. pallida	13–15	17–21	31–34	12–15	16–19	9–11	6–7	6–7+6–7	7–10+13–18
C. pseudopallida	12–14	17–21	29–34	12–15	17–21	9–10	6–7	6–7+6–7	4–7+11–14
C. signata	13	17–19	30–32	13–14	18–20	8–10	6	6–8+5–7	3–5+9–11
Diplophos proximus	36–39	48–55	85–93	9–11	54–62	9–10	8	3–5+3–5	3+9
D. taenia	37–41	52–59	89–99	10–11	59–72	8–10	7–8	3–6+3–4	3+7–9
Gonostoma atlanticum	18	20	38–39	16–18	26–31	9–11	6–8	7–8+6–7	6–7+11–12
G. ebelingi	19–20	23–27	43–46	12–14	26–29	9–13	8	10–12+7–10	8+11–12
G. elongatum	15–16	24–26	39–41	11–15	27–32	10–13	7–8	10–13+8–10	7–9+11–12

Table Gonostomatidae 2. Order of photophore group development (first appearance of photophores in each group) in some gonostomatids. Photophore groups are shown in Figure Stomiiformes 1 and defined in Table Stomiiformes 1; "&" indicates simultaneous development or insufficient specimens to determine sequence.

Species	Photophore group development sequence
Cyclothone acclinidens	BR & VAV & AC, ORB & IV, OP_1 & OP_3, OA
C. signata	BR & VAV & IV, ORB & OP_3 & AC, OA & OP_2
Diplophos proximus	OP_3 & AC, BR & IV, ORB & OP_2 & VAV, OP_1 & OA, SO & others
Gonostoma atlanticum	OP_3, IV, BR & VAV & AC, OP_2, OA, ORB & OP_1 & SO
G. ebelingi	OP_3, IV, BR, VAV & AC & ORB, OA, OP_1
G. elongatum	OP_3, IV, BR, VAV, AC, ORB & OP_1, OA & SO

Table Gonostomatidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the gonostomatid species descriptions. An "L" indicates literature used in the description. No eggs were available for any of the species.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Cyclothone acclinidens	0	10 4.3–5.8	6 5.0–5.9	10 5.7–13.7	9 12.8–21.7	5 23.4–32.8
C. atraria	0	0	0	L[a]	4 11.6–14.2	6 13.6–28.0
C. pseudopallida	0	0	3 5.3–5.7	11 6.0–16.7	5 16.4–20.2	5 22.2–36.8
C. signata	0	10 2.4–5.0	6 4.7–6.1	11 4.8–12.2	4 12.0–14.0	5 12.8–17.8
Diplophos proximus	5 3.3–5.7	10 6.5–18.6	5 18.4–21.6	9 25.3–42.9	2 37.6–39.1	5 45.1–56.6
D. taenia	5 3.4–6.3	10 5.9–19.4	6 19.2–27.3	7 28.4–43.0	3 30.6–41.2	4 44.6–61.8
Gonostoma atlanticum	0	10 3.5–5.4	5 4.5–6.0	12 4.7–14.6	5 17.6–20.7	5 21.9–30.1
G. ebelingi	0	7 3.4–4.6	1 7.0	10 5.2–16.0	2 15.4–16.9	4 16.1–32.7
G. elongatum	0	5 3.9–5.3	5 4.7–6.4	10 6.1–11.0	5 11.9–18.9	5 23.2–31.1

[a] Ozawa and Oda 1986a

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–32	31
Precaudal	13–14	14
Caudal	17–19	17
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14–15
Anal spines	0	0
Anal rays	18–20	19
Pelvic	6–7	6
Pectoral	8–10	9–10
Caudal:		
Principal	10+9	10+9
Procurrent		
Upper	6–7	6–7
Lower	5–6	6
Gill rakers:		
Upper	6–9	7
Lower	12–17	12–14
Branchiostegals	13–15	14

LIFE HISTORY

Range: Throughout CalCOFI region & worldwide in tropical to temperate waters

Habitat: Epi- & mesopelagic, at ca. 50–1900 m with maximum abundance ca. 400–800 m depth

Spawning season: Probably summer–fall, based on occurrence of small larvae

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Gorbunova 1982
Matarese et al. 1989
Olivar and Fortuño 1991
Ozawa & Oda 1986a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.8 mm (B. Sumida MacCall)
Flexion larva, 5.8 mm (B. Sumida MacCall)
Postflexion larvae, 10.0 mm, 13.7 mm (B. Sumida MacCall)
Juvenile, 21.1 mm (W. Watson)

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* Eye slightly oval; horizontal axis is given first, vertical axis second.

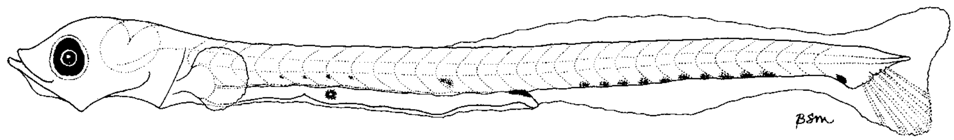
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

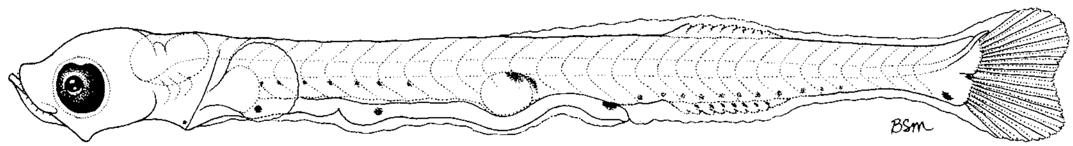
LARVAE
Hatching length:
Flexion length: ca. 5–6 mm
Transformation length: ca. 13–14 mm to ca. 22 mm
Fin development sequence: C_1, A, D & C_2, P_2, P_1
Pigmentation: *Preflexion–postflexion*—Pairs along sides of gut; over gas bladder; 4–9 on myosepta over gut after ca. 4 mm; 9–13 (usually 10–11) on ventral margin of tail from postanal myomere 1–3 (usually 2), gradually becoming internal; double row on A base; 1 under notochord tip/along parhypural; 0–1 at center of hypural margin; 0–1 over notochord tip; series over notochord beginning at myomere 28–30 at 6.5–7 mm, extending to myomere 12–15 by ca. 10 mm. *Transformation*—Between neural & haemal spines; on hypurals; on hindbrain; on margins of branchiostegal membranes; on D & A bases; external midlaterally beginning at ca. 15 mm.
Diagnostic features: Myoseptal pigment above gut; pigment over notochord beginning posteriorly after 6.5 mm, spreading forward to 2–3 melanophores past D origin by transformation; pigment ventrally on tail beginning at postanal myomere 0–2 (usually 1); 8 ceratobranchial gill rakers (by ca. 11 mm); 12–16 preanal myomeres (usually 15–16 before, 12–13 during transformation), 31–33 (usually 31–32) total myomeres.

MORPHOMETRICS (range & mean in %)

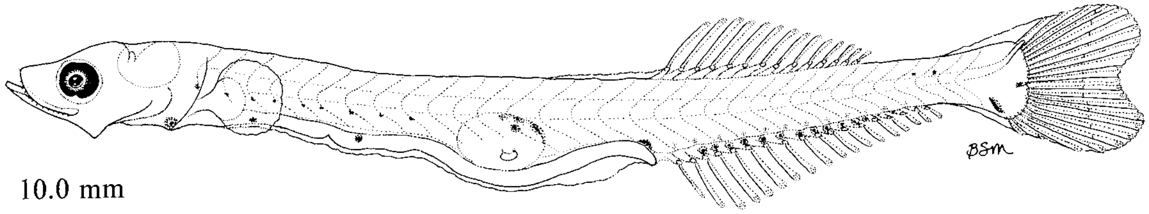
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		56–63 60	59–64 61	56–64 61	49–55 53	48–52 51
BD/BL		9–11 10	8–11 10	9–11 10	14–17 16	14–15 15
HL/BL		16–19 17	17–19 18	16–19 17	23–29 27	24–26 25
HW/HL		53–60 55	49–57 53	43–57 47	27–44 35	29–42 36
SnL/HL		18–23 21	17–23 21	20–24 22	14–20 17	14–19 16
ED/HL*		26–31× 28–32 29×30	24–30× 26–32 26×29	18–25× 18–26 21×22	7–9× 7–10 8×8	6–7× 7–8 7×7
P_1L/BL		3–5 4	3–4 4	2–4 3	12–18 15	9–13 12
P_2L/BL		0–0 0	0–0 0	0–2 0.4	10–19 13	8–11 10



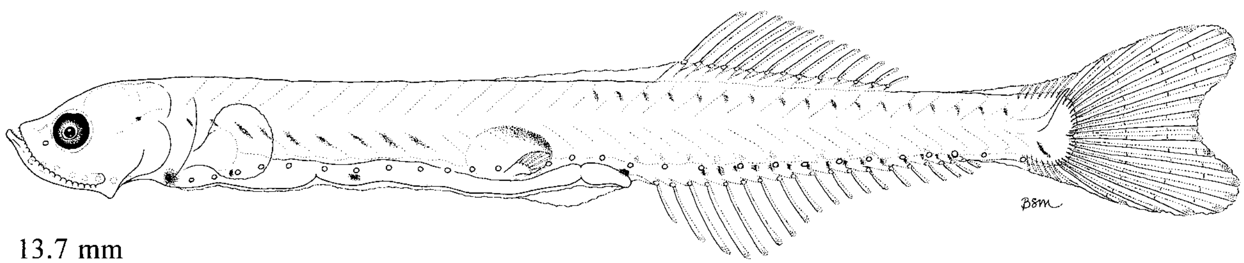
5.8 mm



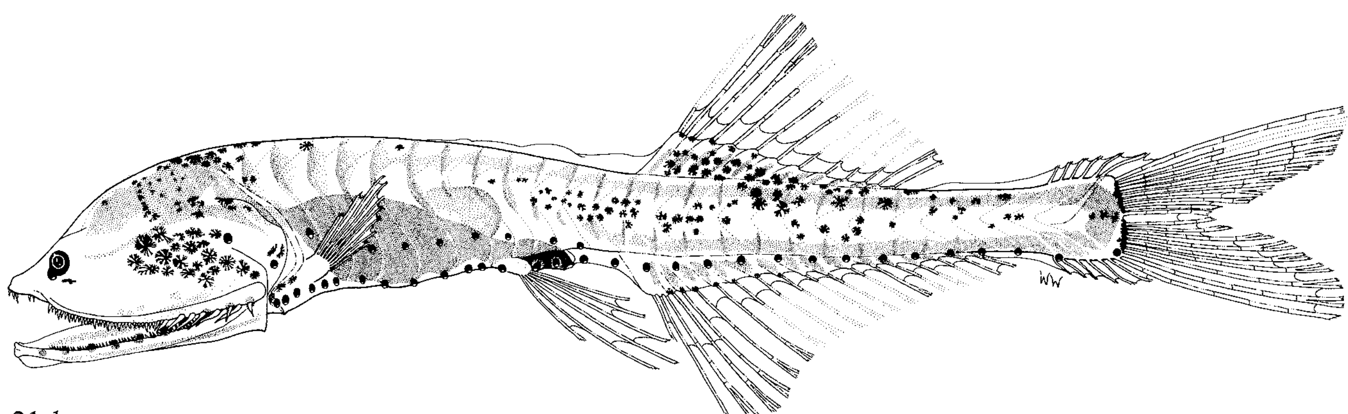
5.8 mm



10.0 mm



13.7 mm



21.1 mm

Figure Gonostomatidae 1. Late preflexion larva, 5.8 mm (CalCOFI 6210, station 103.80); flexion larva, 5.8 mm (CalCOFI 6610, station 123.50); postflexion larva, 10.0 mm (CalCOFI 6601, station 120.55); late postflexion larva, 13.7 mm (CalCOFI 6210, station 103.80); juvenile, 21.1 mm (CFRD 8701, station 78.3.54.5, deep bongo).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–33	32
Precaudal	12–14	14
Caudal	17–20	18
Fins:		
Dorsal spines	0	0
Dorsal rays	12–15	13–14
Anal spines	0	0
Anal rays	17–20	18–19
Pelvic	6–7	6
Pectoral	9–11	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–7	6–7
Lower	5–8	6
Gill rakers:		
Upper	7–10	7
Lower	13–18	13
Branchiostegals	12–14	12

LIFE HISTORY

Range: North Pacific Ocean

Habitat: Meso- and bathypelagic, at ca. 400 m to ≥2400 m depth

Spawning season:

ELH pattern: Protandrous hermaphroditism; oviparous with planktonic eggs & larvae

LITERATURE

Mukhacheva 1964
Miya & Nemoto 1991
Ozawa & Oda 1986a

ORIGINAL ILLUSTRATIONS (Illustrator)

Transformation specimen, 14.2 mm (W. Watson)

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* Hydrated ova: Miya & Nemoto 1991.
† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

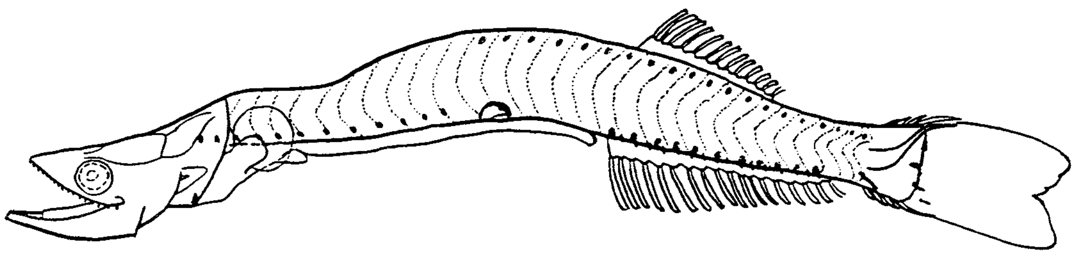
Shell diam.: 0.46–0.58 mm* **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

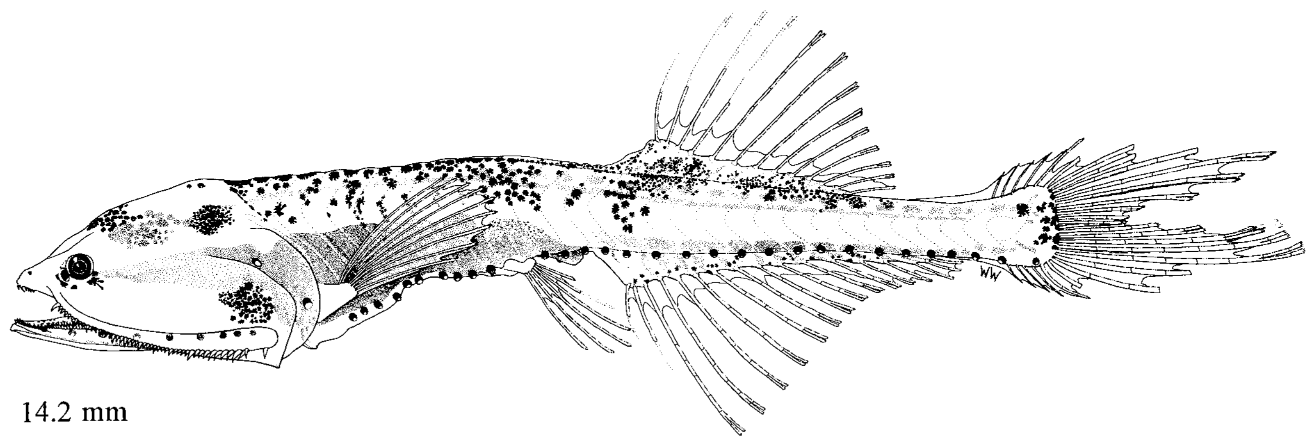
Hatching length:
Flexion length:
Transformation length: ca. 11.5–14 mm
Fin development sequence:
Pigmentation: *Postflexion*—At cleithral symphysis; pair along sides of gut anteriorly; over gas bladder; 1 over end of hindgut; 10 on myosepta above gut anteriorly; 11 internal, ventrally along tail; external on A ray bases; on parhypural; at center of hypural margin; over notochord, extending anteriorly to 6 melanophores past D origin. *Transformation*—Scattered over dorsal surface of head & upper half of body by 14 mm; along margins of branchiostegal membranes by ca. 11.5 mm, covering membranes by 14 mm. *Juvenile*—Black.
Diagnostic features: Myoseptal pigment above gut; pigment over notochord & 6–7 predorsal melanophores (Ozawa & Oda 1986a); 8–9 (usually 9) ceratobranchial gill rakers, present by at least 11.5 mm, probably sooner; transformation specimens with 13–14 (usually 14) preanal myomeres, 31–32 (usually 32) total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL					54–57 55	50–53 51
BD/BL					15–17 16	15–16 15
HL/BL					24–27 26	24–30 27
HW/HL					32–37 34	29–32 31
SnL/HL					14–18 16	14–17 16
ED/HL†					8–10× 8–10 9×10	7–8× 7–8 8×8
P_1L/BL					15–16 16	13–15 14
P_2L/BL					10–12 11	8–13 10



7.5 mm



14.2 mm

Figure Gonostomatidae 2. Postflexion larva, 7.5 mm (Ozawa and Oda 1986a); late transformation specimen, 14.2 mm (CFRD 9104, station 70.85, MOCNESS).

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–34	33
Precaudal	12–14	13
Caudal	17–21	20
Fins:		
Dorsal spines	0	0
Dorsal rays	12–15	13–14
Anal spines	0	0
Anal rays	17–21	19–20
Pelvic	6–7	6
Pectoral	9–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	6–7
Lower	6–7	7
Gill rakers:		
Upper	4–7	4
Lower	11–14	11
Branchiostegals	14	14

LIFE HISTORY

Range: Worldwide north of 30° S

Habitat: Meso- and bathypelagic, at ca. 300–1400 m depth

Spawning season: Postflexion larvae collected in most months with smallest specimens occurring May–October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Gorbunova 1982
Miya & Nemoto 1991
Olivar and Fortuño 1991
Ozawa & Oda 1986a

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 5.5 mm (W. Watson)
Postflexion larva, 10.8 mm (W. Watson)
Transformation specimen, 14.4 mm (W. Watson)
Juvenile, 21.1 mm (W. Watson)

* Hydrated ova: Miya & Nemoto 1991.
† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.48–0.58* **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5–6 mm
Transformation length: ca. 16.5–22 mm
Fin development sequence: C_1, D & A & C_2, P_2, P_1
Pigmentation: *Flexion–transformation*—1–2 pairs along sides of gut anteriorly; pair at cleithral symphysis; over gas bladder; over end of hindgut; 7–12 on myosepta above gut anteriorly, increasing to 10–12; 9–11 internally, ventrally along tail; externally on A ray bases; on parhypural; 1 at center of hypural margin; on lower C rays; on upper C rays after ca. 12 mm; over notochord tip in flexion larvae; over notochord beginning posteriorly, extending anteriorly to 8–11 melanophores past D origin by ca. 16.5 mm; on head in transformation specimens.
Diagnostic features: Myoseptal pigment above gut; pigment over notochord after 5.5 mm, up to 8–11 predorsal melanophores by transformation; pigment ventrally on tail beginning at postanal myomere 0–1 (usually 1) & on lower C rays; 7 ceratobranchial gill rakers (by 10–11 mm); preanal myomeres 12–18 (usually 16 before, 13 during transformation), 32–34 (usually 33) total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			62–62 62	59–72 63	48–58 51	47–52 49
BD/BL			9–9 9	7–10 9	9–17 13	12–13 12
HL/BL			18–19 18	15–20 18	16–27 23	21–23 22
HW/HL			42–54 49	37–51 44	26–30 27	27–34 29
SnL/HL			16–24 21	18–25 23	15–20 17	13–18 15
ED/HL†			24–25× 27–31 25×29	15–25× 16–26 20×21	7–8× 8–9 7×9	6–7× 7–8 7×8
P_1L/BL			4–4 4	2–3 3	3–14 11	11–12 11
P_2L/BL			0–0 0	0–1 0.3	2–14 10	10–12 11

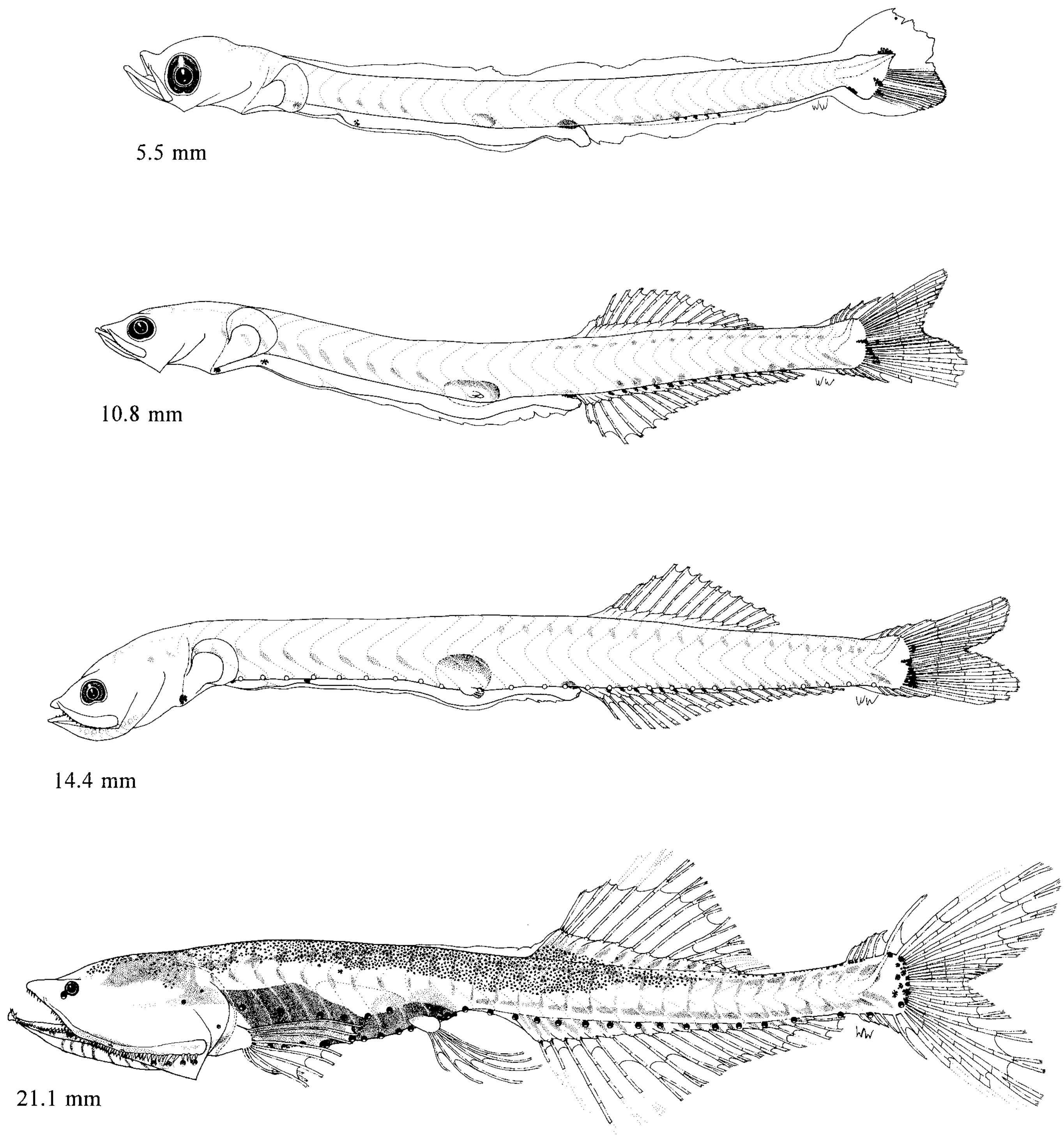


Figure Gonostomatidae 3. Flexion larva, 5.5 mm (CalCOFI 7210, station 20.90); postflexion larva, 10.8 mm (CalCOFI 7210, station 39.141); early transformation specimen, 14.4 mm (FRONTS 85, station 15, tow 1); juvenile, composite of 21.0 mm (head, anterior part of gut, some OA and IV photophores) and 21.1 mm (remainder of fish) specimens (CFRD 9104, MOCNESS; 21.0 mm specimen from station 66.7.90, 21.1 mm specimen from station 70.80).

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–32	31
Precaudal	13	13
Caudal	17–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	13–14	13–14
Anal spines	0	0
Anal rays	18–20	19–20
Pelvic	6	6
Pectoral	8–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	6
Lower	5–7	6
Gill rakers:		
Upper	3–5	3–4
Lower	9–11	9
Branchiostegals	12–14	13

LIFE HISTORY

Range: Eastern & central Pacific; throughout CalCOFI region

Habitat: Epi- & mesopelagic, usually in upper 800 m depth with abundance maxima in upper 100 m & 400–500 m

Spawning season: Possibly summer–fall, or year-round with summer–fall maximum

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom et al. 1984c
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.0 mm (B. Sumida MacCall)
Flexion larva, 5.2 mm (B. Sumida MacCall)
Postflexion larva, 9.2 mm (H. M. Orr)
Transformation specimen, 13.4 mm (H. M. Orr)
Juvenile, 13.3 mm (B. Sumida MacCall)

* Eye oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.4 mm
Flexion length: ca. 5–6 mm
Transformation length: ca. 12–14 mm
Fin development sequence: C_1, A, C_2, D, P_2, P_1
Pigmentation: *Preflexion–flexion*—2–4 pairs along gut; over gas bladder (>4.5 mm), 5–10 (usually 6) on ventral margin of tail beginning at postanal myomere 3–5, usually a gap in middle of series (gap present in 75%); 1 under notochord tip, becomes situated along parhypural. *Postflexion–transformation*—Gut pairs increase to 6–8; tail series increases to 7–12 beginning at postanal myomere 2–4 (usually 3), gap present in 50%; double row along middle of A base (>ca. 8 mm); under hindbrain (>10.5 mm); over vertebral column, beginning posteriorly (>11.5 mm); on stomach (≥12.5 mm).
Diagnostic features: No myoseptal pigment above gut; no pigment over notochord until end of postflexion stage; first 1–3 (usually 2) postanal myomeres unpigmented; usually a gap in middle of ventral tail series; eyes usually distinctly oval; 13–15 (usually 14–15) preanal myomeres, 30–32 (usually 31) total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–61 56	55–59 57	53–61 58	48–51 50	44–48 46
BD/BL		8–10 9	9–11 10	10–12 11	12–14 13	15–16 15
HL/BL		14–17 16	15–18 17	14–19 18	22–23 22	23–27 26
HW/HL		50–68 58	54–59 57	40–64 50	34–41 36	32–42 35
SnL/HL		14–26 20	18–27 21	20–26 23	17–18 17	16–18 17
ED/HL*		27–37× 29–42 30×36	27–29× 32–37 28×34	16–30× 19–34 24×27	10–11× 11–12 11×11	8× 9–10 8×9
P_1L/BL		4–5 5	4–5 4	2–5 3	7–11 9	14–16 15
P_2L/BL		0–0 0	0–0 0	0–2 1	8–9 8	10–13 12

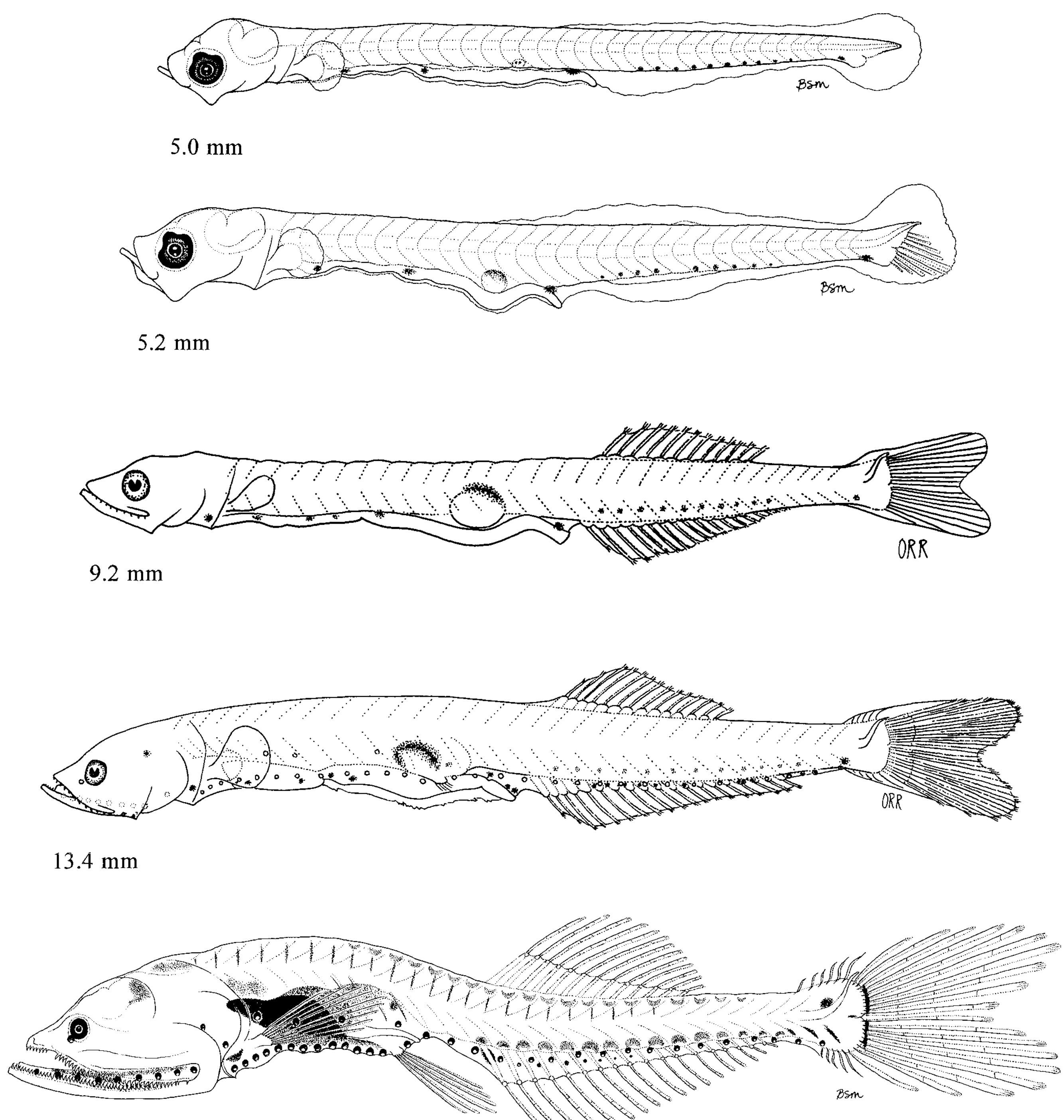


Figure Gonostomatidae 4. Preflexion larva, 5.0 mm (CalCOFI 6609, station 97.55); flexion larva, 5.2 mm (CalCOFI 6609, station 110.50); postflexion larva, 9.2 mm (CalCOFI 7210, station 100.90); late postflexion larva, 13.4 mm (CalCOFI 6608, station 123.40); juvenile, 13.3 mm (CFRD 8701, station 78.2.54.6, MOCNESS).

MERISTICS

	Range	Mode
Vertebrae:		
Total	85–93	86–88
Precaudal	36–39	36–38
Caudal	48–55	49–52
Fins:		
Dorsal spines	0	0
Dorsal rays	9–11	10
Anal spines	0	0
Anal rays	54–62	57–59
Pelvic	8	8
Pectoral	9–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	3–5	4
Lower	3–5	4
Gill rakers:		
Upper	3	3
Lower	9	9
Branchiostegals		

LIFE HISTORY

Range: Eastern tropical Pacific to southern California; uncommon north of southern Baja California

Habitat: Epi- & mesopelagic

Spawning season: Larvae collected principally from October–February

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.1 mm (W. Watson)
Preflexion larva, 7.1 mm (W. Watson)
Flexion larva, 19.2 mm (W. Watson)
Postflexion larva, 48.1 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

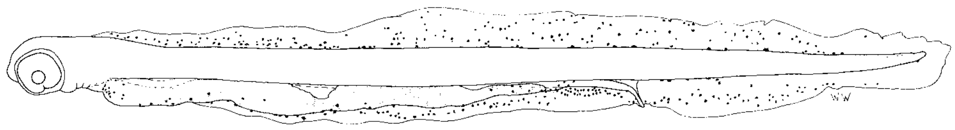
EGGS
- **Shell diam.:**
- **Yolk:**
- **No. of OG:**
- **Diam. of OG:**
- **Shell surface:**
- **Pigment:**
- **Diagnostic features:**

LARVAE
- **Hatching length:** <4.9 mm
- **Flexion length:** ca. 18–19 mm through ca. 22 mm
- **Transformation length:** ca. 38–43 mm*
- **Fin development sequence:** C_1, A, D, C_2, P_2, P_1
- **Pigmentation:** *Yolk-sac*—Many in median finfold, migrating to dorsal & ventral body margins & aggregating into patches. *Preflexion–postflexion*—Patches condense to single melanophores: 14–23 dorsally, 8–15 ventrally on tail, numbers increase with size; 10–17 over gut; 2–3 on isthmus; 1 under hindbrain; on C by 18–19 mm; on inner surface of P_1 base by ca. 22 mm; on mandible by ca. 35 mm; over hindbrain by ca. 39 mm. *Transformation*—Upper half becomes pigmented.
- **Diagnostic features:** Very elongate & slender; relatively large size at flexion & transformation stages; dorsal & ventral series of large melanophores or pigment patches, usually 14–20 dorsally, 11–12 ventrally (on tail), during most of larval development; 40–48 (usually 42–43) preanal myomeres, 85–91 (usually 87–89) total myomeres.

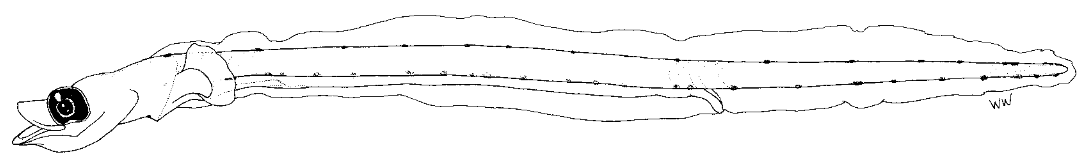
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	66–68 67	61–72 67	60–63 62	56–61 59	49–53 51	48–49 48
BD/BL	5–8 6	4–6 5	4–5 4	4–6 4	8–8 8	7–9 8
HL/BL	11–17 13	12–17 15	11–14 13	10–13 11	15–15 15	14–15 14
HW/HL	36–53 44	32–43 37	31–35 32	26–30 28	31–34 32	26–39 32
SnL/HL	4–18 9	19–33 26	31–35 33	32–37 35	34–36 35	30–34 32
ED/HL†	33–45× 22–38 41×30	15–26× 16–26 21×20	11–17× 13–17 15×15	11–15× 11–14 12×13	13–13× 13–14 13×13	15–16× 15–16 16×15
P_1L/BL	0–3 1	2–3 3	2–2 2	1–3 2	5–9 7	 10‡
P_2L/BL	0–0 0	0–0 0	0–0 0	0–3 1	5–6 5	5–8 7

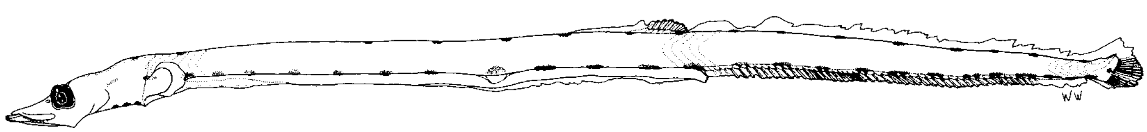
* Larvae shrink during transformation.
† Eye initially oval, becoming nearly round by transformation; "horizontal" axis given first, "vertical" second (long axis of eye typically inclined slightly from true vertical).
‡ Pectoral fin rays broken in all but one juvenile specimen.



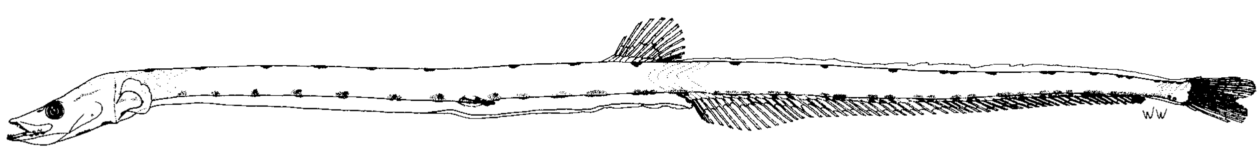
5.1 mm



7.1 mm



19.2 mm



48.1 mm

Figure Gonostomatidae 5. Yolk-sac larva, 5.1 mm (CalCOFI 6001, station 147.50); preflexion larva, 7.1 mm (IATTC Mazatlán Project 4–8–0); flexion larva, 19.2 mm (EASTROPAC II, station 45.379); postflexion larva, 48.1 mm (EASTROPAC I, station MZ 8.9). The fine transverse folds along the hindgut are not shown in these illustrations.

MERISTICS

	Range	Mode
Vertebrae:		
Total	89–99	93–98
Precaudal	37–41	38–40
Caudal	52–59	55–57
Fins:		
Dorsal spines	0	0
Dorsal rays	10–11	11
Anal spines	0	0
Anal rays	59–72	63–66
Pelvic	7–8	8
Pectoral	8–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	3–6	4
Lower	3–4	3–4
Gill rakers:		
Upper	3	3
Lower	7–9	9
Branchiostegals	12–14	13

LIFE HISTORY

Range: Cosmopolitan, from ca. 40° N to 30° S except not in eastern tropical Pacific

Habitat: Epi- & mesopelagic, in upper 100 m at night & at ca. 450–610 m depth during the day

Spawning season: Perhaps year-round based on larval occurrence; highest catches October–November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984c
Grey 1964
Jespersen 1934
Jespersen & Tåning 1919
Ozawa & Oda 1986b
Rudometkina 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.1 mm (W. Watson)
Preflexion larva, 17.2 mm (W. Watson)
Flexion larva, 21.5 mm (W. Watson)
Postflexion larva, 43.0 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

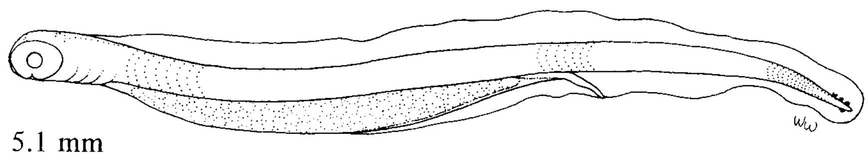
LARVAE

Hatching length: ca. 3.5–5 mm
Flexion length: ca. 19–19.5 mm through ca. 27.5–28 mm
Transformation length: ca. 43 through 30 mm*
Fin development sequence: C_1, A, D, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Apparently limited to end of notochord. *Preflexion–postflexion*—Initially nearly continuous double rows on dorsal & ventral margins of tail, condensing into ca. 20–40 dorsal & 9–22 ventral (tail) melanophores or pigment patches; 11–20 pairs over gut; 1–4 on isthmus after ca. 8 mm; ventrolaterally on hindbrain at ca. 17–20 mm; on mandible by ca. 39 mm; decreasing on notochord tip after ca. 19 mm. *Transformation*—Increasing on entire dorsal surface & along lateral midline.
Diagnostic features: Very elongate & slender; large size at flexion & transformation stages; dorsal & ventral series of melanophores or pigment patches, usually 25–35 dorsal, 15–17 ventral (on tail), during most of larval development; 43–50 (usually 47) preanal myomeres, 89–98 (usually 91–95) total myomeres.

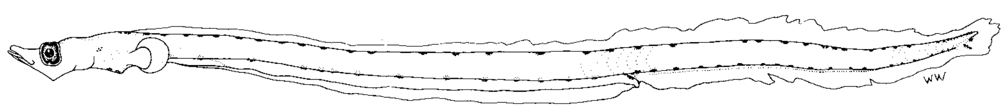
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	63–70 67	62–69 66	60–67 63	57–61 59	49–52 51	47–51 49
BD/BL	5–8 6	4–7 5	4–5 4	4–4 4	7–9 8	7–9 8
HL/BL	14–17 15	11–18 14	11–13 12	10–13 11	16–17 17	14–16 15
HW/HL	31–42 39	29–44 33	28–32 30	25–30 27	22–27 25	22–23 23
SnL/HL	2–12 5	20–28 24	30–38 34	33–37 35	32–35 33	30–33 32
ED/HL†	27–48× 21–31 38×26	16–30× 18–27 29×24	14–17× 16–18 15×16	11–14× 12–14 12×13	11–13× 9–15 12×12	12–16× 11–16 14×14
P_1L/BL	0–2 1	2–4 2	1–2 2	2–2 2	5–6 6	‡
P_2L/BL	0–0 0	0–0 0	0–0 0	0–1 0.3	5–5 5	5–5 5

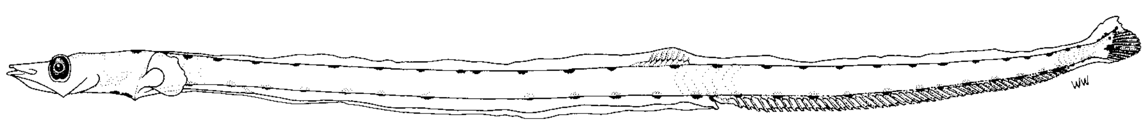
* Larvae shrink during transformation.
† Eye initially oval, becoming nearly round in postflexion; "horizontal" axis given first, "vertical" second (long axis of eye typically inclined slightly from true vertical).
‡ Pectoral fin rays broken in all juvenile specimens examined.



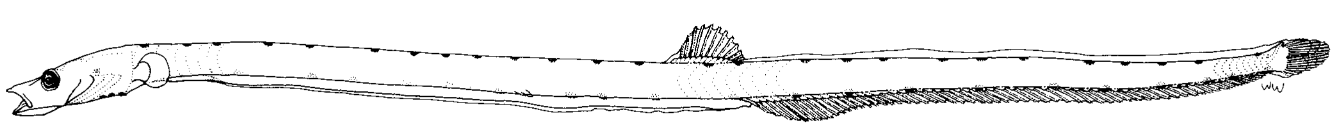
5.1 mm



17.2 mm



21.5 mm



43.0 mm

Figure Gonostomatidae 6. Yolk-sac larva, 5.1 mm (CalCOFI 5908, station 100.85); preflexion larva, 17.2 mm (CalCOFI 5910, station 107.70); flexion larva, 21.5 mm (CalCOFI 6010, station 120.80); postflexion larva, 43.0 mm (CalCOFI 7205, station 20.141). The fine transverse folds along the hindgut are not shown in these illustrations.

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–39	38
Precaudal	18	18
Caudal	20	20
Fins:		
Dorsal spines	0	0
Dorsal rays	16–18	17
Anal spines	0	0
Anal rays	26–31	28–30
Pelvic	6–8	7
Pectoral	9–11	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–8	7–8
Lower	6–7	7
Gill rakers:		
Upper	6–7	
Lower	11–12	11
Branchiostegals	11–12	

LIFE HISTORY

Range: Worldwide; in CalCOFI area, well offshore from Oregon, California, & Baja California

Habitat: Meso- & bathypelagic, at ca. 100–2500 m depth; primarily 150–300 m at night & 490–560 m during the day

Spawning season: Larvae collected in most months with smallest larvae occurring primarily May–October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom et al. 1984c
Ozawa 1986a, 1988a
Rudometkina 1980

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.4 mm (B. Sumida MacCall)
Flexion larva, 6.0 mm (B. Sumida MacCall)
Transformation specimen, 19.8 mm (W. Watson)

* Eye initially oval, becoming round during transformation; horizontal (narrow) axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

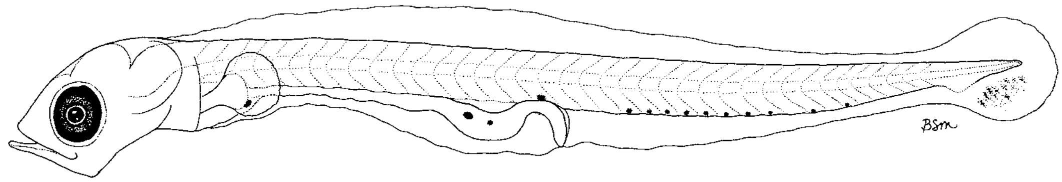
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

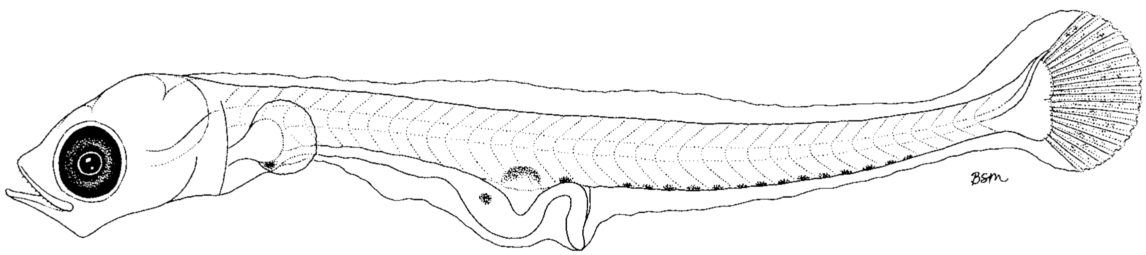
Hatching length: <3.5 mm
Flexion length: ca. 4.5–6 mm
Transformation length: >14.8 mm, <17.6 mm to ca. 21 mm
Fin development sequence: C_1, A & C_2, D, P_1 & P_2
Pigmentation: *Preflexion–flexion*—Series of 5–13 along ventral margin of tail; sparse ventrally on caudal finfold; over gas bladder after ca. 4 mm; pair along sides of gut just behind P_1; present or absent on hindgut loop. *Postflexion–transformation*—17–18 in ventral tail series; double row forms along A base; row along each side of gut from P_1 to hindgut; increasing over entire gut area during transformation; few on caudal peduncle near hypural edges; pair anteriorly on midbrain by ca. 6–7 mm; on hindbrain by ca. 11.5 mm; increases on head.
Diagnostic features: 17–19 preanal myomeres (usually 17–18), 37–40 total myomeres (usually 38); characteristic loop in hindgut below prominent gas bladder; preanal length usually 55–60% BL; oval eye; pigment on ventral margin of tail, dorsally on gas bladder, & laterally on gut; no internal parhypural pigment.

MORPHOMETRICS (range & mean in %)

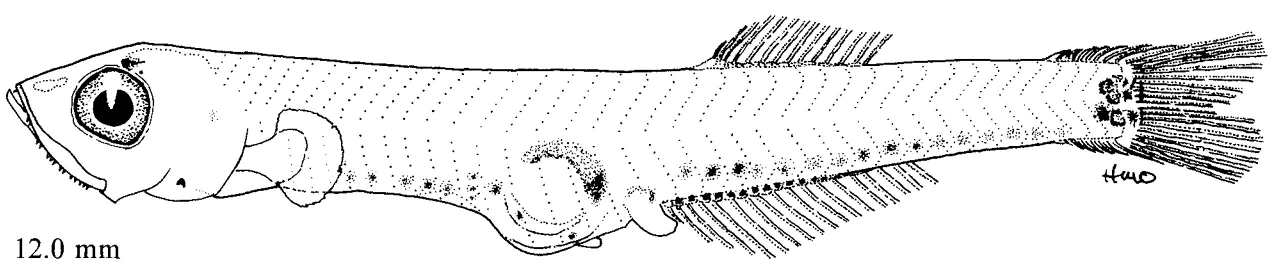
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		55–61 58	56–63 59	54–60 56	55–58 56	53–56 55
BD/BL		8–11 10	10–12 11	11–14 12	14–16 15	17–20 19
HL/BL		17–22 20	19–23 21	19–25 21	21–23 22	23–26 25
HW/HL		46–58 51	47–54 50	37–50 43	32–37 35	32–43 35
SnL/HL		18–31 22	20–27 23	17–29 24	24–27 26	18–22 21
ED/HL*		28–33× 31–43	30–33× 34–37	25–32× 29–37	22–26× 23–28	18–20× 18–20
		31×37	32×36	29×33	25×25	19×19
P_1L/BL		3–6 4	4–5 5	4–5 5	3–4 4	9–12 11
P_2L/BL		0 0	0 0	0–2 0.2	4–5 4	5–7 7



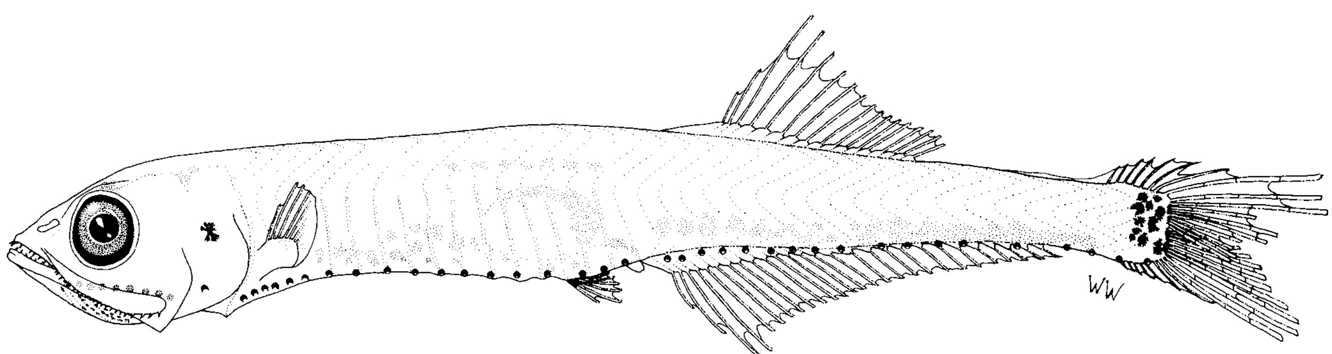
5.4 mm



6.0 mm



12.0 mm



19.8 mm

Figure Gonostomatidae 7. Preflexion larva, 5.4 mm (CalCOFI 7205, station 24.137); flexion larva, 6.0 mm (CalCOFI 6912, station 113.80); postflexion larva, 12.0 mm (Ahlstrom 1974); transformation specimen, 19.8 mm (SIO 73–160).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–46	44–45
Precaudal	19–20	19–20
Caudal	23–27	24–26
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	
Anal rays	26–29	27–28
Pelvic	8	8
Pectoral	9–13	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–12	11
Lower	7–10	8
Gill rakers:		
Upper	8	8
Lower	11–12	12
Branchiostegals		

LIFE HISTORY

Range: Pacific Ocean in warm water; in CalCOFI area, well offshore from California & Baja California

Habitat: Mesopelagic, primarily at ca. 125–300 m depth at night & 520–700 m during the day

Spawning season: Larvae collected primarily April–October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom et al. 1984c

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.5 mm (B. Sumida MacCall)
Flexion larva, 7.0 mm (W. Watson)
Juvenile, 21.0 mm (R. C. Walker)

* Eye moderately narrow; narrow axis is given first, long axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.4 mm
Flexion length: >4.6 mm, ≤5.2–7 mm
Transformation length: ca. 15–16 mm
Fin development sequence: C_1, D & A, C_2, P_1 & P_2
Pigmentation: *Preflexion*—None. *Postflexion*—Initially over gas bladder only; ventrolaterally on hindbrain at ca. 6.5 mm. *Transformation*—Stomach completely pigmented by 15.4 mm; anteriorly over gut area, extends farther around gas bladder.
Diagnostic features: 15–19 preanal myomeres (usually 16), 42–45 total myomeres (usually 44–45); usually 6–7 myomeres between anus & A origin; preanal length usually ca. 47–50% BL; moderately narrow eye before transformation; pigment largely restricted to gas bladder & hindbrain before transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		39–53		44–56	46–56	49–54
		48	51	48	51	52
BD/BL		8–12		10–14	13–16	15–18
		11	10	12	14	16
HL/BL		21–25		17–24	19–22	22–24
		23	20	20	21	23
HW/HL		46–53		38–48	35–42	29–46
		49	42	42	38	39
SnL/HL		18–29		19–26	23–26	19–28
		25	24	22	25	21
ED/HL*		22–27×		22–28×	19–20×	14–19×
		38–41		28–40	26–27	15–24
		25×40	23×31	23×33	19×26	17×20
P_1L/BL		4–7		4–6	5–6	7–21
		5	5	5	6	11
P_2L/BL		0–0		0–3	2–6	7–14
		0	0	1	4	9

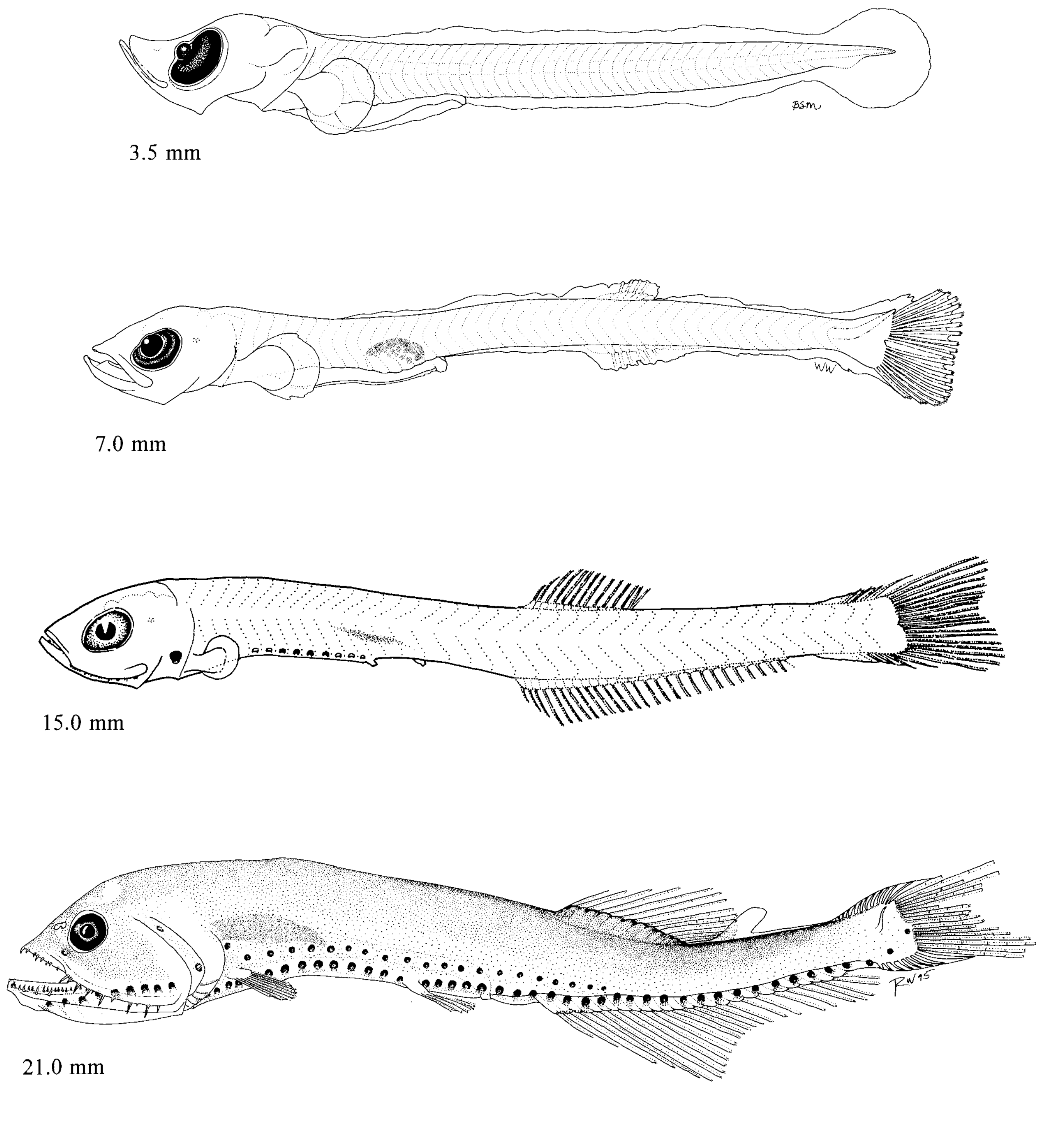


Figure Gonostomatidae 8. Preflexion larva, 3.5 mm (TC 8406, station 191, Tucker trawl); late flexion larva, 7.0 mm (CalCOFI 7205, station 27.145); early transformation specimen, 15.0 mm (Ahlstrom 1974); juvenile, 21.0 mm (TC 8406, station 192, Tucker trawl).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	40–41
Precaudal	15–16	16
Caudal	24–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	11–15	12
Anal spines	0	0
Anal rays	27–32	28
Pelvic	7–8	8
Pectoral	10–13	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–13	11
Lower	8–10	8
Gill rakers:		
Upper	7–9	
Lower	11–12	
Branchiostegals	12–13	

LIFE HISTORY

Range: Worldwide; in CalCOFI area, well offshore from California & Baja California

Habitat: Meso- & bathypelagic, at ca. 60–265 m depth at night and ≥500 m during the day

Spawning season:

ELH pattern: Protandric hermaphroditism; oviparous with planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom et al. 1984c
Grey 1964
Jespersen & Tåning 1919, 1926
Ozawa 1986a, 1988a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.6 mm (B. Sumida MacCall)
Flexion larva, 4.7 mm (W. Watson)

* Eye oval, becoming nearly round by the end of transformation; horizontal (narrow) axis is given first, vertical axis second.

LIFE HISTORY DESCRIPTION

EGGS

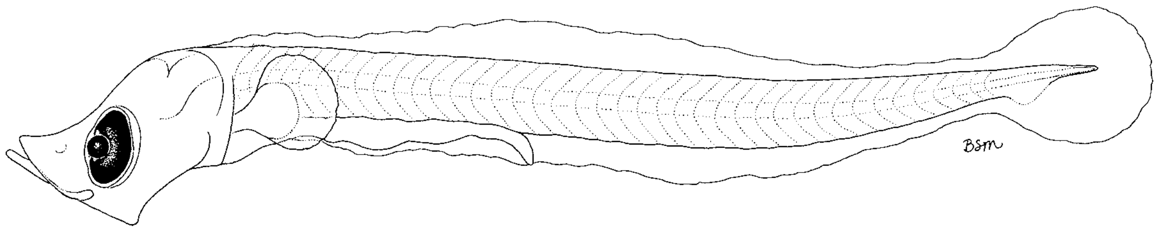
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

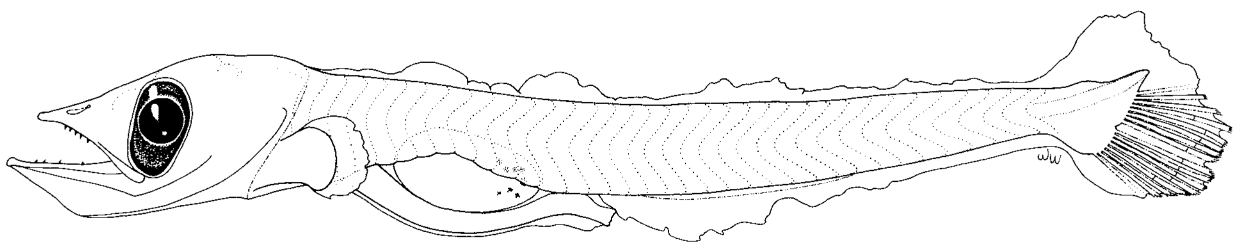
Hatching length: <3.9 mm
Flexion length: ca. 4.7–5.3 mm through ca. 6.1–6.4 mm
Transformation length: ca. 12–19 mm
Fin development sequence: C_1, A, D & C_2, P_1 & P_2
Pigmentation: *Preflexion–flexion*—None initially; over gas bladder by ca. 4.7 mm; ventrolaterally on hindbrain at ca. 5.2 mm. *Postflexion*—Dorsally on most of gut by ca. 10.2 mm; surrounding stomach, beginning at ca. 11 mm; dorsolaterally on hindbrain, beginning between 8–11 mm. *Transformation*—Increasing on gut region & hindbrain; extending onto midbrain by ca. 18.9 mm.
Diagnostic features: 15–18 preanal myomeres (usually 16 through flexion stage, 18 thereafter), 39–41 total myomeres (usually 39); usually 0–1 myomeres between anus & A origin; preanal length usually 45–50% BL through transformation stage; moderately narrow eye; little pigment through postflexion stages; dorsolateral pigmentation on hindbrain by 8–11 mm.

MORPHOMETRICS (range & mean in %)

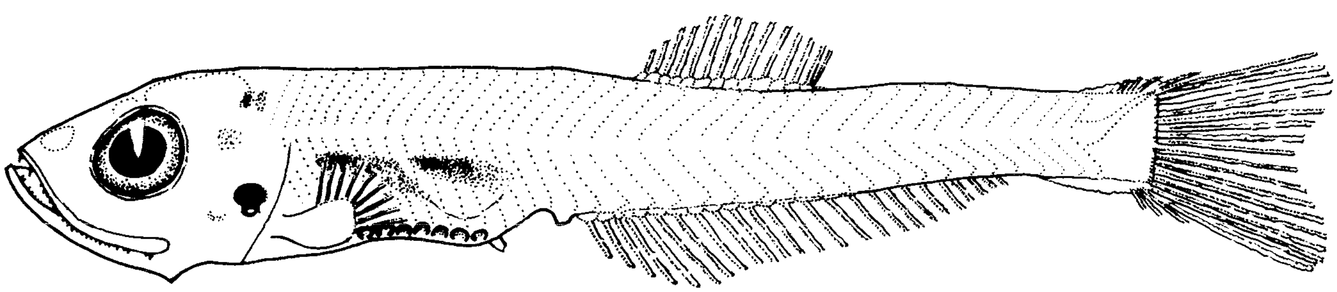
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–50 48	43–54 47	41–59 49	48–50 49	52–54 53
BD/BL		10–12 11	10–13 12	12–20 17	18–20 19	15–18 16
HL/BL		19–22 21	19–23 21	19–28 24	23–27 24	23–25 23
HW/HL		53–57 55	37–55 48	42–51 48	42–54 48	31–49 41
SnL/HL		26–32 29	24–34 29	24–35 30	28–30 30	19–26 24
ED/HL*		23–33× 36–38 27×37	25–34× 35–39 30×38	26–34× 33–39 30×36	26–34× 30–36 29×32	16–17× 16–19 17×17
P_1L/BL		3–6 5	4–6 5	4–9 7	5–9 8	9–19 15
P_2L/BL		0–0 0	0–0 0	0–4 2	6–7 6	9–13 10



4.6 mm



4.7 mm



9.8 mm

Figure Gonostomatidae 9. Preflexion larva, 4.6 mm (Tasaday I, tow 69); flexion larva, 4.7 mm (TC 8406, station 159, Tucker trawl); early transformation specimen, 9.8 mm (Ahlstrom 1974).

STERNOPTYCHIDAE: Hatchetfishes

W. WATSON

Sternoptychidae contains about 49 species in ten genera (Nelson 1994); nine species of four genera occur in the California Current vicinity (Table Sternoptychidae 1). The larvae of *Argyropelecus* (all four species), *Danaphos oculatus*, and *Sternoptyx* (at least two species) are collected regularly in CalCOFI plankton samples; *Valenciennellus tripunctulatus* occurs largely outside the CalCOFI area and its larvae are taken only occasionally at the most offshore stations.

Adult sternoptychids are small (usually <10 cm), compressed, bioluminescent, meso- and bathypelagic fishes. The family contains two subfamilies: Sternoptychinae, the deep-bodied hatchetfishes; and Maurolicinae, elongate fishes that once were included in the Gonostomatidae. All share the common characters of having the photophores within at least some of the photophore groups united in common glands, and of gradually acquiring both the photophore groups and the photophores within each group during transformation to the juvenile stage (Table Sternoptychidae 2). This contrasts with the simultaneous development of most or all photophores, all single, within each photophore group in gonostomatids and phosichthyids.

Sternoptychids are oviparous, with planktonic eggs and larvae: planktonic eggs have been described for *Argyropelecus hemigymnus* (Sanzo 1931a) and *Maurolicus muelleri* (Sanzo 1931a; Mito 1961a, 1966), while planktonic larvae are known for several species representing all but two of the ten genera (e.g., Ahlstrom et al. 1984c). *Argyropelecus hemigymnus* and *M. muelleri* hatch with unpigmented eyes, with a large yolk sac, with an oil droplet and segmented yolk, and without pectoral fins or functional mouth (Sanzo 1931a; Mito 1966). Presumably, the others hatch in a similar state of development. All known larvae initially are elongate and slender (BD ca. 10–15% BL), with a preanal length ca. 33–50% BL, narrow eyes (narrow axis ca. 35–60% of long axis), and little or no melanistic pigment. The sternoptychines become deep-bodied, while the maurolicines remain relatively slender during transformation. In most genera the gut shortens and the eye becomes wider, at least slightly, during transformation. Pigment typically remains very light and is largely internal in the head and gut areas through the beginning of transformation.

Although a large body of literature exists concerning early life history stages of the sternoptychids (e.g., Jespersen and Tåning 1919; Sanzo 1931a; Ahlstrom 1974; Badcock 1977; Belyanina 1983, 1984; Ahlstrom et al. 1984c; Ozawa 1988a), problems with larval identifications remain. *Argyropelecus*, and especially *Sternoptyx*, have been problem genera. The identities of larval *Argyropelecus* in the California Current are now resolved, but the *Sternoptyx* larvae still cannot be separated reliably.

The following species accounts are based on the literature and on detailed examinations of 35 specimens of *Argyropelecus affinis*, 25 *A. hemigymnus*, 32 *A. lychnus*, 37 *A. sladeni*, 35 *Danaphos oculatus*, 52 *Sternoptyx* spp., and 36 *Valenciennellus tripunctulatus* (Table Sternoptychidae 3). Meristic data were obtained from Baird (1971, 1986), Haruta and Kawaguchi (1976), Badcock and Baird (1980), Fujii (1984a); and counts made during this study. Myomere counts given under "Diagnostic features" in the following descriptions refer to counts made on the specimens examined in this study and may not reflect the full range for each species. Ecological information is from Baird (1971, 1986), Clarke (1974), and Badcock and Baird (1980).

Table Sternoptychidae 1. Meristic characters for the sternoptychid species reported to occur in the California Current region. All have 10+9 principal caudal fin rays.

Species	Vertebrae			Fin rays					GR	BrR
	PrCV	CV	Total	D	A	P_1	P_2	C_2		
Argyropelecus affinis	10–11	27–29	38–41	8–9	12–14	10–11	6	10–12+3–4	18–22	10
A. hemigymnus	11	25–28	36–39	8–9	11–12	10–11	6	9–10+5	18–24	10
A. lychnus	11	24–26	35–37	9	12	10–12	6	9–11+6	16–18	10
A. sladeni	11–12	24–26	35–38	9	11–12	9–11	6	10–11+6–7	17–21	10
Danaphos oculatus	12–13	26–28	38–40	6	23–26	10–17	6–7	7–8+2–3	13–15	9–10
Sternoptyx diaphana	11–13	16–18	27–30	9–11	13–16	10–11	5–6	7+7–8	6–9	6
S. obscura	11–13	17–19	29–31	9–11	12–15	9–11	5–6	7+7–8	7–9	6
S. pseudobscura	12–13	16–18	27–31	9–11	13–16	9–11	5–6	7+7–8	7–9	6
Valenciennellus tripunctulatus	12	21–22	32–35	7–10	22–25	12–17	6–9	8–9+5–6	14–17	9–10

Table Sternoptychidae 2. Order of photophore group development (first appearance of photophores in each group) in some Sternoptychidae. Photophore groups are shown in Figure Stomiiformes 1 and defined in Table Stomiiformes 1. An "&" indicates simultaneous development, or insufficient specimens to determine sequence.

Species	Photophore group development sequence
Argyropelecus affinis	AB, SO & BR & I & AN & SC & PO, SP, PRO, PAN & SAB, PTO
A. hemigymnus	AB & BR, I, SO, AN, SC & PO & SP & PRO, PAN & PTO, SAB
A. lychnus	AB, SO & BR & I & AN & SC, PO & SP, PRO, PAN & PTO, SAB
A. sladeni	AB & SO & BR & I, AN, SC, PO, SP, PRO, PAN & SAB & PTO
Danaphos oculatus	BR & AB, SO & I & AN & PO, SC, PRO & SAB
Sternoptyx diaphana	SO, AB & I & PO, BR & PTO, SP, PAN & AN, SC, SAN
S. obscura	SO, PO, AB & BR, PTO & I, SP, AN, PAN & SC, SAN
Valenciennellus tripunctulatus	BR & AB, PAN, PO & I, AN, SO & SP & SC, PRO & SAB

Table Sternoptychidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the sternoptychid species descriptions. An "L" indicates literature used in the description.

Species	Eggs	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Argyropelecus affinis	0	0	10 3.7–6.9	5 8.5–10.8	4 9.4–11.5	11 10.4–14.6	5 14.9–17.8
A. hemigymnus	L[a]	L[a]	2 6.0–6.9	5 7.1–10.0	2 8.6–10.8	11 8.7–11.9	5 13.4–20.5
A. lychnus	0	1 4.6	10 4.5–7.1	6 6.5–10.0	2 9.3–9.7	8 8.7–12.6	5 14.2–19.1
A. sladeni	0	0	10 4.3–7.3	5 6.7–9.4	7 7.8–10.0	10 8.2–13.1	5 14.1–19.0
Danaphos oculatus	0	1 4.5	7 4.5–7.9	5 8.3–13.2	10 12.8–18.1	7 17.5–23.6	5 26.2–34.6
Sternoptyx spp.	0	0	10 3.1–5.8	5 5.9–7.2	12 6.5–9.6	15 6.8–11.3	10 8.4–16.9
Valenciennellus tripunctulatus	0	0	10 3.7–4.6	5 5.2–7.3	10 6.3–8.9	6 9.5–15.9	5 21.2–26.1

[a] Sanzo 1931a

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–41	39
Precaudal	10–11	11
Caudal	27–29	28
Fins:		
Dorsal spines	0	0
Dorsal rays	8–9	9
Anal spines	0	0
Anal rays	12–14	13
Pelvic	6	6
Pectoral	10–11	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–12	11
Lower	3–4	4
Gill rakers:		
Total	18–22	18–20
Upper	7–9	7–8
Lower	9–13	11–12
Branchiostegals	10	10

LIFE HISTORY

Range: Worldwide; in CalCOFI area primarily seaward of the continental shelf

Habitat: Epi- & mesopelagic, primarily ca. 100–600 m depth

Spawning season: Possibly year-round; larvae occur most frequently from fall through spring

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Belyanina 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.2 mm (B. Sumida MacCall)
Flexion larva, 10.4 mm (B. Sumida MacCall)
Transformation specimens, 11.0 mm, 11.5 mm (B. Sumida MacCall)
Juvenile, 16.0 mm (W. Watson)

* Larvae shrink during the early part of transformation.
† Eye is vertically elongate; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.7 mm
Flexion length: ca. 7–8 mm through ca. 9–11 mm
Transformation length: ca. 10.5–11.5 mm through ca. 14.5–15.0 mm*
Fin development sequence: C_1, C_2, A & P_1, D, P_2
Pigmentation: *Preflexion-postflexion*—Internally on notochord at last myomere, extending as far forward as last 5–10 myomeres in some. *Transformation*—Over gas bladder; around stomach; on frontals between eyes; subsequently increasing over fore- & midbrain, on opercular area, on gut; lateral midline series begins at ca. 13–16 mm; internal caudal peduncle pigment condenses to one blotch.
Diagnostic features: Internal pigment at last 1–10 myomeres; short preanal length; 10–15 preanal myomeres (usually 12–13), 38–41 total myomeres (usually 39); photophores in AN & SC groups widely spaced.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		37–45 40	36–46 41	34–42 39	31–54 40	49–55 53
BD/BL		9–13 11	9–11 11	12–14 12	17–40 30	40–43 41
HL/BL		15–20 18	17–18 17	17–18 18	16–28 22	24–28 26
HW/HL		36–51 44	38–50 44	41–49 45	44–62 50	59–89 70
SnL/HL		23–33 28	26–44 37	31–36 34	30–44 34	29–35 33
ED/HL†		17–23× 37–58 20×45	17–21× 34–42 19×38	18–19× 33–38 18×36	20–37× 32–51 33×42	32–40× 35–48 37×45
P_1L/BL		2–5 3	3–4 3	3–4 3	6–27 20	27–29 28
P_2L/BL		0–0 0	0–0 0	0–0 0	0–7 2	6–9 8
CL/HL		0–4 3	2–5 3	2–4 3	0–2 0.3	0–0 0

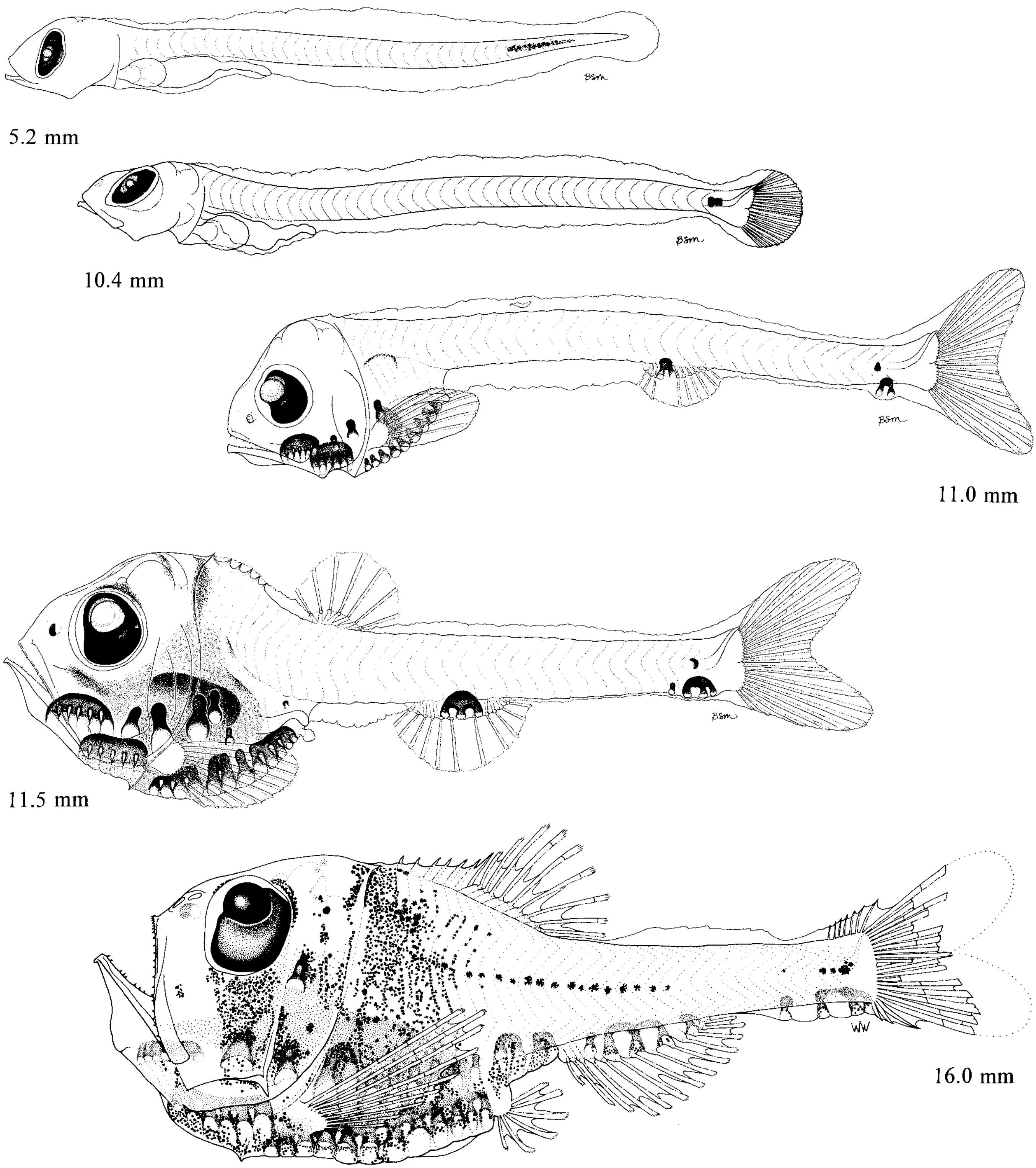


Figure Sternoptychidae 1. Preflexion larva, 5.2 mm (CalCOFI 6301, station 130.45); late flexion stage larva, 10.4 mm (CalCOFI 8803, station 78.3.58.3); early transformation specimen, 11.0 mm (CalCOFI 6201, station 90.80); late transformation specimen, 11.5 mm (CFRD 8701, station 75.2.52.3); juvenile, 16.0 mm (FRONTS 85, station 3, MOCNESS).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–39	37–38
Precaudal	11	11
Caudal	25–28	26–27
Fins:		
Dorsal spines	0	0
Dorsal rays	8–9	8
Anal spines	0	0
Anal rays	11–12	11
Pelvic	6	6
Pectoral	10–11	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	9–10	9–10
Lower	5	5
Gill rakers:		
Total	18–24	19–23
Upper		
Lower		
Branchiostegals	10	10

LIFE HISTORY

Range: Worldwide; throughout California Current area, seaward of the continental shelf

Habitat: Epi- & mesopelagic, principally at ca. 100–700 m depth

Spawning season: Possibly year-round; larvae occur most frequently from winter through spring

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Belyanina 1984
Borodin 1931
Brauer 1906
Ehrenbaum 1909
Jespersen & Tåning 1919
Matarese et al. 1989
Olivar & Fortuño 1991
Sanzo 1931a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 6.9 mm (B. Sumida MacCall)
Flexion larva, 10.8 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.92–1.04 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.26–0.28 mm
Shell surface: Smooth
Pigment: None
Diagnostic features: Segmented yolk; secondary membrane inside chorion

LARVAE

Hatching length: 2.5 mm
Flexion length: ca. 10–11 mm
Transformation length: ca. 7.8–12 mm*
Fin development sequence: C_1, P_1, A & C_2, D, P_2
Pigmentation: *Yolk-sac through postflexion*—None. *Transformation*—None before AN photophores begin to form; around stomach by ca. 10.2 mm; on frontal region adjacent to eye; along lower posttemporal/upper supracleithrum region; on opercle below eye; over gas bladder by ca. 9 mm; subsequently increases on head & gut area. *Juvenile*—Anterior half heavily pigmented; discontinuous stripe along lateral midline.
Diagnostic features: No internal tail pigment; no anterior midbrain pigment in transformation stage; conical choroid tissue below eyes; long preanal length before transformation; 14–18 preanal myomeres before transformation, 11–14 subsequently, 36–39 (usually 37–38) total myomeres.

MORPHOMETRICS (range & mean in %)

	YS	PrF	F	PoF	Tr	Juv
Sn-A/BL		44–52 48	49–53 51	48–59 53	32–54 42	50–56 53
BD/BL		10–10 10	9–12 11	12–14 13	16–43 30	46–51 48
HL/BL		19–20 20	17–21 19	18–20 19	19–26 22	25–29 26
HW/HL		46–49 47	37–47 42	41–45 43	41–78 57	46–109 84
SnL/HL		32–33 33	33–41 36	33–37 35	32–43 36	31–41 36
ED/HL†		14–15× 37–42	13–14× 36–41	11–14× 35–38	12–36× 41–52	32–38× 42–52
		14×40	13×38	13×37	26×45	36×48
P_1L/BL		3–3 3	2–5 3	4–5 4	4–25 15	28–31 29
P_2L/BL		0–0 0	0–0 0	0–0 0	0–6 2	6–9 8
CL/BL		4–9 6	2–7 5	5–9 7	0–7 2	0–0 0

* Larvae shrink during the early part of transformation.
† Eye is vertically elongate; narrow axis is given first, long axis second.

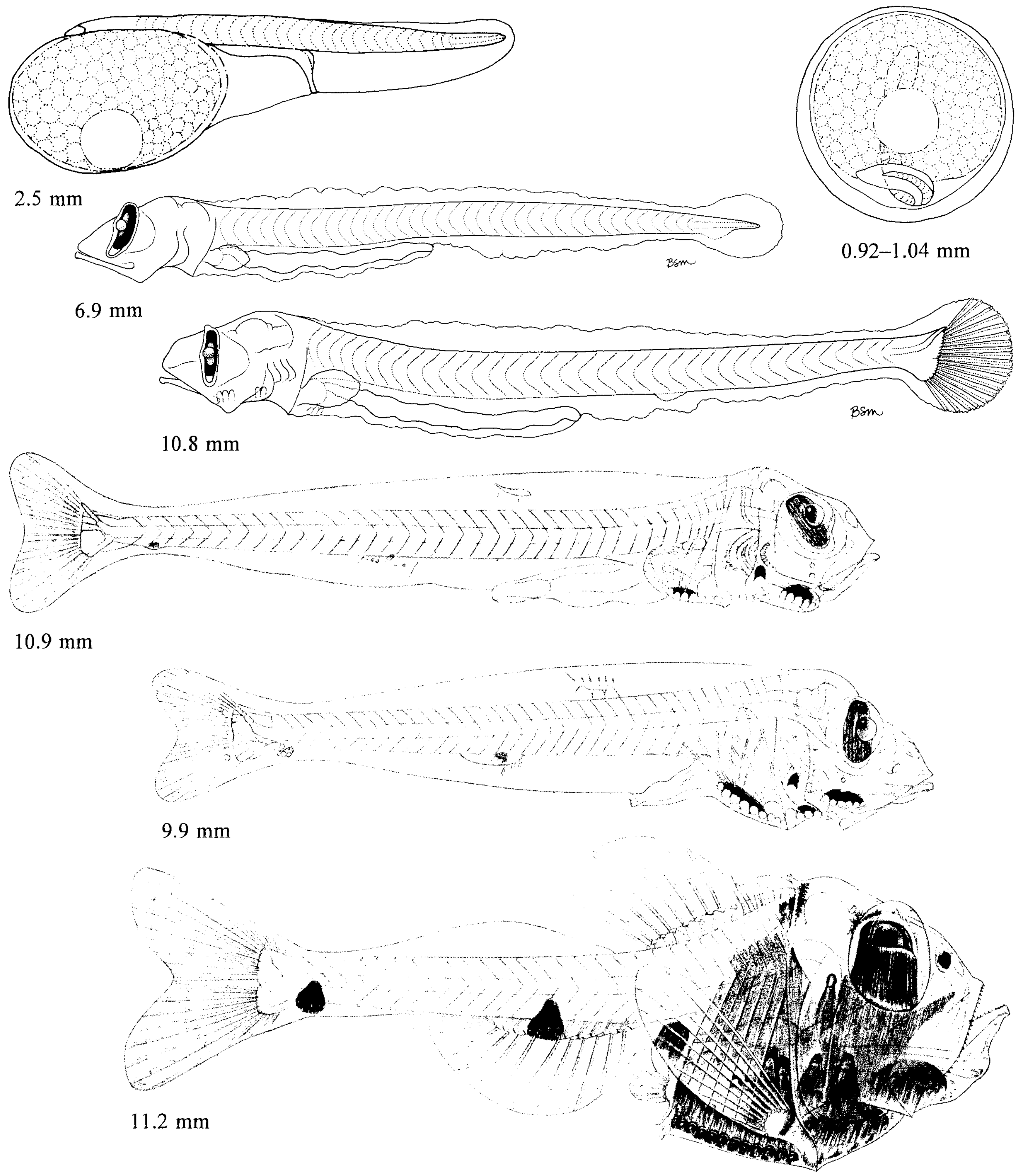


Figure Sternoptychidae 2. Egg, 0.92–1.04 mm; yolk-sac larva, 2.5 mm (redrawn from Sanzo 1931a); preflexion larva, 6.9 mm (CalCOFI 8012, station 83.3.80); flexion larva, 10.8 mm (CalCOFI 6801, station 90.37); early transformation specimen, 10.9 mm; mid-transformation specimen, 9.9 mm; late transformation specimen, 11.2 mm (modified from Sanzo 1931a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–37	36
Precaudal	11	11
Caudal	24–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	9	9
Anal spines	0	0
Anal rays	12	12
Pelvic	6	6
Pectoral	10–12	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	9–11	9–10
Lower	6	6
Gill rakers:		
Total	16–18	
Upper		
Lower		
Branchiostegals	10	10

LIFE HISTORY

Range: Eastern Pacific; possible Indian Ocean record; in California Current area, seaward of continental shelf

Habitat: Epi- & mesopelagic, primarily at ca. 200–700 m depth

Spawning season: Possibly year-round; most larval occurrences from winter through spring

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Belyanina 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.6 mm (B. Sumida MacCall)
Flexion larva, 9.3 mm (W. Watson)
Postflexion larva, 9.3 mm (B. Sumida MacCall)
Transformation specimen, 8.7 mm (B. Sumida MacCall)
Juvenile, 19.1 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

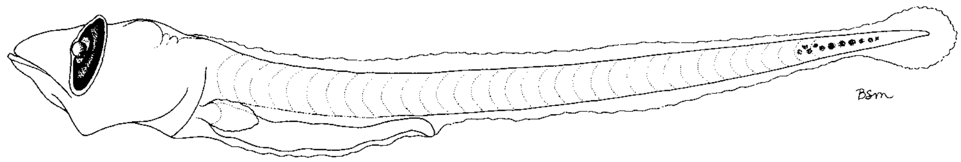
LARVAE

Hatching length: <4.6 mm
Flexion length: ca. 6.5–7.0 mm through ca. 9–10 mm
Transformation length: ca. 8.7–9.3 mm through ca. 12.5 mm*
Fin development sequence: C_1, A, P_1 & C_2, D, P_2
Pigmentation: *Yolk-sac through postflexion*—Internally along notochord at last 2–6 myomeres. *Transformation*—Over gas bladder; around stomach; on frontals between eyes; over midbrain & hindbrain by ca. 9 mm; subsequently increasing on opercular area, along supracleithrum/posttemporal region, and on gut area; internal caudal peduncle pigment condenses.
Diagnostic features: Internal pigment at last 2–6 myomeres; 9–18 preanal myomeres (usually 15–17 through postflexion stage, 9–11 in transformation stage), 35–37 total myomeres (usually 35–36); before transformation, relatively long preanal length and very narrow eye with conical choroid tissue.

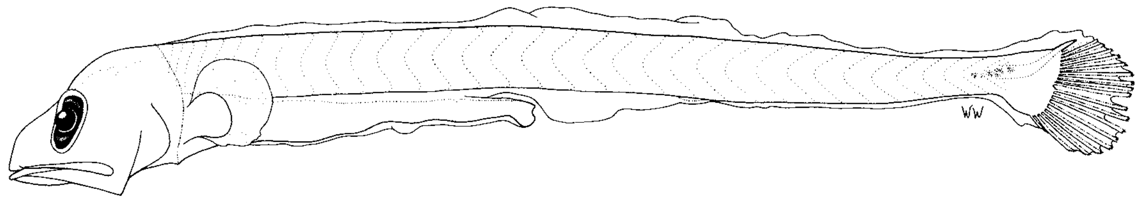
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–55	45–52	43–56	28–57	55–61
	37	50	49	49	39	58
BD/BL		9–11	10–13	12–15	16–61	57–69
	7	11	11	13	33	64
HL/BL		18–22	19–23	18–19	18–32	30–35
	13	20	20	18	23	33
HW/HL		21–34	28–39	28–46	45–81	59–82
	50	29	32	37	52	69
SnL/HL		28–33	28–40	37–40	29–39	28–31
	17	31	35	39	35	29
ED/HL†		12–17× 34–44	12–16× 28–39	14–16× 36–40	16–37× 38–47	31–41× 40–48
	23×50	15×39	14×32	15×38	29×42	35×43
P_1L/BL		2–3	3–5	3–5	5–33	33–36
	0.4	2	4	4	20	34
P_2L/BL		0–0	0–0	0–0	0–8	10–11
	0	0	0	0	2	10
CL/HL		4–10	3–8	3	0–3	0–0
	0	7	6	3	1	0

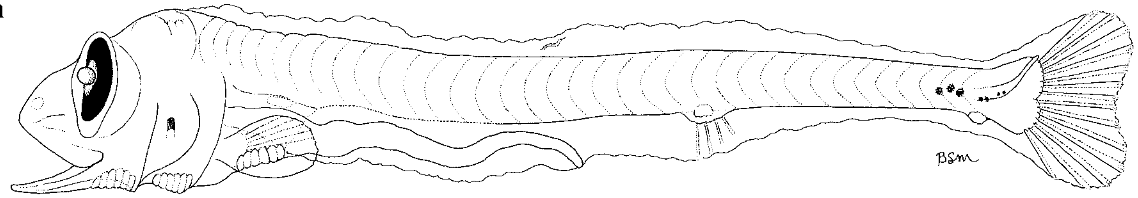
* Larvae shrink during the early part of transformation.
† Eye is vertically elongate; horizontal axis given first, vertical second.



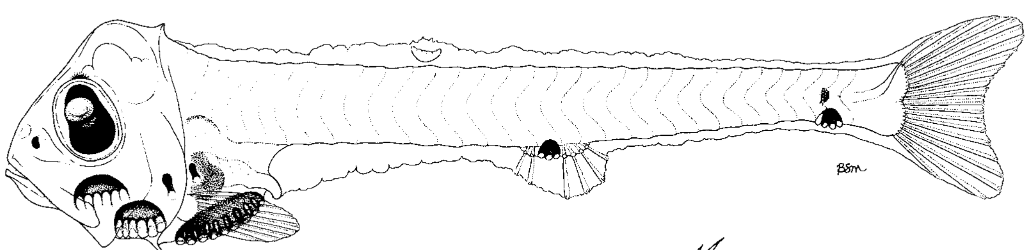
5.6 mm



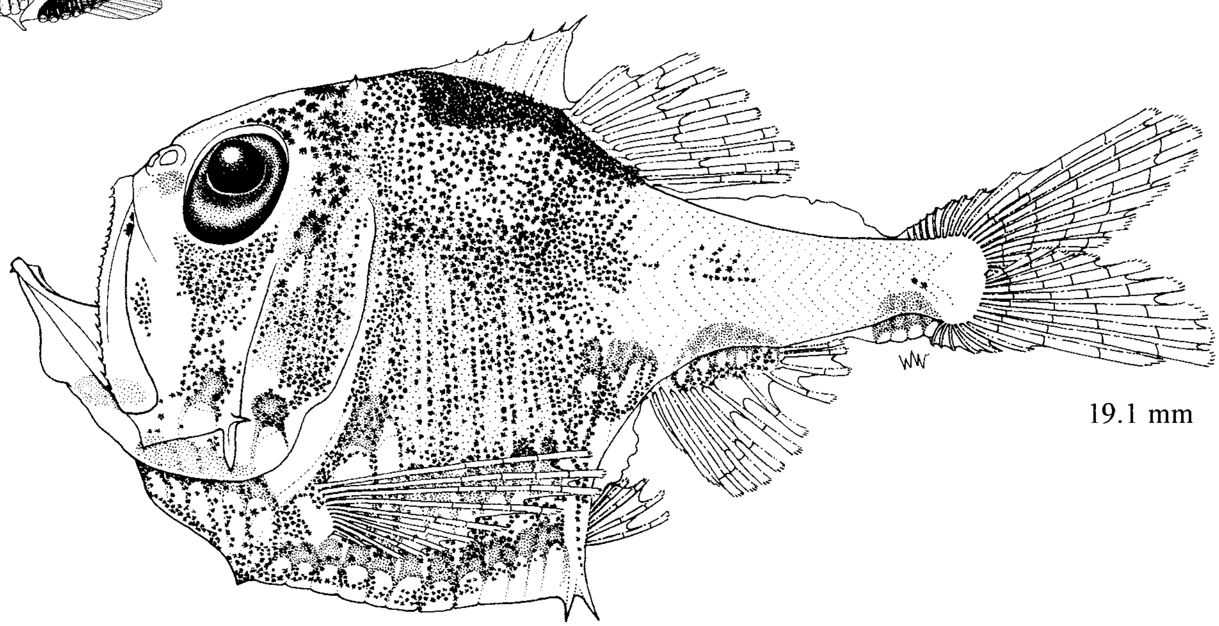
9.3 mm



9.3 mm



8.7 mm



19.1 mm

Figure Sternoptychidae 3. Preflexion larva, 5.6 mm (CalCOFI 7501, station 107.60); late flexion larva, 9.3 mm (CalCOFI 5902, station 90.60); postflexion larva, 9.3 mm (CalCOFI 7712, station 113.35); transformation specimen, 8.7 mm (FRONTS 85, station 8, MOCNESS); juvenile, 19.1 mm (CFRD 8803, station 74.8.55.2).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	36
Precaudal	11–12	11
Caudal	24–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	9	9
Anal spines	0	0
Anal rays	11–12	12
Pelvic	6	6
Pectoral	9–11	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	10–11	10
Lower	6–7	6
Gill rakers:		
Total	17–21	
Upper	7–8	
Lower	10–11	
Branchiostegals	10	10

LIFE HISTORY

Range: Worldwide; in CalCOFI area, primarily seaward of continental shelf

Habitat: Epi- & mesopelagic, primarily at 100–600 m depth

Spawning season: Possibly year-round; most larval occurrences from fall through spring

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Belyanina 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.2 mm (B. Sumida MacCall)
Flexion larva, 9.4 mm (B. Sumida MacCall)
Postflexion larva, 10.0 mm (B. Sumida MacCall)
Transformation specimen, 8.2 mm (B. Sumida MacCall)
Juvenile, 13.8 mm (W. Watson)

* Larvae shrink during the early part of transformation.
† Eye is vertically elongate; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 7.5 mm through ca. 8.5–9.4 mm
Transformation length: ca. 8.2–10.0 mm through ca. 13.0 mm*
Fin development sequence: C_1, P_1, A & C_2, D & P_2
Pigmentation: *Preflexion–postflexion*—None. *Transformation*—None before SC photophores form; by ca. 9.2–9.5 mm (white SC photophores present at this size) on frontal region adjacent to eye, anteriorly on each side of midbrain, along lower posttemporal/upper supracleithrum region, over gas bladder, around stomach; subsequently increases over gut area, laterally above gut, on opercular area, & over brain.
Diagnostic features: No internal pigment in tail; pair of large melanophores anteriorly over midbrain in transformation stage; narrow choroid tissue mass below eye; short preanal length; 11–12 preanal myomeres (usually 12), 35–37 total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–42 39	37–43 41	36–43 39	33–58 44	56–62 58
BD/BL		10–12 11	12–14 13	14–17 15	21–52 40	52–57 54
HL/BL		18–20 19	19–21 20	18–22 20	19–31 25	27–29 28
HW/HL		40–50 45	37–46 40	39–49 43	40–111 76	84–117 96
SnL/HL		29–43 34	24–36 31	29–37 34	31–36 33	29–32 31
ED/HL†		14–20× 35–47	13–19× 34–44	14–19× 37–49	20–37× 41–52	33–42× 44–51
		16×40	16×38	16×40	32×44	38×48
P_1L/BL		2–6 4	3–5 4	3–7 4	9–31 23	30–32 31
P_2L/BL		0–0 0	0–0 0	0–0 0	0–9 3	8–11 9
CL/HL		0–4 2	1–3 2	1–3 3	0–3 1	0–0 0

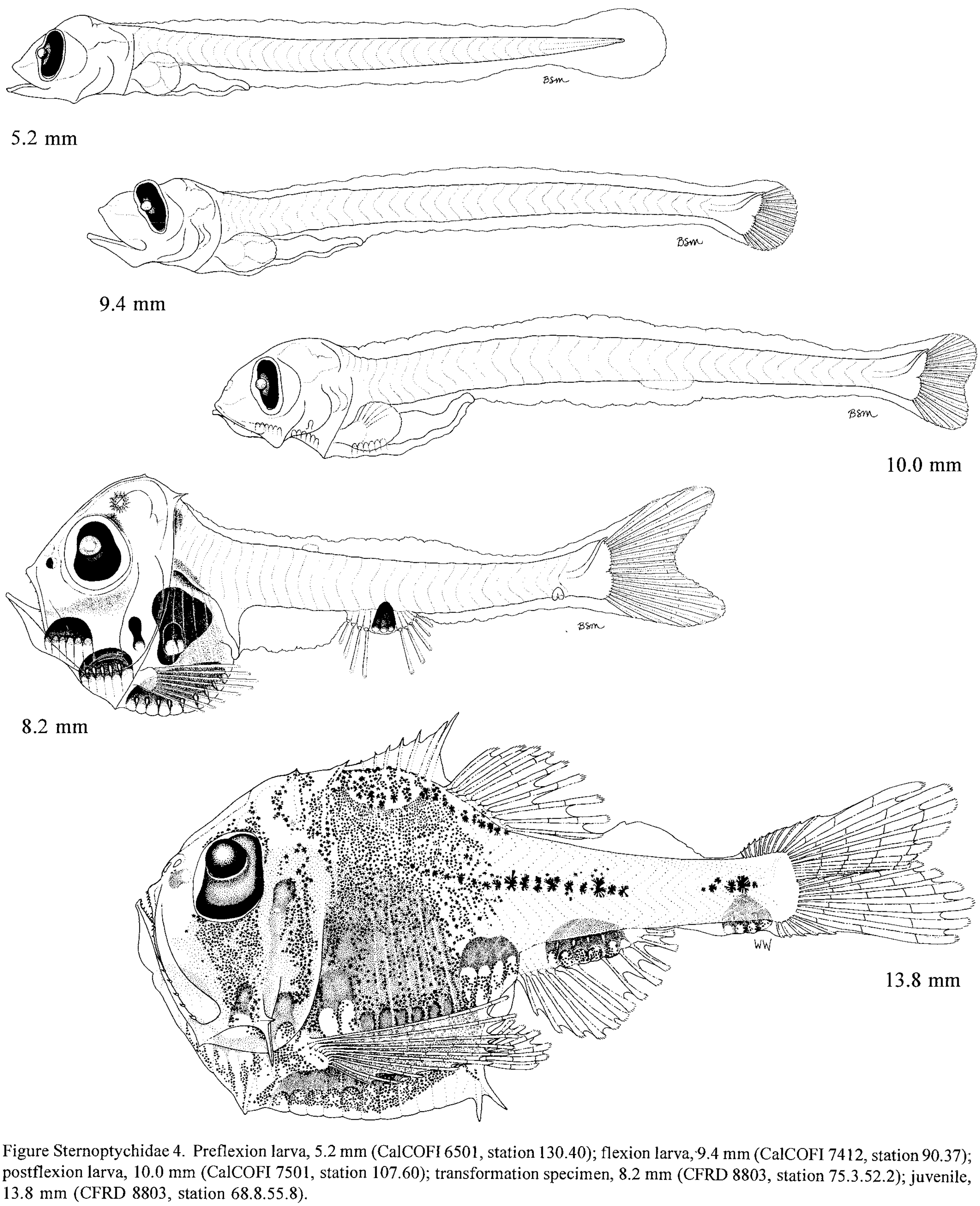


Figure Sternoptychidae 4. Preflexion larva, 5.2 mm (CalCOFI 6501, station 130.40); flexion larva, 9.4 mm (CalCOFI 7412, station 90.37); postflexion larva, 10.0 mm (CalCOFI 7501, station 107.60); transformation specimen, 8.2 mm (CFRD 8803, station 75.3.52.2); juvenile, 13.8 mm (CFRD 8803, station 68.8.55.8).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–40	38–39
Precaudal	12–13	12
Caudal	26–28	26–27
Fins:		
Dorsal spines	0	0
Dorsal rays	6	6
Anal spines	0	0
Anal rays	23–26	25
Pelvic	6–7	7
Pectoral	10–17	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–8	8
Lower	2–3	3
Gill rakers:		
Total	13–15	
Upper	2	2
Lower	11–13	
Branchiostegals	9–10	10

LIFE HISTORY

Range: Pacific Ocean; throughout California Current area, seaward of the continental shelf

Habitat: Epi- & mesopelagic, primarily at 183–914 m depth

Spawning season: Larvae collected throughout the year with highest catches January–August.

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom et al. 1984c
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 4.5 mm (W. Watson)
Preflexion larva, 5.2 mm (B. Sumida MacCall)
Flexion larva, 13.2 mm (B. Sumida MacCall)
Postflexion larva, 16.5 mm (B. Sumida MacCall)
Transformation specimen, 19.2 mm (W. Watson)

* Eye initially vertically elongate, becoming nearly round in juvenile stage. Narrow axis is given first, long axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 8 mm through ca. 13 mm
Transformation length: 16.5–18.0 mm through ca. 23.5 mm
Fin development sequence: C_1, A, C_2, P_1, P_2, D
Pigmentation: *Preflexion–postflexion*—None until end of postflexion stage when pigment forms over gas bladder. *Transformation*—Only on gas bladder initially; posteriorly on midbrain & around stomach by ca. 21.5 mm; increases to cover most of gut region & head by ca. 23.5 mm; dorsolateral series of ca. 1/myomere forms on first 7–8 myomeres by ca. 23.5 mm, extends along lateral midline to caudal peduncle in juvenile stage.
Diagnostic features: 11–15 preanal myomeres (usually 14–15 through postflexion stage, 11–12 in transformation stage), 37–39 total myomeres (usually 38–39); eye less narrow than in *Argyropelecus*; transformation beginning at large size (≥16.5 mm); long A base, short D base; only first 3 AN photophores with common base.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–54	48–53	40–49	34–39	40–44
	45	51	50	44	37	43
BD/BL		7–10	7–8	6–10	9–21	22–24
	8	8	8	8	14	23
HL/BL		17–21	16–18	12–17	16–21	17–21
	15	19	17	15	18	19
HW/HL		38–56	39–50	43–60	35–56	58–76
	36	48	44	47	43	65
SnL/HL		17–28	20–25	26–38	32–42	30–35
	6	21	24	31	36	33
ED/HL*		15–18× 35–53	15–18× 34–40	13–21× 31–43	20–33× 32–43	39–54× 39–50
	30×47	16×44	17×38	16×35	25×38	43×43
P_1L/BL		2–6	3–5	3–6	7–20	20–23
	1	4	4	4	13	22
P_2L/BL		0–0	0–0	0–0	1–8	9–10
	0	0	0	0	3	9

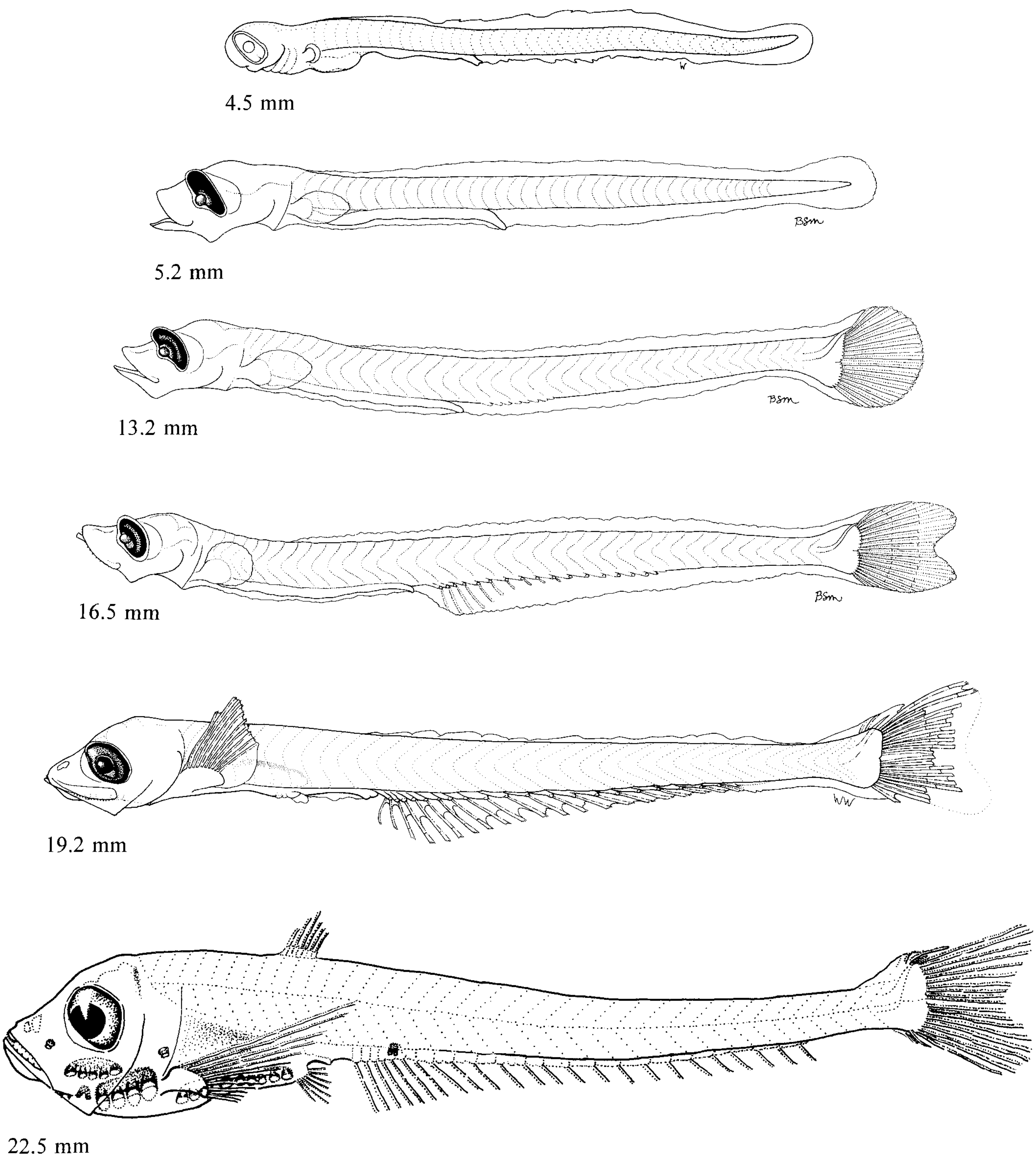


Figure Sternoptychidae 5. Yolk-sac larva, 4.5 mm (CFRD 9104, station 71.7.75); preflexion larva, 5.2 mm (CalCOFI 7503, station 97.45); late flexion larva, 13.2 mm (CalCOFI 6912, station 77.65); postflexion larva, 16.5 mm (CalCOFI 7412, station 113.50); early transformation specimen, 19.2 mm (CFRD 9104, station 73.3.80, MOCNESS); late transformation specimen, 22.5 mm (Ahlstrom 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27–31	
Precaudal	11–13	
Caudal	16–19	
Fins:		
Dorsal spines	0	
Dorsal rays	9–11	
Anal spines	0	
Anal rays	12–16	
Pelvic	5–6	
Pectoral	9–11	
Caudal:		
Principal	10+9	
Procurrent:		
Upper	7	
Lower	7–8	
Gill rakers:		
Total	6–9	
Upper	2–3	
Lower	4–7	
Branchiostegals	6	

LIFE HISTORY

Range: Worldwide except Mediterranean & polar seas; in California Current region, seaward of continental shelf

Habitat: Meso- & bathypelagic, at ca. 400–1500 m depth

Spawning season: Larvae collected throughout the year in CalCOFI area, with winter catches somewhat larger

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984c
Badcock & Baird 1980
Belyanina 1983
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.2 mm (W. Watson)
Flexion larva, 6.4 mm (H. M. Orr)
Transformation specimen, 11.2 mm (H. M. Orr)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3 mm
Flexion length: ca. 6–7 mm
Transformation length: Variable within ca. 7–11 mm range
Fin development sequence: C_1, P_1, C_2, A, D, P_2
Pigmentation: *Preflexion–postflexion*—Initially none; develops on head & gut area; may be present or absent in any of the following areas on any specimen—anterior margin of forebrain, posterior margin of midbrain, under hindbrain, at tip of lower jaw, on middle of gular membrane, at anterior margin of gut, on gas bladder, on inner surface of P_1 base, on P_1 membrane; internal on notochord in tail of some *S. diaphana*. *Transformation*—Increasing on head & gut areas; developing on upper trunk, extending caudad & ventrad.
Diagnostic features: Myomeres 27–30 (usually 28–29); preanal length very short before transformation, body very deep during & after transformation; lightly pigmented; internal pigment in tail of some *S. diaphana*, usually posteriorly.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		31–36 34	29–36 32	31–41 36	32–62 45	44–57 51
BD/BL		14–18 15	19–22 20	23–32 26	22–79 47	73–97 83*
HL/BL		19–25 22	20–25 23	20–27 23	21–31 26	26–37 31
HW/HL		42–56 49	50–62 55	46–82 60	52–116 79	52–122 94
SnL/HL		27–45 37	34–46 41	30–49 38	25–48 39	19–40 30
ED/HL†		20–27× 36–48	24–32× 38–46	22–39× 36–46	22–54× 32–60	33–62× 43–67
		23×41	27×41	30×40	36×44	48×53
P_1L/BL		3–5 3	3–6 4	6–12 9	11–37 21	30–40 35
P_2L/BL		0–0 0	0–0 0	0–0 0	0–7 3	8–12 10

* BD/BL= 84–97% (mean 91%) for *S. diaphana*, 73–77% (mean 75%) for *S. obscura*.

† Eye vertically elongate (usually more so for *S. obscura* than for *S. diaphana*), becoming nearly round during transformation for *S. diaphana* or in the juvenile for *S. obscura*; narrow axis is given first, long axis second.

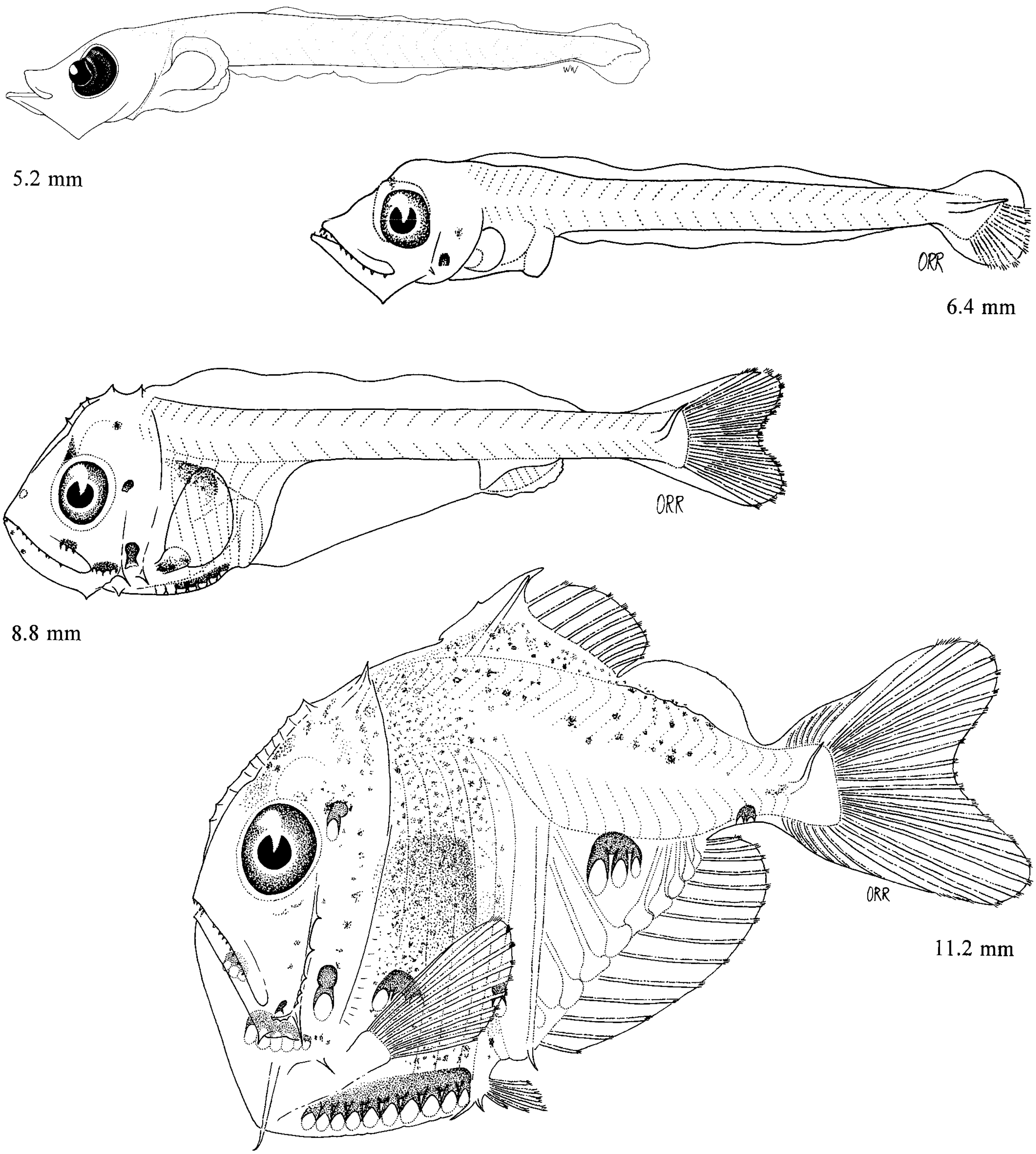


Figure Sternoptychidae 6. Preflexion larva (probably *S. obscura*), 5.2 mm (EASTROPAC II, station 75.036); early flexion larva (possibly *S. diaphana*), 6.4 mm (NORPAC, station 156); postflexion larva (probably *S. obscura*), 8.8 mm (Ahlstrom et al. 1984c; although neither pectoral fin rays nor procurrent caudal rays are shown in this illustration, formation of both normally is nearing completion in specimens of this size); transformation specimen of *S. diaphana*, 11.2 mm (CalCOFI 5009, station 70.175).

MERISTICS

	Range	Mode
Vertebrae:		
Total	32–35	33
Precaudal	12	12
Caudal	21–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	7–10	7–8
Anal spines	0	0
Anal rays	22–25	24
Pelvic	6–9	7
Pectoral	12–17	15–16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	9
Lower	5–6	5
Gill rakers:		
Total	14–17	15
Upper	2–4	3
Lower	12–13	12
Branchiostegals	9–10	10

LIFE HISTORY

Range: Worldwide in warm water; well offshore in CalCOFI area

Habitat: Primarily mesopelagic, at ca. 100–700 m depth

Spawning season: Larvae collected in spring in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom et al. 1984c
Badcock 1977
Grey 1964
Ozawa 1988a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.1 mm (W. Watson)
Flexion larva, 7.3 mm (B. Sumida MacCall)
Postflexion larva, 8.6 mm (B. Sumida MacCall)
Juvenile, 26.7 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length: ca. 5 mm through ca. 6.3–7.3 mm
Transformation length: ca. 9.5 through ca. 16.0 mm
Fin development sequence: C_1, C_2, A, P_1, D & P_2
Pigmentation: *Preflexion–flexion*—None. *Postflexion*—None initially, over gas bladder by ca. 8.5–9.0 mm. *Transformation*—Initially over gas bladder only; on stomach by ca. 12.0 mm, increases over gut region; little over midbrain, few in dorsolateral series along trunk, beginning to form near end of stage.
Diagnostic features: 12–15 preanal myomeres (usually 14–15 initially, decreasing to 12–13 in transformation stage), 32–34 total myomeres (usually 33–34); slender gut with Sn-A/BL ca. 55–60% through postflexion stage; gas bladder far posterior (ca. myomeres 10–12); pigment only over gas bladder before transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		59–69 63	60–64 62	54–63 58	46–52 49	44–48 46
BD/BL		9–11 10	10–12 11	10–13 11	13–25 18	24–27 25
HL/BL		20–25 23	20–25 23	21–24 22	20–23 22	21–34 24
HW/HL		46–54 48	36–51 46	46–54 49	40–71 51	54–70 63
SnL/HL		25–34 30	27–33 31	28–40 35	34–45 38	21–40 31
ED/HL*		21–23× 39–40 22×40	18–20× 37–42 19×39	17–24× 35–45 21×39	22–34× 38–47 27×42	29–44× 29–48 38×42
P_1L/BL		3–8 5	2–5 4	4–7 5	7–11 9	 23†
P_2L/BL		0–0 0	0–0 0	0–0 0	0.2–8 4	8–8 8

* Eye vertically elongate; narrow axis is given first, long axis second.
† Pectoral fin rays broken in all but one of the juvenile specimens examined.

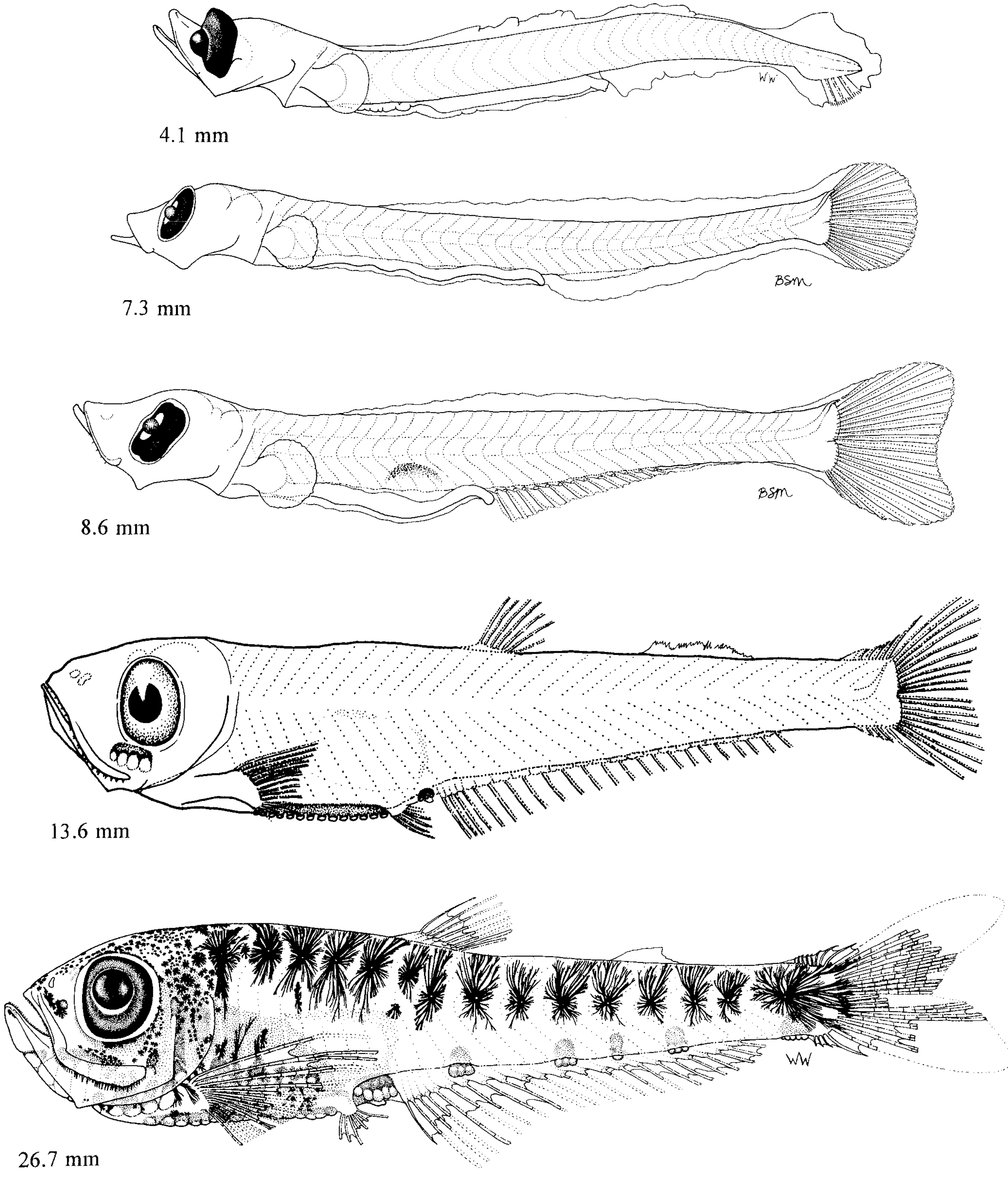


Figure Sternoptychidae 7. Preflexion larva, 4.1 mm (TC 8405, station 41, Tucker trawl); late flexion larva, 7.3 mm (CalCOFI 6301, station 97.110); postflexion larva, 8.6 mm (CalCOFI 7205, station 27.139); transformation specimen, 13.6 mm (Ahlstrom 1974); juvenile, 26.7 mm (CalCOFI 7205, station 31.145).

PHOSICHTHYIDAE: Lightfishes

W. WATSON

Phosichthyidae (commonly referred to as Photichthyidae, a more descriptive but incorrect spelling—see Eschmeyer 1990) contains about 18 species in seven genera. Six species in three genera occur in the CalCOFI region (Table Phosichthyidae 1); among these, only larvae of *Vinciguerria lucetia* and, to a lesser extent, *Ichthyococcus irregularis* occur regularly in CalCOFI ichthyoplankton samples. Larvae of most of the others are taken from time to time, usually at the outer CalCOFI stations, but their distributions are primarily seaward of the CalCOFI area.

Adult phosichthyids are small (usually <10 cm), slender (except *Ichthyococcus*), compressed, bioluminescent fishes that are largely meso- and bathypelagic. They differ little from gonostomatids in external appearance.

Phosichthyids are oviparous, with planktonic eggs and larvae: planktonic eggs have been described for *Ichthyococcus ovatus* (Sanzo 1930) and several *Vinciguerria* species (Ahlstrom and Counts 1958; Sanzo 1931a), while planktonic larvae are known for five of the seven genera (e.g., Ahlstrom et al. 1984c). Eggs are small (<1 mm) and spherical with a segmented yolk. An oil droplet may be present or absent, and the egg shell may consist of a double membrane, or not, depending on species. At hatching, larvae have unpigmented eyes, lack a functional mouth, and have a large yolk sac. Throughout larval development all species are characterized by being elongate and slender (BD usually ≤10% BL), with a long preanal length (usually ≥66% BL). The gut may trail, or not, depending on species. Eyes typically are oval, at least during the preflexion stage, but usually become round by the postflexion or transformation stage. Pigment is light to moderate; when moderate it typically occurs mainly on the lower half of the body.

Larval phosichthyids resemble the larvae of some gonostomatids and sternoptychids; no single set of larval characters allows the separation of all species at the level of family. However, all genera and most species can be identified by using a combination of morphometric (especially preanal length and eye shape), meristic (especially myomere counts), and pigment characters.

Life histories are well known for three of the six species in the CalCOFI region: *Vinciguerria lucetia*, *V. nimbaria* and *V. poweriae* (e.g., Ahlstrom and Counts 1958; Ozawa 1988a). Limited information is available for *Ichthyococcus elongatus* (Ozawa 1988a). The following species accounts are based on the literature (*Vinciguerria*), and on detailed examinations of 30 specimens of *I. irregularis*, 35 *Vinciguerria lucetia*, 27 *V. poweriae*, and 20 specimens of *Woodsia nonsuchae* (Table Phosichthyidae 2). Although *I. elongatus* is reported to range as far south and east as the northern part of the CalCOFI area (Rechnitzer and Böhlke 1958), no larvae were found in CalCOFI samples and that species is not described here. Larval *V. nimbaria* occur very rarely in CalCOFI samples and also are not described here. See Ahlstrom and Counts (1958), Silas and George (1969), Ozawa (1973, 1988a), Rudometkina (1975), Miller et al. (1979) and Gorbunova (1981) for descriptions and illustrations of larval *V. nimbaria*. Meristic data were obtained from the literature (Ahlstrom and Counts 1958; Rechnitzer and Böhlke 1958; Grey 1964; Mukhacheva 1980; Fujii 1984a) and from counts made during this study. Myomere counts given under "Diagnostic features" in the following descriptions refer to counts made on the specimens examined in this study and may not reflect the full range for each species.

Table Phosichthyidae 1. Meristic characters for the phosichthyid species reported to occur in the California Current region. All have 10+9 principal caudal rays.

Species	Vertebrae			Fin rays					GR	BrR
	PrCV	CV	Total	D	A	P_1	P_2	C_2		
Ichthyococcus elongatus	29–30	16–18	45–47	14–16	14–17	7–8	7–8	6+3–4	31–37	12–13
I. irregularis	24–25	13–15	38–39	11–13	13–15	7–8	7–8	5–6+3	8+17–19	12
Vinciguerria lucetia	22–24	16–19	39–43	13–16	13–17	10	7	7–10+4–5	8–11+18–23	12
V. nimbaria			39–44	13–15	13–16	9–11	7	8–10+4	5–7+13–17	11
V. poweriae	22–23	16–18	38–41	13–15	12–15	9–11	7	7–9+4–5	3–4+11–13	11
Woodsia nonsuchae	23	19–20	42–45	11–12	14–16	9–10	7–8	4+4	3–5+13	17

Table Phosichthyidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the phosichthyid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Ichthyococcus irregularis	0	1 4.1	9 3.3–7.9	5 7.8–9.4	10 10.0–21.7	0	5 21.6–30.2
Vinciguerria lucetia	L[a]	L[a]	10 2.2–5.5	6 5.7–7.0	10 7.3–18.9	5 14.8–21.6	4 27.4–36.2
V. poweriae	L[a]	0	7 4.2–6.5	3 6.6–8.2	10 8.6–22.6	2 17.3–22.6	5 21.1–24.1
Woodsia nonsuchae	0	0	8 2.8–6.2	2 5.7–8.1	10 7.6–14.1	0	0

[a] Ahlstrom and Counts 1958

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–39	39
Precaudal	24–25	25
Caudal	13–15	14
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	11–12
Anal spines	0	0
Anal rays	13–15	13
Pelvic	7–8	7
Pectoral	7–8	8
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–6	5
Lower	3	3
Gill rakers:		
Upper	8	8
Lower	17–19	17–19
Branchiostegals	12	12

LIFE HISTORY

Range: Eastern Pacific Ocean; throughout California Current region, seaward of continental shelf

Habitat: Meso- & bathypelagic

Spawning season: Larvae occur throughout the year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 4.1 mm (B. Sumida MacCall)
Preflexion larva, 6.9 mm (B. Sumida MacCall)
Flexion larva, 8.8 mm (B. Sumida MacCall)
Postflexion larva, 18.4 mm (B. Sumida MacCall)

* Eye is oval; narrow (~horizontal) axis is given first, long (~vertical) axis second.
† P_1LL refers to length of elongate lower lobe of fin.

EARLY LIFE HISTORY DESCRIPTION

EGGS

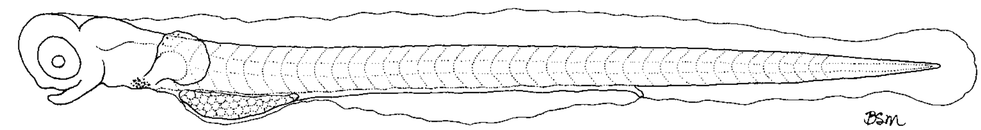
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

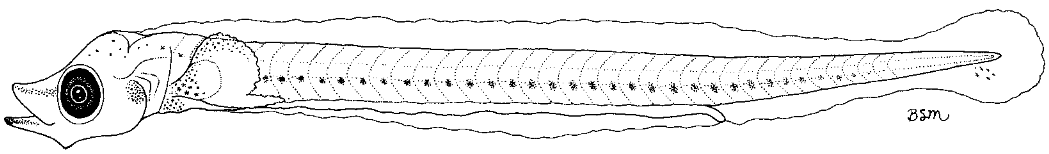
Hatching length: ca. 3–4 mm
Flexion length: 7.8–7.9 mm through ca. 9.5 mm
Transformation length: ca. 21–22 mm
Fin development sequence: C_1, D, A & C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Small ventral patch between P_1 bases; on P_1 bases. *Preflexion–postflexion*—Ventrolateral series along myosepta, increases with larval size, extends onto caudal finfold by ca. 6 mm; increases on P_1 base & ventrum between bases, spreads onto isthmus by 6 mm; patch on branchiostegal membrane by 4.9 mm; pair of longitudinal bands on snout; along mandibular symphysis extending along sides of lower jaw by 8 mm; on trailing part of gut.
Diagnostic features: P_1 with elongate lower portion; trailing gut after ca. 5–6 mm; pigmented along lower part of myosepta, on P_1 & ventrum between P_1, on branchiostegal membrane, stripes on snout; 25–27 preanal myomeres (usually 25), 37–40 total myomeres (usually 37–39).

MORPHOMETRICS (range & mean in %)

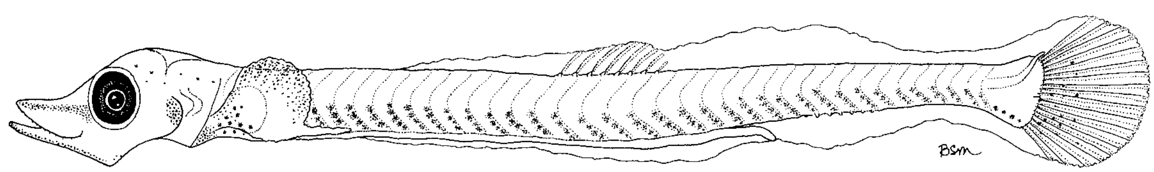
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		66–74	69–73	70–74		74–81
	71	71	72	72		78
BD/BL		7–10	7–8	6–8		34–42
	7	8	8	8		39
HL/BL		13–18	16–20	15–20		25–34
	14	16	18	17		31
HW/HL		52–63	46–55	29–59		45–92
	48	57	52	51		66
SnL/HL		29–36	33–44	36–43		26–36
	14	32	39	40		31
ED/HL*		22–30× 28–43	19–22× 22–29	16–22× 18–25		27–38× 34–43
	28×35	25×33	21×26	19×23		32×37
P_1L/BL		3–5	3–5	2–5		23–27
	1	4	4	3		25
P_1LL/BL†		6–13	6–13	6–13		0–0
	1	9	9	8		0
P_2L/BL		0–0	0–0	0–1		14–20
	0	0	0	0.4		17
TGL/BL		0–3	2–8	3–17		0–0
	0	2	5	12		0



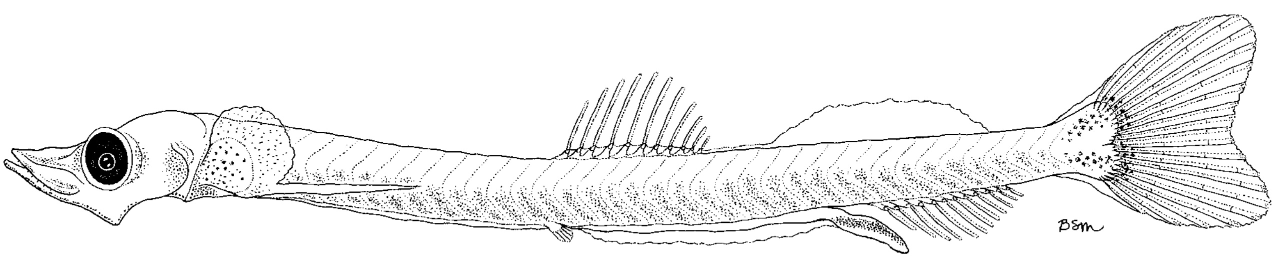
4.1 mm



6.9 mm



8.8 mm



18.4 mm

Figure Phosichthyidae 1. Yolk-sac larva, 4.1 mm (CalCOFI 7203, station 117.80); preflexion larva, 6.9 mm (CalCOFI 5908, station 103.50); late flexion larva (composite illustration, principally of 8.8 mm specimen from CalCOFI 5105, station 103.70; details of head and gut added from 9.4 mm specimen, CalCOFI 6204, station 117.90); postflexion larva, 18.4 mm (CalCOFI 7712, station 93.29).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–43	40–41
Precaudal	22–24	22–23
Caudal	16–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	13–16	14–15
Anal spines	0	0
Anal rays	13–17	15
Pelvic	7	7
Pectoral	10	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–10	8–9
Lower	4–5	4
Gill rakers:		
Upper	8–11	8–10
Lower	18–23	18–23
Branchiostegals	12	12

LIFE HISTORY

Range: Eastern Pacific Ocean; throughout CalCOFI region, usually south of Point Conception & seaward of shelf

Habitat: Epi- & mesopelagic

Spawning season: Year-round, higher in summer and autumn with September–October peak

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1974
Ahlstrom & Counts 1958
Gorbunova 1981

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* Yolk diameter was estimated from Ahlstrom & Counts (1958), Figure 2.
† Larvae shrink during the initial phase of transformation.
‡ Eye initially elongate, becoming round during transformation; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.58–0.74 mm **Yolk:** Segmented; 0.4–0.5 mm diam.*
No. of OG: None **Diam. of OG:**
Shell surface: Smooth
Pigment: Dorsolateral series along sides of embryo mid-way through development, extending onto head and ventrally on tail in late embryo.
Diagnostic features: Double shell membrane; no OG; irregularly segmented yolk; ca. 0.6–0.7 mm diameter.

LARVAE

Hatching length: ca. 2 mm
Flexion length: 5.6 mm through ca. 7 mm
Transformation length: ca. 19–21.6 mm through ca. 14.8 mm†
Fin development sequence: C_1, D, A & C_2, P_2, P_1
Pigmentation: *Yolk-sac*—10–12 dorsolaterally along each side; little on ventral margin of tail. *Preflexion-postflexion*—Dorsolateral pigment migrates ventrad, disappears by ca. 4 mm; usually 1 at cleithrum after ca. 4 mm; 1 above end of hindgut; 1–3 on ventral margin of tail; 1–4 along A base by ca. 7.5 mm; along bases of C_1 rays by ca. 6–7 mm. *Transformation*—Develops over gut, on dorsal surface of head, & internally below vertebral column in caudal peduncle.
Diagnostic features: Elongate, slender body; preanal length ca. 70% BL; moderately narrow eye; D ray 1 over myomere 21–22 (vs. myomere 19–20 in *V. nimbaria*); A ray 1 opposite D ray 9–10 (vs. opposite D 10–11 in *V. nimbaria*); usually 25 preanal myomeres, 40–41 total myomeres; dorsolateral melanophore series on larvae <ca. 4 mm; after 4 mm, usually a large melanophore ventrally near end of caudal peduncle; pigment on A & C bases in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		70–75 73	73–74 74	70–79 74	66–67 67	64–71 67
BD/BL		7–9 8	7–9 8	8–11 9	12–18 16	18–20 19
HL/BL		16–21 19	20–21 20	18–22 20	21–26 23	24–25 24
HW/HL		44–66 54	46–54 50	43–51 46	41–47 44	43–47 45
SnL/HL		11–29 22	23–28 26	21–36 29	26–32 30	28–31 29
ED/HL‡		15–28× 29–39 18×33	14–18× 27–31 16×29	15–18× 18–31 16×25	20–37× 23–41 31×32	35–39× 36–39 37×37
P_1L/BL		1–6 4	3–4 4	3–4 4	8–20 16	13–19 16
P_2L/BL		0–0 0	0–0 0	0–5 1	8–14 12	11–12 12

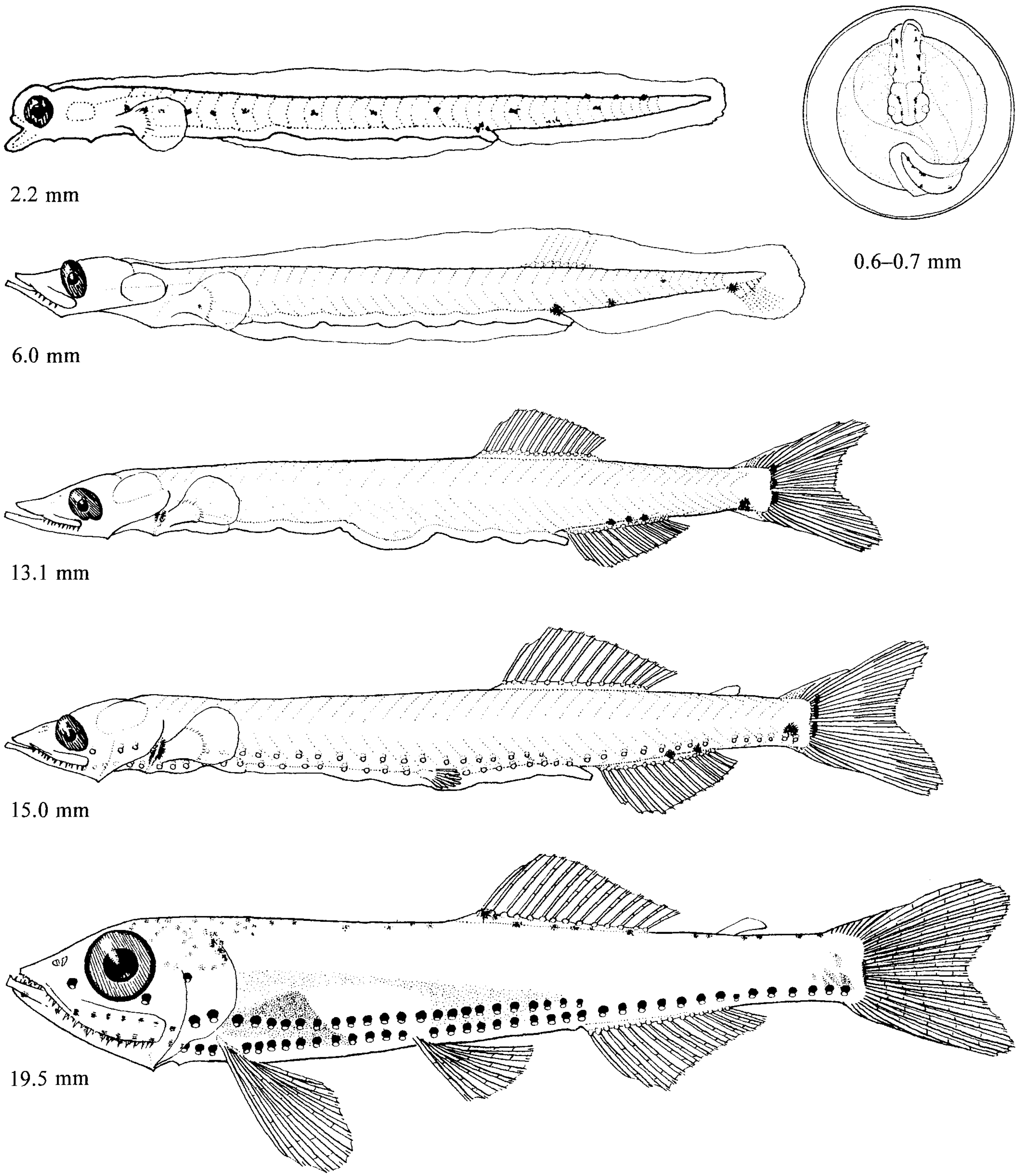


Figure Phosichthyidae 2. Egg, ca. 0.6–0.7 mm; early preflexion larva, 2.2 mm; late preflexion larva, 6.0 mm; postflexion larva, 13.1 mm; early transformation specimen, 15.0 mm; early juvenile 19.5 mm (Ahlstrom and Counts 1958).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–41	40
Precaudal	22–23	23
Caudal	16–18	17
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	12–15	13
Pelvic	7	7
Pectoral	9–11	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	4+5	4
Gill rakers:		
Upper	3–4	3
Lower	11–13	12
Branchiostegals	11	11

LIFE HISTORY

Range: Worldwide in warm water; at seaward edge of CalCOFI pattern

Habitat: Epi-, meso- & bathypelagic, principally at 50–600 m depth

Spawning season: Principally summer in Atlantic & Mediterranean (Grey 1964); larvae collected throughout the year in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Counts 1958
Ahlstrom et al. 1984c
Gorbunova 1981
Grey 1964
Jespersen & Tåning 1926

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.0 mm (W. Watson)
Flexion larva, 6.6 mm (W. Watson)
Postflexion larva, 10.1mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.75–0.85 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.17–0.19 mm
Shell surface: Smooth
Pigment: None
Diagnostic features: Segmented yolk; no thin inner shell membrane; single OG

LARVAE

Hatching length:
Flexion length: ca. 6.5–8.5 mm
Transformation length: ca. 22.6 mm through ca. 17 mm*
Fin development sequence: C_1, D, C_2, A, P_2, P_1
Pigmentation: *Preflexion–flexion*—Unpigmented (ca. 40%) or 1 on lateral midline at middle of tail, usually on one side only. *Postflexion*—None (specimens <ca. 11 mm) or 1 midlateral, on each side of caudal peduncle. *Transformation*—Developing & increasing dorsally & dorsolaterally, spreading caudad & ventrad.
Diagnostic features: Elongate, slender; preanal length usually ≥70% BL; narrow eye; 25–28 preanal myomeres (usually 26–27), 39–42 total myomeres (usually 40); moderately large size at flexion & transformation stages; little or no pigment through postflexion stage; caudal peduncle melanophore midlateral when present.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		71–75 73	72–81 77	67–79 75	68–69 69	68–69 68
BD/BL		6–8 7	6–8 7	6–9 7	11–19 15	20–22 21
HL/BL		14–20 17	17–20 19	16–21 19	18–25 22	26–28 27
HW/HL		42–59 52	44–52 49	39–46 43	49–59 54	42–53 46
SnL/HL		20–29 25	26–27 26	23–36 31	35–37 36	25–34 31
ED/HL†		15–21× 32–40 18×36	14–16× 31–31 15×31	13–17× 23–31 15×27	22–34× 27–38 28×32	31–33× 32–35 32×33
P_1L/BL		3–5 4	3–4 4	2–3 3	5–19 12	17–20 19
P_2L/BL		0–0 0	0–0 0	0–5 1	7–13 10	13–15 14

* Larvae shrink during transformation
† Eye initially elongate, becoming nearly round during transformation. Horizontal axis is given first, vertical second.

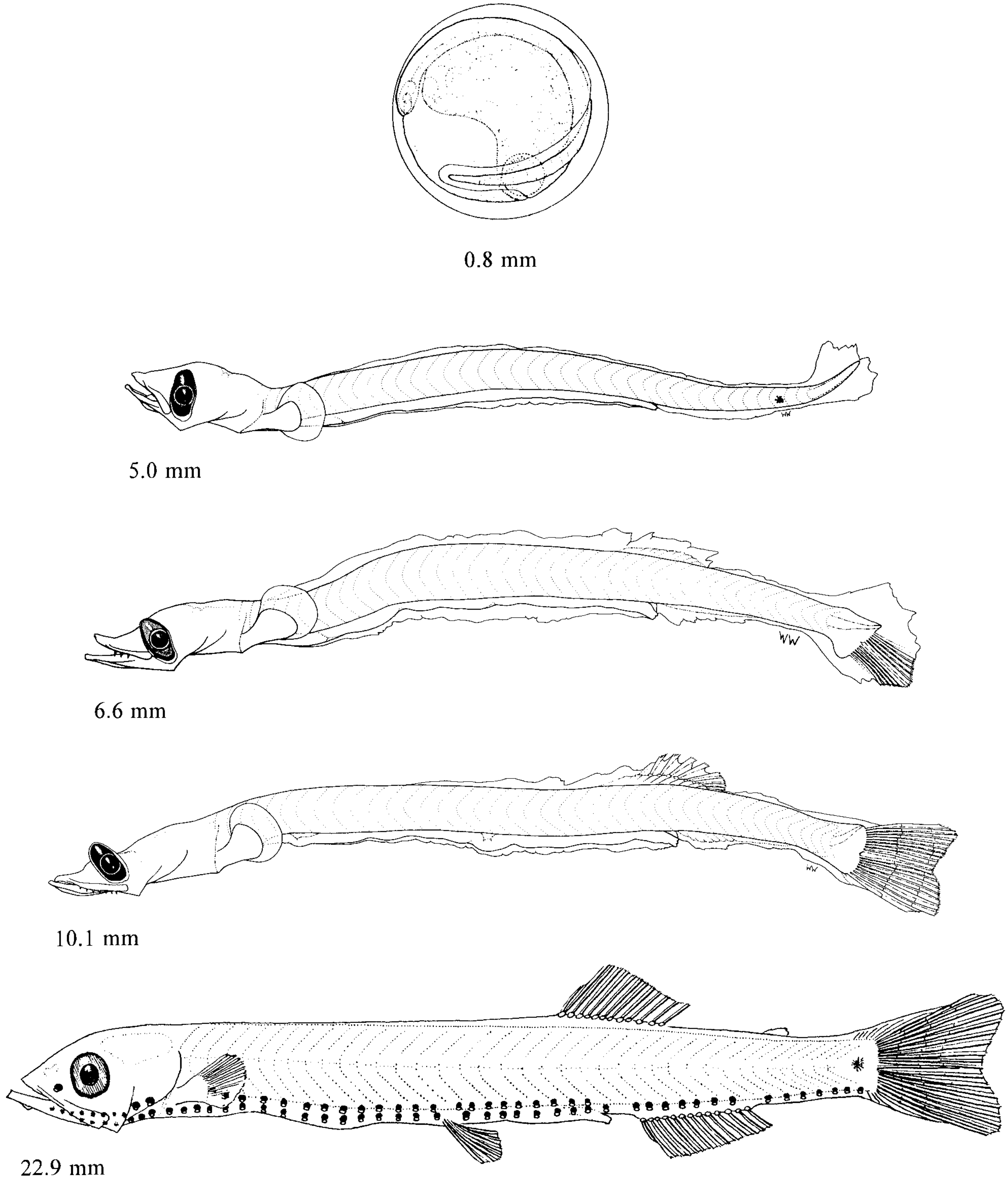


Figure Phosichthyidae 3. Egg, ca. 0.8 mm (Ahlstrom and Counts 1958); preflexion larva, 5.0 mm (CalCOFI 7804, station 90.150); flexion larva, 6.6 mm (CalCOFI 7804, station 90.150); postflexion larva, 10.1 mm (CalCOFI 7804, station 93.200); transformation specimen, 22.9 mm (Ahlstrom and Counts 1958).

MERISTICS

	Range	Mode
Vertebrae:		
Total	42–45	42
Precaudal	23	23
Caudal	19–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	11–12	12
Anal spines	0	0
Anal rays	14–16	14–16
Pelvic	7–8	
Pectoral	9–10	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	4	4
Gill rakers:		
Upper	3–5	
Lower	13	13
Branchiostegals	17	17

LIFE HISTORY

Range: Tropical & subtropical, ranging into southern part of California Current area, well seaward of the continental shelf

Habitat: Meso- & bathypelagic, at ca. 530–1335 m depth

Spawning season: Larvae collected spring through autumn

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984c
Ozawa 1988a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.4 mm (B. Sumida MacCall)
Flexion larva, 5.7 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

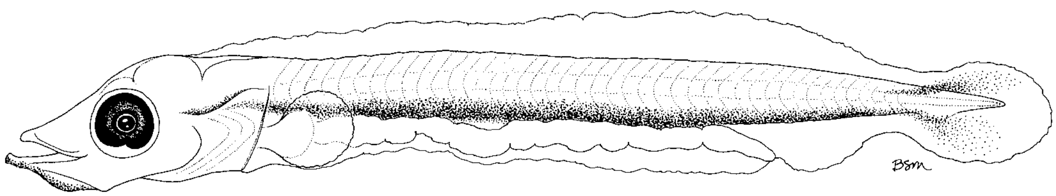
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

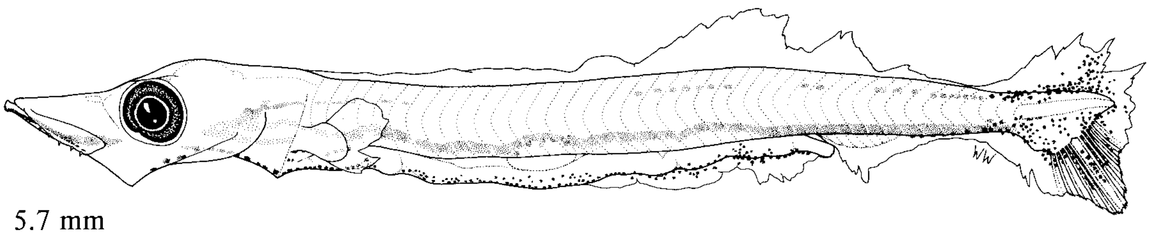
Hatching length: <2.8 mm
Flexion length: ca. 6 mm, through ca. 7.5–8 mm
Transformation length: Begins >14.1 mm, <20.3 mm
Fin development sequence: C_1, D & A, P_2 & C_2, P_1
Pigmentation: *Preflexion*—Series along ventral margin of gular membrane; series along ventral margin of isthmus & gut; heavy along dorsal margin of gut, continuing along ventral margin of tail; internal series along dorsal margin of notochord; around notochord tip & on caudal finfold. *Postflexion*—Disappears on dorsal part of C by ca. 10 mm; few on A base, present or not on A rays; series along midline of roof of mouth by ca. 11 mm.
Diagnostic features: Moderately heavy pigment, mainly on lower half of body; 29–31 preanal myomeres (usually 29), 41–44 total myomeres (usually 42); preanal length ca. 70–80% BL; gut trails little, if at all; middle C rays elongate; D insertion 4–5 myomeres (usually 5) ahead of A origin.

MORPHOMETRICS (range & mean in %)

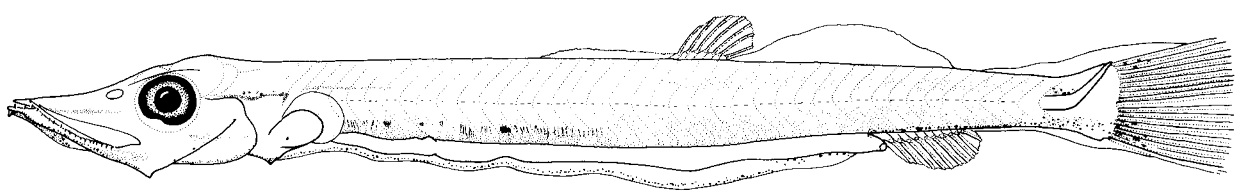
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		66–80 74	72–77 74	76–83 79		
BD/BL		8–11 9	8–11 9	8–12 9		
HL/BL		20–30 24	21–28 24	23–29 26		
HW/HL		31–41 36	35–35 35	29–35 31		
SnL/HL		32–39 35	38	33–42 40		
ED/HL		19–25 22	20	16–22 19		
P_1L/BL		1–5 3	3–5 4	2–3 3		
P_2L/BL		0–0 0	0–0 0	0–1 0.2		



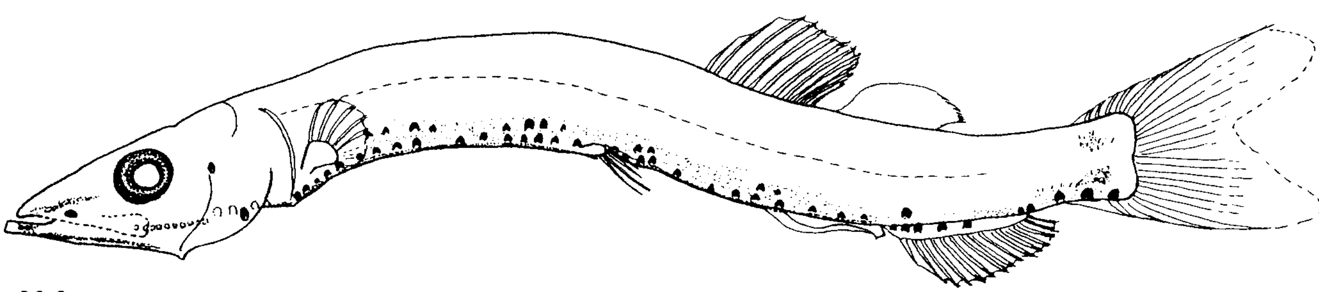
5.4 mm



5.7 mm



11.5 mm



20.3 mm

Figure Phosichthyidae 4. Preflexion larva, 5.4 mm (EASTROPAC II, station 46.054); flexion larva, 5.7 mm (TC 8405, station 58, Tucker trawl); postflexion larva, 11.5 mm (modified from Ahlstrom et al. 1984c); late transformation specimen, 20.3 mm (Ozawa 1988a).

STOMIOIDEA

H. G. Moser

Although Fink (1985) demonstrated monophyly of stomioid fishes (see Stomiiformes above) he did not propose a formal classification for these or other stomiiforms. Eschmeyer (1990) listed the traditional six stomioid families in his classification but did not recognize Weitzman's (1974) superfamily Stomioidea. In this guide we use the superfamily as a convenience in separating the six stomioid families from other stomiiforms and to efficiently summarize information on meristics (Table Stomioidea 1) and specimens used in preparing species descriptions (Table Stomioidea 2).

Stomioid larvae are distinctive and many have highly specialized morphological structures. Typically, stomioid larvae have an elongate body and gut; in many groups the gut trails freely from the body. In some the gut is voluminous but lacks mucosal striations. Fin rays, particularly the pelvic and pectoral rays, form late in larval development. The pectoral fins are positioned low on the body and in most species have a ventral orientation. Usually the finfolds are large; however, the fins form in their adult position and not out in the finfold.

Table Stomioidea 1. Meristic characters for the stomioid species in the California Current vicinity. All taxa have 10+9 principal caudal fin rays except *Bathophilus brevis* which has 5+6. Sources for meristic information are listed in the introductory section of each family.

	Vertebrae			Fin rays				
Taxon	PrCV	CV	Total	D	A	P_1	P_2	C_2
Chauliodontidae								
Chauliodus macouni	53–56	3–5	56–62	5–7	9–14	9–14	6–10	8–10+3–5
Stomiidae								
Stomias atriventer	66–67	3–5	69–74	16–20	16–22	6	5	7+4–5
Astronesthidae								
Astronesthes spp.			46–58	10–21	12–22	5–9	5–9	
Borostomias panamensis	38–40	15–18	54–57	15–17	16–21	7–8	7	10–12+4–5
Neonesthes capensis	33–35	19–24	51–57	8–12	22–28	6–9	6–8	8–10+4
Melanostomiidae								
Bathophilus brevis	31–33	2	33–35	10–11	9–12	11–13	8–14	1+1
B. filifer	43–45	3–5	45–50	13–16	14–17	1	4–5	4+3
B. flemingi	42–45	3–4	44–48	14–16	15–17	4–8	15–19	5–6+2–3
Eustomias spp.			56–69	20–30	32–46	0–13	6–8	
Flagellostomias boureei	50–53	11–15	63–65	13–17	21–26	8–12	7	6–8+4–5
Leptostomias spp.			75–83	16–22	20–29	9–11	7–8	
Melanostomias spp.			50–57	12–18	16–20	4–7	7–8	
Opostomias mitsuii	48–50	15	63–65	21–24	21–25	1+4	7–8	7–8+4–5
Photonectes spp.			49–65	15–24	17–24	0–3	6–7	
Tactostoma macropus	67–68	12–14	79–82	14–18	19–22	0	8–10	8–9+4
Malacosteidae								
Aristostomias scintillans	50–53	5–7	54–58	21–25	25–29	4–8	6–7	9–11+5–6
Idiacanthidae								
Idiacanthus antrostomus			81–85	54–66	28–43	0	6	11–14+7–10

Table Stomioidea 2. Number of specimens (above) and size range (in mm, below) used in the preparation of the stomioid species descriptions. An "L" indicates literature used in the description. Taxa with descriptive summaries in chapter introductions are indicated by an asterisk.

Taxon	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Chauliodontidae							
Chauliodus macouni	L[a]	1	6	4	9	1	3
		4.7	10.0–16.4	18.1–21.3	23.7–48.7	42.3	32.6–35.7
Stomiidae							
Stomias atriventer	L[a]	2	6	6	6	3	0
		2.7–3.4	4.4–10.0	10.6–15.7	17.1–29.9	30.3–41.3	
Astronesthidae							
Astronesthes sp.*	0	0	1	1	0	0	0
			5.9	8.1			
*Borostomias panamensis**	0	0	0	0	3	0	0
					13.7–17.2		
*Neonesthes capensis**	0	0	0	0	1	0	0
					15.2		
Melanostomiidae							
*Bathophilus brevis**	0	0	0	1	0	0	0
				9.3			
B. filifer	0	3	9	4	4	0	2
		3.0–3.9	3.7–8.1	8.3–12.0	12.4–22.3		30.4–43.3
B. flemingi	0	1	8	4	6	0	3
		3.7	5.6–11.0	12.0–13.5	15.0–24.4		39.4–45.7
Eustomias sp.*	0	0	0	1	0	0	0
				18.6			
*Flagellostomias boureei**	0	0	0	0	1	0	0
					36.4		
Leptostomias sp.*	0	0	0	0	1	0	0
					16.1		
Melanostomias sp.*	0	0	0	0	1	0	0
					16.0		
*Opostomias mitsuii**	0	0	0	1	0	0	0
				15.0			
Photonectes sp.*	0	0	0	0	1	0	0
					15.9		
Tactostoma macropus	L[a,b]	3	9	5	7	3	3
		5.6–6.0	6.1–13.0	14.5–23.4	22.7–48.0	52.2–55.2	59.1–69.0
Malacosteidae							
Aristostomias scintillans	0	0	7	4	10	0	3
			6.6–11.8	13.0–17.4	17.1–47.0		44.6–60.7
Idiacanthidae							
Idiacanthus antrostomus	0	0	8	5	8	0	3
			4.5–17.1	21.2–32.3	32.0–67.4		77.9–85.1

[a] Kawaguchi and Moser 1984
[b] Kawaguchi and Moser 1993

CHAULIODONTIDAE: Viperfishes

H. G. MOSER

Chauliodontidae consists of eight species in the genus *Chauliodus* (Parin and Novikova 1974). One species, *C. macouni*, occurs in the California Current region. It ranges from central Baja California, Mexico north to the Gulf of Alaska and westward across the north Pacific transition zone to northern Japan. Larvae of *C. macouni*, the second most abundant larval stomioid in the CalCOFI surveys, extend southward to central Baja California and peak in abundance at ca. 100–200 n.mi. from the coast. *Chauliodus sloani* occurs in the warm regions of nearly all oceans and Loeb (1980) identified its larvae in the central water mass to the west of the CalCOFI study area.

Viperfishes are small to medium-size (<30 cm), slender, compressed fishes. They have five rows of large deciduous scales embedded in shallow pockets, each with a more or less hexagonal pigment pattern. Coloration is iridescent grey or blue over a black background. The large mouth has huge fanglike teeth on the premaxillary and mandible. The dorsal fin is well forward on the body and has an elongate first ray terminating in a fleshy tab. The pelvic fins are anterior to midbody, and the anal fin is well posterior. There is a large dorsal adipose fin and a small ventral adipose fin anterior to the anus. The photophore pattern is distinctive with postorbital and suborbital organs and prominent lateral and ventral longitudinal series on the body. Small luminous organs are present on each scale area and small organs are present elsewhere on the head and body. A short chin barbel is present in some species. Viperfishes are relatively common predators of the meso- and bathypelagic zones of the world oceans; in some species the smaller individuals migrate to shallow epipelagic waters at night (Morrow 1964a; Gibbs 1984, 1986b).

Chauliodontids are oviparous and have large (2.2–3.6 mm) round planktonic eggs with segmented yolk and no oil globule. Initial yolk diameter of *C. macouni* eggs is ca. one-half the shell diameter, leaving a large perivitelline space, and this may be a characteristic of all chauliodontids (Belyanina 1977; Kawaguchi and Moser 1984; Matarese and Sandknop 1984). Larvae hatch at 6–7 mm and have an elongate yolk sac. Larvae are slender, elliptical in cross section, and have an extremely long, non-trailing gut that extends the entire length of the body. The head is relatively small, with a short, pointed snout and slightly ovoid eyes. The median finfold is small and best developed on the posterior region of the body. All fins, except the caudal, are slow to develop and appear in late postflexion larvae. Larvae reach a large size (some species >40 mm) and undergo considerable shrinkage during transformation (Kawaguchi and Moser 1984). Larval pigment is absent except for minute melanophores observed at the notochord tip in yolk-sac larvae of *C. sloani* by Mito (1961a). This pigment has not been reported for larvae of other *Chauliodus* species.

Chauliodus eggs are larger than any other stomiiform egg presently identified. Eggs of *C. macouni* (2.7–3.1 mm) may be confused with those of Pacific sardine, *Sardinops sagax*, but have a larger shell diameter and lack an oil globule. Larvae of *C. macouni* and *Stomias atriventer* are somewhat similar; both are slender and elongate but *C. macouni* reaches a larger size (ca. 50 mm vs. 30 mm). The gut is straight and elongate in both species but extends nearly the entire length of the body in *C. macouni* and is relatively shorter and greater in diameter in *S. atriventer*. Also, *S. atriventer* has serial pigment above and below the gut and *C. macouni* lacks pigment. The following description is based on published literature and on detailed observations of 24 specimens of *C. macouni* (Table Stomioidea 2). Meristic data were obtained from the Miller and Lea (1972), Matarese et al. (1989), and from counts made during this study. Ecological information was obtained from the above sources and from Morrow (1964a), Fitch and Lavenberg (1968), and Gibbs (1984, 1986b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	56–62	60
Precaudal	53–56	54
Caudal	3–5	4
Fins:		
Dorsal spines	0	0
Dorsal rays	5–7	6
Anal spines	0	0
Anal rays	9–14	12
Pelvic	6–10	7
Pectoral	9–14	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–10	9–10
Lower	3–5	4
Gill rakers:		
Upper		
Lower		
Branchiostegals	16–21	

LIFE HISTORY

Range: Northern Japan, Bering Sea, & Gulf of Alaska to central Baja California

Habitat: Epi- to bathypelagic to depths >4000 m

Spawning season: Larva present throughout year in CalCOFI samples with highest abundance in February

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Kawaguchi & Moser 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Transformation specimen, 42.3 mm (N. Arthur)
Juvenile, 32.6 mm (N. Arthur)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.7–3.2 mm
Yolk: Segmented; 1.3–1.5 mm diam.
No. of OG: 0
Diam. of OG:
Shell surface: Smooth
Pigment: None
Diagnostic features: Large diameter; large perivitelline space; segmented yolk; no OG

LARVAE

Hatching length: At least 4.7 mm
Flexion length: 18–22 mm
Transformation length: ca. 33–49 mm
Fin development sequence: C_1, D, A, P_2 & C_2, P_1
Pigmentation: None
Diagnostic featnres: Slender, elongate, attaining a maximum length of almost 50 mm; elongate straight gut >90% of body length; small head, arched ventrad; all fins except C late-forming, D far forward; lack of pigment.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		86–92	93–94	93–97		80–83
	87	90	94	95	88	81
BD/BL		4–6	4–4	4–5		14–15
	4	5	4	4	7	14
HL/BL		10–12	9–9	7–10		16–17
	9	11	9	8	10	17
HW/HL		33–40	40–41	37–49		38–42
	57	38	41	42	41	40
SnL/HL		23–29	30–32	30–39		22–26
	14	26	31	34	33	24
ED/HL*		17–25× 29–34	20–24× 28–31	19–24× 28–40		22–23× 22–23
	52×33	22×32	22×30	21×32	22×26	22×22
P_1L/BL		1–2	2–2	1–14		13–14
	0	2	2	3	4	13
P_2L/BL		0–0	0–0	0–1		18–19
	0	0	0	0.2	5	19

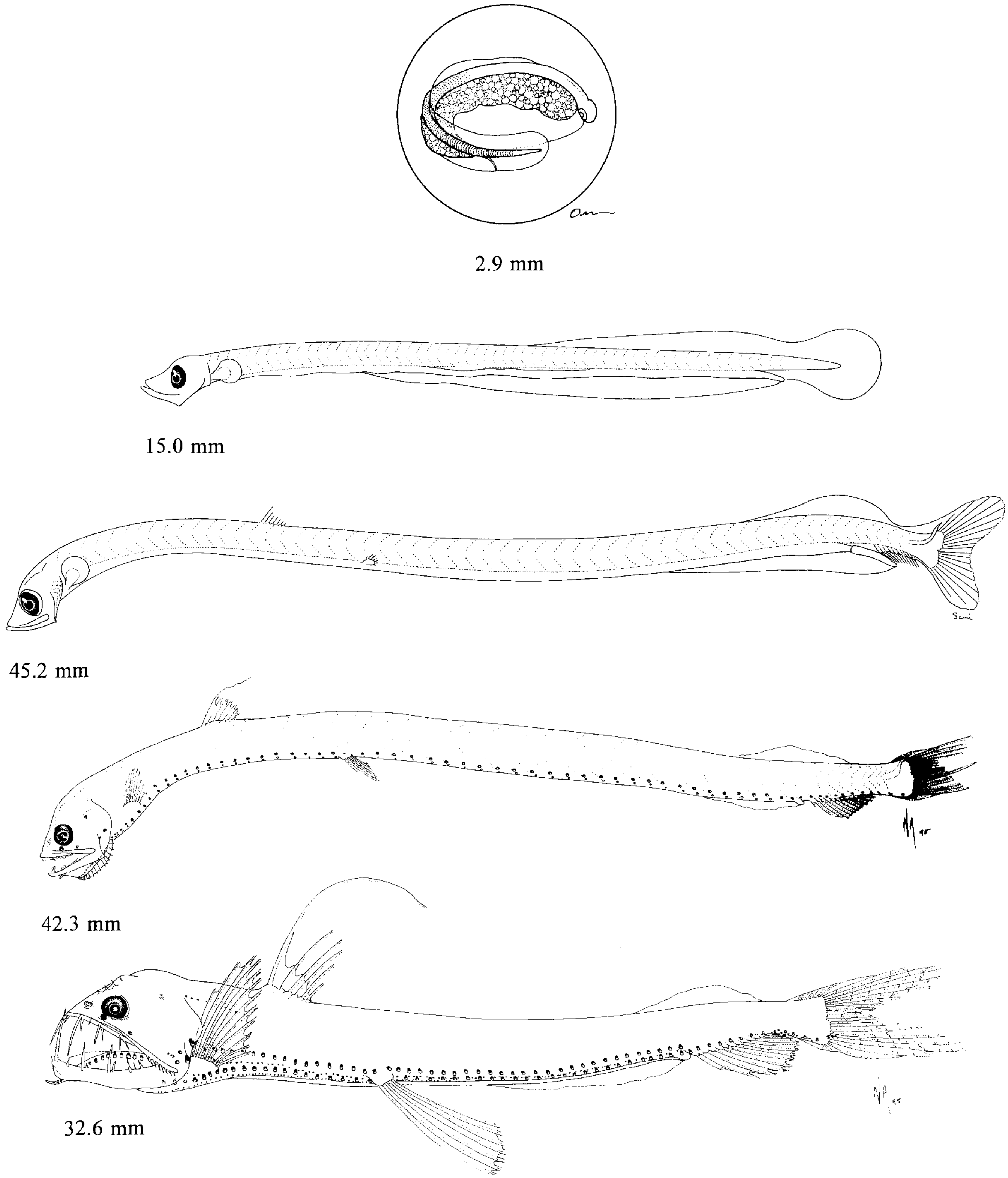


Figure Chauliodontidae 1. Egg, 2.9 mm (Matarese and Sandknop 1984); preflexion larva, 15.0 mm; postflexion larva, 45.2 mm (Kawaguchi and Moser 1984); transformation specimen, 42.3 mm (CFRD 8701, station 62.2.56.0); juvenile, 32.6 mm, pigment not shown (CFRD 9104, station 70.0.62.5, MOCNESS).

STOMIIDAE: Scaly dragonfishes

H. G. MOSER

Stomiidae includes 11 species in the genus *Stomias* (Morrow 1964b; Gibbs 1969, 1984, 1986a; Fink and Fink 1986). *Stomias atriventer* occurs in the California Current region from central California south to the Gulf of California. It is the most abundant larval stomioid in the CalCOFI surveys and has an abundance peak at ca. 300–350 n.mi. from the coast.

Scaly dragonfishes are small to moderate-size (to ca. 40 cm), slender, compressed fishes. The body is covered with 5–6 rows of pigmented hexagonal areas, each with a scalelike structure, covered by a gelatinous membrane in life. Coloration is iridescent black or dark green. The large mouth has moderate-size fanglike teeth. Dorsal and anal fins are near the caudal fin and the pelvic fins are well posterior to midbody in most species. There are two rows of prominent photophores ventrally on each side and the hexagonal areas each have one or more small photophores. The chin barbel ranges from shorter than the head to a maximum of 3/4 of body length, depending on the species; it terminates in a bulb with filaments. Scaly dragonfishes are relatively common midwater predators of all oceans, usually found at meso- to bathypelagic depths; young individuals of some species apparently migrate to near-surface waters at night (Gibbs 1984, 1986a).

Stomias is oviparous; pelagic eggs are round with diameters ranging from 0.88 to 1.5 mm, depending on the species. Eggs have a single oil globule, segmented yolk, and a distinct inner membrane (Kawaguchi and Moser 1984; Matarese and Sandknop 1984). Larvae hatch at 3–4 mm and have an elongate yolk sac. Larvae are slender, round in cross section with a long gut that is slightly shorter in relative length than that of *Chauliodus*. The head is relatively small, with a moderately long snout and slightly ovoid eyes. The median finfold is small. Dorsal and anal fins develop in early postflexion larvae but the pelvic fins do not appear until late in the postflexion stage. Late-stage embryos of *S. atriventer* and some other species have dorsal melanophores that migrate ventrad to form paired series above the gut that extend posteriad to the notochord tip in preflexion larvae. These subsequently become less apparent and a ventral median series develops below the gut. Some species develop a midlateral series along the body and others have scattered melanophores over the entire body (Kawaguchi and Moser 1984).

Larvae of five *Stomias* species have been described: *S. colubrinus* (Pertseva-Ostroumova and Rass 1973); *S. atriventer* (Kawaguchi and Moser 1984); and *S. affinis*, *S. nebulosus*, and *S. pacificus* (Ozawa 1988a). *Stomias colubrinus* occurs south of the CalCOFI area in the eastern tropical Pacific; its larvae are easily distinguished from those of *S. atriventer*, since they have melanophores covering the lower half of the body. The following description is based on published literature and on detailed observations of 23 specimens of *S. atriventer* (Table Stomioidea 2). Meristic data were obtained from counts made during this study. Ecological information was obtained from Gibbs (1984, 1986a), and Fitch and Lavenberg (1968).

MERISTICS

	Range	Mode
Vertebrae:		
Total	69–74	72
Precaudal	66–67	67
Caudal	3–5	5
Fins:		
Dorsal spines	0	0
Dorsal rays	16–20	17
Anal spines	0	0
Anal rays	16–22	19
Pelvic	5	5
Pectoral	6	6
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7	7
Lower	4–5	4
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Central California to Gulf of California & from the equator to northern Chile

Habitat: Meso- & bathypelagic at <100–1500 m depth

Spawning season: Larvae present throughout year in CalCOFI surveys with peaks in February & September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Kawaguchi & Moser 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Transformation specimen, 30.3 mm (N. Arthur)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.88–0.92 mm **Yolk:** Segmented; 0.70 mm diam.
No. of OG: 1 **Diam. of OG:** 0.20–0.25 mm
Shell surface: Smooth
Pigment: Paired series on dorsum of embryo, continuing forward to outline brain
Diagnostic features: Small size, inner membrane, single OG, segmented yolk

LARVAE

Hatching length: 2–3 mm
Flexion length: 10–16 mm
Transformation length: ca. 30 mm
Fin development sequence: C_1 & D & A, C_2 & P_2 & P_1
Pigmentation: *Yolk-sac–early preflexion*—Dorsal pigment series migrates to form paired ventrolateral series between gut & trunk extending posteriad to notochord tip; short series above notochord tip. *Late preflexion–flexion*—Series lateral to isthmus; gular patch; on lower jaw, postorbital region; lateral hindbrain, & terminal gut section. *Postflexion*—Series above gut recessed in ventral trunk; sparse on C, D, & A; on postorbital region.
Diagnostic features: Slender, elongate, attaining a maximum length of ca. 30 mm; elongate straight gut (ca. 85–90% BL); small head arched ventrad; small elliptical eyes (EL ca. 15% of HL at postflexion stage); series above & below gut; D & A form near C at flexion stage; paired fins form at transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	74–82 76	84–90 86	87–89 88	87–91 89	84–86 85	
BD/BL	7–7 7	6–8 7	5–6 6	5–6 6	9–9 9	
HL/BL	15–18 16	14–16 15	13–14 13	9–13 11	11–12 12	
HW/HL	40–42 41	32–46 38	30–37 33	32–35 33	41–50 44	
SnL/HL	17–20 18	26–32 29	33–40 36	32–38 36	26–31 28	
ED/HL*	33–44× 29–32 39×31	13–23× 17–29 18×23	11–16× 15–20 13×18	9–12× 13–17 10×15	16–19× 16–19 18×18	
P_1L/BL	0–0 0	2–4 3	2–2 2	1–2 2	9–11 10	
P_2L/BL	0–0 0	0–0 0	0–0 0	0–0.4 0.2	9–12 11	

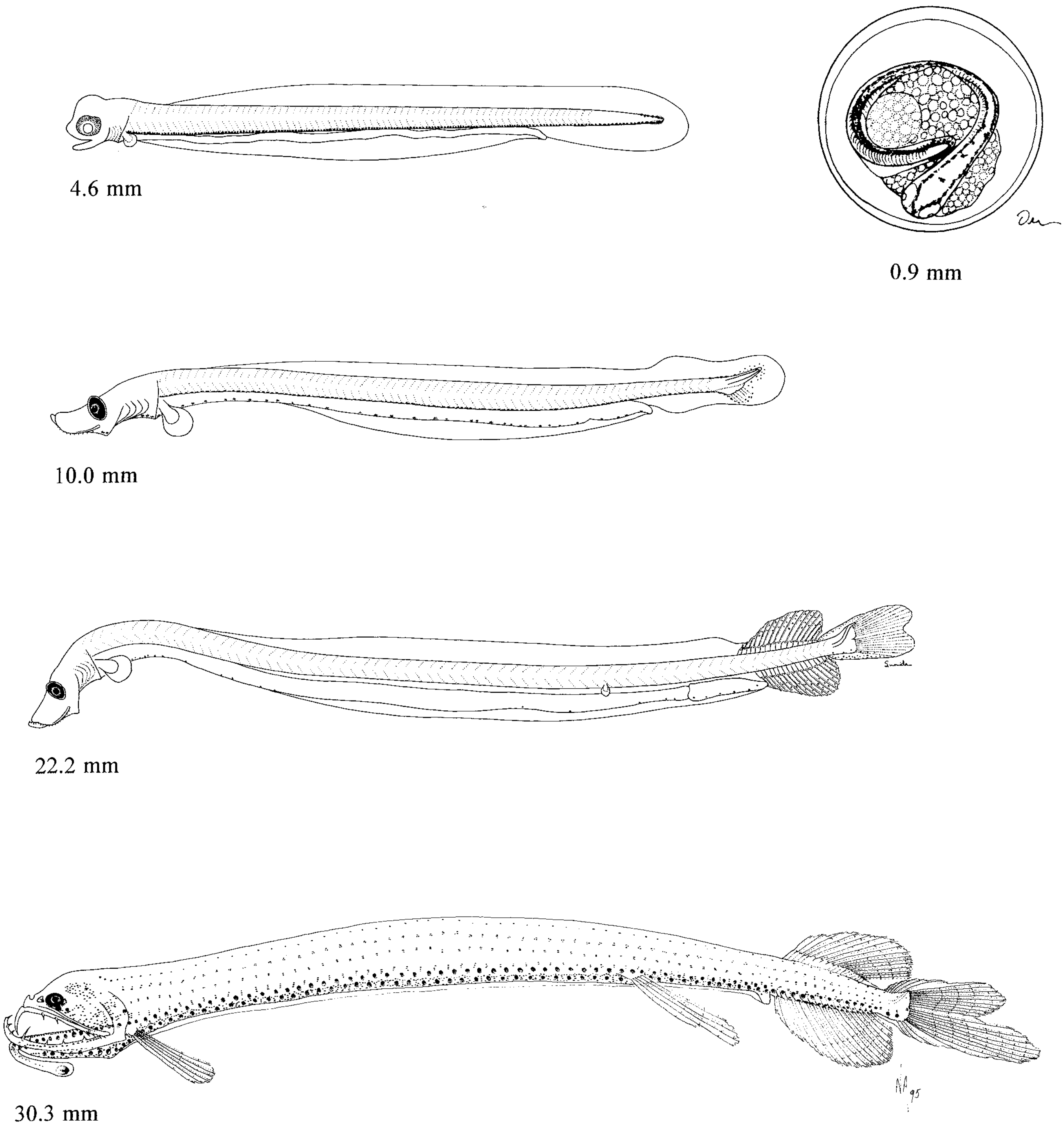


Figure Stomiidae 1. Egg, 0.9 mm (Matarese and Sandknop 1984); preflexion larva, 4.6 mm; flexion larva, 10.0 mm; postflexion larva, 22.2 mm (Kawaguchi and Moser 1984); transformation specimen, 30.3 mm (CalCOFI 5406, station 130.50).

ASTRONESTHIDAE: Snaggletooths

H. G. Moser

Astronesthidae includes 5 genera and ca. 35 species of midwater predators that occur principally in tropical and subtropical waters. Astronesthids are relatively rare in midwater collections from the CalCOFI survey area (Table Stomioidea 1). Only *Borostomias panamensis*, an eastern tropical Pacific species, and *Neonesthes capensis*, a subtropical cosmopolite, are reported from California Current waters (Fitch and Lavenberg 1968; Hubbs et al. 1979). Astronesthid larvae are rare in the CalCOFI time series, occurring in only three samples during 1951–1984, all off Baja California.

Astronesthids are small to moderate in size (up to 40 cm) and have moderately compressed, elongate, scaleless bodies. Pigmentation is black; some species have silvery sides. The mouth is large, often with fanglike teeth. The dorsal fin origin is at, or slightly posterior to, midbody, well in advance of the anal fin origin. A dorsal adipose fin is present in all except *Radinesthes* and some species have a ventral adipose fin anterior to the anal fin. There are two prominent ventral photophore rows and numerous small photophores over the head and body. The chin barbel may be shorter than the head or several times the head length and a terminal bulb is present in some species. Some species migrate from mesopelagic depths to surface waters at night and others apparently are benthopelagic (Gibbs 1964a, 1984, 1986c).

Presumably, Astronesthids are oviparous but planktonic eggs have not been described. Larvae are highly diverse and have a great number of morphological specializations; however, no complete developmental series, with transformation specimens, has been described and identifications in the literature are tentative (Kawaguchi and Moser 1984). The described larvae can be grouped into two morphs: 1) laterally compressed body with elongate, sometimes slightly trailing gut and 2) body rounded in cross-section with trailing gut deflected from the body posterior or anterior to midbody. Some species of the latter type have the dorsal and anal fins on cartilaginous pedestals and have large median finfolds. In one species the trailing gut is ornamented with leaflike appendages and in another the preanal finfold is keel-like. Pigmentation patterns range from few or no melanophores, to heavy pigmentation on the finfolds and myosepta, or punctate melanophores along the body (Kawaguchi and Moser 1984; Ozawa 1988a). Astronesthid larvae can be distinguished from other stomioids by the forward placement of the dorsal fin. Larvae of the lanternfish *Myctophum aurolaternatum* have the dorsal fin at midbody and a trailing gut and are sometimes confused with astronesthid larvae; however, *M. aurolaternatum* has stalked eyes, a feature not found in known larval astronesthids. Pertseva-Ostroumova and Rass (1973) mistakenly identified an astronesthid larva as the phosichthyid *Ichthyococcus*.

The three larvae (5.9–8.1 mm BL) from CalCOFI surveys appear to be the same species, probably in the genus *Astronesthes*. The 8.1 mm specimen (Figure Astronesthidae 1) is beginning notochord flexion. It is moderately slender (BD depth 11% BL). The trailing gut is deflected ventrad from the body at ca. 64% BL and is broken off at a preanal length 70% BL. Head length is 22% BL. The eye is small (EL 18% HL) and elliptical. The dorsal fin originates at 62% BL and the anal fin at 75% BL. A patch of melanophores is present over the hindgut and adjacent finfold. Another patch is present at the dorsal fin and finfold in the smallest specimen (5.9 mm), however, the 8.1 mm specimen is faded and a dorsal patch is not discernible on it. It has ca. 58 myomeres, 12 pterygiophores in the dorsal fin base, and an anal fin base slightly longer than the dorsal.

Larvae similar to those identified as *Borostomias panamensis* by Pertseva-Ostroumova and Rass (1973) are available from EASTROPAC II (station 46.079). A 13.7 mm early postflexion larva (Figure Astronesthidae 1) is slender (BD 10% BL) with a trailing (incomplete) gut (preanal length 79% BL) that is deflected ventrad from the body at ca. 58% BL. The eye is elliptical and small (EL 19% HL). The dorsal fin originates at 60% BL and the anal fin at 77% BL. Pigmentation consists of paired melanophores ventrolateral to the midbrain and the hindbrain, a pair of dorsolateral melanophores at the nape, 3–4 lateral melanophores alternating on each side of the body, and melanophores on the trailing gut. The most advanced specimen available (17.2 mm) has 11 dorsal and 13 anal fin rays forming and 53 myomeres. The fin ray complements are incomplete and the counts are lower than those from adult *B. panamensis* examined in this study (Table Stomioidea 1). Identification as *B. panamensis* is tentative.

We have no larvae of eastern Pacific *Neonesthes capensis*; however, two astronesthids captured over the Hancock Seamount on NMFS Hawaii Laboratory Cruise TC 8501 appear to be that species. A 15.2 mm postflexion specimen (Figure Astronesthidae 1) is slender (BD 8% BL) with a moderately elongate non-trailing gut (Sn-A 81% BL). The eye is large (EL 33% HL) and slightly ovoid. The corneal area and surrounding sclera are bulged outward and within the eye a funnel shaped, lightly pigmented membrane extends outward from the margin of the pupil. The dorsal fin origin is slightly posterior to midbody (56% BL), well separated from the anal fin origin at 76% BL. The pelvic fin bud is anterior to midbody (47% BL). Pigmentation is as follows: a melanophore on the forebrain in the interorbital region; a pair ventrolateral to the hindbrain; a series of dorsal median melanophores, 6–7 anterior and ca. 5 posterior to the dorsal fin (those anterior to the dorsal fin are larger); a single melanophore on the anterior edge of the dorsal fin base; 2 between the trunk and hindgut; 2 ventrally on the tail above the anal fin; a few on the margin of the ventral finfold at ca. midbody; and a few distally on the anal fin rays and at the bases of the upper and lower principal caudal fin rays. The 15.2 mm larva has 9 dorsal fin rays, ca. 25 anal rays (complement not complete), and 55 myomeres. Dorsal fin ray length increases posteriorly with the penultimate ray the longest (20% BL). The meristic counts and fin positions of this larva match those of adult *N. capensis* (Table Stomioidea 1). Recently, Evseenko and Suntsov (1995) described a 25 mm larva from northeast of Hawaii that is similar in morphology and pigmentation to our larvae, but lacks eyes. They tentatively identified their specimen as *N. capensis*.

Larval descriptions of astronesthid species found in the CalCOFI region are limited to the above comments with illustrations of single specimens (Table Stomioidea 2; Figure Astronesthidae 1). Identification of astronesthid larvae will remain severely limited until complete larval series and transformation specimens are described. Meristic data were obtained from Gibbs (1964a, 1984, 1986c), Kawaguchi and Moser (1984), and from counts made during this study. Ecological information was obtained from Gibbs (1964a, 1984, 1986c) and Fitch and Lavenberg (1968).

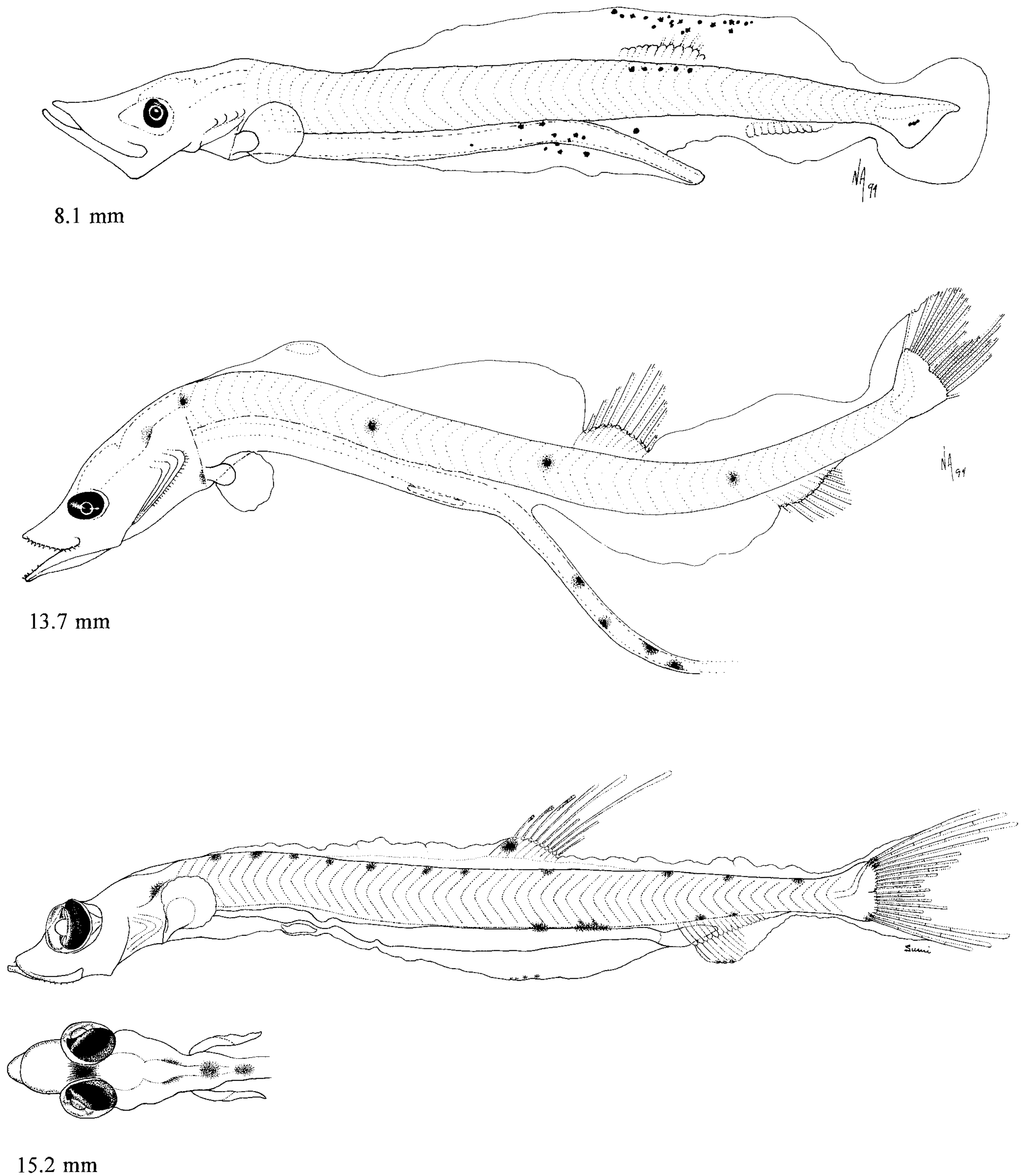


Figure Astronesthidae 1. Astronesthid larvae: *Astronesthes* sp., flexion stage, 8.1 mm (CalCOFI 6207, station 117.90; since the specimen is faded, the dorsal pigmentation of a 5.9 mm larva [CalCOFI 6201, station 133.35] is shown where it would occur in this specimen; original illustration by N. Arthur); *Borostomias panamensis*, postflexion stage, 13.7 mm (EASTROPAC II, station 46.79; original illustration by N. Arthur); *Neonesthes capensis*, postflexion stage, 15.2 mm, with dorsal view of head (TC 8501, station 59; original illustration by B. Sumida MacCall).

MELANOSTOMIIDAE: Scaleless dragonfishes

H. G. MOSER

Melanostomiidae, the largest stomioid family, contains 16 genera and about 200 species (Morrow and Gibbs 1964; Gibbs 1984, 1986d; Fink 1985). Eight genera are found in the California Current region (Berry and Perkins 1966; Hubbs et al. 1979; pers. obs.). *Bathophilus* is represented by three species, *B. flemingi*, *B. filifer*, and *B. brevis*. *Bathophilus flemingi* ranges from the Alaskan Gyre throughout the California Current to central Baja California. *Bathophilus filifer*, an eastern tropical Pacific species, ranges north to southern Baja California. *Bathophilus brevis* is broadly distributed in the tropical and subtropical Pacific and Atlantic and is taken occasionally in the western part of the California Current region. The monotypic *Tactostoma macropus* is endemic to the subarctic and transitional waters of the north Pacific; it ranges from northern Baja California northward in the California Current to the Gulf of Alaska and westward to northern Japan. The monotypic *Flagellostomias boureei* is widely distributed in the tropical and subtropical waters of the world. *Opostomias mitsuii* ranges across the temperate north Pacific. Specimens of *Eustomias*, *Photonectes*, *Leptostomias*, and *Melanostomias* are collected rarely in midwater trawls in the CalCOFI region; representatives of these genera range into the CalCOFI region from the eastern tropical Pacific and from the central water mass. Specific identifications of these genera should be considered tentative since the taxonomy of their eastern Pacific representatives has not been resolved.

Melanostomiids are small to moderate-size fishes (to near 40 cm) with a variety of body shapes ranging from laterally compressed and deep-bodied to slender and rounded in cross section. The skin lacks scales and is black or dark in coloration, sometimes with silver or metallic iridescence. There are two ventral rows of prominent photophores on each side and numerous small photophores on the head and body. The dorsal and anal fins are close to the caudal. The pelvic fins are at midbody or somewhat posterior to midbody; in *Bathophilus* they are elevated to the side of the body. An adipose fin is lacking in all but one genus. The barbel ranges from small to several times the length of the body and may or may not have terminal ornamentation. Melanostomiids are meso- and bathypelagic predators that sometimes migrate to near surface waters at night; some species may be benthopelagic (Morrow and Gibbs 1964; Gibbs 1984, 1986d).

Melanostomiids are oviparous with pelagic eggs. *Tactostoma macropus* is the only species whose pelagic eggs have been described; they are spherical and large (1.38–1.55 mm) with segmented yolk, a single oil globule and large perivitelline space (Kawaguchi and Moser 1984, 1993). Eggs of *T. macropus* may be confused with those of Pacific sardine, *Sardinops sagax*, since they overlap in size and are similar in other characteristics; however, the oil globule is larger in *T. macropus* (ca. 0.30–0.40 mm vs. ca. 0.16–0.18 mm) and the yolk segments are smaller than in sardine and are spherical (vs. somewhat polygonal in sardine). Melanostomiid larvae are elongate and have a straight, elongate gut with a pronounced muscular terminus. The gut is non-trailing except in *Eustomias*. The body is round to laterally compressed in cross section; the head and jaws are relatively large and the eyes are small and elliptical. Maximum larval size is typically 20–30 mm but some species exceed 30 mm (e.g., *Flagellostomias*) or 40 mm (e.g., *Tactostoma*). The usual pigment pattern consists of one or more melanophores on the dorsal surface of each myomere and one or more on the hypaxial myosepta. *Eustomias* differs from other melanostomiids in having large isolated dorsal melanophores, *Bathophilus* differs in having melanophores on the ventral surface of each myomere (Beebe and Crane 1939; Kawaguchi and Moser 1984).

The most significant early study of melanostomiid larvae was by Beebe and Crane (1939) who described and illustrated larvae of four species: *Leptostomias gladiator*, *Melanostomias bartonbeani*, *Photonectes parvimanus*, *Flagellostomias boureei*. They illustrated larvae of *Bathophilus* and *Eustomias* but transformation series were not available to permit specific identification. The larval pigmentation could be observed through the skin of newly transformed juveniles of *Odontostomias micropogon* and *Grammatostomias flagellibarba*, thus providing a means of identifying their larvae, although they were not available to Beebe and Crane (1939). Kawaguchi and Moser (1984) summarized the larval characters of melanostomiid genera and described and illustrated larvae of *Bathophilus brevis*, *Opostomias mitsuii* and *Tactostoma macropus*. Ozawa and Aono (1986) and Ozawa (1988a) added *Melanostomias tentaculatus*, *Echiostoma barbatum*, *Photonectes margarita*, *P. albipennis*, and *Eustomias bifilis* to the list of melanostomiid larvae known from the North Pacific.

Larvae of *Bathophilus filifer*, *B. flemingi*, and *T. macropus* are common enough in CalCOFI collections to permit detailed descriptions of larval series. Identifying characteristics of larvae of other melanostomiids whose larval or adult stages occur rarely in the CalCOFI region are summarized briefly below.

A damaged 6.6 mm preflexion larva of *Bathophilus brevis* was identified in CalCOFI samples (CalCOFI 6407, station 80.200). A 15.7 mm postflexion specimen (Kawaguchi and Moser 1984) from the western Pacific is shown in Figure Melanostomiidae 1. A 9.3 mm midflexion specimen (Table Stomioidea 2) from the central water mass west of the CalCOFI survey area is representative of *B. brevis* larvae. It is deep-bodied (BD 17% BL) and has an elongate voluminous gut (Sn-A 94% BL) with a sigmoid terminal section, characteristic of the late postflexion larvae of most other *Bathophilus* species. The head is large (HL 26% BL) with slightly ovoid, moderately large eyes (EL 18% HL). *Bathophilus brevis* is unique among stomioids in having an extremely low vertebral count (33–35) and only 5+6 principal caudal fin rays. Other stomiiforms have 10+9 principal caudal rays. The 9.3 mm larva has 34 myomeres, 5+6 principal caudal fin rays and incomplete dorsal and anal fin complements. Body pigmentation consists of dorsal and ventral paired series of melanophores, one melanophore on the dorsal and ventral surface of each myomere, and fine speckling on the dorsal finfold, the dorsal and anal fins, and along the lateral and ventral regions of the gut. Head pigmentation consists of a paired series ventral to the isthmus, serial melanophores along the lower jaw, paired melanophores over the mid- and hindbrain, embedded melanophores ventrolateral to the hindbrain, and fine speckling on the snout, gular, and opercular regions.

Eustomias is represented in standard CalCOFI survey collections by nine specimens from eight stations at the western margin of the survey area; most of the specimens are in poor condition and not usable for a developmental series. An 18.6 mm flexion specimen of *Eustomias* sp. (Figure Melanostomiidae 1; Table Stomioidea 2) is typical of the larval type of this genus from CalCOFI samples. The larva is extremely slender (BD 5% BL) with a rounded cross section. The gut is straight, relatively small in diameter, and diverges ventrad from the trunk at 77% BL. The head is long (HL 23% BL) and markedly compressed dorsoventrally. The eye is oval and relatively small (EL 15% HL). The eye is pedunculate but does not protrude beyond the lateral margin of the head. The dorsal fin origin is at ca. 84% BL and the anal fin origin at 77% BL. Fin ray and myomere development are incomplete, however it appears the dorsal fin count will be in the mid-twenties, the anal fin count will be >40, and there will be >60 myomeres. The dorsal finfold is large (maximum depth ca. twice the trunk depth) and the ventral finfold is small. Pigmentation consists of a symphysial blotch and a series of seven, large, evenly spaced melanophores along the dorsal midline from the nape to the dorsal fin origin. Most of the other specimens had seven dorsal spots, however one had six and another (probably a different species) had ten. The smallest specimens had apposing pigment at the notochord tip but this is not present in the larger larvae.

Larvae of *Flagellostomias boureei* were not found in CalCOFI samples. A 36.4 mm postflexion larva (Kawaguchi and Moser 1984) from the central water mass west of the CalCOFI survey area is representative of the late larvae of this species (Figure Melanostomiidae 1; Table Stomioidea 2). The larva is relatively deep bodied (BD 17% BL) with an elongate straight gut (Sn-A 85% BL) of moderate diameter that diverges ventrad from the trunk just anterior to the anal fin. The head is large (HL and head depth 17% BL) with a steep dorsal profile; the jaws are large. The eye is elliptical, narrow, and small (EL 12% HL). The median fins are far posteriad (dorsal fin origin 89% BL, anal fin origin 82% BL). Pelvic fins are just posterior to midbody (origin 59% BL). Meristics for this larva were: D 15, A 26, P_2 7, myomeres 67. Heights of both dorsal and anal finfolds equal or exceed trunk depth. There is one large melanophore per myomere along the dorsum and one to three smaller ones in the hypaxial myosepta. Other pigment is scanty: scattered melanophores on the dorsal and anal fins and on the finfold below the posterior gut region; minute melanophores along the lower jaw, on the branchiostegal membrane, lateral to the nares on the snout, above the brain, and on the posterior opercular and gular regions.

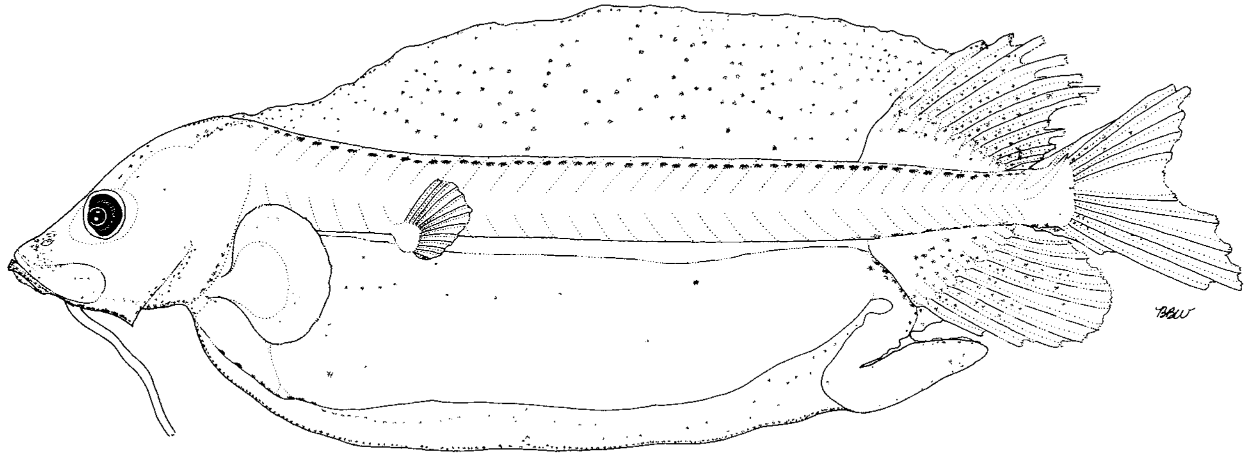
Larvae of *Melanostomias* were not found in CalCOFI samples. A 16.0 mm postflexion larva (Kawaguchi and Moser 1984) from the western Pacific is representative of the genus (Figure Melanostomiidae 2; Table Stomioidea 2). The larva is slender (BD 11% BL) with an elongate straight gut (Sn-A 93% BL) of moderate diameter. The head is relatively small (HL 17% BL) with a short snout and moderate jaw size. The eye is oval and moderate in size (EL 22% HL). The pelvic fin bud is well posteriad (origin 66% BL). The dorsal and anal fin complements are not fully formed but there are ca. 15 in the dorsal and 18 in the anal fin base. There are ca. 56 myomeres. Dorsal finfold height is slightly less than trunk depth and the ventral finfold is small. The dorsal pigment series are discontinuous with one pair of dorsal melanophores on each of the anteriormost eight myomeres and one on each myomere posterior to the dorsal fin origin. Hypaxial myosepta have one to three small melanophores. Other pigmentation consists of: melanophores above and ventrolateral to the brain; at the nares; along the lower jaw, gular region, and isthmus; below the liver; along the median finfold margins; scattered on the dorsal and anal fins and on the finfold below the posterior gut region; and minute melanophores along the lower jaw, branchiostegal membrane, lateral to the nares, and scattered on the caudal fin. This larva appears to be *M. tentaculatus* based on characters presented by Ozawa and Aono (1986) and on examination of a transformation series of that species from the Atlantic (pers. obs.). Larvae of *Melanostomias* transform at a small size, typically <20 mm. Another type of *Melanostomias* larva has continuous dorsal pigment, however larvae of this type have not been identified. Adult *Melanostomias valdiviae* have been reported from the CalCOFI region (Berry and Perkins 1966) but their larvae are unknown.

The only larval *Opostomias mitsuii* identified in CalCOFI samples is a 15.0 mm late flexion specimen from CalCOFI 6204, station 60.140 (Table Stomioidea 2). This larva is similar to a 15.0 mm larva illustrated by Kawaguchi and Moser (1984) (Figure Melanostomiidae 2). The CalCOFI larva is moderately deep-bodied (BD 15% BL) with an elongate straight gut (Sn-A 93% BL) that tapers posteriad and does not diverge ventrad from the trunk. The head is large (HL 21% BL) with a moderately sloping dorsal profile and with large jaws. The eye is elliptical and moderate in size (EL 16% HL). The dorsal fin origin (83% BL) is slightly forward of the anal fin origin (85% BL). Dorsal finfold height at midbody is equal to trunk depth and ventral finfold height is slightly less than trunk depth. There is one large melanophore per myomere along the dorsum and one or two minute ones in the hypaxial myosepta. Epaxial and hypaxial myosepta below the dorsal fin base have up to five melanophores forming an incomplete bar. Head pigment consists of a Y-shaped patch of melanophores above the mid- and hindbrain and minute melanophores on the posterior gill arches. Other pigmentation is on the dorsal and anal fin bases and proximal rays, and on the finfold below the terminal gut region. The larva has 64 myomeres; the dorsal and anal fin ray complements are incomplete and the pelvic fin bud is not visible.

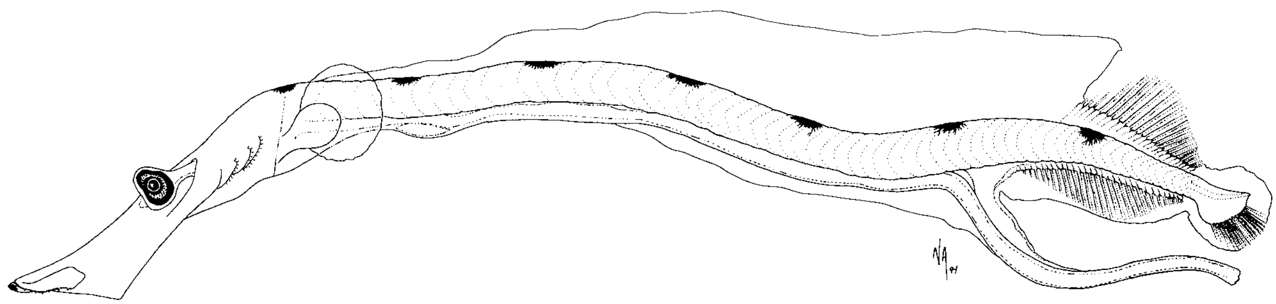
Larvae of *Photonectes* sp. are found at the most seaward region of the CalCOFI sampling pattern. A 15.9 mm postflexion larva (CalCOFI 6507, station 90.120) is representative of the larval form found in the California Current region. A more advanced postflexion larva from the same area is illustrated in Figure Melanostomiidae 2. Notochord flexion occurs at ca. 10–15 mm and larvae metamorphose at ca. 30 mm SL. The 15.9 mm larva is slender (BD 10% BL) with an elongate straight gut (Sn-A 91% BL) of moderate diameter. The head is relatively small (HL 17% BL) with moderate snout (SnL 37% HL) and jaws. The eye is narrow and relatively small (EL 19% HL). The pelvic fin bud is well posteriad (origin 67% BL). Dorsal finfold height is slightly less than trunk depth and the ventral finfold is small. The dorsal and anal fin complements are not fully formed in this larva but the largest postflexion specimen has ca. 16 dorsal and 19 anal rays. There are ca. 60 myomeres. Pigmentation consists of minute melanophores. The dorsal series consists of clumps of several small melanophores above each myomere; hypaxial myosepta have several minute melanophores. In the largest larvae, melanophores increase to ca. 7 per myomere in the dorsal series and to 7–10 in the hypaxial series. Other body pigmentation consists of a linear patch below the liver and a line above the terminal section of the gut. Pigment is distributed throughout the dorsal and ventral finfolds except near the body, with a concentrated line at the finfold margin. The dorsal, anal, and caudal rays and the pectoral fin base become pigmented in late postflexion. Head pigment is found above the brain, on the opercular region, snout, lower jaw, gular region, covering the isthmus, and at the edge of the branchiostegal membrane. A single *Photonectes* species, *P. margarita*, is reported for the region (Berry and Perkins 1966; Hubbs et al. 1979); however, recent work suggests that more than one species may be present in the California Current region and *P. margarita* may not occur there (Cynthia Klepadlo, Scripps Institution of Oceanography, pers. comm.).

Leptostomias larvae were not collected within the regular CalCOFI sampling area; however, they have been captured on stations just west of the most seaward CalCOFI stations. Although notochord flexion occurs at a comparatively small size (10–15 mm) in *Leptostomias* from this region, postflexion larvae may reach 40 mm SL before metamorphosis. A 16.1 mm postflexion larva (Table Stomioidea 2; Figure Melanostomiidae 2), from CalCOFI 7210, station 31.135, is representative of *Leptostomias* from the region. The larva is moderately deep-bodied anteriorly (BD 12% BL) but tapers gradually posteriad to the caudal region. The gut is elongate and straight (Sn-A 94% BL) and has a large diameter anteriorly, tapering to a narrow diameter posteriorly. The head is relatively large (HL 20% BL) with a moderate snout (SnL 34% HL) and jaws. The eye is narrow and relatively small (EL 14% HL). The pelvic fin bud is well posteriad (origin 68% BL). Dorsal and ventral finfolds are narrow. The dorsal and anal fin complements are not fully formed in this larva but the largest postflexion specimen available has ca. 15 dorsal and 20 anal rays. There are ca. 79 myomeres. Body pigmentation consists of paired dorsal series and both hypaxial and epaxial myoseptal pigment. There is one large melanophore per myomere in the dorsal series sometimes accompanied by one or more minute melanophores. The anteriormost 10–12 melanophores in the dorsal series are larger than the more posterior ones. In smaller larvae there are no epaxial melanophores and the hypaxial series consists of a single melanophore in each myoseptum. In the 16.1 mm larva there are one to three melanophores in the epaxial and hypaxial series and in larger larvae the myosepta are completely lined with melanophores. Other body pigmentation consists of scattered melanophores below the liver and a line above the terminal section of the gut. The posterior region of the dorsal and ventral finfolds have minute melanophores and there are some on the basal region of the anal fin. The head is pigmented above the brain, on the opercular region, snout, lower jaw, gular region, isthmus, and gill arches. *Leptostomias* larvae from the region west of the CalCOFI sampling area cannot be identified until the taxonomy of *Leptostomias* species in the north Pacific is resolved.

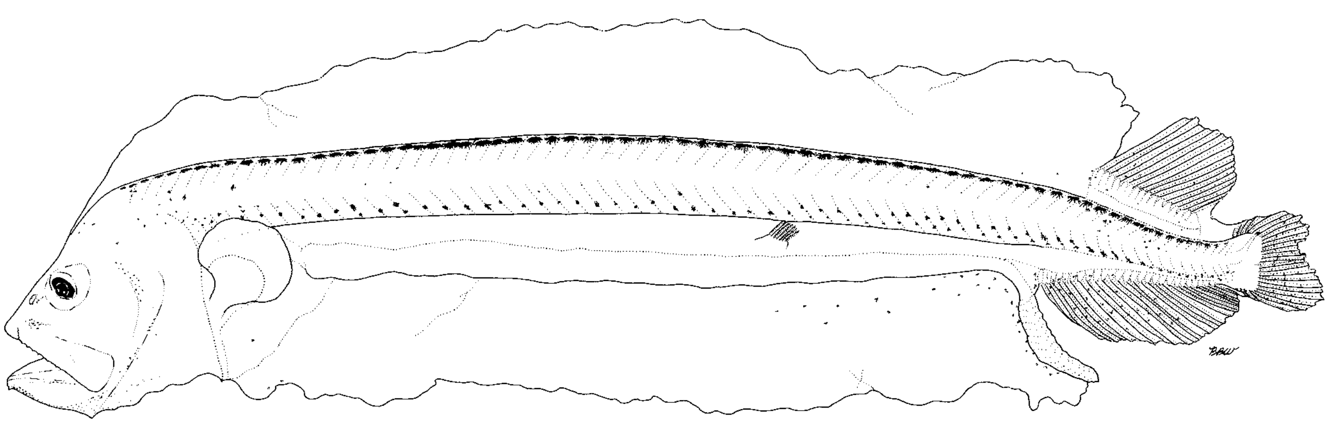
The following descriptions are based on the literature and on detailed observations of 22 specimens of *Bathophilus filifer*, 22 specimens of *B. flemingi*, and 30 specimens of *Tactostoma macropus* (Table Stomioidea 2). Meristic data were obtained from the literature (Morrow and Gibbs 1964; Kawaguchi and Moser 1984; Fujii 1984b; and Matarese et al. 1989) and from observations made during this study.



15.7 mm



18.6 mm



36.4 mm

Figure Melanostomiidae 1. Larval melanostomiids: *Bathophilus brevis*, postflexion stage, 15.7 mm (Kawaguchi and Moser 1984); *Eustomias* sp., flexion stage, 18.6 mm (CalCOFI 9210, station 90.140; original illustration by N. Arthur); *Flagellostomias boureei*, postflexion stage, 36.4 mm (Kawaguchi and Moser 1984).

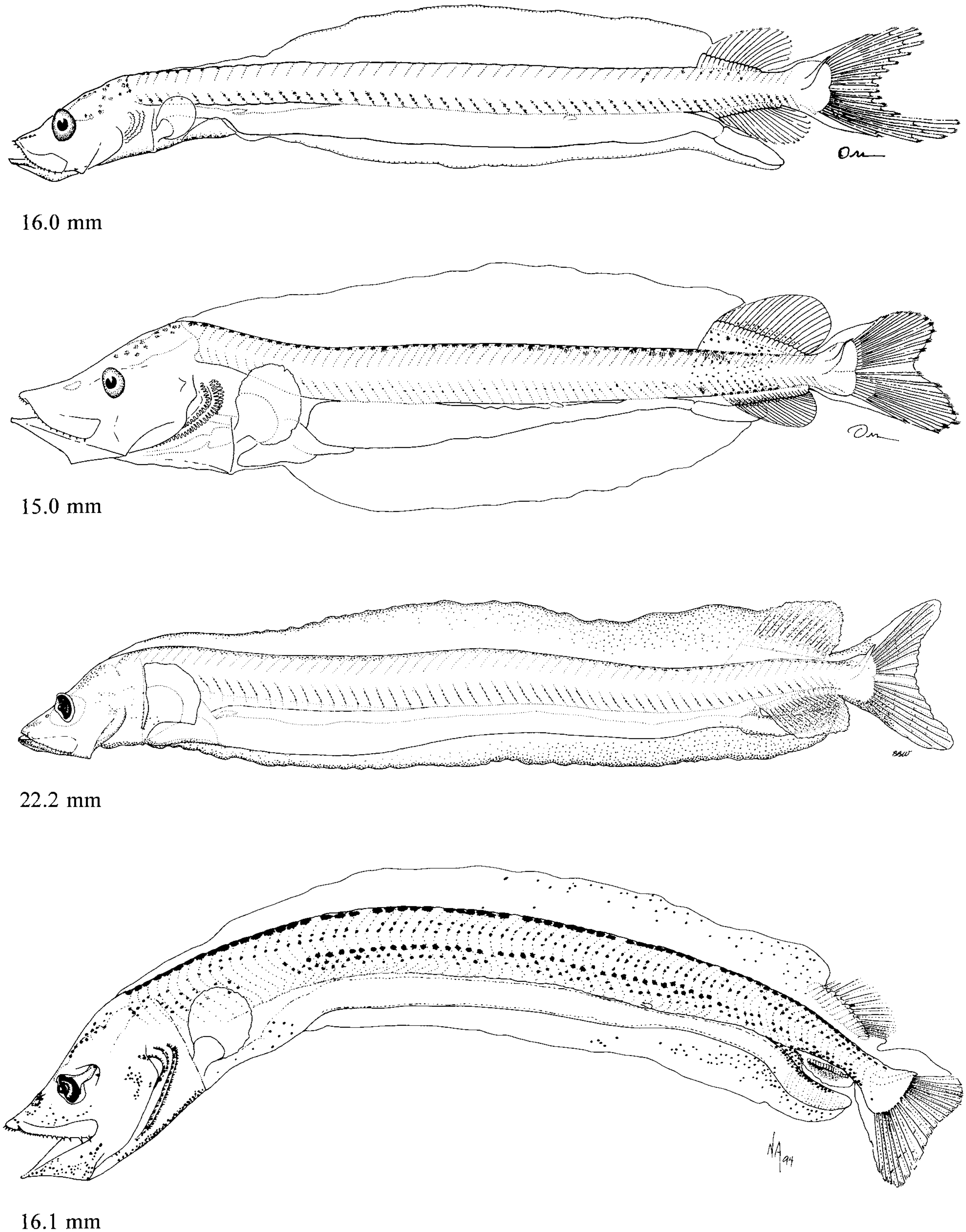


Figure Melanostomiidae 2. Larval melanostomiids: *Melanostomias* sp., postflexion stage, 16.0 mm; *Opostomias mitsuii*, postflexion stage, 15.0 mm; *Photonectes* sp., postflexion stage, 22.2 mm (Kawaguchi and Moser 1984); *Leptostomias* sp., postflexion stage, 16.1 mm (CalCOFI 7210, station 31.135; original illustration by N. Arthur).

MERISTICS

	Range	Mode
Vertebrae:		
Total	45–50	48
Precaudal	43–45	45
Caudal	3–5	4
Fins:		
Dorsal spines	0	0
Dorsal rays	13–16	16
Anal spines	0	0
Anal rays	14–17	16
Pelvic	4–5	5
Pectoral	1	1
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	3	3
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Eastern & central tropical Pacific northward to the Gulf of California & the southernmost part of the CalCOFI survey area

Habitat: Mesopelagic; possible vertical migration

Spawning season: Larvae captured mostly during fall & winter on CalCOFI surveys

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Pertseva-Ostroumova & Rass 1973

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.0 mm (N. Arthur)
Preflexion larva, 4.8 mm (N. Arthur)
Flexion larva, 11.1 mm (N. Arthur)
Postflexion larva, 22.3 mm (N. Arthur)

* Eye is somewhat oval; horizontal axis is given first, vertical axis second.
† P_1 rays broken in all juvenile specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: 3 mm
Flexion length: 8–12 mm
Transformation length: ca. 25 mm
Fiu development sequence: C_1 & D & A, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—Paired ventral series; postanal median ventral series to tip of tail; scattered on head; fairly heavy on dorsal & ventral finfolds, concentrated at margins. *Preflexion*—Paired dorsal series from nape to near notochord tip where the series join; approximately 1 per myomere in dorsal & ventral series; 1 to several ventrolateral to hindbrain; 1 to several on ventral region of P_1 base; above & below terminal gut section. *Flexion–postflexion*—Ventral series becomes obscured by hypaxial musculature; fewer in dorsal & ventral series; a patch over hindbrain; faint series on isthmus in some specimens; on finfolds in some specimens.
Diagnostic features: Elongate, voluminous gut; terminal section of gut deflected at slight angle, no acute sigmoid flexure as in late postflexion *B. flemingi*; head large, deflected ventrad; liver small, (length is 5–6% BL), recessed anterior to gut; paired dorsal & ventral pigment series; melanophores minute, pigment faint.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	73–80 78	80–89 86	90–93 92	91–100 95		81–83 82
BD/BL	7–9 8	10–12 11	11–12 11	10–12 11		12–13 12
HL/BL	14–19 16	20–25 23	21–22 21	17–22 20		17–17 17
HW/HL	41–54 47	38–50 42	37–38 37	33–42 38		44–44 44
SnL/HL	11–14 12	25–41 34	37–41 38	34–35 35		23–29 26
ED/HL*	38–46× 28–33 42×31	15–23× 18–34 18×24	15–18× 16–19 16×17	13–15× 16–18 15×17		19–20× 19–20 20×20
P_1L/BL	0–1 0.3	2–6 5	4–4 4	2–3 3		†
P_2L/BL	0–0 0	0–0 0	0–0 0	0.5–2 1		14–17 16
LvL/BL		5–6 6	5–5 5	5–6 6		

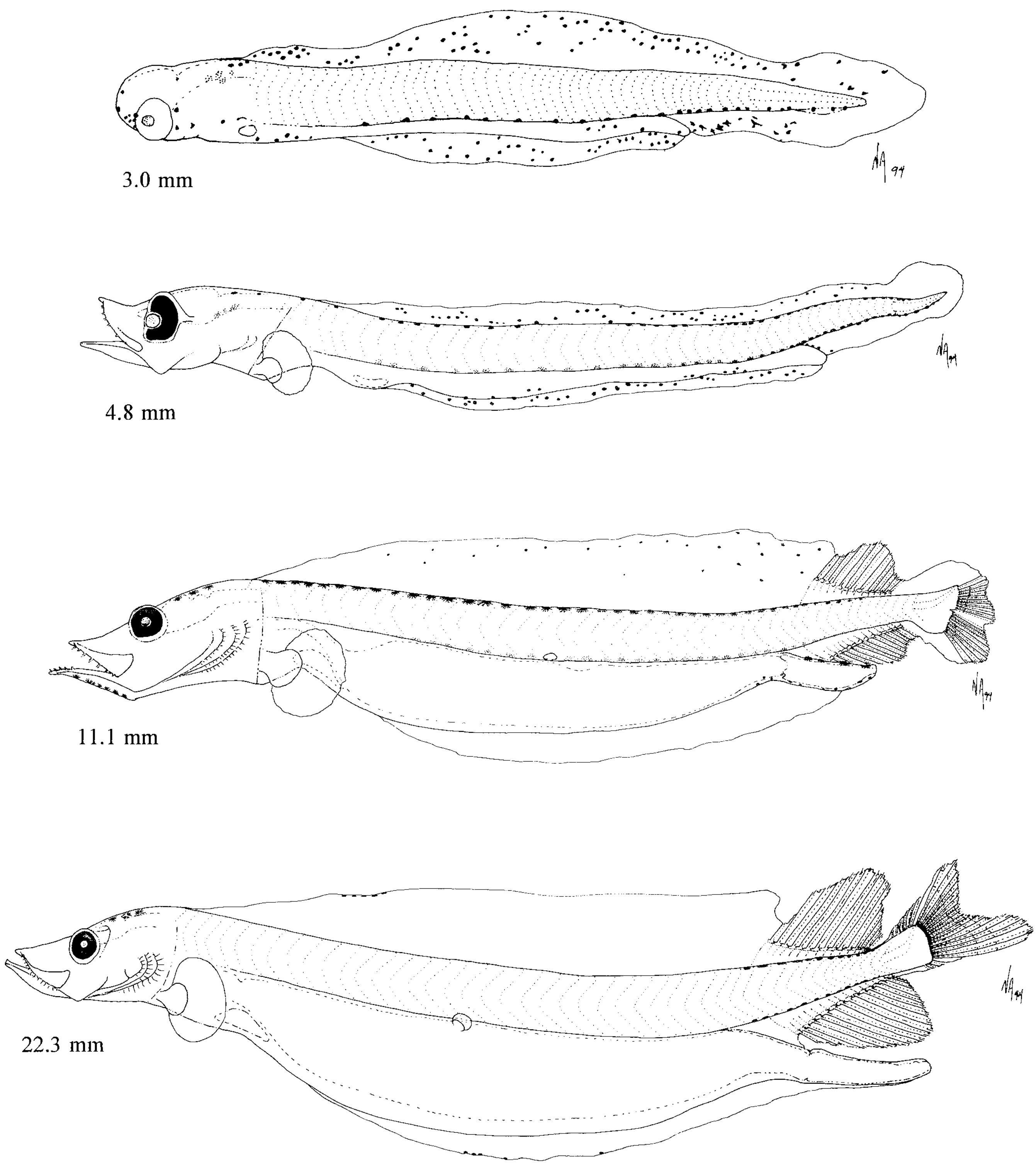


Figure Melanostomiidae 3. Yolk-sac larva, 3.0 mm (CalCOFI 7210, station 157G.40); preflexion larva, 4.8 mm (CalCOFI 7202, station 153.30); flexion larva, 11.1 mm (CalCOFI 7205, station 150.110); postflexion larva, 22.3 mm (EASTROPAC II, station 46.84).

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–48	47
Precaudal	42–45	43
Caudal	3–4	4
Fins:		
Dorsal spines	0	0
Dorsal rays	14–16	15
Anal spines	0	0
Anal rays	15–17	16
Pelvic	15–19	15
Pectoral	4–8	6
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–6	5
Lower	2–3	3
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Gulf of Alaska to central Baja California; offshore to western part of California Current

Habitat: Meso- to bathypelagic

Spawning season: Maximum larval abundance in CalCOFI collections in spring & summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Kawaguchi & Moser 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.7 mm (N. Arthur)
Preflexion larva, 5.6 mm (N. Arthur)
Flexion larva, 13.0 mm (N. Arthur)
Postflexion larva, 23.5 mm (N. Arthur)

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* Eye is somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3 mm
Flexion length: 12–15 mm
Transformation length: ca. 25–30 mm
Fin development sequence: C_1 & D & A, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—On dorsal & ventral finfolds; scattered over head. *Preflexion*—Dorsal & ventral paired series, ca. 1 per myomere; single median series at notochord tip; patch on snout; embedded at otic region & ventrolateral to hindbrain; median series below liver; paired series on isthmus; by 9 mm, dorsal series with 1–3 per myomere; gular patch; patch above hindbrain; by 11 mm, scattered over D & A & associated finfolds; on margin of branchiostegal membrane. *Flexion*—Concentrated proximally on ventral finfold, heaviest below liver; throughout dorsal finfold; along lower jaw; ventral series recessed; above & below terminal gut section. *Postflexion*—Many per myomere in dorsal & ventral series; patch covers midbrain; at cleithral region; on opercle, & concentrated at nares.
Diagnostic features: Similar to *B. filifer* but terminal section deflected at greater angle & sigmoid flexure present in late larvae; liver larger than in *B. filifer* (length typically 6–8% BL) & less recessed; melanophores larger & pigmentation heavier than in *B. filifer*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		79–91	88–93	90–94		82–83
	76	85	90	93		83
BD/BL		8–12	12–13	12–14		13–13
	8	10	12	13		13
HL/BL		20–22	21–23	19–22		17–18
	16	21	22	20		17
HW/HL		33–41	37–41	34–45		53–63
	43	38	39	40		58
SnL/HL		31–44	35–41	32–41		26–29
	17	35	38	36		27
ED/HL*		13–17× 18–23	13–14× 16–18	12–14× 14–17		18–20× 18–20
	37x33	15×21	13×17	13×15		19×19
P_1L/BL	0–0	3–5	0.3–5	3–4		23–39
	0	4	3	4		31
P_2L/BL	0–0	0–0	0–9	0.3–1		23–26
	0	0	2	0.7		25
LvL/BL	0–0	5–8	8–8	6–9		
	0	6	8	8		

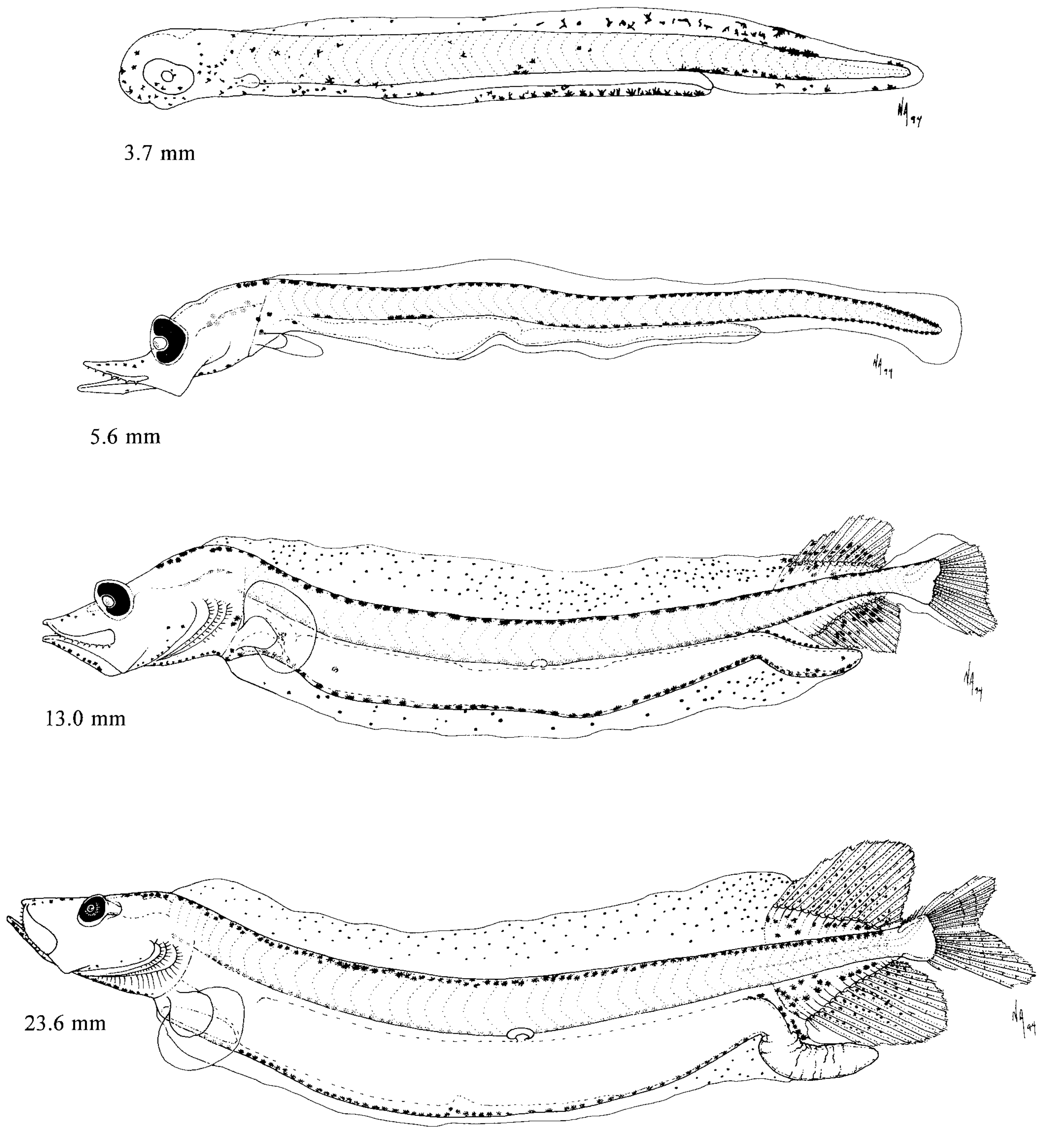


Figure Melanostomiidae 4. Yolk-sac larva, 3.7 mm (FRONTS 85, station 18); preflexion larva, 5.6 mm (CalCOFI 7507, station 103.80); flexion larva, 13.0 mm (CalCOFI 7804, station 90.200); postflexion larva, 23.6 mm (CalCOFI 6207, station 100.60).

MERISTICS

	Range	Mode
Vertebrae:		
Total	79–82	81
Precaudal	67–68	67
Caudal	12–14	14
Fins:		
Dorsal spines	0	0
Dorsal rays	14–18	16
Anal spines	0	0
Anal rays	19–22	19
Pelvic	8–10	9
Pectoral	0	0
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	8
Lower	4	4
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Subarctic & transitional north Pacific westward to Japan & southward in the California Current region to central Baja California

Habitat: Mesopelagic migrating into epipelagic at night

Spawning season: Larvae are most abundant in CalCOFI surveys during summer, with peaks in July & September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Amaoka et al. 1992
Kawaguchi & Moser 1984, 1993
Matarese et al. 1989

* Eye is somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.38–1.55 mm
Yolk: Segmented; 0.78–0.89 mm diam.
No. of OG: 1
Diam. of OG: 0.30–0.40 mm
Shell surface: Smooth
Pigment:
Diagnostic features: Moderate shell diameter, large perivitelline space, large OG

LARVAE

Hatching length: ca. 4 mm
Flexion length: 13–24 mm
Transformation length: ca. 50–55 mm
Fin development sequence: C_1, D & A, C_2, P_2
Pigmentation: *Yolk-sac*—Paired dorsal & ventrolateral series continuous with dense supra- & infracaudal series in late yolk-sac stage. *Preflexion*—Dorsal series increases to a maximum of 50–60 at 7–9 mm & decreases thereafter; ventrolateral series developing as 2–3 melanophores on each myoseptum. *Flexion*—On lower jaw symphysis, isthmus, P_1 base, cleithral region, base of C rays, & terminal gut section. *Postflexion*—Paired dorsal series absent in larvae >25 mm.
Diagnostic features: Extremely elongate, laterally compressed body, not round in cross section as in *Chauliodus*; high myomere count; heavy caudal peduncle pigment; loss of melanophores in dorsal paired series; finfolds narrow & unpigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	80–82	84–88	88–92	91–96	83–92	82–84
	81	86	91	93	87	83
BD/BL	6–7	6–8	6–7	5–6	5–6	6–7
	6	7	6	6	6	7
HL/BL	12–13	13–18	14–16	11–15	10–10	10–11
	13	16	15	13	10	10
HW/HL	43–54	33–50	35–39	35–39	47–50	30–36
	49	41	38	37	48	32
SnL/HL	11–19	27–34	27–36	27–33	20–25	19–21
	15	31	33	30	23	20
ED/HL*	30–32× 23–30	14–25× 20–30	13–15× 17–19	12–15× 14–17	16–24× 19–24	19–24× 19–24
	31×27	18×23	14×18	13×16	20×21	21×21
P_1L/BL	0–1	2–4	2–3	2–2	0–2	0–0
	0.4	3	2	2	0.5	0
P_2L/BL	0–0	0–0	0–0.6	0–0.8	2–10	9–12
	0	0	0.3	0.3	6	11

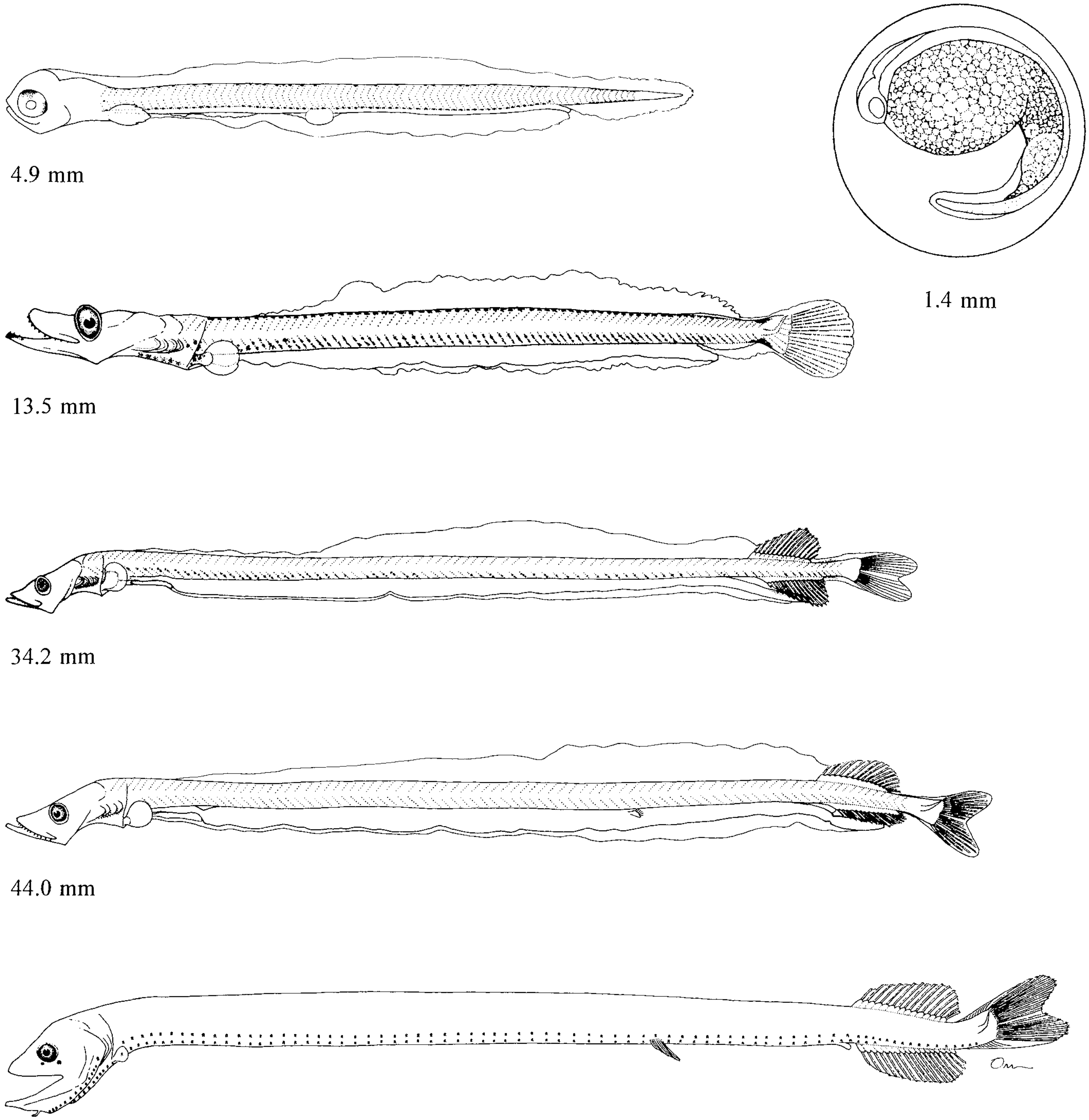


Figure Melanostomiidae 5. Egg, 1.4 mm; late yolk-sac larva, 4.9 mm; flexion larva, 13.5 mm; postflexion larvae, 34.2 mm, 44.0 mm; transformation specimen, 49.4 mm (Kawaguchi and Moser 1993).

MALACOSTEIDAE: Loosejaws

H. G. Moser

Malacosteidae includes three genera and about 15 species; *Aristostomias scintillans* is the only species in the CalCOFI survey area, although other genera and species are found in equatorial water and in the central water mass to the west of the CalCOFI area. Larvae of *A. scintillans* occur offshore (beyond 200 n.mi.) in the central region of the CalCOFI survey area, primarily between Point Conception, California and central Baja California. Adults have been collected as far north as the Bering Sea and westward to the eastern margin of the central water mass.

Malacosteids are small to moderate-size (<25 cm) predators of the meso- and bathypelagic zones with extremely large jaws that extend well posterior to the relatively small skull. Teeth are large and fanglike. There is no floor in the mouth and specialized jaw musculature permits an extraordinarily large jaw opening. The body is relatively elongate and compressed. Dorsal and anal fins are far posteriad leaving a short caudal peduncle. The skin is black, smooth, and scaleless. There are two prominent ventrolateral rows of photophores, consisting of evenly spaced or grouped light organs. Numerous small photophores stud the body and head. Postorbital light organs are present; preorbital and suborbital organs are present or absent. A hyoid barbel is present in some species; in *A. scintillans* it is more than half the length of the body and has a bulb-like terminus (Morrow 1964c; Gibbs 1984; Fink 1985; Goodyear and Gibbs 1986).

Presumably, malacosteids are oviparous; planktonic eggs are unknown. Larvae are elongate and slender with a large dorsoventrally compressed head and slender trailing gut that may be several times longer than the body in some species (Moser 1981; Kawaguchi and Moser 1984). Eyes are relatively small and ovoid. Several types of larval pigmentation are found in malacosteids. Typically, larvae have paired dorsal and ventral melanophore series with none on the hypaxial myosepta. The paired ventral series become recessed in the developing musculature and are difficult to see. The gut is pigmented and the head may be pigmented in various places (e.g., brain, snout, jaws, isthmus). One unidentified form with an extremely long gut lacks pigment except on the gut (Kawaguchi and Moser 1984). *Eustomias* larvae have a trailing gut and a body shape similar to that of malacosteids but the head is flatter, the eyes are nearly round, the dorsal pigmentation consists of fewer (5–10) melanophores located in the midline, and the trailing gut lacks melanophores.

The following description of *A. scintillans* is based on the literature (Kawaguchi and Moser 1984) and on detailed examination of 21 larvae and 3 juveniles (Table Stomioidea 2). Meristic and ecological information were obtained from the literature (Morrow 1964c; Fitch and Lavenberg 1968; Hart 1973; Kawaguchi and Moser 1984; Goodyear and Gibbs 1986; Matarese et al. 1989) and from observations made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	54–58	57
Precaudal	50–53	50
Caudal	5–7	7
Fins:		
Dorsal spines	0	0
Dorsal rays	21–25	23
Anal spines	0	0
Anal rays	25–29	28
Pelvic	6–7	6–7
Pectoral	4–8	4–8
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	9–11	11
Lower	5–6	5–6
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Bering Sea to California Current region to central Baja California & west to margin of central water mass

Habitat: Epi- to mesopelagic; apparently some diurnal migration; large larvae captured in neuston

Spawning season: Larvae taken year-round in CalCOFI surveys with peak abundance in April–May

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Kawaguchi & Moser 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 9.0 mm (N. Arthur)
Flexion larva, 16.2 mm (N. Arthur)

* Eye is somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <6 m
Flexion length: 13–17 mm
Transformation length: ca. 45 mm
Fin development sequence: C_1, D & A, C_2, P_2, P_1
Pigmentation: *Preflexion*—Short, dense, apposing median series just anterior to notochord tip; paired dorsal series form first posteriorly, then gradually are augmented anteriorly; paired ventral series just beginning to form posteriorly in smallest larvae, augmented anteriorly; pairs ventrolaterally & posteriorly in the otic region, a pair dorsolateral to hindbrain, & a pair on snout; by 8.0 mm, dorsal series complete to nape & consist of about 11–14 pairs. *Flexion*—Additional pairs (large) in dorsal series & smaller ones added between larger ones; ventral series extends forward to head, recessed in trunk musculature above gut, spaced ca. 3–4 myomeres apart; series on isthmus, patch on gular region, above brain, & just forming on lower jaw; on trailing gut, proximally on C rays. *Postflexion*—More added to dorsal & ventral series, eventually each series continuous; more on gut, forming vague ring-like pattern in some specimens.
Diagnostic features: Elongate slender body & gut; trailing gut deflected away from body at A origin; elongate, flattened head; long snout, ovoid eyes; dorsal & ventral paired pigment series; *Eustomias* larvae lack ventral series & gut pigment.

MORPHOMETRICS (rauge & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				115–144		76–78
		100	>100	126		77
BD/BL		6–8	6–7	7–8		13–19
		7	6	7		16
HL/BL		16–19	20–22	18–23		18–25
		17	21	20		22
HW/HL		38–46	32–35	30–39		37–49
		43	34	34		44
SnL/HL		27–50	38–45	38–43		22–29
		39	41	40		26
ED/HL*		11–17× 17–25	9–11× 13–15	9–12× 11–13		23–28× 23–28
		14×21	10×14	10×12		26×26
P_1L/BL		3–4	3–3	2–3		6–31
		4	3	2		19
P_2L/BL		0–0	0–0	0.1–2		7–16
		0	0	0.9		12

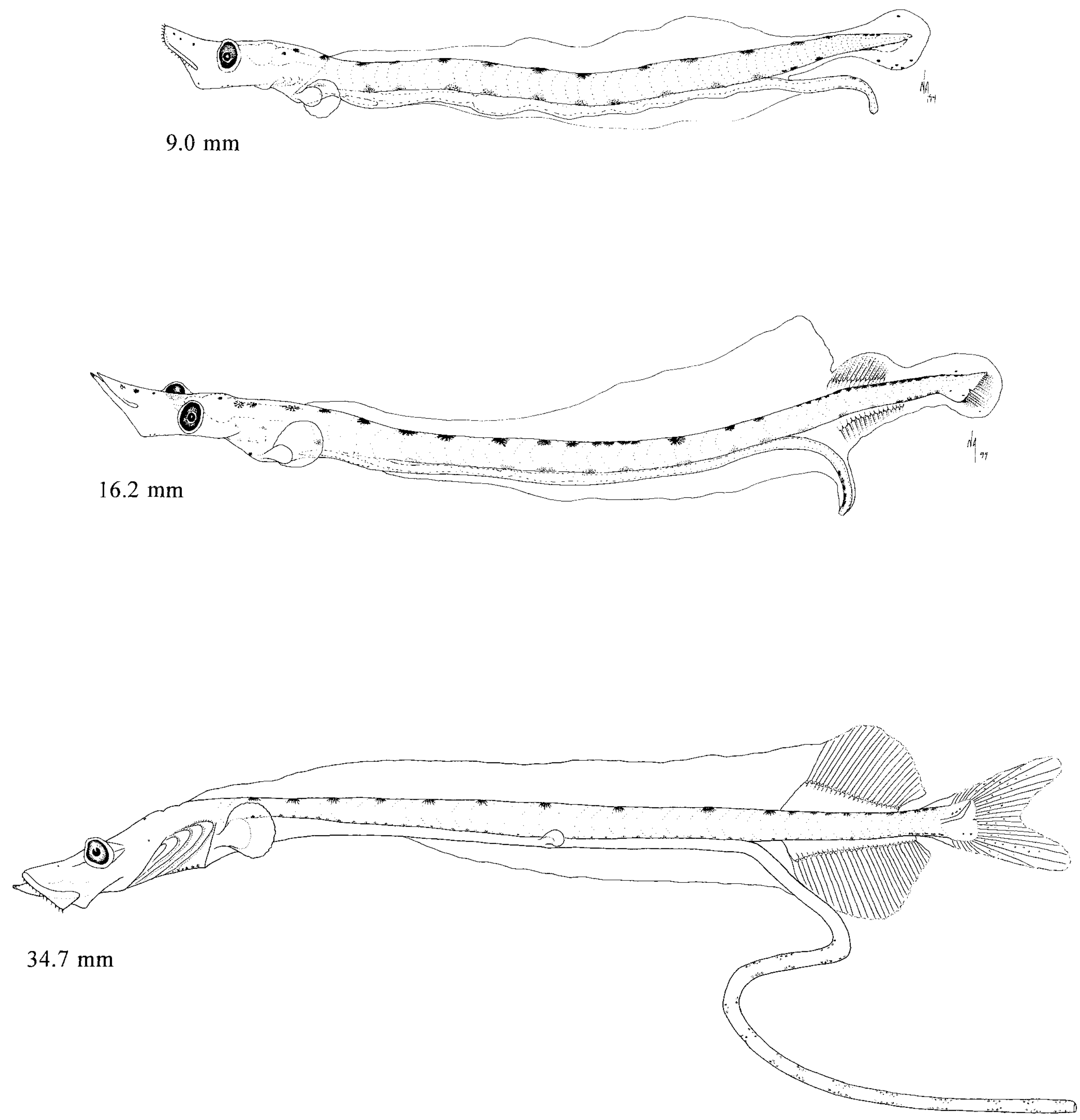


Figure Malacosteidae 1. Preflexion larva, 9.0 mm (CalCOFI 6204, station 100.120); flexion larva, 16.2 mm (CalCOFI 6301, station 90.110); postflexion larva, 34.7 mm (Kawaguchi and Moser 1984).

IDIACANTHIDAE: Blackdragons

H. G. Moser

The family consists of about four species of the genus *Idiacanthus*. A single species, *I. antrostomus*, occurs in the California Current from northern California southward to the eastern tropical Pacific. The eastern tropical Pacific species *I. panamensis* is probably conspecific with *I. antrostomus* (Gibbs 1964b; Novikova 1967). Westward of the California Current, *I. antrostomus* is replaced by the central water mass species *I. fasciola*.

Idiacanthids exhibit marked sexual dimorphism with females growing to ca. 40 cm length in some species and males <7 cm. Females are extremely elongate with black, scaleless skin and large jaws with fanglike teeth. The dorsal and anal fins are long-based with the dorsal extending from just forward of the caudal fin to about two-thirds of the body length; the anal fin extends forward from the caudal fin to about one-third of the body length. A pair of specialized spiny projections is present anterior to each dorsal and anal ray. Pectoral fins are lost at metamorphosis. Two rows of prominent photophores are present ventrally on each side; smaller photophores are distributed over the head and in vertical rows on the body. A small postorbital photophore is present and the chin barbel has a leaflike terminus. Males lack teeth, paired fins, a chin barbel and have relatively large eyes and a large postorbital photophore. The gut is poorly developed and the gonads are large and extend the entire length of the body cavity. The vent has a fleshy structure, supported by the modified first anal ray, that may function in sperm transmission. Females are midwater predators with a broad bathymetric range extending from epi- to bathypelagic depths and apparently are vertical migrators. Males are bathypelagic and shortlived (Beebe 1934; Gibbs 1964b, 1984).

Presumably idiacanthids are oviparous; pelagic eggs are unknown. Larvae are extremely slender and elongate with a slender gut that is deflected from the body at the anal fin origin and is trailing in flexion and postflexion larvae. The head is flattened and the elliptical eyes are borne on long stalks supported by a cartilaginous rod. Dorsal finfold height is about equal to body depth and the ventral finfold is small. The dorsal fin begins forming well posterior on the body; rays are added anteriorly and fin base length is ca. 10% BL at the end of the larval period. Rays are added rapidly during metamorphosis when the fin enlarges to two-thirds the body length. At metamorphosis the cartilaginous rods supporting the eye stalks are resorbed and the pectoral fins are lost. The sparse larval pigmentation consists of a series of melanophores on the isthmus, a series on the hypaxial myomeres, and scattered spots on the trailing gut (Beebe 1934; Novikova 1967; Weihs and Moser 1981; Kawaguchi and Moser 1984; Matarese et al. 1989).

Beebe (1934) and Novikova (1967) described and illustrated larval development and metamorphosis in *I. fasciola*. Kawaguchi and Moser (1984) summarized larval development of *I. antrostomus* and illustrated a late postflexion larva. The following description is based on published literature and on detailed observations of 24 specimens of *I. antrostomus* (Table Stomioidea 2). Meristic data were obtained from Matarese et al. (1989) and from counts made during this study (Table Stomioidea 1). Ecological information was obtained from Beebe (1934), Gibbs (1964b, 1984), and Fitch and Lavenberg (1968).

MERISTICS

	Range	Mode
Vertebrae:		
Total	81–85	81–85
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	0
Dorsal rays	54–66	58
Anal spines	0	0
Anal rays	28–43	35
Pelvic	6	6
Pectoral	0	0
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	11–14	12–13
Lower	7–10	8–9
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Temperate to tropical eastern Pacific, westward to margin of central water mass; also in temperate northwestern Pacific

Habitat: Epi- to bathypelagic; females migrate diurnally

Spawning season: In CalCOFI surveys, larvae most abundant during summer & fall with peaks in August & November

ELH pattern: Oviparous; planktonic eggs & larvae; extreme sexual dimorphism, with larvoid males

LITERATURE

Beebe 1934
Kawaguchi & Moser 1984
Matarese et al. 1989
Novikova 1967

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.1 mm (N. Arthur)
Flexion larva, 21.8 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <5 mm
Flexion length: ca. 20–32 mm
Transformation length: 67–76 mm
Fin development sequence: C_1 & D, A, C_2, P_2
Pigmentation: *Preflexion*—At ca. 6.0 mm, a series of ca. 8 embedded dashes along isthmus; at ca. 9.0 mm, a series of oblique dashes begins to form at posterior margin of each hypaxial myomere. *Flexion–postflexion*—Isthmus dashes tend to form three groups, range of 5–13 (usually 8); hypaxial dashes spread into myosepta when expanded; scattered on trailing gut.
Diagnostic features: Body extremely slender & elongate; gut elongate & slender, trailing in flexion & postflexion; head flat; elliptical eyes on elongate stalks supported by cartilaginous rods (up to 27% BL); P_1 lost at transformation; diminutive males lack P_2, have poorly developed gut, large gonads, large eyes & postorbital luminous gland.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv*
Sn-A/BL		80–95 89	 93	129–139 134		68–69 69
BD/BL		4–6 5	3–4 3	2–3 3		5–5 5
HL/BL		13–18 15	13–15 14	10–15 12		9–10 9
HW/HL		41–50 46	39–45 41	36–40 38		41–48 45
SnL/HL		17–44 35	42–50 46	44–53 49		23–25 24
ED/HL†		10–27× 19–40 17×27	11–12× 18–21 11×20	10–13× 17–21 11×19		20–21× 20–21 20×20
P_1L/BL		1–4 3	2–2 2	1–2 1		0–0 0
P_2L/BL		0–0 0	0–0 0	0–0.2 0.1		6–10 7
ESL/BL		11–24 20	19–23 20	12–21 16		0–0 0

* Females.
† Eye is oval; horizontal axis is given first, vertical axis second.

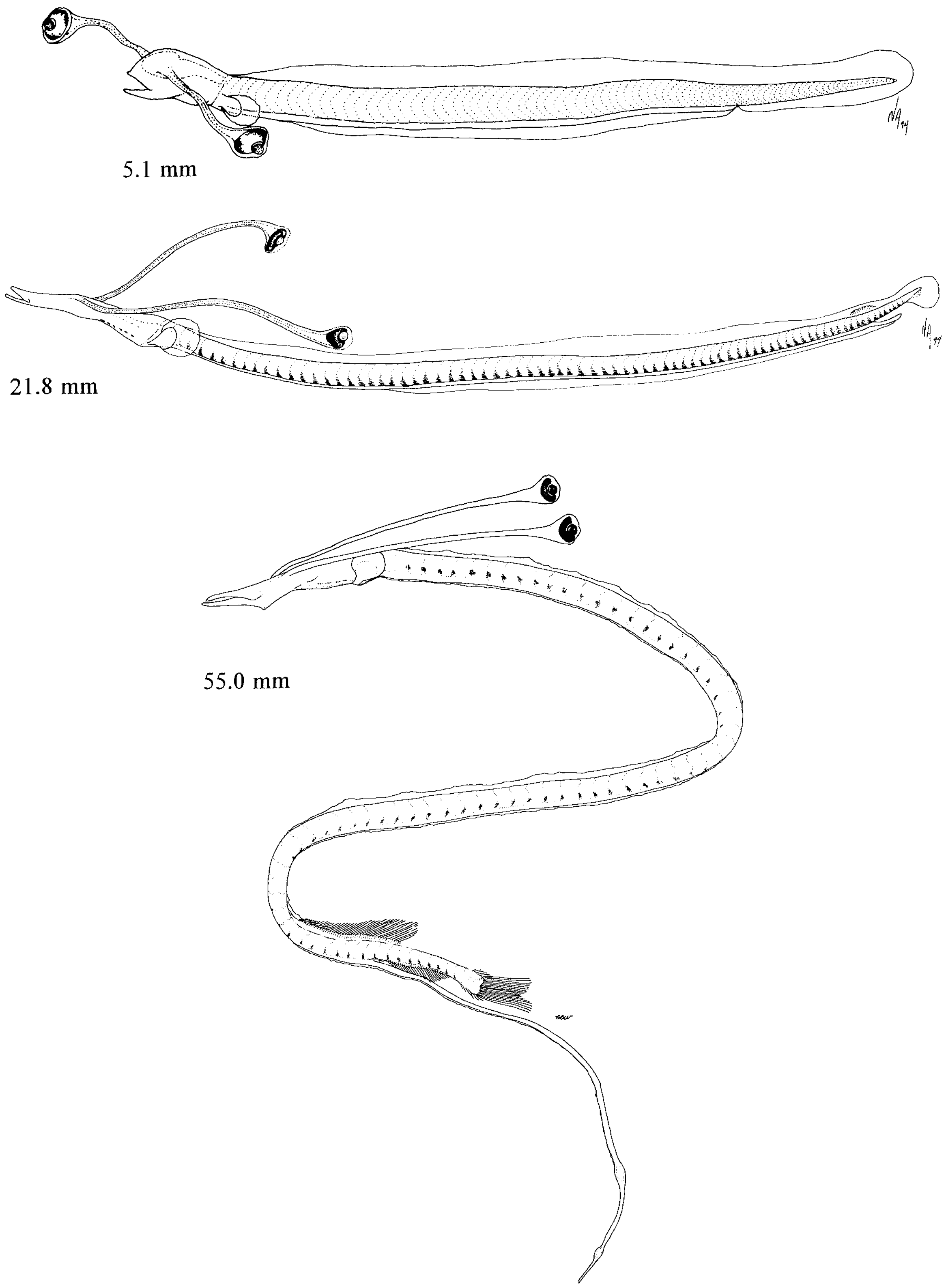


Figure Idiacanthidae 1. Preflexion larva, 5.1 mm (CalCOFI 6110, station 80.120); flexion larva, 21.8 mm (CalCOFI 5010, station 70.130); postflexion larva, 55.0 mm (Kawaguchi and Moser 1984).

AULOPIFORMES

W. WATSON

The aulopiform fishes originally were apportioned between the myctophiform suborders Myctophoidei and Alepisauroidei (Gosline et al. 1966; Okiyama 1984b). Rosen (1973) restricted the Myctophiformes to Myctophidae and Neoscopelidae, and placed all others in a new order, Aulopiformes, on the basis of several putative synapomorphies, most of which subsequently were questioned and/or rejected (e.g., Fink and Weitzman 1982; Johnson 1992). However, the structural synapomorphies of the upper gill arches (Rosen 1973; Johnson 1992) commonly are accepted as a basis for recognition of a monophyletic Aulopiformes (some authors differ from this view, e.g., Okiyama 1984b; Stiassny 1986). The component families are variously arranged in different classifications; in this volume we follow Eschmeyer's (1990) classification in which the order contains two suborders, Aulopoidei and Alepisauroidei (see Nelson 1994 for an example of a different aulopiform classification). All four aulopoid families (Aulopidae, Chlorophthalmidae, Scopelarchidae, Notosudidae) and seven of the eight alepisauroid families (Synodontidae, Giganturidae, Paralepididae, Anotopteridae, Evermannellidae, Alepisauridae, Omosudidae) have been recorded from the California Current vicinity, and larvae of all families except Chlorophthalmidae, Giganturidae, and Omosudidae have been collected during CalCOFI surveys.

The aulopoids range from mesopelagic to demersal, while the alepisauroids are primarily meso- and bathypelagic (synodontids are coastal benthic residents). Most are hover-and-strike or ambush predators. All are more or less elongate and compressed, usually with large eyes (tubular in scopelarchids, giganturids, and some evermannellids) and with large mouths, usually armed with large teeth. The fins contain only segmented rays and most species also have a small dorsal adipose fin. Pectoral fins are near the longitudinal body axis in aulopoids, but commonly are nearer the ventral margin and set at an oblique angle that suggests a paravane-like function in the alepisauroids. There are no photophores and other luminous tissues occur only in some scopelarchids and evermannellids.

The aulopiform fishes apparently all are oviparous; hermaphroditism is common (e.g., Okiyama 1984a). Spawned eggs are known for only a few species, and maturing ova have been described for a few others. Planktonic eggs typically range from ca. 1.0–1.5 mm, with none to several oil globules, and usually with sculpturing on the chorion. Maturing ova suggest that the lower end of the egg size range may be near 0.5 mm (e.g., Bertelsen et al. 1976; Okiyama 1984a). Newly hatched larvae are unknown for most aulopiforms; those that are known typically have unpigmented eyes, a partially formed mouth, and a small to moderate yolk sac. Larvae are moderately to very elongate, slightly to strongly compressed, with preanal length ranging from less than one-third to more than two-thirds of body length. All aulopoids and most alepisaruoids lack spines on the head and pectoral girdle (present in some paralepidids and alepisaurids). Larval pigmentation ranges from nearly absent to nearly complete, but most commonly is relatively light. Distinctive peritoneal melanophore patches or bands characterize the larvae of several families in both suborders (e.g., Okiyama 1984a,b).

The following chapters include only the eight aulopiform families whose larvae have been collected in the CalCOFI study area. See Okiyama (1984a, 1988d) for illustrations of chlorophthalmids, Johnson and Bertelsen (1991) for *Gigantura indica*, and Rofen (1966b) for *Omosudis lowei.*

Suborders and families included:

- Aulopoidei
  - Aulopidae
  - Scopelarchidae
  - Notosudidae
- Alepisauroidei
  - Synodontidae
  - Paralepididae
  - Anotopteridae
  - Evermannellidae
  - Alepisauridae

AULOPIDAE: Aulopids

D. A. AMBROSE

About 11 species in 2 genera (*Aulopus* and *Hime*) of these marine benthic fishes are found in the tropical and subtropical waters of the Atlantic and Pacific (Parin and Kotlyar 1989). All three Atlantic species are *Aulopus* and all Pacific species, except *A. bajacali*, are *Hime*. Lee and Chao (1994) recognize *Hime* as a generic synonym for *Aulopus*. Only *Aulopus bajacali* occurs in the CalCOFI area (Parin and Kotlyar 1984). Most larvae have been collected near the southern tip of Baja California from both the Pacific and the Gulf of California; others have been taken in the eastern tropical Pacific near Cocos Island. The benthic adults occur primarily at 82–230 m depth, where they may be abundant.

Adult aulopids are slender and moderate in length, usually less than ca. 60 cm. The dorsal fin origin is in the anterior third of the body and a well developed adipose fin is located over the posterior end of the anal fin base (Mead 1966). Pelvic fins are thoracic and pectorals are lateral. The eye and pupil are round and directed laterally. Two supramaxillae and fulcral scales on the caudal peduncle are characteristic. Meristic counts for the family are: D 14–22, A 8–14, P_1 11–14, P_2 9, V 36–53, and BrR 10–17 (Okiyama 1984a; Nelson 1994). Johnson (1992) and Patterson and Johnson (1995) suggest that the aulopids may be the sister group of the Synodontidae and Pseudotrichonotidae.

Complete early life history series including eggs are known only for *Hime japonica* (Okiyama 1974, 1984a, 1988b). Eggs are spherical (1.18–1.34 mm), pelagic, transparent, without an oil globule, and with irregularly raised hexagonal meshes on the chorion surface. Larvae of *H. japonica* and *A. bajacali* are elongate (BD 12–20% BL), with a large head (HL 20–32% BL), and a preanal length ca. 52–64% BL. The anus is far anterior to the anal fin origin. Both species have a single large pigment patch, which expands during larval development, dorsolaterally on the peritoneum, and another patch laterally on the tail. Development is gradual and direct, with little additional pigmentation throughout the pelagic stage. In *H. japonica* notochord flexion and fin ray development occur at a smaller size, the pigment patches are relatively smaller, and the total number of myomeres are fewer than in *A. bajacali* (41–43 vs. 47–49).

The following species account is based on detailed examination of 8 preflexion larvae (3.8–7.5 mm); 3 flexion larvae (7.5–8.4 mm); 6 postflexion larvae (8.8–12.3 mm); and 5 juveniles (41.6–56.5 mm) of *A. bajacali*. Meristic data were obtained from Parin and Kotlyar (1984) and from counts made during this study on 16 specimens (108–151 mm) from the SIO Marine Vertebrates Collection. Adult ecological information was based on SIO field collection notes.

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–49	48
Precaudal	31–34	31
Caudal	15–17	17
Fins:		
Dorsal spines	0	0
Dorsal rays	14–15	14
Anal spines	0	0
Anal rays	12–13	12
Pelvic	9	9
Pectoral	13–14	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–10	8–10
Lower	8–10	8–10
Gill rakers:		
Upper	2–4	3
Lower	8–11	10
Branchiostegals	14	14

LIFE HISTORY

Range: Rocas Alijos, Baja California (ca. 24°50′ N) to Cocos Island, 5°34′ N, 83°26′ W; most specimens collected near southern tip of Baja California Sur

Habitat: Demersal on soft bottom at 82–230 m depth

Spawning season: Larvae collected in CalCOFI tows in January-March, June, with a November-December peak

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Okiyama 1974, 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: ca. 7.5–8.5 mm
Transformation length: >13 mm, <41 mm
Fin development sequence: C, A, D, P_1, P_2
Pigmentation: *Preflexion-flexion*—Patch dorsolaterally on peritoneum; lateral patch on tail in A region. *Postflexion*—Patches enlarging; occasionally melanophore present ventrally on hypural region. *Juvenile*—On snout; upper & lower jaws; over brain; vertical band behind eye; on opercle; proximally on P_1; usually patches proximally & distally on first 5 D rays; covering dorsum, pale ventrally; ca. 9 irregularly-shaped blotches dorsally that also extend more narrowly below lateral line; proximally on C, more extensive ventrally.
Diagnostic features: 47–48 total vertebrae; D 14–15; P_1 13–14; single large saddled-shaped patch on peritoneum & patch laterally on tail in A region.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		52–57 54	55–56 56	59–62 60		61–64 62
BD/BL		13–15 14	12–14 13	13–16 14		15–18 16
HL/BL		20–22 21	20–22 21	24–26 25		29–32 31
HW/HL		56–84 69	76–80 77	70–79 73		41–43 42
SnL/HL		12–24 18	23–28 26	21–36 28		23–27 25
ED/HL		32–40 35	33–35 34	29–32 30		22–29 26
P_1L/BL		5–9 7	4–5 5	6–7 7		15–17 16
P_2L/BL		0–0 0	0–0 0	0–1 0.2		23–26 25

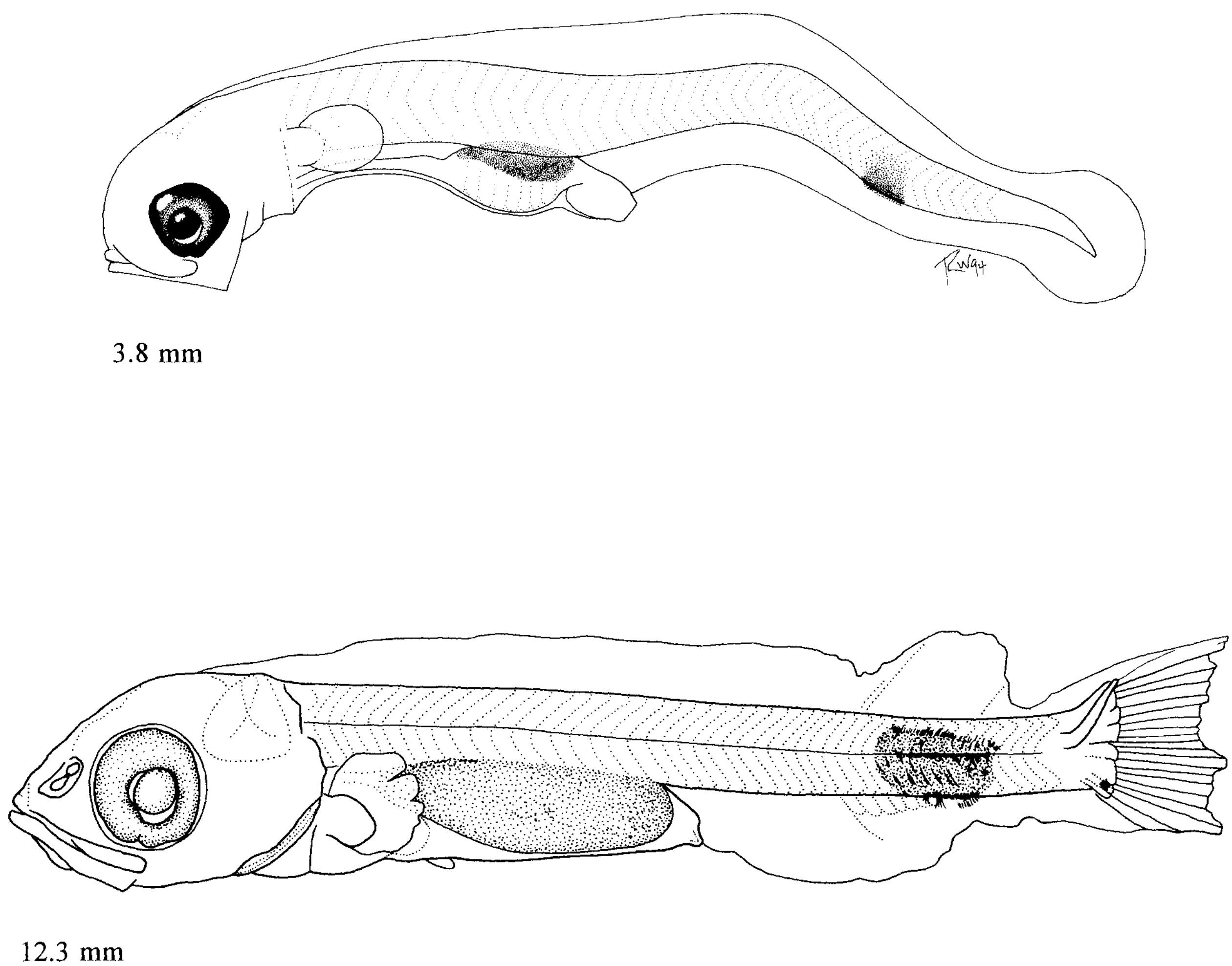


Figure Aulopidae 1. Preflexion larva, 3.8 mm (CalCOFI 6611, station 147.20); postflexion larva, 12.3 mm (Okiyama 1974).

SCOPELARCHIDAE: Pearleyes

W. WATSON AND E. M. SANDKNOP

Scopelarchidae contains 18 species in four genera (Johnson 1984a; Okiyama and Johnson 1986); five species representing all four genera, occur in the California Current vicinity (Table Scopelarchidae 1). All five species range well beyond the limits of the CalCOFI study area; within the study area, *Benthalbella dentata* is widely distributed while the others range southward from southern California or Baja California (Johnson 1974). Larvae of all five species occur in CalCOFI ichthyoplankton collections, most frequently and in highest abundance during summer and autumn at offshore stations.

Adult scopelarchids are small to medium-size (ca. 10–30 cm) meso- and bathypelagic predators in all seas except the Arctic and Mediterranean (Johnson 1974, 1984a). They are moderately elongate, moderately to strongly compressed, with preanal length about half to two-thirds of body length. The short-based dorsal fin, which like the long-based anal fin is composed only of segmented rays, inserts ahead of midbody. An adipose fin is located posteriorly, above about the last third of the anal fin. The mouth is large and well armed with long lanceolate teeth as well as smaller, more numerous, conical teeth. The tubular eyes are directed upward or obliquely forward, and have a characteristic pearly patch of tissue, the pearl organ, from which the common name for the family derives. At least one species, *B. infans*, is bioluminescent and *Scopelarchoides kreffti* may be bioluminescent as well (Johnson 1974).

Scopelarchids are synchronous hermaphrodites (Johnson 1974). Eggs and larval development at hatching are undescribed. Recently hatched larvae tentatively identified as scopelarchids (*Scopelarchus* or *Scopelarchoides*) are 3.6–4.0 mm long, unpigmented, with oval unpigmented eyes, partially formed to open mouth, short preanal length (ca. 30% BL), and small yolk sac. Older larvae are known for all but one species (Johnson 1984a). Larvae range from deep-bodied and robust with a large head to moderately slender and elongate with a moderately small head. The mouth is large, the snout is long and wedge-shaped, and the eye is narrow, usually with its longer "vertical" axis inclined obliquely forward. Preanal length is about one-third to one-half of body length. The gut is a straight or somewhat "S"-shaped tube at the bottom of the moderately to very deep abdominal cavity and is separated from the hypaxial musculature by a more or less broad translucent perivisceral membrane. Clearly visible within this membrane are the characteristic large melanophore patches or saddles over the gut, except in *Benthalbella* which is unpigmented, or nearly so, as a larva. In addition to this pigment, larval *Rosenblattichthys* and *Scopelarchoides* may have a few melanophores on the dorsal and ventral margins, and laterally on the tail. Larval *B. dentata* and *Rosenblattichthys* may have melanophores on the pectoral fin; pectoral fin rays develop precociously in *Rosenblattichthys*.

Larval scopelarchids are easily recognized, particularly by their moderate to large head with large mouth and narrow eyes, usually wide translucent space between the gut and the hypaxial musculature, and the characteristic pigment patches over the gut. They are unlikely to be confused with any other fish larvae in the CalCOFI study area. Larger scopelarchid larvae can be identified to species by use of a combination of meristic, morphometric, and pigment characters, but the smallest larvae cannot always be identified below the level of genus.

The following descriptions are based on literature (Johnson 1974, 1984a) and on detailed observation of 25–33 specimens of each species (Table Scopelarchidae 2). Meristic and ecological data were obtained from Johnson (1974); additional meristic counts were made during this study.

Table Scopelarchidae 1. Meristic characters for the scopelarchid species in the California Current vicinity. All have 9 pelvic fin rays, 10+9 principal caudal fin rays, and 8 branchiostegal rays.

Species	Vertebrae			Fin rays			
	PrCV	CV	Total	D	A	P_1	C_2
Benthalbella dentata	20–23	31–35	54–55	6–8	17–21	21–25	13–16+13–16
Rosenblattichthys volucris	17–18	32–33	49–51	9–10	21–24	23–26	14+13–14
Scopelarchoides nicholsi	16–20	26–30	45–48	6–7	20–23	20–23	13–14+15–17
Scopelarchus analis	17–18	29–30	44–49	7–9	21–26	18–22	12–15+13–15
S. guentheri	17–18	29–33	46–51	7–8	24–29	18–21	13–16+13–16

Table Scopelarchidae 2. Number of specimens (above) and size ranges (in mm, below) used in preparation of the scopelarchid species descriptions.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Benthalbella dentata	2 4.0, 4.1	10 4.2–12.7	5 13.3–19.3	6 30.8–49.5	2 51.9–56.5	1 67.3
Rosenblattichthys volucris	0	10 3.4–8.6	6 8.9–12.7	9 14.2–39.2	4 45.8–57.7	2 49.0–58.1
Scopelarchoides nicholsi	0	10 4.0–9.3	4 9.0–12.4	10 12.0–18.1	5 27.2–44.4	4 54.4–69.8
Scopelarchus analis	0	5 4.6–7.3	5 9.8–12.6	8 14.2–23.7	6 27.6–31.5	2 33.7–47.2
S. guentheri	0	6 3.6–8.7	5 9.2–12.5	8 15.8–31.2	3 33.7–41.7	3 55.6–81.5

MERISTICS

	Range	Mode
Vertebrae:		
Total	54–55	54–55
Precaudal	20–23	
Caudal	31–35	
Fins:		
Dorsal spines	0	0
Dorsal rays	6–8	7
Anal spines	0	0
Anal rays	17–21	18–20
Pelvic	9	9
Pectoral	21–25	23–24
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–16	
Lower	13–16	15–16
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: Gulf of Alaska (57°46'N) to Isla de Guadalupe, Mexico (29°12.1–13.8′ N), primarily east of 150°101′ W

Habitat: Mesopelagic, primarily 500–1000 m depth

Spawning season: In CalCOFI area, larvae collected October–July with maximum during March–April

ELH pattern: Oviparous, synchronous hermaphrodites; larvae are planktonic

LITERATURE

Belyanina 1982b
Johnson 1974, 1984a
Ozawa 1988c

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 6.5 mm, 9.2 mm (B. Sumida MacCall)
Flexion larva, 18.5 mm (B. Sumida MacCall)
Postflexion larva, 42.5 mm (B. Sumida MacCall)

* Both yolk-sac specimens damaged, SnL, ED & P_1L could not be measured; juvenile specimen damaged, eyes missing.
† Eye oval; "horizontal" axis is given first, "vertical" axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 4 mm
Flexion length: ca. 13–19 mm
Transformation length: ca. 50–55 mm through ca. 57 mm
Fin development sequence: C_1, P_1, D & A, C_2, P_2
Pigmentation: *Yolk-sac through postflexion*—None except few to many scattered on P_1 blade or fin membrane. *Transformation*—Little on occiput & snout at beginning of stage, increasing & spreading over snout & around eyes; on lower jaw after ca. 53 mm; scattered laterally on trunk & tail beginning posteriorly by ca. 52 mm; on peritoneum beginning dorsally just behind level of P_1 & spreading caudad & ventrad to enclose gut by end of stage.
Diagnostic features: Myomeres 13–18+37–42=54–55; P_2 ahead of D origin; unpigmented except on P_1 before transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	37–40 38	40–52 46	46–50 48	41–48 45	57–61 59	63
BD/BL	10–10 10	11–18 15	17–20 18	14–19 16	12–13 13	11
HL/BL	17–18 18	18–26 23	22–23 23	19–22 21	22–24 23	22
HW/HL	29	35–62 51	49–60 55	42–49 45	33–36 35	35
SnL/HL	*	23–43 35	39–44 42	38–45 41	36–36 36	33
ED/HL†		15–28× 26–46	13–16× 24–33	12–18× 25–28	20–20× 23–25	
	*	19×34	14×28	14×26	20×24	*
P_1L/BL	*	4–8 5	4–5 4	3–8 6	15–16 16	11
P_2L/BL	0–0 0	0–0 0	0–1 0.1	1–14 8	14–18 16	12

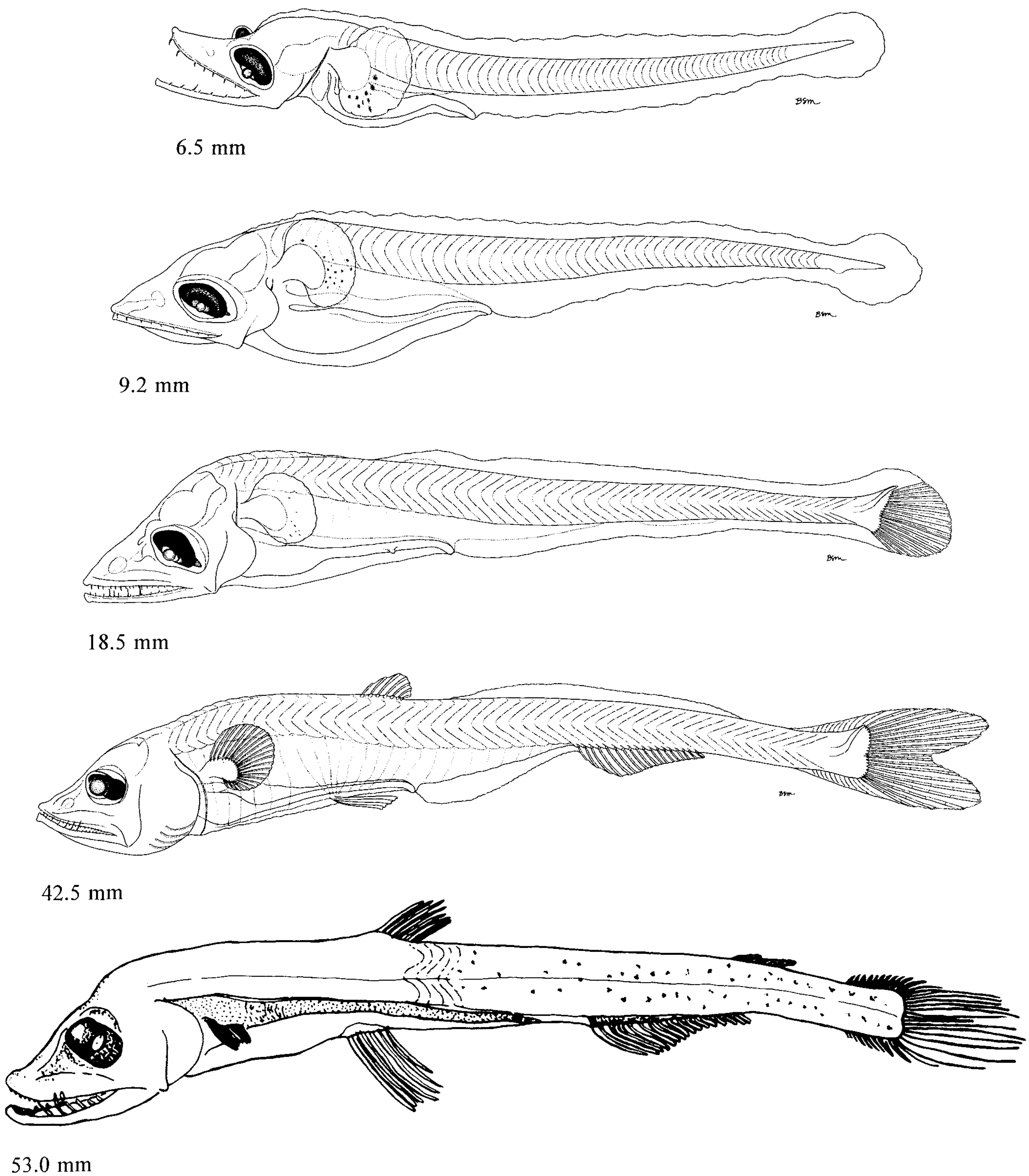


Figure Scopelarchidae 1. Preflexion larvae, 6.5 mm (CalCOFI 6902, station 67.60), 9.2 mm (CalCOFI 7803, station 97.60); flexion larva, 18.5 mm (CalCOFI 7804, station 80.70); postflexion larva, 42.5 mm (CFRD 8812, station 27.9.26.2); transformation specimen, 53.0 mm (Johnson 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	49–51	50
Precaudal	17–18	18
Caudal	32–33	32
Fins:		
Dorsal spines	0	0
Dorsal rays	9–10	9
Anal spines	0	0
Anal rays	21–24	23
Pelvic	9	9
Pectoral	23–26	24–25
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	14	14
Lower	13–14	
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: California Current vicinity from southern California to central Baja California Sur (ca. 33–25° N) & equatorial eastern Pacific (ca. 6° N to 3° S)

Habitat: Mesopelagic

Spawning season: In CalCOFI area, larvae collected throughout the year with largest catches on average during August–January

ELH pattern: Oviparous, synchronous hermaphrodites; larvae are planktonic

LITERATURE

Belyanina 1982b
Johnson 1974, 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 7.0 mm (H. M. Orr)
Flexion larva, 13.0 mm (H. M. Orr)
Transformation specimen, 37.0 mm (H. M. Orr)

* Eye oval; "horizontal" axis is given first, "vertical" axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.2 mm
Flexion length: ca. 9–14 mm
Transformation length: ca. 28–60 mm
Fin development sequence: P_1, C_1, C_2, D & A, P_2
Pigmentation: *Preflexion*—None to few distally on inner surface of P_1 base & scattered on P_1 blade; large peritoneal patch above anterior half to 60% of gut. *Flexion*—On ventral margin between myomeres 34–38 by 9.5 mm; on dorsal margin between myomeres 34–38 by 12 mm & between myomeres 22–24 by 12.7 mm; 1 midlaterally at myomere 45–47 by 12.1 mm. *Postflexion*—Near bases of 1 or 2 lower middle C_1 rays by 14.7 mm; near bases of 1 or 2 upper middle C_1 rays by 14.8 mm; at bases of A rays 2 & 3 by 22.8 mm. *Transformation*—Over & on mid- & hindbrain; at nape; dorsolaterally at ca. myomeres 16–38; on dorsal margin at ca. myomere 38–50; internally on first 7 A pterygiophores between 31–32 mm; peritoneal patch spreads posteriorly & ventrally.
Diagnostic features: Large head with long snout & large mouth; deep body; myomeres 12–18+33–36 during preflexion stage, 23–27+25–27 by postflexion stage, total 47–52 (usually 50–51); single large peritoneal pigment patch; up to 2 blotches each on dorsal & ventral margins; 1 blotch laterally on caudal peduncle, 2 on C.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		37–52 44	55–62 57	59–64 62	62–64 63	62–62 62
BD/BL		12–21 16	21–28 24	17–27 24	16–18 17	17–17 17
HL/BL		20–34 24	31–34 32	30–39 35	27–31 29	31–32 32
HW/HL		47–77 54	43–53 47	30–44 39	27–35 31	28–32 30
SnL/HL		24–48 37	46–55 50	44–57 50	33–34 33	31–31 31
ED/HL*		11–35× 23–48 19×33	7–12× 19–24 9×21	6–12× 15–21 10×18	17–24× 20–24 19×21	18–20× 17–23 19×20
P_1L/BL		5–16 8	9–16 12	11–22 17	21–23 22	22–23 22
P_2L/BL		0–0 0	0–0 0	1–14 7	15–19 18	19–20 19

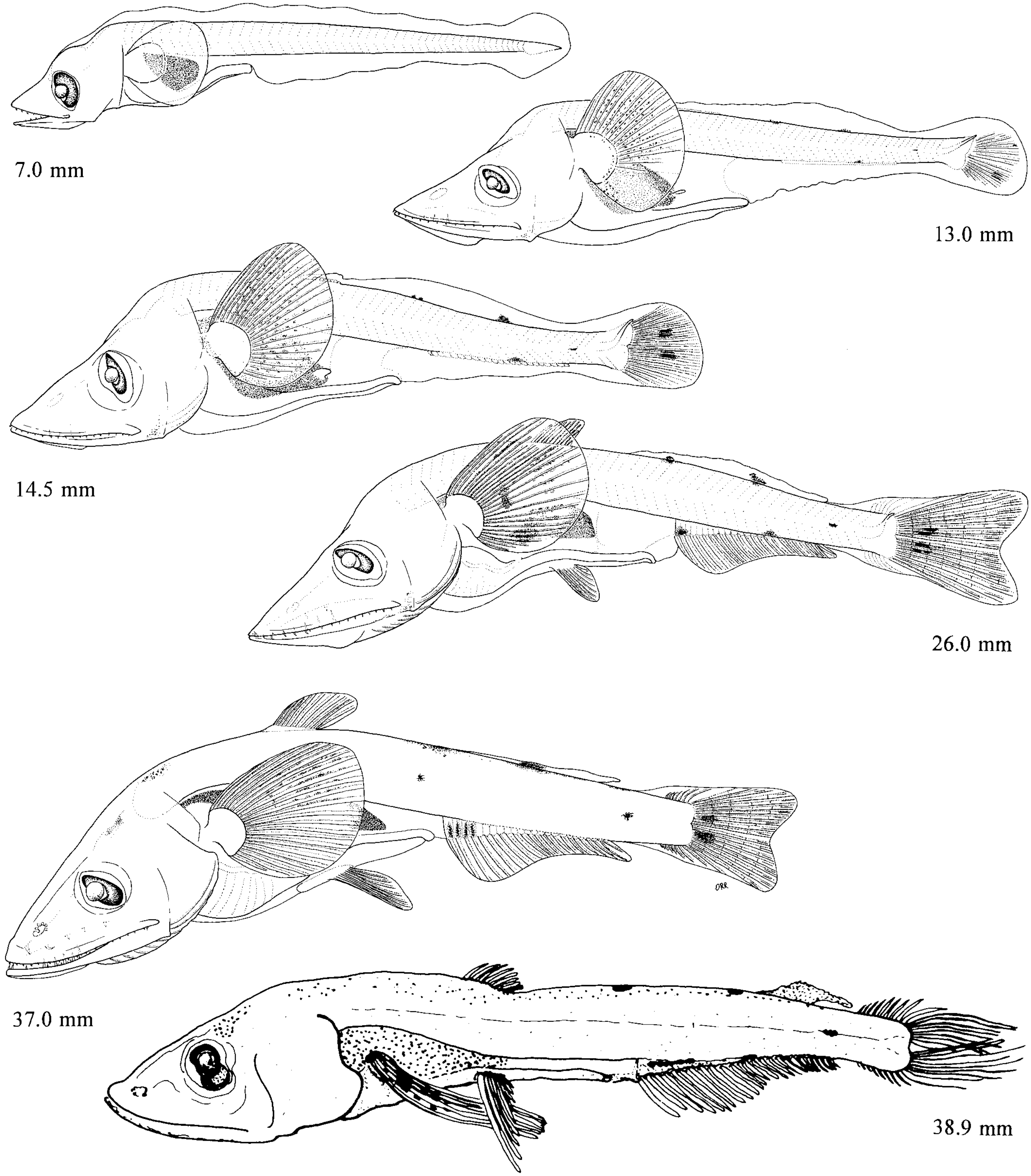


Figure Scopelarchidae 2. Preflexion larva, 7.0 mm (CalCOFI 6607, station 107.65); flexion larva, 13.0 mm (CalCOFI 6706, station 107.50); postflexion larvae, 14.5 mm, 26.0 mm (Johnson 1984a); transformation specimens, 37.0 mm (CFRD DSJ–50, station 11), 38.9 mm (Johnson 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	45–48	46–47
Precaudal	16–20	17
Caudal	26–30	28–30
Fins:		
Dorsal spines	0	0
Dorsal rays	6–7	7
Anal spines	0	0
Anal rays	20–23	21–22
Pelvic	9	9
Pectoral	20–23	21–22
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–14	13
Lower	15–17	15
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: Vicinity of Isla Cedros, Baja California (ca. 27° N) to equatorial waters off Panama & Colombia (5°–9° N, west to 136° W) & off Peru (ca. 6°–12° S)

Habitat: Epi- & mesopelagic; occurs in shallower part of depth range at night, deeper during the day

Spawning season: Larvae reported to occur throughout the year; larvae collected in February, June & November in CalCOFI area

ELH pattern: Oviparous, synchronous hermaphrodites; larvae are planktonic

LITERATURE

Belyanina 1982b
Johnson 1974, 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 16.8 mm (H. M. Orr)
Transformation specimen, 33.4 mm (H. M. Orr)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

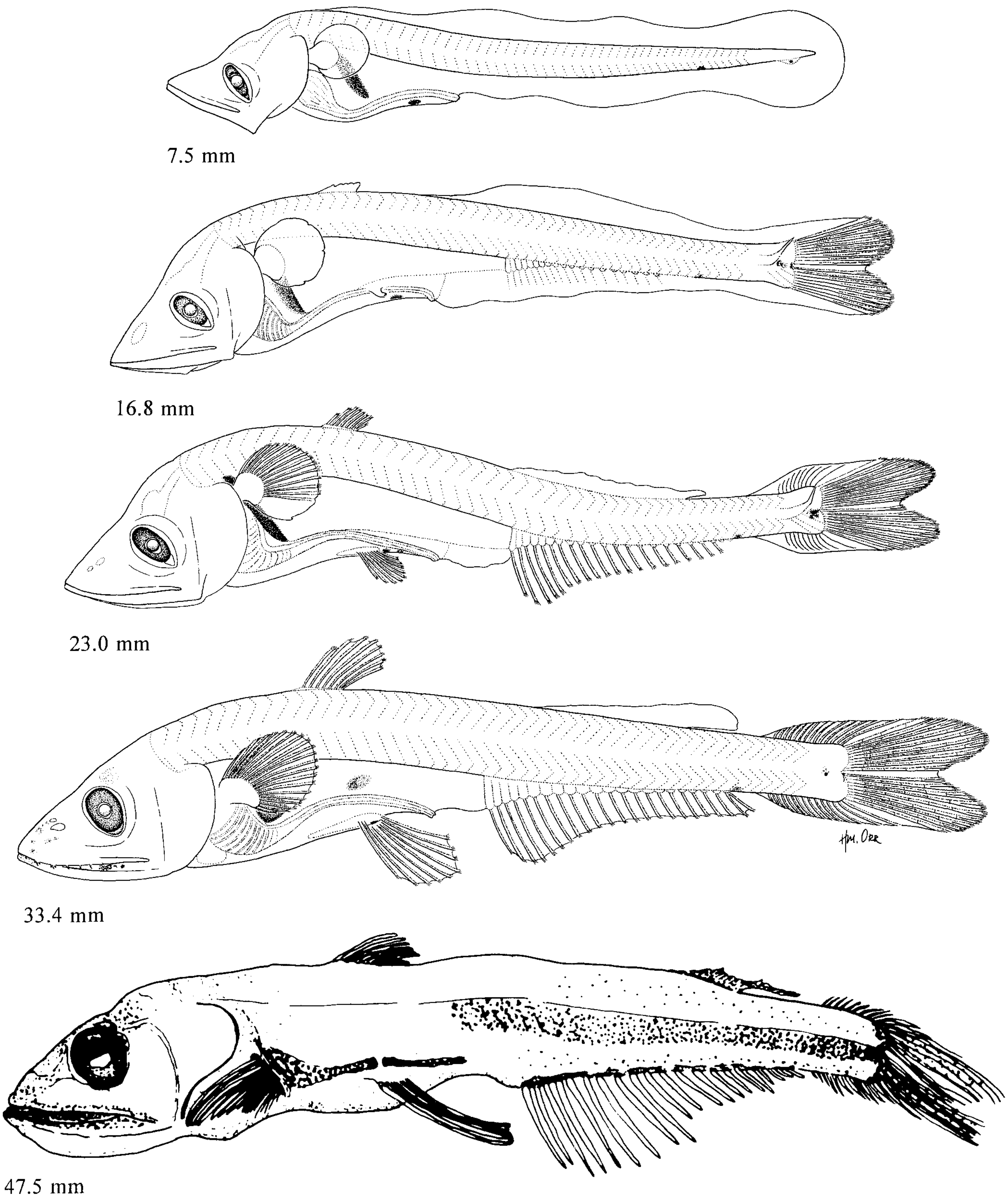
LARVAE

Hatching length: <4.0 mm
Flexion length: 9–9.3 mm through ca. 12–12.4 mm
Transformation length: ca. 26–28 mm through ca. 40–45 mm
Fin development sequence: C_1, C_2, A, P_2, D, P_1
Pigmentation: *Preflexion–postflexion*—Large peritoneal patch over upper part of gut at level of P_1; 0–2 (usually 1) on ventral margin of gut at level of P_2 buds (buds form during flexion stage); 0–few (usually 1) on ventral margin of tail in vicinity of myomeres 34–39; 1 laterally on each side over middle of hypurals by 8–9 mm. *Transformation*—Series forms laterally on articular & dentary beginning posteriorly at ca. 26 mm & spreading anteriorly; dorsally over brain & on snout & around eye between 32–36 mm; dorso- and ventrolaterally on tail beginning on caudal peduncle at ca. 30–32 mm & spreading cephalad; pair of peritoneal patches added at level of P_2 at 26–27 mm.
Diagnostic features: Myomeres 45–48 (usually 47–48), 12–13+34–36 in preflexion stage, 18–19+29–30 in postflexion stage; single peritoneal pigment patch anteriorly until ca. 26 mm, then smaller pair of patches added at level of P_2; single melanophores usually present posteriorly on ventral margins of hindgut & tail, laterally over middle of hypurals.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–47 41	45–50 47	47–52 49	52–53 53	50–54 53
BD/BL		12–16 15	15–20 18	18–21 20	15–20 17	15–17 16
HL/BL		18–25 22	22–28 25	21–26 23	25–29 27	25–27 26
HW/HL		54–67 58	56–64 59	52–74 61	41–54 47	38–43 40
SnL/HL		24–41 30	35–49 43	35–44 40	34–39 36	27–34 30
ED/HL*		12–18× 23–36 14×29	10–14× 19–23 11×21	11–17× 20–27 13×23	13–18× 17–23 15×20	18–20× 20–22 19×21
P_1L/BL		3–6 5	4–5 4	4–5 4	8–16 12	12–16 15
P_2L/BL		0–0 0	0–0.1 0.02	0–3 1	11–18 14	16–17 17

* Eye oval; "horizontal" axis is given first, "vertical" axis second.



47.5 mm

Figure Scopelarchidae 3. Preflexion larva, 7.5 mm (Johnson 1984a); postflexion larvae, 16.8 mm (CalCOFI 6611, station 150.60), 23.0 mm (Johnson 1984a); transformation specimen, 33.4 mm (EASTROPAC I, station 13.255); juvenile, 47.5 mm (Johnson 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–49	46–48
Precaudal	17–18	17–18
Caudal	29–30	29
Fins:		
Dorsal spines	0	0
Dorsal rays	7–9	8
Anal spines	0	0
Anal rays	21–26	22–25
Pelvic	9	9
Pectoral	18–22	20
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–15	13–14
Lower	13–15	14–15
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: Circumglobal in warm water; in CalCOFI area off southern California & Baja California peninsula

Habitat: Mesopelagic

Spawning season: Larvae collected throughout the year

ELH pattern: Oviparous, synchronous hermaphrodites; larvae are planktonic

LITERATURE

Belyanina 1982b
Johnson 1974

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.9 mm (R. C. Walker)
Flexion larva, 11.7 mm (R. C. Walker)
Postflexion larva, 18.8 mm (R. C. Walker)

* Eye oval; "horizontal" axis is given first, "vertical" axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.8 mm
Flexion length: ca. 10–13 mm
Transformation length: ca. 25 mm through 33–55 mm
Fin development sequence: C_1, C_2 & P_1, A, D, P_2
Pigmentation: *Preflexion–postflexion*—None except on choroid tissue below eye before ca. 9 mm; 1 peritoneal patch above anterior middle of gut by 10 mm, shifting forward to level of P_1 by ca. 15 mm; pair of dorsolateral peritoneal patches above hindgut midway between P_2 & anus at ca. 20 mm. *Transformation*—Dorsolateral & ventrolateral stripes form adjacent to lateral midline of tail by 25 mm, spread cephalad & caudad, become connected as bar across end of caudal peduncle by ca. 28 mm; over midbrain by 25 mm; on snout & jaws by 30 mm; on P_1 after 25 mm; peritoneal sections fuse by 33–55 mm.
Diagnostic features: Myomeres 9+36–37 early in preflexion stage, 19–22+27–30 by postflexion stage, total 45–49 (usually 46–47); HL ≥20% BL (usually 20–23%); A rays ≤25 (usually 22–23); no peritoneal pigment before ca. 9.8 mm, then one anterior patch through 19 mm, dorsolateral pair of patches added posteriorly by 20 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–43 38	43–49 46	49–56 53	50–56 54	57–65 61
BD/BL		13–14 14	10–15 13	16–18 17	13–16 15	16–17 17
HL/BL		20–23 22	21–22 22	20–23 21	20–25 22	25–28 26
HW/HL		41–43 41	44–47 46	45–63 52	41–53 47	41–43 42
SnL/HL		32–38 35	28–41 37	38–46 43	31–37 34	33–34 34
ED/HL*		11–15× 27–38 12×33	11–13× 26–30 12×28	7–11× 23–27 9×24	10–17× 21–25 13×23	18× 22–23 18×23
P_1L/BL		3–8 5	4–5 4	3–6 5	11–16 13	18–24 21
P_2L/BL		0–0 0	0–0 0	0–2 1	5–11 8	11–23 17

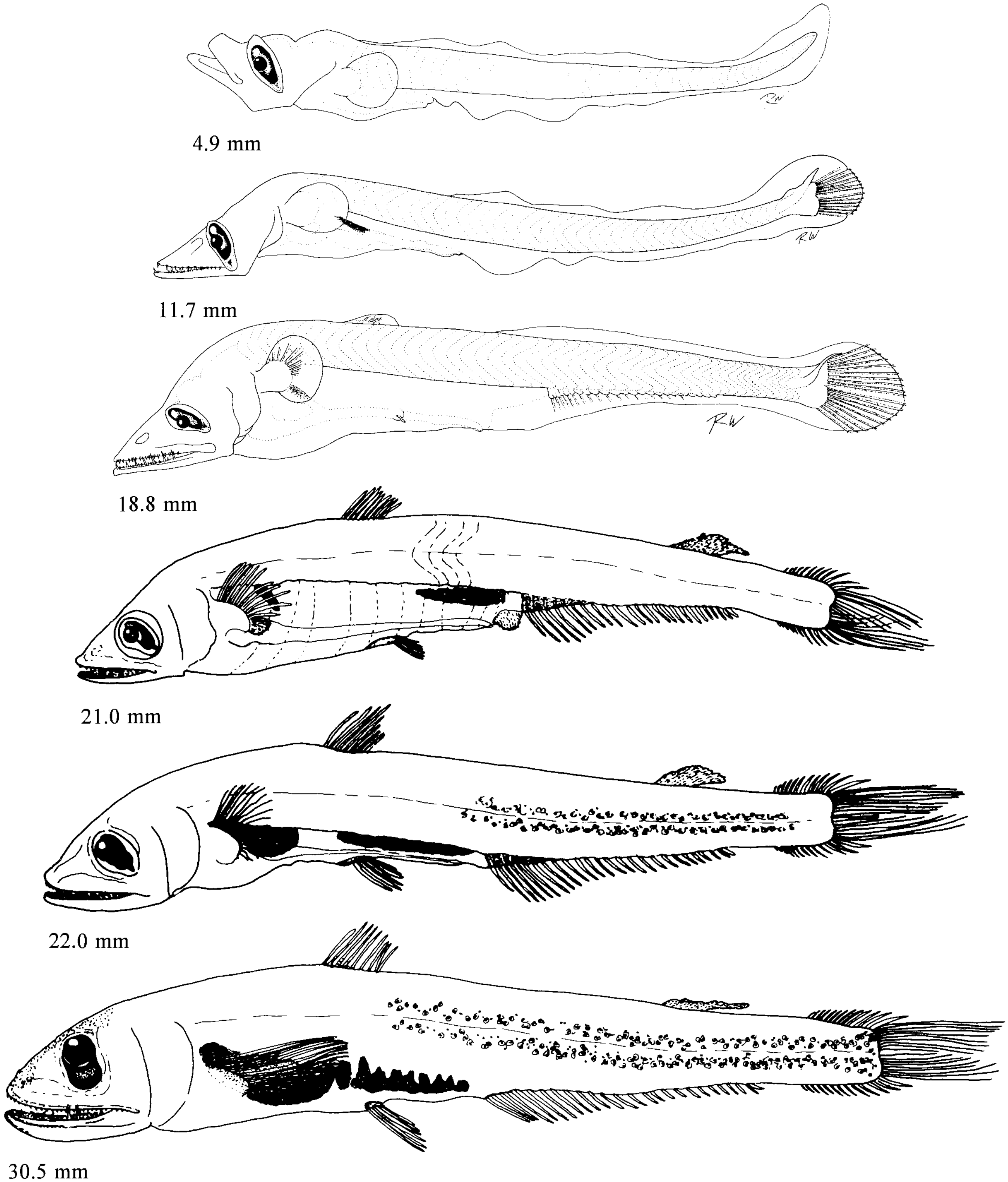


Figure Scopelarchidae 4. Preflexion larva, 4.9 mm (CalCOFI 6204, station 100.160); flexion larva, 11.7 mm (CalCOFI 6207, station 90.140); postflexion larvae, 18.8 mm (CalCOFI 5207, station 97.90), 21.0 mm (Johnson 1974); transformation specimens, 22.0 mm, 30.5 mm (Johnson 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	46–51	49
Precaudal	17–18	17
Caudal	29–33	33
Fins:		
Dorsal spines	0	0
Dorsal rays	7–8	8
Anal spines	0	0
Anal rays	24–29	25–27
Pelvic	9	9
Pectoral	18–21	20–21*
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–16	14–15
Lower	13–16	15
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: Circumglobal in warm water; in CalCOFI area primarily off southern California & Baja California peninsula

Habitat: Lower epipelagic & mesopelagic

Spawning season: Larvae collected throughout the year

ELH pattern: Oviparous, synchronous hermaphrodites; larvae are planktonic

LITERATURE

Belyanina 1982b
Johnson 1974, 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 6.5 mm (H. M. Orr)
Flexion larva, 11.5 mm (H. M. Orr)
Postflexion larvae, 18.5 mm, 22.5 mm (H. M. Orr)
Transformation specimen, 33.5 mm (H. M. Orr)

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* P_1 20–21 are most common counts in the eastern North Pacific; elsewhere *S. guentheri* has P_1 18–19 (Johnson 1974).
† Eye oval; "horizontal" axis is given first, "vertical" axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.5 mm
Flexion length: ca. 9–12 mm
Transformation length: ca. 33 mm through 50–55 mm
Fin development sequence: C_1, C_2, P_1, A, D, P_2
Pigmentation: *Preflexion–flexion*—Single peritoneal patch above midgut by ca. 6 mm, usually shifts slightly cephalad by ca. 10 mm; pair of dorsolateral peritoneal patches posteriorly by 8.4 mm. *Postflexion*—Few externally over hypural area by 15–16 mm, spreading cephalad as dorsolateral & ventrolateral stripes adjacent to lateral midline beginning at ca. 25 mm; internally on hindbrain by 28 mm. *Transformation*—Externally over midbrain by 33 mm, spreading over forebrain by ca. 42 mm; on snout, upper jaw, & gular membrane; on D by 42 mm; peritoneal sections fuse.
Diagnostic features: Myomeres 10–14+33–36 during preflexion stage, 18–22+26–31 in postflexion stage, total 46–50; HL ≤21% BL (usually 19–20%); A ≥24 (usually 25–27); peritoneal pigment present midway to anteriorly over gut by 6 mm, dorsolateral pair added posteriorly by 8.4 mm; laterally on caudal peduncle after 15–16 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		37–43 39	43–51 47	50–57 52	50–53 52	53–58 55
BD/BL		11–12 11	11–14 13	14–19 16	13–16 15	16–18 18
HL/BL		17–21 19	18–21 19	20–23 21	23–26 24	22–27 24
HW/HL		38–46 43	48–59 53	40–53 49	33–36 34	43–49 45
SnL/HL		33–43 36	38–48 45	37–48 42	30–36 33	25–29 27
ED/HL†		12–17× 24–40 15×33	9–14× 26–30 11×28	9–13× 23–26 10×24	16–17× 23–24 17×23	24–29× 27–34 26×31
P_1L/BL		4–6 4	3–5 4	4–10 6	11–15 13	20–21 20
P_2L/BL		0–0 0	0–0 0	0–7 3	8–10 9	10–11 10

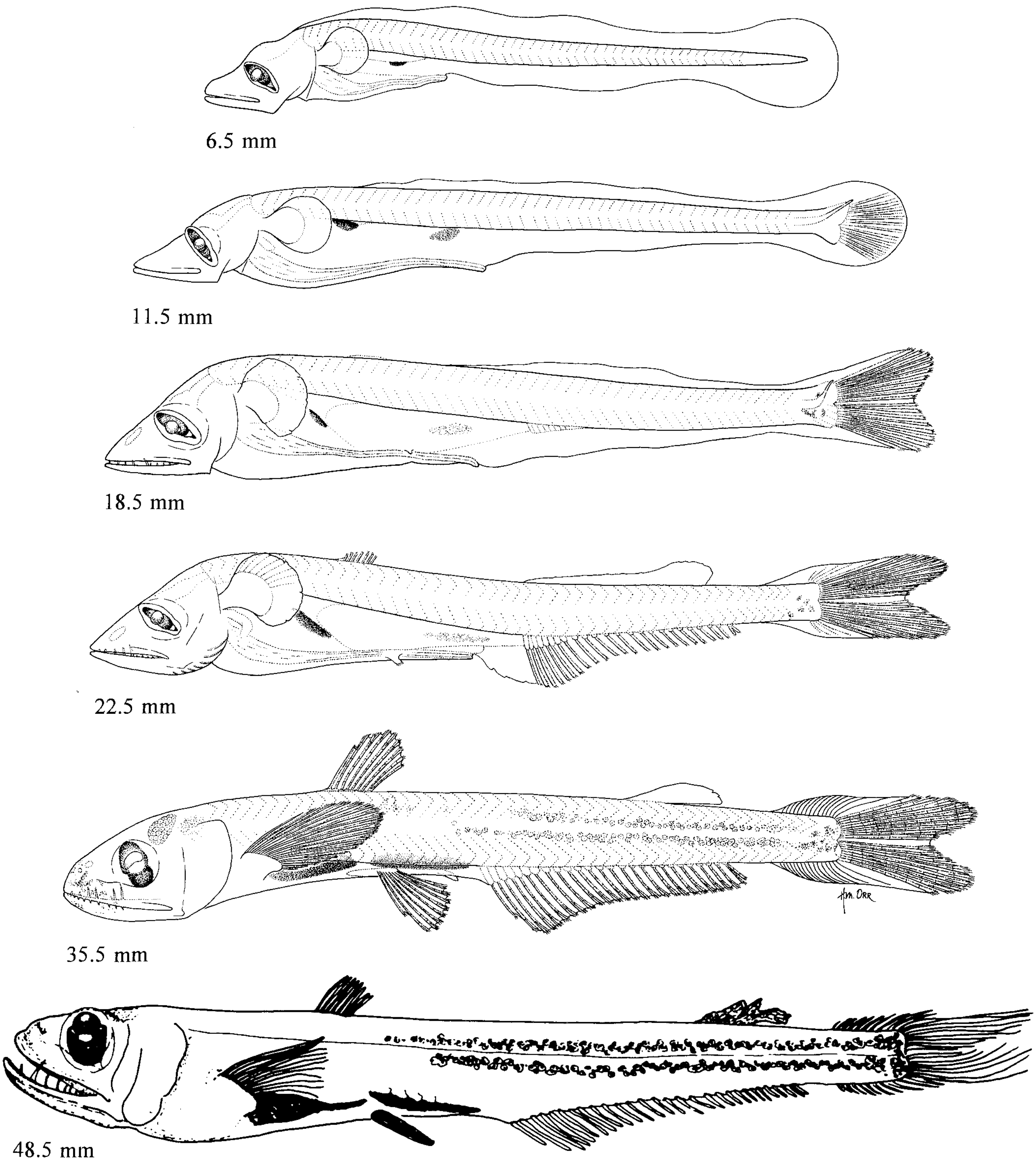


Figure Scopelarchidae 5. Preflexion larva, 6.5 mm (CalCOFI 6608, station 117.65); flexion larva, 11.5 mm (CalCOFI 6712, station 117.35); postflexion larvae, 18.5 mm (CalCOFI 6607, station 107.45), 22.5 mm (CalCOFI 6901, station 113.50); transformation specimens, 35.5 mm (CalCOFI 6210, station 130.80), 48.5 mm (Johnson 1974).

NOTOSUDIDAE: Paperbones

W. WATSON AND E. M. SANDKNOP

Two of the approximately 19 notosudid species, representing two of the three genera, have been reported from the California Current vicinity. *Ahliesaurus brevis*, primarily an Indo-Pacific species, ranges eastward to near the seaward edge of the CalCOFI study area off central Baja California, while *Scopelosaurus harryi* ranges throughout the CalCOFI area and across the North Pacific between about 20°–60° N (Bertelsen et al. 1976). Larval notosudids, apparently all *S. harryi*, occur relatively commonly in CalCOFI ichthyoplankton samples, primarily at the seaward stations during spring and summer.

Adult notosudids are small to medium-size (ca. 15–50 cm) fishes that are meso- and bathypelagic or epibenthic on continental or insular slopes (Bertelsen et al. 1976; Krefft 1984). They are primarily predators on pelagic crustaceans and small fish (Bertelsen et al. 1976). Notosudids are long and slender, with a slightly to moderately depressed head and cylindrical to compressed trunk tapering to a strongly compressed caudal peduncle. The head is long with a long wedge-shaped snout, large mouth, and horizontally elongate, oval eyes. Preanal length is about 50–60% of body length. The fins contain only segmented rays. The short-based dorsal fin is near midbody and the longer-based anal fin is far posterior. The dorsal adipose fin is above the last few anal fin rays. The cheeks, trunk, and tail are covered with large cycloid scales. Teeth and gill rakers are well developed in older larvae and juveniles, but may be slowly resorbed in adults or are lost at maturity; both are absent in individuals ready to spawn (Bertelsen et al. 1976; Krefft 1984, 1986). There are no luminous tissues. Notosudids are brown, usually with a darker head, dark brown to black gill covers, and dark margins on the scale pockets. Some species have silvery scales.

Notosudids are synchronous hermaphrodites (Bertelsen et al. 1976). Planktonic eggs are unknown, but Bertelsen et al. (1976) reported that maturing ovarian eggs of *A. brevis* are 0.55–0.65 mm with a single oil globule. Recently hatched *S. harryi* are ca. 4.3 mm, with unpigmented eyes, an open mouth, and a small yolk sac. Larval notosudids are elongate, slightly compressed becoming more compressed posteriorly, with a head that is slightly compressed to slightly depressed, becoming more depressed with growth. The eyes are horizontally elongate, becoming more rounded during transformation. The initially short snout quickly becomes long and wedge-shaped. The gut is a short, straight tube (preanal length ca. 40–50% BL, increasing to 50–60% just before or during the transformation stage). There are no spines on the head or pectoral girdle. Larval pigmentation is light and largely limited to the caudal peduncle and finfold or fin before transformation, except in *Ahliesaurus* which also has a midlateral melanophore series (Bertelsen et al. 1976).

Larval notosudids are unlikely to be confused with any other larvae in the CalCOFI study area. Primary characters are the elongate, slender body with somewhat depressed head, long wedge-shaped snout, horizontally elongate eyes, relatively short preanal length, and pigment largely limited to a band of melanophores on the caudal peduncle. Among the notosudid species, *S. harryi* is most likely to be collected within the CalCOFI study area. It is easily distinguished from *A. brevis* by its higher myomere count (57–61 vs. 42–50), shorter preanal length (ca. 30–40% BL vs. ca. 50%, lengthening to ca. 45–50% vs. ca. 60% during transformation and early juvenile stages), and by lacking the midlateral melanophores that characterize *A. brevis* from at least the flexion stage onward.

The following description is based on detailed examination of 29 larvae (2 yolk-sac, 4.3–4.6 mm; 10 preflexion, 5.0–12.5 mm; 7 flexion, 14.3–20.2 mm; 7 postflexion, 22.3–41.5 mm; 3 transformation, 40.0–45.2 mm) and 4 juveniles (37.5–50.5 mm) of *S. harryi*. Since no larval *A. brevis* were identified from CalCOFI samples, a separate description is not given here, but flexion and postflexion stage larvae are shown in Figure Notosudidae 1. Refer to Bertelsen et al. (1976) and Ozawa (1978) for descriptions and additional information.

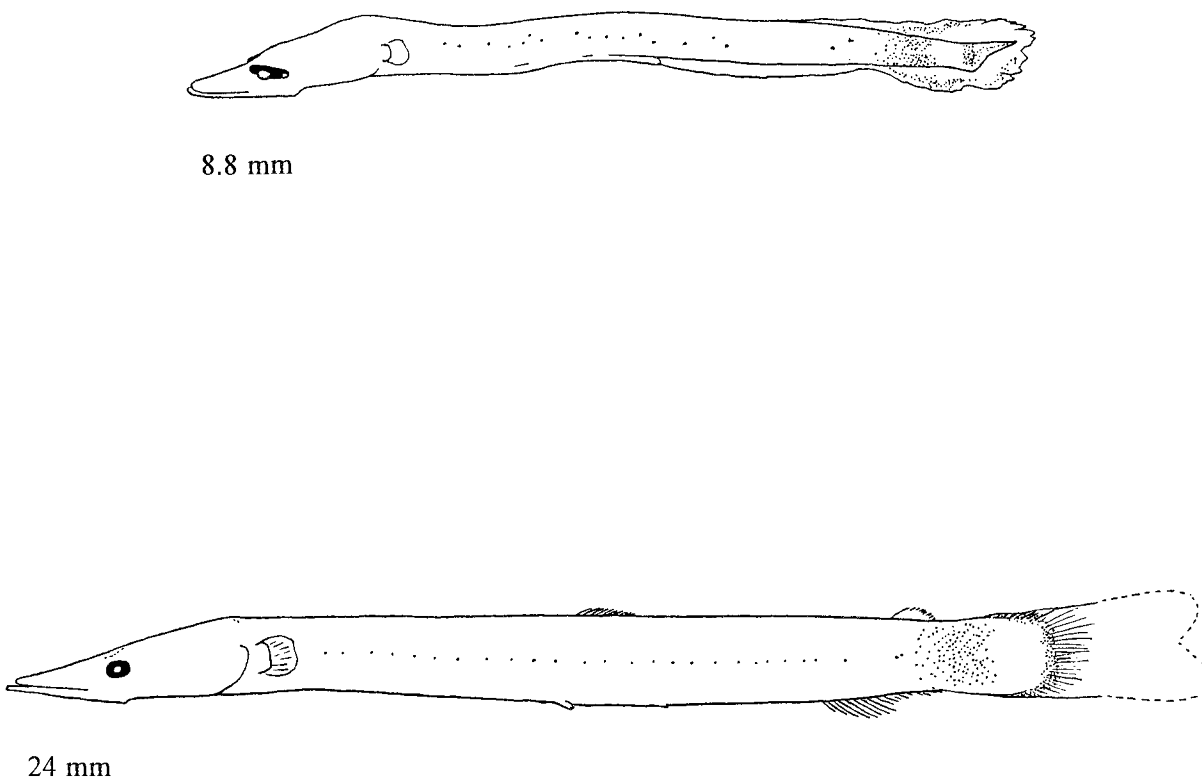


Figure Notosudidae 1. *Ahliesaurus brevis*: flexion larva, 8.8 mm; postflexion larva, 24 mm (Bertelsen et al. 1976).

MERISTICS

	Range	Mode
Vertebrae:		
Total	58–61	59
Precaudal	26–30	
Caudal	29–32	
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	10
Anal spines	0	0
Anal rays	16–19	18
Pelvic	9–10	9
Pectoral	10–14	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12	12
Lower	11–12	12
Gill rakers:		
Upper	0–1	0
Lower	17–20	18
Branchiostegals	10	10

LIFE HISTORY

Range: North Pacific between ca. 20°–60° N; throughout CalCOFI study area

Habitat: Juveniles mesopelagic, adults primarily epibenthic on continental & insular slopes

Spawning season: In CalCOFI area, larvae collected in spring & summer (March-August)

ELH pattern: Oviparous, synchronous hermaphrodites; planktonic larvae

LITERATURE

Bertelsen et al. 1976
Matarese et al. 1989
Okiyama 1984a,b
Ozawa 1978, 1988c

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 5.8 mm, 12.8 mm (N. Arthur)
Postflexion larva, 33.8 mm (N. Arthur)

* Both yolk-sac specimens damaged, precluding measurement of snout length.
† Eye oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

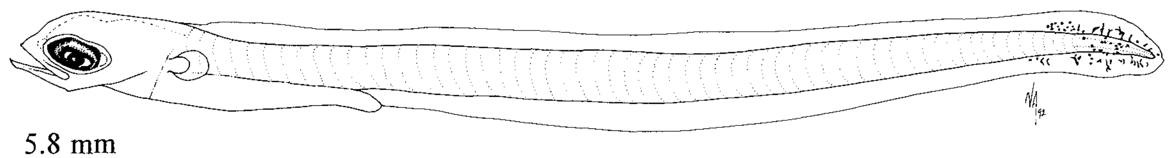
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

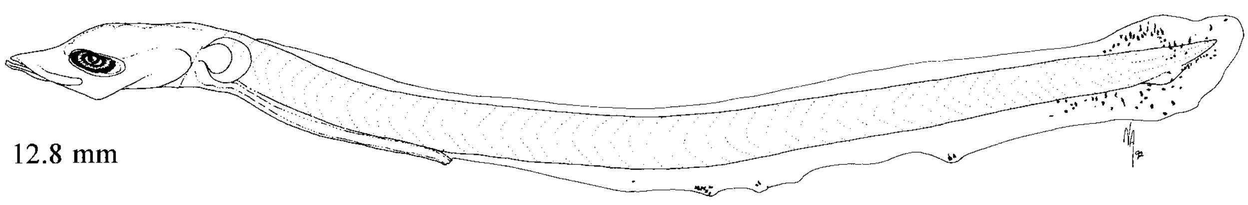
Hatching length: ca. 4 mm
Flexion length: ca. 14–20 mm
Transformation length: 40–50 mm, shrinking to ca. 37.5 mm
Fin development sequence: C_1, A, C_2, P_2 & Ad, D & P_1
Pigmentation: *Yolk-sac & preflexion*—0–few on ventral margin & ventral finfold near middle of tail (usually none before ca. 8–9 mm), located nearer finfold margin with increasing larval length; on dorsal & ventral margins of last few myomeres & notochord tip, extending onto caudal finfold, forming dorsal & ventral bands by ca. 11 mm; laterally on notochord tip by ca. 7 mm. *Flexion-postflexion*—Series along distal margin of hypurals after ca. 14 mm; by 33 mm, laterally on caudal peduncle & embedded along ventral margin of caudal peduncle; few on A rays after 22 mm; few on C rays, decreasing with growth.
Diagnostic features: Elongate, slender; preanal length 31–43% BL in larvae ca. <25 mm; horizontally elongate oval eyes; myomeres 57–61 (9–12+47–50 through early postflexion stage, gradually shifting to 21–22+39–40 by late postflexion stage); pigment largely limited to caudal peduncle.

MORPHOMETRICS (range & mean in %)

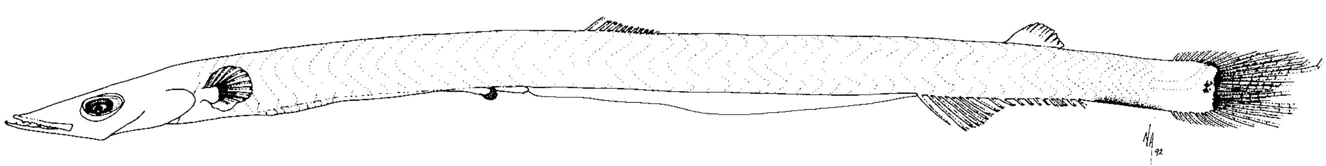
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	31–34 32	32–40 36	40–43 42	41–46 43	43–45 44	48–51 50
BD/BL	8–9 9	5–9 6	5–6 5	5–6 5	6–6 6	7–8 7
HL/BL	14–15 14	14–18 15	16–18 17	16–19 17	16–19 18	24–26 25
HW/HL	32–44 38	29–49 36	27–33 30	24–35 29	23–30 27	23–26 25
SnL/HL	*	11–30 25	36–42 39	38–42 39	37–41 39	33–36 34
ED/HL†		23–41× 11–21	18–22× 8–10	14–18× 8–11	12–15× 8–11	16–17× 11–15
	47×28	26×15	20×10	15×10	14×10	17×13
P_1L/BL	1–1 1	1–3 2	1–2 1	1–3 2	2–3 3	4–6 5
P_2L/BL	0–0 0	0–0 0	0–0 0	0–2 1	3–4 3	6–7 7



5.8 mm



12.8 mm



33.8 mm

Figure Notosudidae 2. Preflexion larvae, 5.8 mm (CalCOFI 7205, station 42.143), 12.8 mm (CalCOFI 7205, station 39.139); postflexion larva, 33.8 mm (CalCOFI 9107, station 88.60).

SYNODONTIDAE: Lizardfishes

E. G. STEVENS[1] AND H. G. MOSER

The family Synodontidae includes three subfamilies: Synodontinae (lizardfishes), Harpadontinae (Bombay ducks), and Bathysaurinae. Bathysaurinae, with 2 species in a single genus, is represented in the CalCOFI region by *Bathysaurus mollis* (Hubbs et al. 1979; Sulak et al. 1985). Larvae were discussed by Johnson (1974), Okiyama (1988), and Matarese et al. (1989). Synodontinae contains two genera and about 35 species and is represented in the CalCOFI survey area by at least four species in the genus *Synodus* (Table Synodontidae 1). The northern limit for most of these is Bahía Magdalena, Baja California Sur and only *S. lucioceps* ranges northward into California waters (Allen and Robertson 1994; Bussing and Lavenberg 1995). Larvae of *S. lucioceps* occur in nearshore waters as far north as Monterey Bay, California.

Synodontines are medium-size (up to ca. 60 cm) benthic predators found worldwide in tropical and subtropical coastal waters and bays, sometimes entering brackish waters. They are elongate, cylindrical, and slightly tapering with a broad head and sharply pointed triangular snout. Jaws are large, extend well beyond the eye, and bear sharp depressible teeth. The head and body are covered with cycloid, tightly adhering scales. The caudal fin is deeply forked. The dorsal fin is somewhat anterior to midbody, the anal is well posteriad, and the pelvic fins are abdominal, originating well foreward of the dorsal. An adipose fin is present. Most species are brown to gray or red dorsally and laterally and pale ventrally; some species have a pattern of dusky saddles, lateral spots, or bars (Anderson et al. 1966; Fitch and Lavenberg 1971; Cressey 1986).

Synodontines spawn spherical planktonic eggs (0.95–1.48 mm in diameter) that are colorless, lack an oil globule, and have a moderately large perivitelline space. The surface of the egg shell is covered with a polygonal network; polygon diameters range from 0.034 to 0.063 mm, depending on the species (Zvyagina 1965; Sumida et al. 1972). Larvae hatch at 2.5–3.8 mm and rapidly develop a series of large lateral gut blotches (5–12, depending on species) that remain throughout the larval period. The body and gut are elongate and the head is somewhat rounded. Larvae of most species reach a large size (up to ca. 40 mm) and undergo a gradual transformation to the juvenile stage. Transparent individuals >60 mm in length with juvenile morphology and lateral body blotches are known for some species (Jones et al 1978; Sumida et al. 1979; Moser 1981; Okiyama 1984; Ozawa 1988; Matarese et al. 1989).

Synodus eggs may be confused with those of the pleuronectid genus *Pleuronichthys* since their eggs also have polygonal sculpturing on the shell. Eggs can be identified by their shell diameter and by the shape of the polygons. Those in *Pleuronichthys* are usually six-sided and uniform whereas those in *Synodus* are usually five-sided and less regularly arranged. The elongate larvae with their elongate gut, rounded heads, and paired series of black spots laterally on the gut are easily separated from other nearshore fish larvae. Paired peritoneal spots are also a distinctive feature of larval *Trachinocephalus*, *Harpodon*, *Saurida*, and juvenile *Pseudotrichonotus*.

The description of *Synodus lucioceps* is based on the literature (Moser 1981; Okiyama 1984; Matarese et al. 1989) and on detailed examination of 23 larvae (5 yolk-sac, 3.0–3.8 mm; 7 preflexion, 3.7–9.2 mm; 5 flexion, 8.1–11.1 mm; 6 postflexion, 15.4–41.9 mm), 4 transformation specimens (54.5–63.8 mm) and 3 juveniles (67.3–88.6 mm). Meristic data and ecological information were obtained from the literature (Fitch and Lavenberg 1971; Miller and Lea 1972) and from observations made during this study. Most of the specimens used in the description were from localities north of Punta Eugenia, Baja California Sur, where *Synodus* species other than *S. lucioceps* are rare. The morphological and pigment characters of southern larvae (south of Bahía Sebastián Viscaíno) used for the description are consistent with those from more northern localities where only *S. lucioceps* is found.

[1] Formerly, at La Jolla Laboratory, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Table Synodontidae 1. Meristic characters for the *Synodus* species in the California Current vicinity. All species have 10+9 principal caudal fin rays and 8 pelvic rays.

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	P_1	C_2
S. evermanni	39–40	8	47–48	10–12	10–11	12–13	12–13+11–12
S. lacertinus	51–53	7–9	59–61	11–13	8–9	11–12	15–16+13–15
S. lucioceps	50–55	9–10	60–63	11–13	12–15	13–15	12–15+12–14
S. scituliceps	50–52	9–10	59–62	10–12	11–14	12–13	11–14+10–13
S. sechurae	46–50	8–9	55–58	10–11	11–12	13–14	11–12+10–11

MERISTICS

	Range	Mode
Vertebrae:		
Total	60–63	61
Precaudal	50–55	51
Caudal	9–10	9
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	11
Anal spines	0	0
Anal rays	12–15	12
Pelvic	8	8
Pectoral	13–15	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–15	13
Lower	12–14	12
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: San Francisco Bay, California, to Gulf of California

Habitat: Sand or mud bottoms of continental shelf & bays

Spawning season: In CalCOFI surveys, larvae are most abundant in fall & winter with a peak during September–November

ELH pattern: Oviparous; planktonic eggs & larvae; prolonged larval period

LITERATURE

Matarese et al. 1989
Moser 1981
Okiyama 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, ca. 1.4 mm (H. M. Orr)
Yolk-sac larva, 3.6 mm (B. Sumida MacCall)
Preflexion larva, 6.1 mm (H. M. Orr)
Postflexion larva, 34.0 mm, lateral & ventral views (H. M. Orr)
Postflexion larva, 41.9 mm (H. M. Orr)
Transformation specimen, 63.7 mm (B. Sumida MacCall)

* Eye is somewhat oval, becoming round during transformation; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.2–1.5 mm **Yolk:** Homogeneous; 0.9–1.1 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Covered with irregular polygons
Pigment: Paired dorsal series that migrate ventrad before hatching
Diagnostic features: Large size; homogeneous yolk; polygonal sculpturing on shell surface

LARVAE

Hatching length: ca. 3.0 mm
Flexion length: 8–11 mm
Transformation length: 50–64 mm
Fin development sequence: C_1, A, C_2, P_1, D, P_2
Pigmentation: *Yolk-sac*—6 ventrolateral patches from P_1 base to near notochord tip; scattered over head & yolk sac. *Preflexion*—Ventrolateral blotches over intestine increase from 4 to 6; 1 postanal median ventral blotch & 1 at hypural region. *Flexion–postflexion*—7 ventrolateral blotches over intestine; on hypural margin; on A base at ca. 25 mm; on hindbrain & cerebellum at ca. 40 mm; lateral blotch anterior to C. *Transformation*—8 lateral blotches, some diamond shaped; opercular region; brain covered.
Diagnostic features: Slender body; elongate gut; rounded head in preflexion larvae; large round ventrolateral blotches increasing from 4 at hatching to 7 at flexion stage; single ventral postanal blotch; hypural pigment; diamond-shaped lateral blotches in transformation specimens; large size (50–64 mm) at transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	61–67 64	66–72 69	71–76 74	67–80 73	70–74 72	71–74 73
BD/BL	12–15 13	10–16 13	10–12 11	7–9 8	9–12 11	10–11 11
HL/BL	15–19 16	13–18 16	15–19 18	15–17 16	16–22 19	20–23 21
HW/HL	61–71 68	58–88 72	54–68 61	45–60 51	44–53 47	41–59 48
SnL/HL	11–26 20	14–19 16	13–22 19	16–22 19	22–24 23	21–29 24
ED/HL*	43–46× 36–40 44×38	24–39× 30–50 32×41	25–26× 30–35 25×33	25–28× 26–34 26×28	21–25 23	20–22 21
P_1L/BL	3–6 4	6–10 7	6–8 7	6–8 7	8–13 11	12–13 12
P_2L/BL	0–0 0	0–0 0	0–0 0	0–4 1	7–14 11	14–16 15

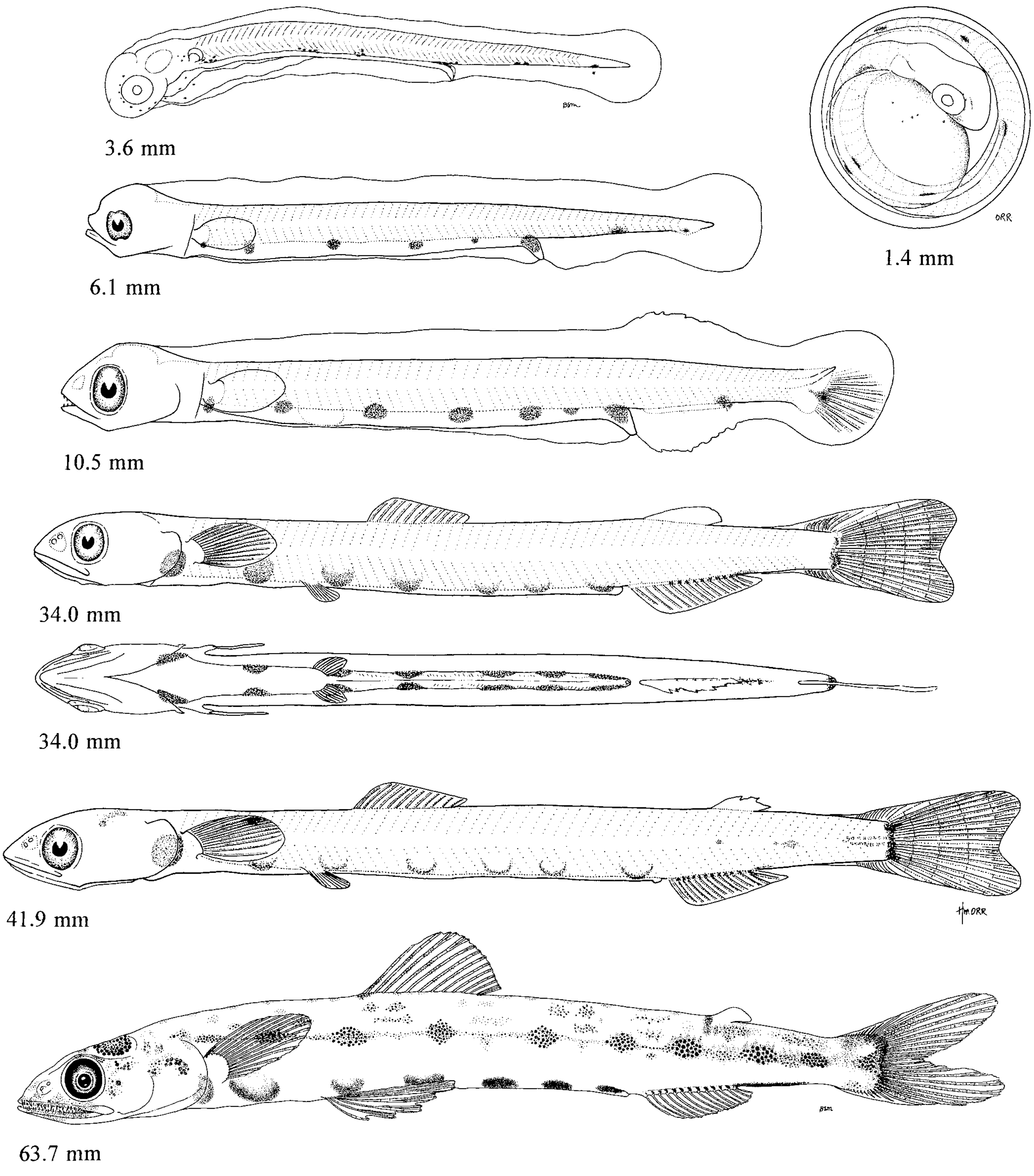


Figure Synodontidae 1. Egg, 1.4 mm (CalCOFI); yolk-sac larva, 3.6 mm (CalCOFI 7510, station 97.28.8); preflexion larva, 6.1 mm (CalCOFI 6610, station 120.35); flexion larva, 10.5 mm (Okiyama 1984a); postflexion larvae, 34.0 mm, lateral and ventral views (CFRD Ref. Coll., Bahía Ascuncion, Baja California Sur), 41.9 mm (SIO 60–17); transformation specimen, 63.7 mm (SK 88396, Torrey Pines Beach, California).

PARALEPIDIDAE: Barracudinas

D. A. Ambrose

Paralepididae includes 12 genera and about 56 species (Nelson 1994). At least nine paralepidid species occur in the CalCOFI area (Table Paralepididae 1), but larvae of only four (*Lestidiops neles*, *Lestidiops ringens*, *Arctozenus risso*, and *Stemonosudis macrura*) are collected regularly in CalCOFI ichthyoplankton samples. Larvae of *Lestidiops pacificum* and *Sudis atrox* are collected occasionally in adjacent central Pacific and equatorial water masses. *Magnisudis atlantica* larvae are rare. Larvae of *Lestidiops sphyraenopsis* have not been identified in CalCOFI samples. Larvae of *Macroparalepis johnfitchi* are undescribed.

Adults are small to medium-sized (ca. 15 – >100 cm) elongate, slender, laterally compressed fishes that occur in the epi-, meso-, and bathypelagic zones. Adults of some species are still unknown (e.g., *S. macrura*). A short-based single dorsal fin is positioned behind midbody. The anal fin is long-based and originates well behind the dorsal fin. A dorsal adipose fin is present above the last anal fin rays. A ventral adipose fin preceding the anal fin is present in some genera (e.g., *Lestidiops*, *Stemonosudis*, and *Sudis*). Pelvic fins are abdominal and their position with respect to the dorsal fin is a useful taxonomic feature. Pectoral fins are low on the body. The snout is pointed and mouth terminal with large, sharp, depressible and fixed teeth on dentary and palatine bones. Gill rakers are reduced to teeth or spines in multiple series on bony plates; gill raker counts refer to the number of bony plates. Some species have no scales, except along the lateral line (subfamily Sudinae and tribe Lestidini); other species have cycloid scales (tribe Paralepidini, e.g., *Arctozenus* and *Magnisudis*). Light organs are present in two genera (*Lestidium* and *Lestrolepis*). Adults of the tribe Lestidini have been observed swimming rapidly and drifting vertically (Houot 1958). Fishes are the principal prey observed in radiographs of juvenile and adult paralepidids during this study. Barracudinas are important food for whales and fishes such as salmons and tunas (Fitch and Lavenberg 1968). Among recent fishes, paralepidids are thought to be most closely related to Anotopteridae (Rofen 1966c).

Paralepidids are hermaphroditic and presumed to be oviparous with planktonic eggs, but eggs are unknown (Okiyama 1984a). Larvae of *L. neles* and *L. ringens* hatch with unpigmented eyes and without a functional mouth; presumably the other paralepidid species hatch at a similar stage of development. Larval paralepidids are noted for their slender, elongate body, short trunk in early larvae, marked elongation of the gut during ontogeny, and numerous peritoneal pigment patches that increase in number as the gut lengthens. Other larval pigment typically is on top of the head, at the bases of the dorsal and anal fins, and in the caudal peduncle region. Dorsal body pigment generally forms during transformation but early-forming dorsal pigment blotches are characteristic of certain species in a few genera (e.g., *Stemonosudis*, *Uncisudis*). Advanced larvae have a large head (ca. 15–40% of SL) with an elongate pointed snout and a straight profile. Eyes are slightly to strongly oval, depending on species, but become round by transformation.

Numerous characters may be used to distinguish the larvae of genera and species in the CalCOFI region. Spines are lacking in all paralepidid larvae except *Sudis* which has a large spine at the preopercular angle. *Stemonosudis macrura* larvae have a distinctive prolongation of the lower jaw. *Arctozenus risso* and *Magnisudis atlantica* larvae have peritoneal pigment sections that decrease in size posteriad; however, the latter is the only paralepidid in the CalCOFI region with a total vertebral count in the 60's (Table Paralepididae 1). *Lestidiops neles* larvae have heavy caudal pigment and lack lower lip pigment. *Lestidiops pacificum* larvae possess pigment on the tip of the lower jaw but lack pigment on the dorsal body margin. Larval *Lestidiops ringens* have lower lip pigment as well as pigment on the dorsal body margin by late preflexion.

The following descriptions of paralepidid early life history stages are based on literature (*M. atlantica*) and on detailed examinations of between 25 and 36 specimens each of the other species (Table Paralepididae 2). Larvae of *L. neles* are described for the first time. Meristic data were obtained from counts made during this study and from the literature (Hubbs 1916; Ege 1930, 1953, 1957; Parr 1931; Harry 1953; Rofen

1966a; Shores 1969; Miller and Lea 1972; Ozawa 1986d, 1988e; Post 1987; Okiyama 1984a; Matarese et al. 1989; and Amaoka et al. 1992). Caudal vertebral counts usually have not been provided in the literature for this family and this count is also excluded from the list of meristics in this study. Principal sources of ecological information were Ege (1953), Rofen (1966a), Okiyama (1984a), and Post (1986b, 1987).

Post (1987) has suggested that the subfamily Sudinae should be a separate family, that tribes Paralepidini and Lestidini be raised to subfamily rank, and that *Notolepis risso* and *Paralepis atlantica* be renamed *Arctozenus risso* and *Magnisudis atlantica*, respectively. "*Lestidiops pacificum*" is listed by Post (1972) as *Lestidiops jayakari pacifica*. Rofen (1966a) and Amaoka et al. (1992) listed it as a distinct species.

Table Paralepididae 1. Selected meristic characters for the paralepidid species that occur in the California Current region. All species have 10+9 principal caudal fin rays.

	Vertebrae		Fin rays				
Species	PrCV	Total	D	A	P_1	P_2	C_2
Arctozenus risso	35–42	72–86	8–13	28–34	10–13	8–12	12–13+12–13
Lestidiops neles	39–42	84–88	8–10	28–31	10–11	9–10	15–17+15–17
L. pacificum	35–41	76–89	9–10	26–30	11–12	8–9	14–15+14–15
L. ringens	41–45	82–91	8–13	26–33	11–12	8–11	13–20+13–20
L. sphyraenopsis	49–51	96–100	11–12	27–30	10–12	8	18–20+19
Macroparalepis johnfitchi	51	98	12	29	12		
Magnisudis atlantica	31–41	60–69	9–12	20–24	15–18	9–10	13–17+14–17
Stemonosudis macrura	29–34	85–97	7–9	33–38	10–11	9	17+17
Sudis atrox	27–30	52–55	10–12	21–22	13–15	8–9	16–18+15–17

Table Paralepididae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the paralepidid descriptions. An "L" indicates literature used in the description.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Arctozenus risso	0	6 5.5–10.8	6 12.4–23.7	10 23.6–33.0	3 34.0–46.5	4 60.1–96.1
Lestidiops neles	4 3.7–3.9	10 3.7–10.2	6 11.7–17.6	2 26.3–27.2	6 42.4–55.2	5 63.5–87.0
L. pacificum	0	2 7.8–7.8	4 11.5–14.5	10 14.7–25.7	5 28.5–41.2	4 49.0–80.5
L. ringens	0	10 3.0–14.8	6 16.5–21.5	10 23.3–37.5	5 39.1–53.1	5 63.5–86.1
Magnisudis atlantica	0	L[a]	L[a]	2 11.2–16.3	3 23.3–26.6	7 34.0–73.0
Stemonosudis macrura	0	7 3.4–9.8	7 10.2–22.8	9 23.7–29.8	5 34.7–52.8	5 56.0–83.4
Sudis atrox	0	10 3.2–5.8	6 7.4–13.3	10 11.0–18.2	5 19.8–21.4	5 27.8–45.4

[a] Ege 1930

MERISTICS

	Range	Mode
Vertebrae:		
Total	72–86	80
Precaudal	35–42	36
Fins:		
Dorsal spines	0	0
Dorsal rays	8–13	9
Anal spines	0	0
Anal rays	28–34	30
Pelvic	8–12	10
Pectoral	10–13	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	12–13	12
Lower	12–13	12
Gill rakers:		
Upper	3–9	
Lower	18–36	
Branchiostegals	8	8

LIFE HISTORY

Range: Worldwide in temperate & tropical waters; in the eastern Pacific from British Columbia (55° N) to at least north central Baja California (28° N)

Habitat: Epi-, meso-, & bathypelagic

Spawning season: Preflexion larvae occur year-round in CalCOFI ichthyoplankton collections.

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Ege 1930
Matarese et al. 1989
Okiyama 1984a
Rofen 1966a

* Eye slightly to moderately elongate (horizontally); horizontal axis is given first, vertical second. Eyes in 96.1 mm juvenile specimen are damaged & not included.

† P_1 measured on 40.4 mm transformation specimen & on 79.3 & 96.1 mm juvenile specimens; P_1 damaged on remainder of these specimens.

‡ P_2 measured on 60.1 & 96.1 mm juvenile specimens; P_2 damaged on other juvenile specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 12–24 mm
Transformation length: ca. 34 – >46 mm, gradual
Fin development sequence: C_1, A, D, P_1, C_2, P_2, Ad
Pigmentation: *Preflexion*—1 peritoneal patch. *Flexion*—1–4 peritoneal patches, decreasing in size posteriad. *Postflexion*—On tip of snout; lower jaw; infraorbital region; cranium; above & below notochord from posterior part of A through caudal peduncle; 4–9 peritoneal patches; by ca. 25 mm, on base of D & bases of first few A rays. *Transformation*—On dorsum from D to C. *Juvenile*—Along entire dorsum, 8–12 peritoneal patches.
Diagnostic features: In preflexion larvae, head pigment absent, 1 peritoneal pigment patch, HW ca. 50% of HL, 72–86 vertebrae; in flexion–postflexion larvae, 1–9 peritoneal pigment patches, decreasing in size posteriad; P_2 posterior to a vertical through D origin in transformation & juvenile specimens.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		29–35 31	29–33 30	32–42 36	44–68 57	71–73 72
BD/BL		8–11 9	8–9 9	8–10 9	7–8 8	7–7 7
HL/BL		17–23 18	16–19 17	18–22 20	24–25 25	24–25 24
HW/HL		44–51 48	35–49 43	26–36 31	21–24 23	16–23 18
SnL/HL		26–41 36	33–50 41	46–50 48	50–52 51	49–52 51
ED/HL*		36–42× 17–21 40×19	26–37× 19–23 32×21	19–28× 18–22 23×20	15–18× 14–17 16×15	12–17× 11–16 14×13
P_1L/BL†		2–4 3	2–3 2	2–2 2	5	7–8 8
P_2L/BL‡		0–0 0	0–0 0	0.8–2 1	2–3 2	4–4 4

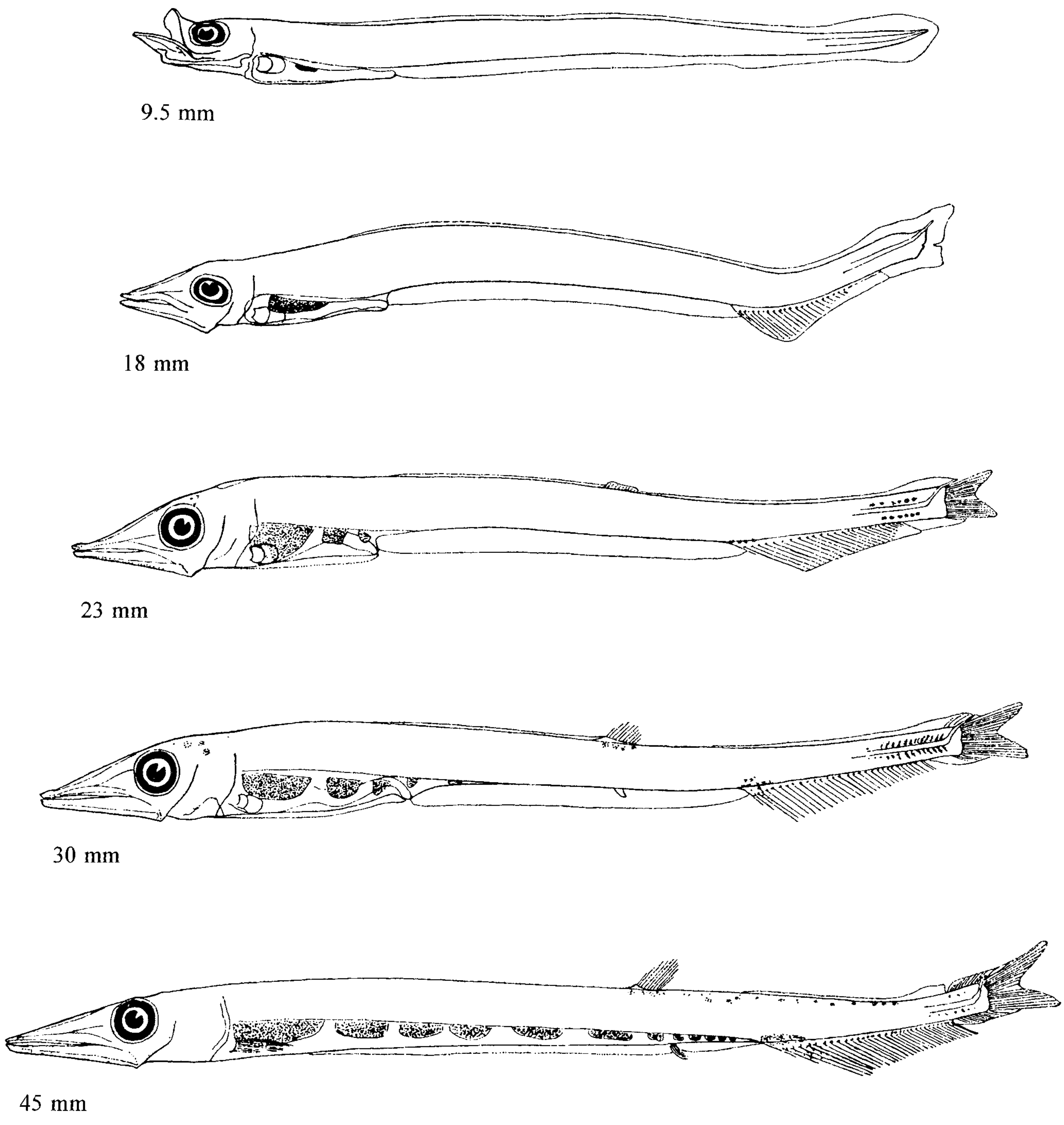


Figure Paralepididae 1. Preflexion larva, 9.5 mm; flexion larva, 18 mm; postflexion larvae, 23 mm, 30 mm; transformation specimen, 45 mm (Ege 1930).

MERISTICS

	Range	Mode
Vertebrae:		
Total	84–88	86
Precaudal	39–42	42
Fins:		
Dorsal spines	0	0
Dorsal rays	8–10	9
Anal spines	0	0
Anal rays	28–31	30
Pelvic	9–10	9
Pectoral	10–11	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	15–17	17
Lower	15–17	17
Gill rakers:		
Upper	7–9	
Lower	27–31	
Branchiostegals	8–9	8

LIFE HISTORY

Range: Vicinity of Cabo San Lucas, Baja California to at least Costa Rica (8° N)

Habitat: Epi- to mesopelagic

Spawning season: Yolk-sac & preflexion larvae collected in CalCOFI samples in January & October

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Harry 1953

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.7 mm (M. T. Vona)
Preflexion larva, 10.1 mm (M. T. Vona)
Flexion larva, 17.6 mm (M. T. Vona)

* Eye slightly elongate (horizontally); horizontal axis is given first, vertical second.

† P_1 damaged in largest yolk-sac specimen (3.9 mm) & smallest two transformation specimens (42.4 & 43.6 mm); P_1 of damaged specimens not included in range or mean.

‡ P_1 & P_2 damaged in largest juvenile (87.0 mm) & are not included in range or mean.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3.5 mm
Flexion length: ca. 11 mm through ca. 22 mm
Transformation length: ca. 40 mm through ca. 60 mm
Fin development sequence: A, D, C_1, P_1, C_2, P_2, Ad
Pigmentation: *Yolk-sac*—Forming on eyes, on body margin & finfold, primarily on ventral end of tail. *Preflexion*—Posterior to angle of lower jaw; on body margins & finfolds near origins of future D & A fin; heavy on end of tail; peritoneal patches increasing from 0 to 4. *Flexion–postflexion*—Over brain; row along lower jaw; row on preopercle; 5–8 peritoneal patches, infraorbital row by postflexion. *Transformation–juvenile*—On fin rays, heavy on C & Ad, gradually scattering over dorsum, 7–8 peritoneal patches.
Diagnostic features: In flexion–preflexion larvae, lip pigment absent & caudal pigment extends into finfold; in postflexion larvae to juvenile stage, anus well behind a vertical from the insertion of the D, 7–8 peritoneal pigment patches, & ED decreases from 14% to ca. 10% of HL; nostrils over posterior tip of maxilla by transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	27–32 29	22–44 28	51–69 62	69–72 71	68–72 70	65–67 66
BD/BL	6–7 7	7–10 8	6–7 7	4–5 4	5–6 5	5–6 6
HL/BL	13–15 14	13–16 14	15–17 16	18–19 19	19–22 20	22–23 22
HW/HL	33–46 40	32–54 46	25–33 30	20–20 20	15–18 17	15–17 16
SnL/HL	10–19 13	14–36 25	34–49 40	54–57 56	53–60 57	55–58 56
ED/HL*	33–42× 23–35 38×30	26–42× 25–36 36×31	21–30× 18–24 26×22	14–14× 13–14 14×14	11–14× 10–14 12×12	9–11× 8–10 10×9
P_1L/BL†	2–2 2	2–4 3	2–3 2	1–1 1	4–6 5	5–7 6
P_2L/BL‡	0–0 0	0–0 0	0–0 0	1–1 1	2–4 3	4–5 5

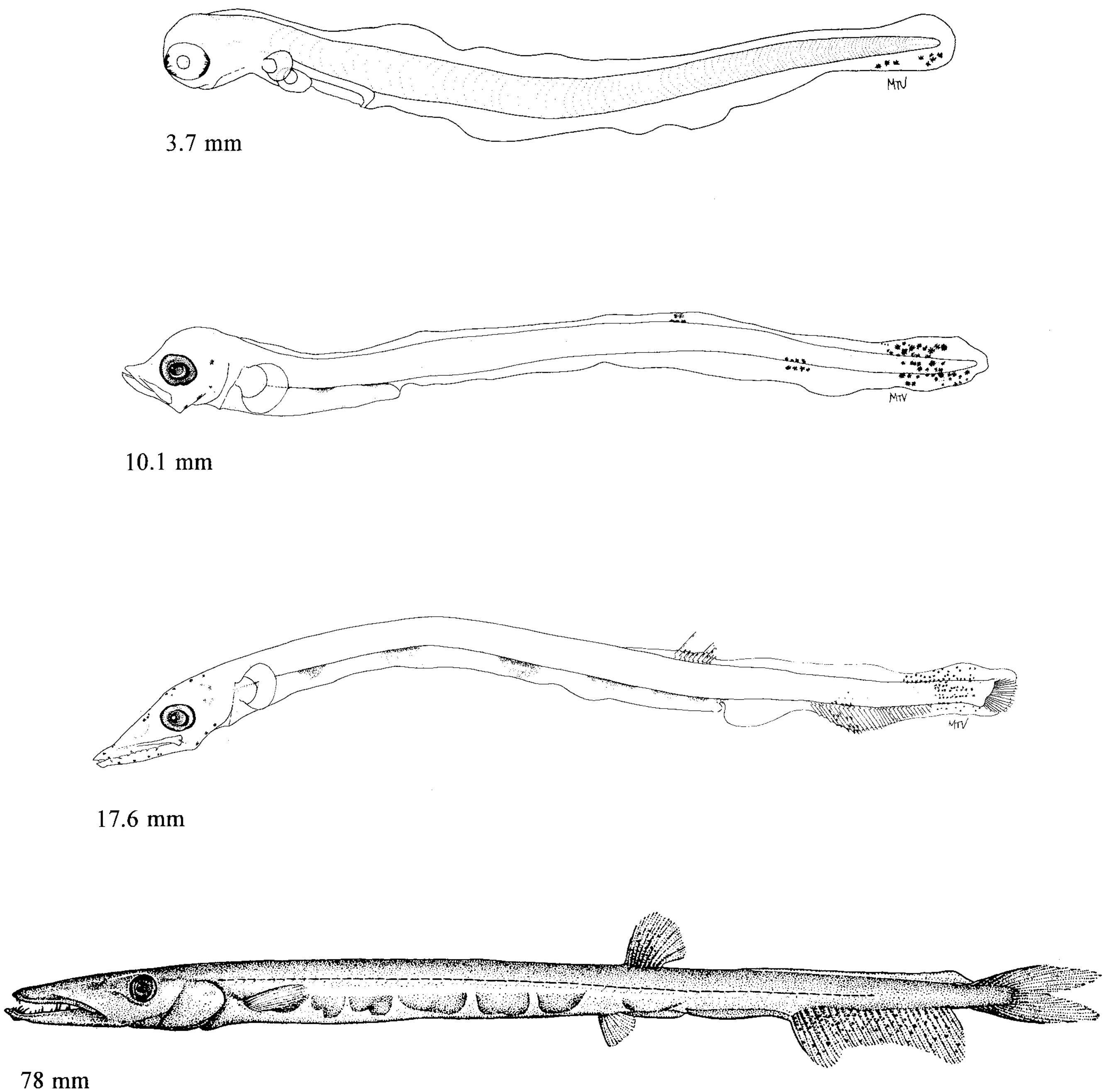


Figure Paralepididae 2. Yolk-sac larva, 3.7 mm (CalCOFI 6001, station 157.40); preflexion larva, 10.1 mm (CalCOFI 7202, station 157.10); flexion larva, 17.6 mm (CalCOFI 7210, station 157.50); juvenile, 78 mm (Harry 1953).

MERISTICS

	Range	Mode
Vertebrae:		
Total	76–89	82
Precaudal	35–41	36
Fins:		
Dorsal spines	0	0
Dorsal rays	9–10	10
Anal spines	0	0
Anal rays	26–30	30
Pelvic	8–9	8
Pectoral	11–12	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	14–15	15
Lower	14–15	15
Gill rakers:		
Upper	5	
Lower	36	
Branchiostegals	8	8

LIFE HISTORY

Range: In the northeastern Pacific, south from ca. 38° N & east of ca. 173° W; also collected in Gulf of Panama, off Chile, & north of New Zealand.

Habitat: Epi-, meso-, & bathypelagic

Spawning season: Preflexion specimens collected in June & August

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Amaoka et al. 1992
Ege 1953
Pertseva–Ostroumova and Rass 1973
Rofen 1966a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 7.8 mm (N. Arthur)
Flexion larva, 11.5 mm (N. Arthur)
Postflexion larva, 14.7 mm (N. Arthur)

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* Only one preflexion specimen with an eye.

EARLY LIFE HISTORY DESCRIPTION

EGGS

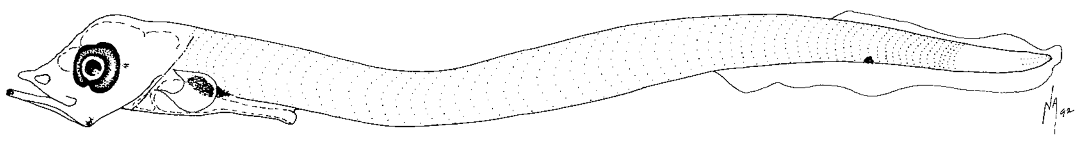
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

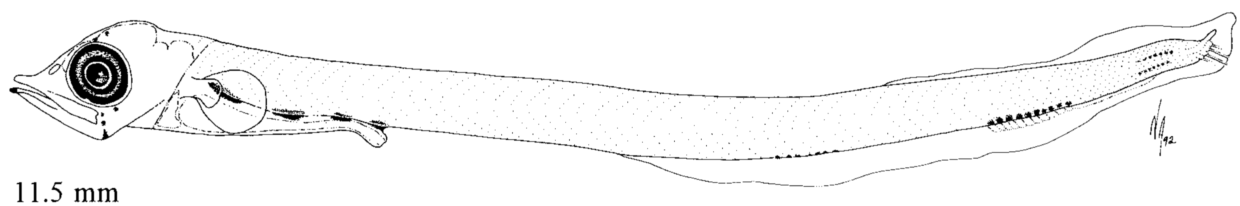
Hatching length:
Flexion length: ca. 11.5–15 mm
Transformation length: ca. 28–42 mm
Fin development sequence: C_1 & A, D, C_2, P_1, P_2, Ad
Pigmentation: *Preflexion*—On lip; internal behind eye; along ventral body margin where A will develop; peritoneal patches increase from 1 to 4. *Flexion–postflexion*—Crescent-like row between fore- & midbrain dorsally; infraorbital row; posterior to lower jaw; row along midventral body margin between anus & A; above & below the notochord & along the ventral body margin in the caudal peduncle region; peritoneal patches increase to 4–12. *Transformation–juvenile*—On snout, isthmus; over cranium; at base of D, ventral lobe of C; gradually extending along dorsum; 11–12 peritoneal patches.
Diagnostic features: In preflexion–flexion larvae, pigment absent from dorsal body margin & caudal finfold, embedded pigment behind eye, & pigment rows above & below notochord in caudal peduncle; at postflexion stage, pigment row along tail margin between anus & A & crescent-shaped row of pigment between fore- & midbrain; in transformation–juvenile specimens, 11–12 peritoneal pigment patches, ventral half of C more heavily pigmented than dorsal half, & anus under D.

MORPHOMETRICS (range & mean in %)

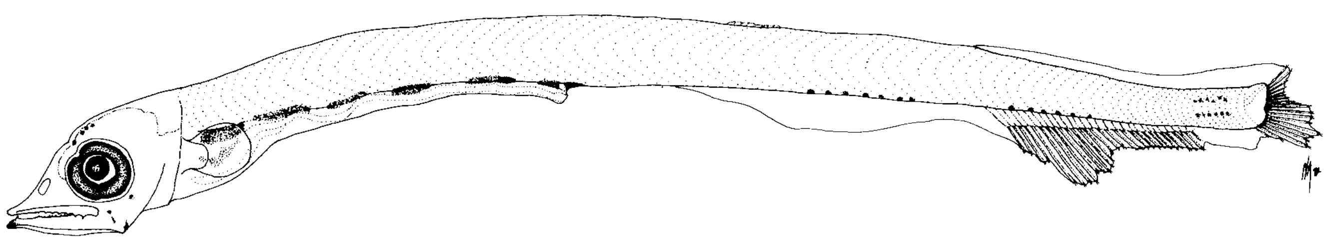
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		25–25 25	27–44 34	54–60 57	57–62 60	57–60 59
BD/BL		9–9 9	7–8 8	5–8 6	5–6 6	7–9 8
HL/BL		16–18 17	13–15 14	14–16 15	16–17 17	19–21 20
HW/HL		33–38 36	35–39 38	31–40 34	24–32 27	22–25 23
SnL/HL		26–30 28	31–36 33	35–48 42	42–48 44	43–45 45
ED/HL		30*	31–35 33	23–32 28	20–23 21	17–21 19
P_1L/BL		2–2 2	2–3 2	2–3 2	2–5 3	4–7 6
P_2L/BL		0–0 0	0–0 0	0–2 0.5	3–4 3	6–7 6



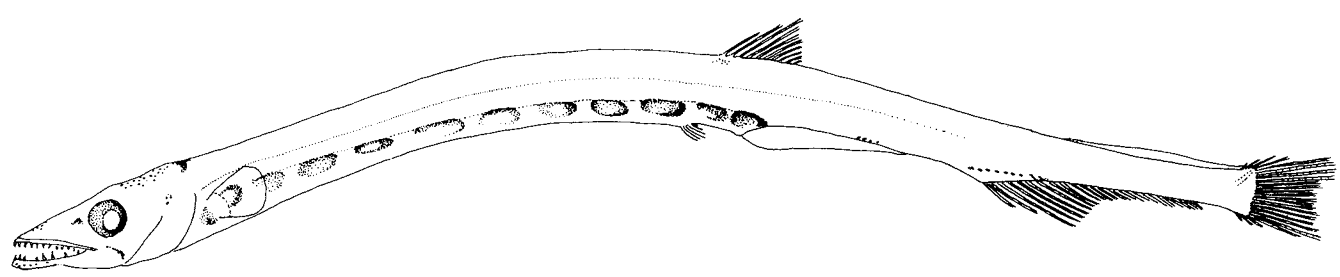
7.8 mm



11.5 mm



14.7 mm



33.0 mm

Figure Paralepididae 3. Preflexion larva, 7.8 mm (Cato I, station A 1); flexion larva, 11.5 mm (Climax II, station A 5); postflexion larva, 14.7 mm (Climax II, station A 5); transformation specimen, 33.0 mm (Amaoka et al. 1992), pectoral fin should have rays.

MERISTICS

	Range	Mode
Vertebrae:		
Total	82–91	86
Precaudal	41–45	41
Fins:		
Dorsal spines	0	0
Dorsal rays	8–13	12
Anal spines	0	0
Anal rays	26–33	28
Pelvic	8–11	9
Pectoral	11–12	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–20	17
Lower	13–20	17
Gill rakers:		
Upper	3–9	
Lower	21–31	
Branchiostegals	8	8

LIFE HISTORY

Range: North Pacific subarctic and transition zone; in the eastern Pacific from British Columbia to Cedros Island, Baja California

Habitat: Epi-, meso-, & bathypelagic

Spawning season: Preflexion larvae occur throughout the year in CalCOFI ichthyoplankton collections

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Amaoka et al. 1992
Ege 1953
Moser 1981
Matarese et al. 1989
Rofen 1966a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.6 mm (H. M. Orr)
Transformation specimen, 58.0 mm (H. M. Orr)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <ca. 3 mm
Flexion length: ca. 15–22 mm
Transformation length: ca. 40–60 mm, gradual
Fin development sequence: C_1, A, D, P_1, C_2 & P_2, Ad
Pigmentation: *Preflexion*—On tip & angle of lower jaw; a row on ventral body margin near where A will form; by ca. 9 mm, 2 peritoneal patches & 2 on dorsal body margin. *Flexion*—On fore- & midbrain; 3 patches on dorsal body margin & 2 rows in the lateral caudal peduncle region; by ca. 20 mm, 2 patches on ventral body margin & 6 peritoneal patches. *Postflexion*—On anterior rays of A & D; crescent-shaped row on infraorbital region. *Transformation–juvenile*—Rows on upper & lower jaws; on C & P_1 rays; scattered on dorsal body; 7 peritoneal patches.
Diagnostic features: In preflexion–flexion larvae, pigment on lip & angle of lower jaw, internal pigment behind eye absent, 2 pigment patches on dorsal body margin; in postflexion larvae, 3 pigment patches on dorsal body margin; in transformation–juvenile specimens, 7 peritoneal pigment patches, 41–45 precaudal vertebrae, & anus well anterior to a vertical through the D origin.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		20–25 22	36–51 42	52–58 55	57–59 58	56–58 57
BD/BL		7–12 8	5–6 6	5–5 5	5–5 5	5–6 6
HL/BL		12–15 13	13–15 14	14–15 15	15–16 15	16–18 17
HW/HL		36–57 42	26–31 29	22–30 26	20–23 22	20–24 22
SnL/HL		22–36 29	34–43 39	40–49 44	44–49 45	46–49 48
ED/HL		27–39 32	23–34 27	18–24 22	17–19 18	18–19 18
P_1L/BL		2–7 4	2–3 3	2–3 2	2–5 4	5–6 6
P_2L/BL		0–0 0	0–0 0	0–2 0.4	2–3 3	4–5 5

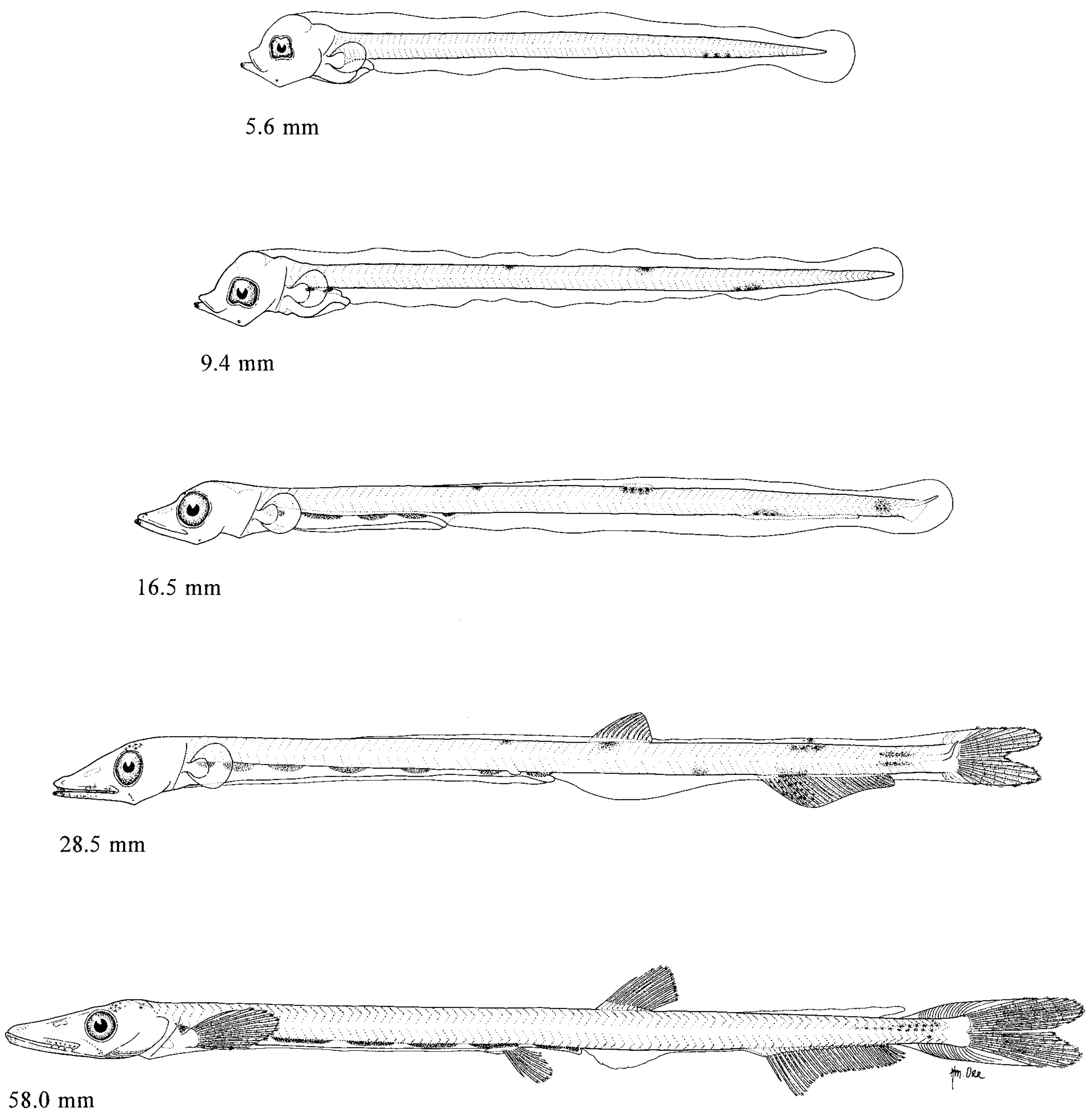


Figure Paralepididae 4. Preflexion larvae, 5.6 mm (CalCOFI 6706, station 103.40), 9.4 mm; flexion larva, 16.5 mm; postflexion larva, 28.5 mm (Moser 1981); late transformation specimen, 58.0 mm (CalCOFI 6208, station 60.80).

MERISTICS

	Range	Mode
Vertebrae:		
Total	60–69	68
Precaudal	31–41	31
Fins:		
Dorsal spines	0	0
Dorsal rays	9–12	10
Anal spines	0	0
Anal rays	20–24	22
Pelvic	9–10	9
Pectoral	15–18	16–17
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	13–17	17
Lower	14–17	17
Gill rakers:		
Upper	7–10	8
Lower	25–32	30
Branchiostegals	8	8

LIFE HISTORY

Range: Atlantic & Pacific; in eastern Pacific from southeast Alaska (59° N) to Chile; broadest known distribution of any paralepidid

Habitat: Epi-, meso-, & bathypelagic; large adults approach the coasts in temperate & polar zones

Spawning season: Mainly March–June in western Atlantic but larvae found year-round; larvae rare in CalCOFI ichthyoplankton collections

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Ege 1930
Rofen 1966a
Okiyama 1984a
Ozawa 1986d
Matarese et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 8.5–10.5 mm
Transformation length: ca. 23–47 mm, gradual
Fin development sequence: C_1, A, D, P_1, C_2, P_2, Ad
Pigmentation: *Preflexion*—1 peritoneal patch increasing to 2. *Postflexion*—On cranium, snout, jaws, & D & A origins; above & below notochord near end of A; by late postflexion stage, on nape, patch between Ad & A, & 3 peritoneal patches decreasing in size posteriad. *Transformation–juvenile*—Along dorsal body margin; tail patch expands; crescent-like row on infraorbital region.
Diagnostic features: Vertebral number (60–69) appears to be only reliable character to separate early larvae from those of *Arctozenus risso* (72–86); P_1 rays (15–18) most numerous in the family & A rays (20–24) are among the fewest; 1 peritoneal pigment patch, increasing to 2 (preflexion–flexion stage), & 3 by late postflexion–juvenile stage; anus at final position (64–72% SL) by 13–15 mm (early postflexion stage).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF*	F*	PoF	Tr	Juv
Sn-A/BL		35–38	39	40–71	67–72	64–71
		37		56	70	69
BD/BL				11–13	13–14	12–14
				12	13	12
HL/BL				23–33	34–36	31–35
				28	35	33
HW/HL				23–39	21–23	19–25
				31	22	22
SnL/HL				48–59	54–56	48–54
				53	55	51
ED/HL†				14–27×	13–16×	11–18×
				14–19	14–16	11–17
				21×17	15×15	15×14
P_1L/BL‡					7–7	7–7
				5	7	7
P_2L/BL§					2–2	2–3
				3	2	3

* Adapted from Ege (1930).
† Eye slightly to moderately elongate (horizontally); horizontal axis given first, vertical second.
‡ P_1 measured on 16.3 mm postflexion larva & on 25.7 & 26.6 mm transformation specimens only; P_1 damaged on remainder of these specimens.
§ P_2 measured on 34.0 & 38.6 mm juvenile specimens only; P_2 damaged on remainder of juvenile specimens.

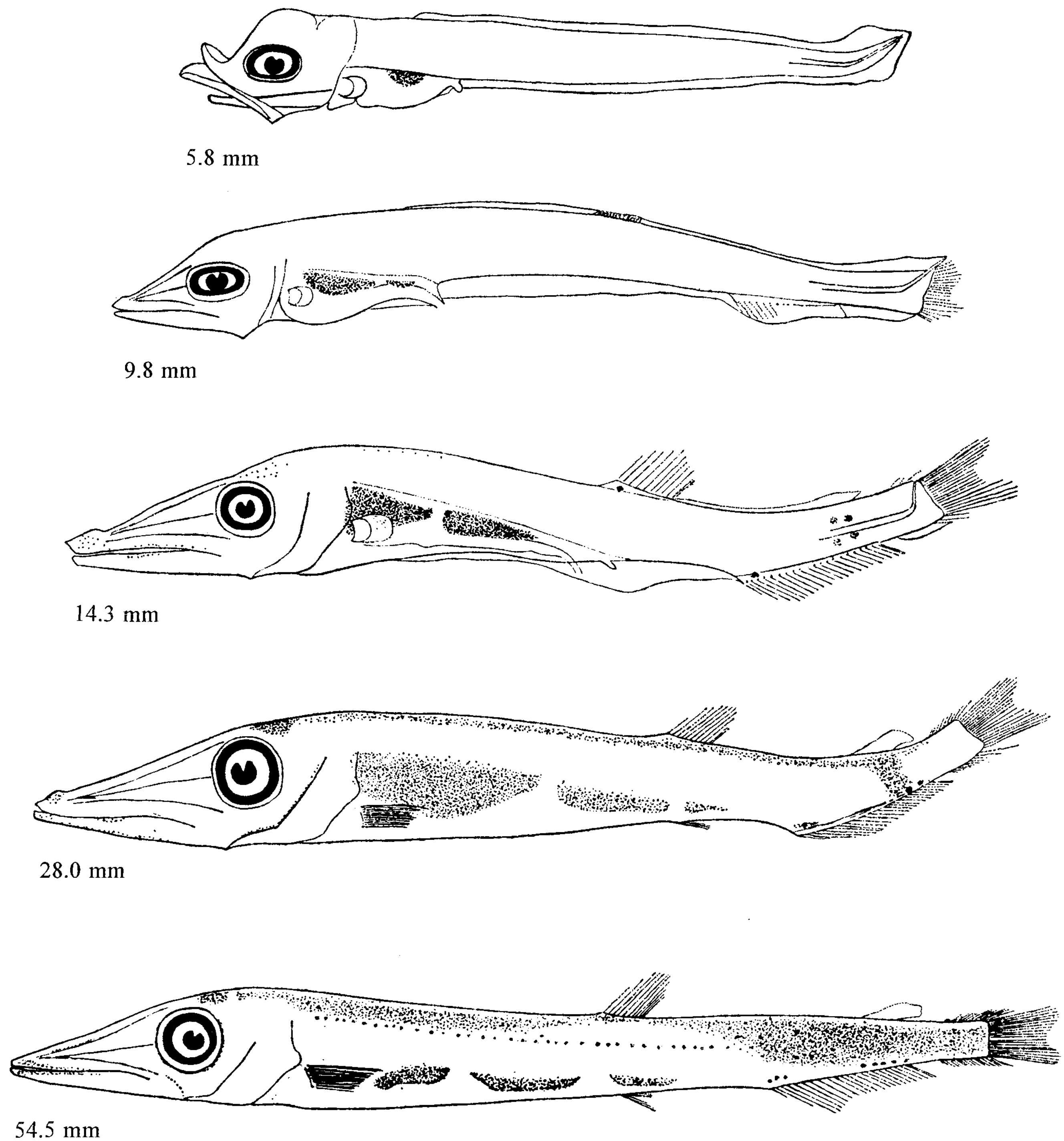


Figure Paralepididae 5. Preflexion larva, 5.8 mm; flexion larva, 9.8 mm; postflexion larva, 14.3 mm; transformation specimen, 28.0 mm; juvenile, 54.5 mm (Ege 1930).

MERISTICS

	Range	Mode
Vertebrae:		
Total	85–97	92
Precaudal	29–34	31
Fins:		
Dorsal spines	0	0
Dorsal rays	7–9	8
Anal spines	0	0
Anal rays	33–38	35
Pelvic	9	9
Pectoral	10–11	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	17	17
Lower	17	17
Gill rakers*:		
Upper	0	
Lower	19	
Branchiostegals	8	8

LIFE HISTORY

Range: Warm waters of the Indian & Pacific; in the eastern Pacific, from Point Conception, California, to Chile

Habitat: Epi- to mesopelagic

Spawning season: Preflexion larvae occur in CalCOFI ichthyoplankton collections year-round; known only from juveniles up to ca. 150 mm

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Ege 1957
Okiyama 1984a
Ozawa 1986d, 1988e
Rofen 1966a
Pertseva-Ostroumova and Rass 1973

* Bony plates still forming in largest specimen examined (SIO 63–407, 135 mm).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 10–23 mm
Transformation length: ca. 35–53 mm, gradual
Fin development sequence: A, C_1, D, P_1, C_2, P_2, Ad
Pigmentation: *Preflexion*—On prolongation of lower jaw, snout, base of cranium behind eye; by ca. 7 mm, 3–5 patches on peritoneum; by ca. 8 mm, 4–5 rows along ventral tail margin & 2–3 patches along dorsal tail margin. *Flexion–postflexion*—Above & below end of notochord; peritoneal patches increases from 4 to 15. *Transformation–juvenile*—Row along body margin between anus & A; row along base of A; 2 rows on lateral caudal peduncle region; row along dorsal body margin increases with development; 16–17 peritoneal patches.
Diagnostic features: A prominent cartilaginous prolongation of the lower jaw present through transformation stage; juveniles with 16–17 peritoneal pigment patches & a row of punctate melanophores along each side of dorsal body margin; 85–97 vertebrae; 33–38 A rays.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		24–29 26	25–58 42	53–59 58	53–57 56	52–63 56
BD/BL		8–11 9	4–7 6	4–5 4	3–5 4	3–5 4
HL/BL		16–22 18	15–19 17	16–19 17	13–17 15	13–15 14
HW/HL		27–41 32	17–26 21	13–17 14	10–15 13	15–23 18
SnL/HL		24–34 30	33–53 41	49–55 52	41–53 50	50–54 52
ED/HL		21–35 27	13–21 17	10–14 12	9–11 10	9–13 10
P_1L/BL		3–5 4	2–3 2	1–2 1	1–3 2	3–5 4
P_2L/BL		0–0 0	0–0 0	0–3 2	1–3 3	2–4 3

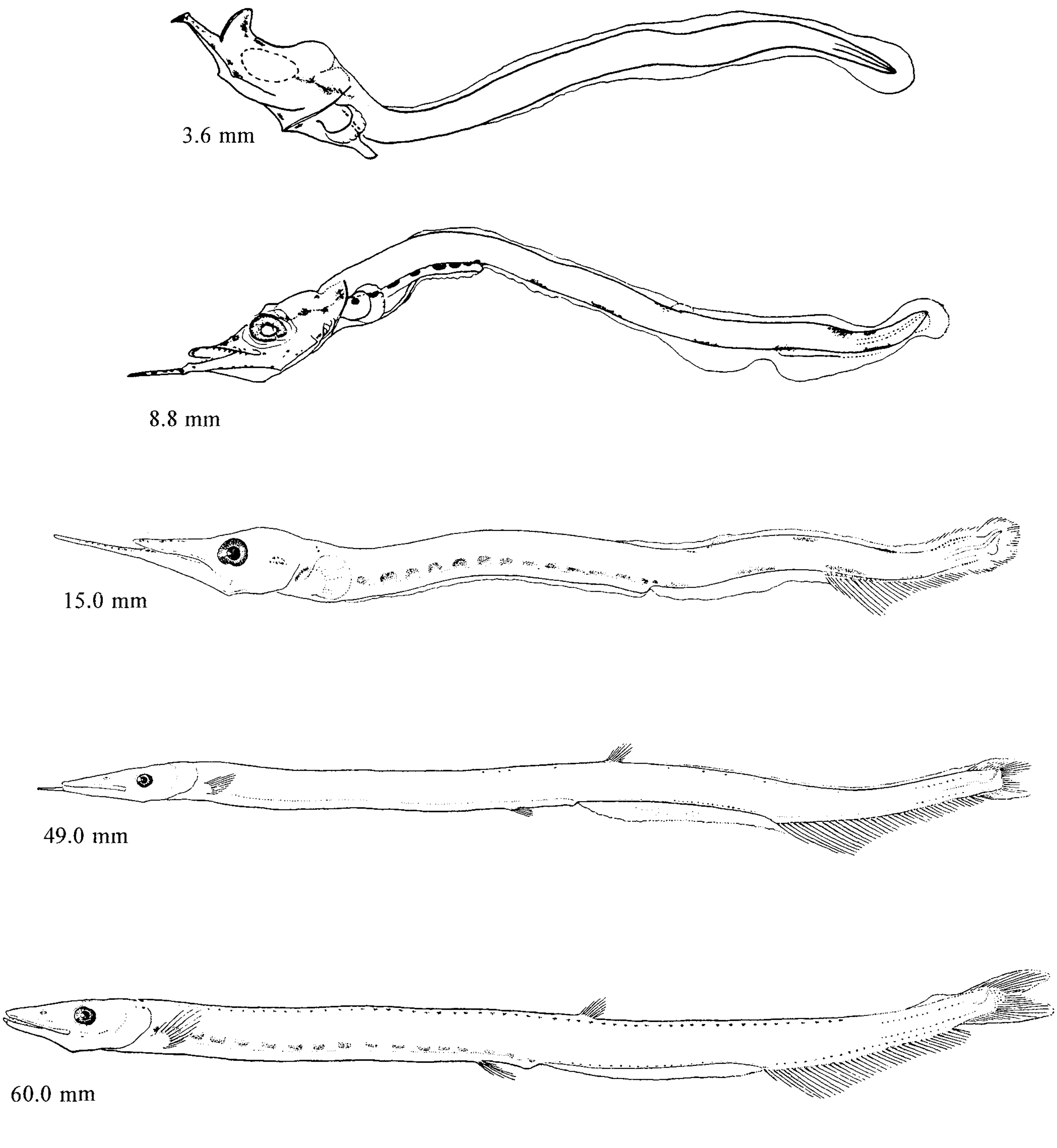


Figure Paralepididae 6. Preflexion larvae, 3.6 mm, 8.8 mm (Ozawa 1986d); flexion larva, 15.0 mm; transformation specimen, 49.0 mm, peritoneal pigment patches faded; juvenile, 60.0 mm (Ege 1957).

MERISTICS

	Range	Mode
Vertebrae:		
Total	52–55	54
Precaudal	27–30	27
Caudal	25–28	27
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	12
Anal spines	0	0
Anal rays	21–22	21
Pelvic	8–9	8
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	16–18	17
Lower	15–17	17
Gill rakers:		
Upper	5–10	
Lower	21–28	
Branchiostegals	8	8

LIFE HISTORY

Range: Tropical western Atlantic & Pacific; in eastern Pacific from at least 32° N to Chile

Habitat: Epi-, meso-, & bathypelagic

Spawning season: Early-stage larvae occur mainly from February through July in CalCOFI ichthyoplankton samples

ELH pattern: Oviparous; planktonic larvae, primarily in upper 250 m

LITERATURE

Belyanina 1982a
Berry & Perkins 1966
Okiyama 1984a
Ozawa 1986d, 1988e
Rofen 1966a
Shores 1969

* Eye slightly to moderately elongate (horizontally); horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5–6 mm through 11–13 mm
Transformation length: ca. 20 mm, gradual
Fin development sequence: C_1, A, D & P_1, P_2, C_2 & Ad
Pigmentation: *Preflexion*—Three patches along peritoneum. *Flexion*—On preoperculum; 5 peritoneal patches. *Postflexion*—On snout tip, lower jaw, midbrain, hindbrain, preopercular spine, & caudal peduncle. *Transformation–juvenile*—On dorsal body margin; vertical line at base of C; line at base of P_2; row along dorsal P_1 rays; 6 peritoneal patches.
Diagnostic features: Low number of vertebrae (52–55); in preflexion larvae, elliptical eyes, 3 large preopercular spines, & 3 peritoneal pigment spots; in flexion larvae, longitudinal series of fine serrations above eye & 5 peritoneal pigment patches; in postflexion larvae, large preopercular spine with serrated edges & a few retrorse hooks & row of fine serrations along mandible & snout; in transformation–juvenile specimens, large, elongate P_1 & 6 peritoneal pigment patches.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		44–57 52	57–65 61	65–71 68	65–69 66	62–67 65
BD/BL		9–11 11	10–13 11	13–16 14	13–15 14	12–15 13
HL/BL		21–24 22	22–32 26	35–44 40	35–41 39	30–36 32
HW/HL		57–77 66	37–67 49	23–30 27	24–28 26	23–27 25
SnL/HL		26–39 31	32–54 41	52–57 54	48–53 51	51–53 52
ED/HL*		32–40× 15–21 36×18	23–33× 13–18 29×16	14–21× 14–21 16×17	15–18× 14–20 16×17	15–16× 12–17 16×15
P_1L/BL		4–8 5	4–5 5	5–13 9	11–18 15	15–22 19
P_2L/BL		0–0 0	0–0 0	3–7 6	6–7 7	7–7 7

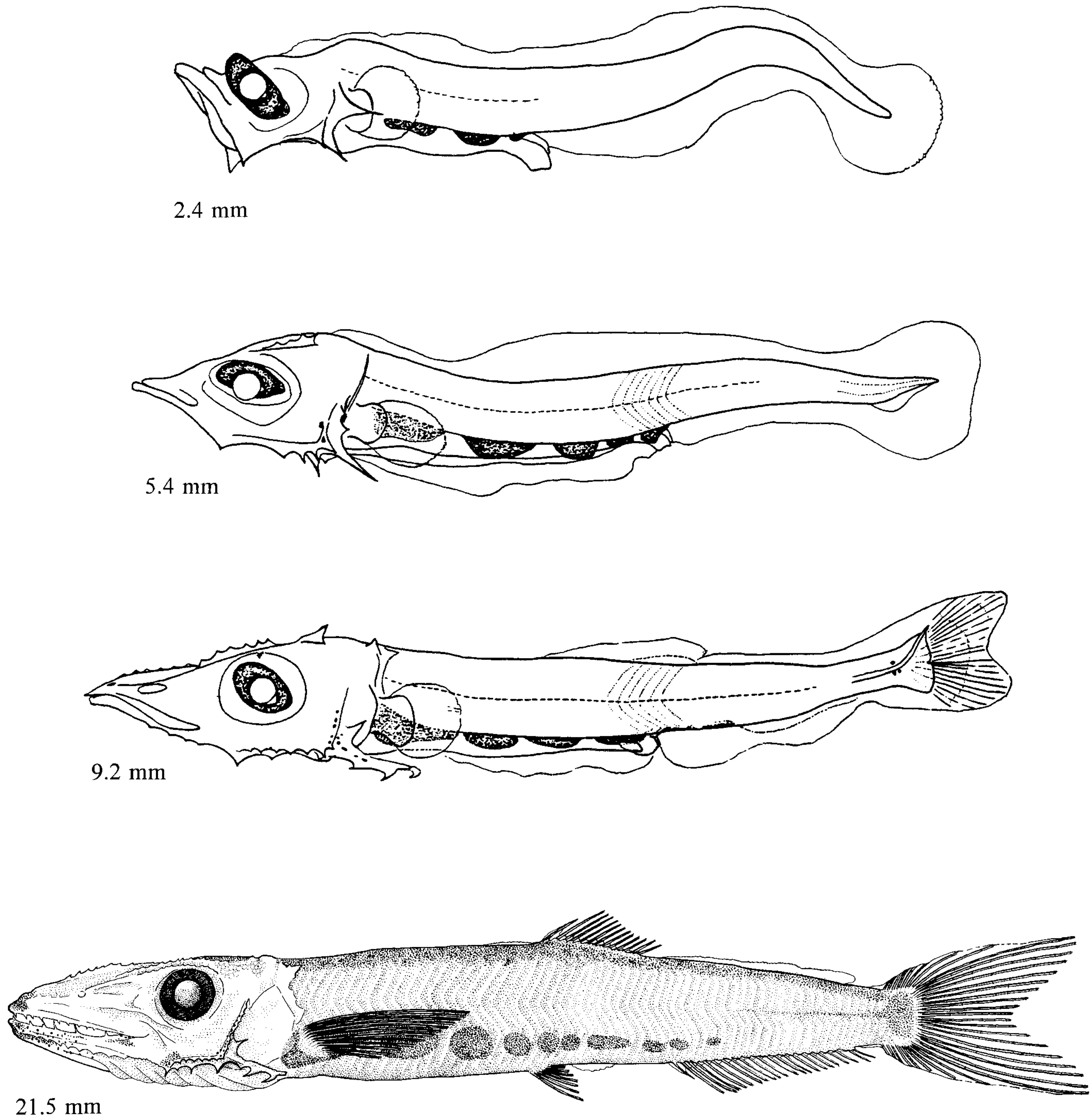


Figure Paralepididae 7. Preflexion larva, 2.4 mm; flexion larva, 5.4 mm; postflexion larva, 9.2 mm (Ozawa 1986d); late transformation specimen, 21.5 mm (Berry and Perkins 1966).

ANOTOPTERIDAE: Daggertooth

D. A. AMBROSE

Anotopterus pharao is the single anotopterid species known (Nelson 1994). Larvae are rarely collected in the CalCOFI region. Adults are slender, elongate, lack a dorsal fin, but have a well developed adipose fin above a small anal fin. The mouth is large, with strong teeth, the largest of which are the fanglike palatine teeth. An elongate projection is present on the lower jaw tip. The largest recorded specimen was 147 cm long and weighed only 1.6 kg (Eschmeyer et al. 1983). *A. pharao* was thought to have an antitropical distribution in the Atlantic and Pacific (Hubbs et al. 1953); however, a single 41 mm specimen has since been collected at 0°5.8′ S, 139°8.0′ W (SIO 60–23) and Fourmanoir (1979) has recorded the species from New Caledonia from the stomach contents of scombrids, as well as northwest of Madagascar. Rofen (1966c) observed that the larger adults inhabit colder waters toward the poles, whereas, the young and smaller adults inhabit more temperate regions. Anotopteridae is thought to be most closely related to the Paralepididae (Okiyama 1984b).

Anotopterids are hermaphroditic (Okiyama 1984a); eggs are unknown. The smallest available larva (8.5 mm) has a slender body, a large head with pointed snout, a fleshy prolongation at the tips of both jaws, a palatine canine tooth, undeveloped fin rays, and a gut that extends past midbody and lacks peritoneal pigment patches. By about 25 mm, rays are forming in all fins and a sinuous tube runs along the dorsum between the head and adipose fin. Development is direct.

The following species account is based on detailed examination of an 8.5 mm preflexion larva (CalCOFI 8403, station 110.100), a 25.1 mm transitional specimen (SIO 70–105), and literature (Rofen 1966c; Okiyama 1984a). Meristic data were obtained from literature (Hubbs et al. 1953; Rofen 1966c; Miller and Lea 1972). Ecological information was obtained mainly from Rofen (1966c) and Eschmeyer et al. (1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	78–83	79–80
Precaudal	49–53	52
Caudal		
Fins:		
Dorsal spines	0	0
Dorsal rays	0	0
Anal spines	0	0
Anal rays	14–17	14
Pelvic	9–11	10
Pectoral	12–16	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	14–17	
Lower	14–16	
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	7–9	7

LIFE HISTORY

Range: Primarily temperate & polar waters of the world

Habitat: Epi- to at least mesopelagic; open ocean

Spawning season: Preflexion larvae collected in CalCOFI region during January, March, May & September

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Maul 1952
Nybelin 1948
Okiyama 1984a, 1988g
Rofen 1966c

* Morphometrics include measurements from illustrations of 14.2 mm preflexion larva (Okiyama 1984a) & 50 mm juvenile (Rofen 1966c).
† Eye missing from 8.5 mm preflexion larva.

EARLY LIFE HISTORY DESCRIPTION

EGGS

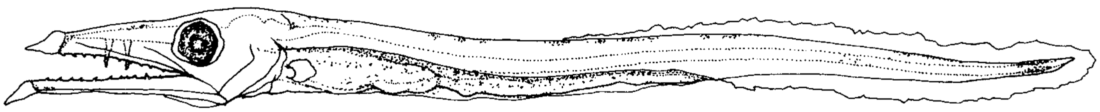
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <8 mm
Flexion length: >14 mm, <25 mm
Transformation length: ca. 25 mm
Fin development sequence: C, A, Ad, P_1, P_2
Pigmentation: *Preflexion*—By 8.5 mm, on lower jaw projection, scattered on snout & brain, lateral patch posterior to eye, dorsolaterally along gut, along ventral margin of tail, & at edges of finfold in A & Ad regions; along posterior half of dorsum; absent from end of tail. *Transitional*—By ca. 25 mm, scattered over body, & concentrated along dorsum.
Diagnostic features: Total vertebrae 78–83; preanal length >60% BL; head large with pointed snout; a fleshy prolongation at tips of both jaws; no D; large fanglike teeth on palatines; peritoneal pigment patches absent; by ca. 29 mm, sinuous tube along dorsum between head & Ad.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		61–66 64			69	69
BD/BL		8–9 8			8	7
HL/BL		25–30 27			35	32
HW/HL		22			19	
SnL/HL		52–60 56			66	59
ED/HL†		14			13	10
P_1L/BL		2–2 2			3	4
P_2L/BL		0–0 0			0.8	1



14.2 mm

50.0 mm

Figure Anotopteridae 1. Preflexion larva, 14.2 mm (Okiyama 1984a); juvenile, 50.0 mm (Rofen 1966c).

EVERMANNELLIDAE: Sabertooth fishes

D. A. AMBROSE

Evermannellidae includes 3 genera and 7 or 8 species (Johnson 1982, 1984b; Swinney 1994). *Evermannella ahlstromi* and *E. indica* are reported from the California Current region; however, only larvae of *E. ahlstromi* have been identified in CalCOFI samples. Sabertooth fishes are small (maximum length ca. 18 cm) mesopelagic predators of the open ocean between ca. 40° N and 40° S. They possess an externally visible tripartite division of the tail musculature, tubular or semi-tubular eyes in six of the seven species, a large head, massive jaws, monstrous anteriormost palatine fangs, a deep body, and scales (when present) are restricted to the lateral line region. Meristic counts for the family are D 10–13, A 26–37, P_1 11–13, and vertebrae 45–54. Sabertooth fishes are thought to be a sister group to the Omosudidae plus Alepisauridae (Johnson 1982, 1984b; but see Patterson and Johnson 1995).

Evermannellids are synchronous hermaphrodites whose eggs are unknown. Larvae have been described for all genera (Schmidt 1918; Rofen 1966d; Johnson and Glodek 1975; Wassersug and Johnson 1976; Johnson 1982; Ozawa 1986c). Larvae are moderately elongate and compressed with a pointed snout, large mouth, oblong eye, moderate to large unpaired peritoneal pigment sections, melanophores along the myosepta, and the anus located a little behind midbody. Teeth appear in very small larvae. Development is direct and the gradual transition to juvenile is completed by 30 mm SL. The peritoneal pigment patches coalesce and completely enclose the gut by 35–45 mm SL.

Larval *Evermannella* have three peritoneal pigment patches and melanophores on the caudal fin base. Caudal peduncle melanophores are more numerous in *E. indica* than in *E. ahlstromi* larvae.

The following descriptions are based on detailed examinations of 7 preflexion larvae (3.4–4.9 mm), 6 flexion larvae (4.9–7.9 mm), 8 postflexion larvae (10.1–22.4 mm), 4 transformation specimens (23.0–29.0 mm), and 4 juveniles (35.6–56.1 mm) of *E. ahlstromi* and 4 postflexion larvae (8.8–18.3 mm), 4 transformation specimens (20.4–26.0 mm), and 4 juveniles (30.0–58.5 mm) of *E. indica*. Larvae of *E. ahlstromi* smaller than 10.2 mm are described here for the first time. Meristic data were obtained from the literature (Johnson and Glodek 1975; Johnson 1982). Ecological information was obtained from Johnson (1982).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–49	48
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	11
Anal spines	0	0
Anal rays	29–32	30–31
Pelvic	9	9
Pectoral	12	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: Eastern Pacific; transitional waters off Baja California, equatorially to ca. 145° W, & in transitional waters between equatorial & central waters of the North & South Pacific

Habitat: Open ocean; adults mesopelagic

Spawning season: Larvae occur in CalCOFI samples from February–April & July–October

ELH pattern: Oviparous; planktonic larvae usually collected in upper 100 m

LITERATURE

Johnson 1982, 1984b
Johnson & Glodek 1975

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.4 mm (R. C. Walker)
Flexion larva, 7.5 mm (R. C. Walker)
Postflexion larva, 10.1 mm (R. C. Walker)

* Eye elongate vertically; horizontal axis given first, vertical second; measurements are of entire eye capsule not just pigmented portion.
† P_1 & P_2 damaged on all juvenile specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.4 mm
Flexion length: ca. 4.9–7.9 mm
Transformation length: ca. 23–30 mm
Fin development sequence: C_1, D, P_2 & A, C_2, P_1
Pigmentation: *Preflexion*—On isthmus; laterally on hindbrain; internally at P_1 base; 3 patches dorsolaterally on gut; 1–2 melanophores on gut dorsal & posterior to anus; 3–4 in a row anteriorly on dorsum; on distal edge of finfold middorsally; 8–13 scattered at mid-dorsum; 2–7 dorsolaterally on posterior tail myosepta; 17–27 ventrally along tail. *Flexion*—On lower jaw tip; snout; line between fore- & midbrain; on mid- & hindbrain; spreading into myosepta from 3 dorsal patches & from ventral tail row. *Postflexion*—On upper jaw & angular; vertical row on operculum; on all fins; 7 patches in epaxial myosepta, 2 in midlateral myosepta, 5 in hypaxial myosepta; line at base of C. *Transitional*—Heavy blotches linearly associated with 3 muscle bands. *Juvenile*—Generally covering iridescent body; blotches more numerous.
Diagnostic features: 47–49 total vertebrae; D 10–12, usually 11; A 29–32, usually 31; caudal peduncle pigmentation light; by transformation stage, gill filaments elongate & projecting beyond gill cover.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–55 52	51–59 57	50–63 56	47–52 49	53–60 55
BD/BL		13–16 14	14–18 16	17–20 18	17–18 17	20–22 21
HL/BL		24–29 27	29–33 30	23–31 26	23–26 24	28–29 28
HW/HL		50–57 51	29–43 36	25–38 26	38–42 39	32–36 34
SnL/HL		29–44 36	34–46 39	30–43 36	28–33 30	23–26 24
ED/HL*		15–19× 31–47 17×38	14–18× 22–33 15×28	12–16× 18–24 14×21	17–20× 23–25 18×24	22–26× 23–27 23×26
P_1L/BL†		4–6 5	3–5 4	3–ca. 11	12–13 12	>14
P_2L/BL†		0–0 0	0–2 0.5	7–9 8	9–10 9	>9

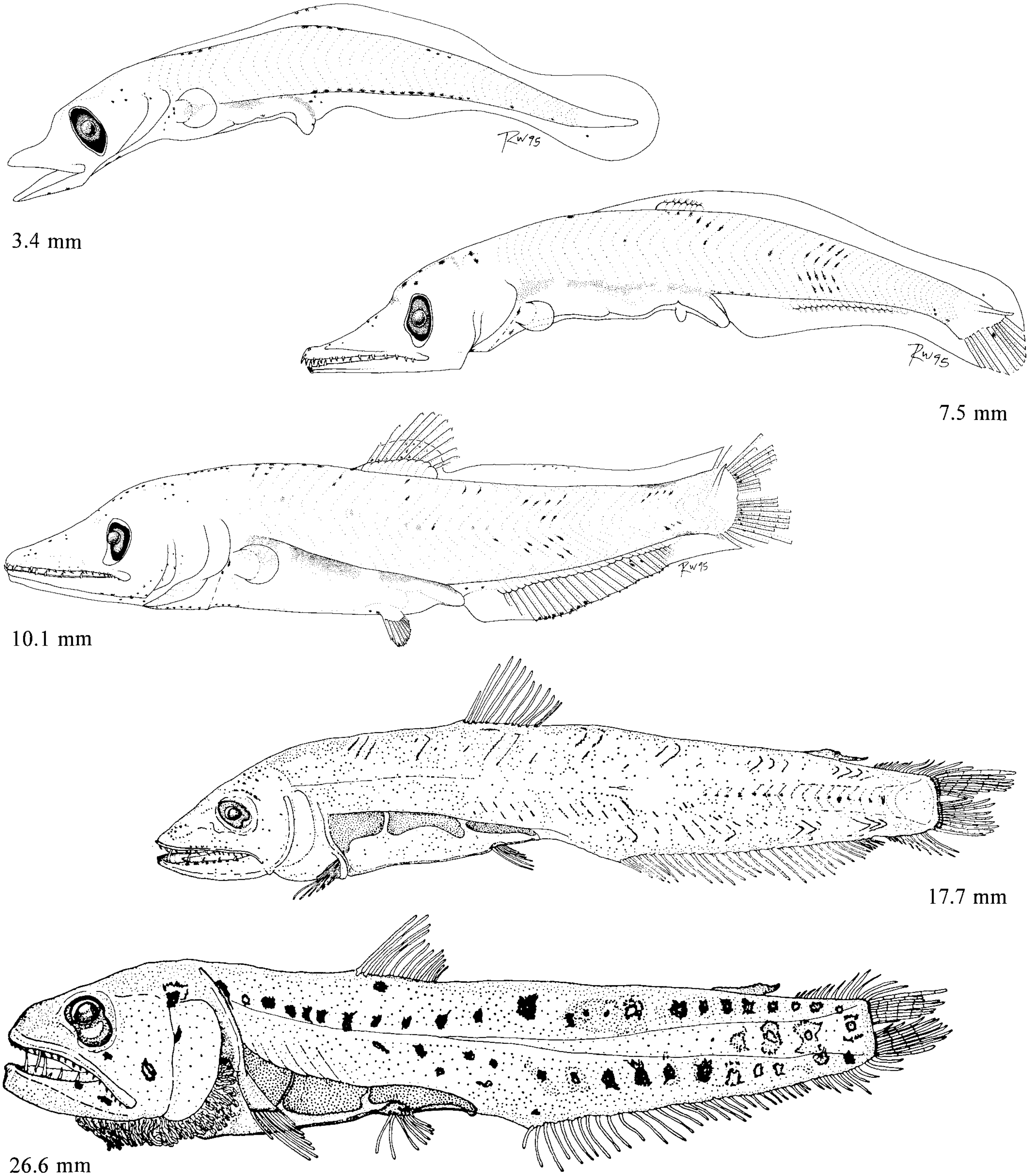


Figure Evermannellidae 1. Preflexion larva, 3.4 mm (EASTROPAC II, station 46.052); flexion larva, 7.5 mm (CalCOFI 7205, station 20.125); postflexion larvae, 10.1 mm (CalCOFI 5910, station 107.90), 17.7 mm; transformation specimen, 26.6 mm (Johnson and Glodek 1975).

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–52	50
Precaudal	17	17
Caudal	33	33
Fins:		
Dorsal spines	0	0
Dorsal rays	12–13	12
Anal spines	0	0
Anal rays	27–31	29
Pelvic	9	9
Pectoral	11–12	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	8	8

LIFE HISTORY

Range: Central & equatorial waters of the Atlantic, Indian & Pacific Oceans; generally absent from eastern Pacific equatorial waters

Habitat: Open ocean; upper 100–800 m depth, usually taken in hauls exceeding 400 m

Spawning season: Larvae & small juveniles taken throughout the year but none identified in CalCOFI samples

ELH pattern: Oviparous; planktonic larvae collected in upper 100 m

LITERATURE

Johnson 1982, 1984b
Johnson & Glodek 1975
Ozawa 1986c
Rofen 1966d

* Eye elongate vertically; horizontal axis given first, vertical second; measurement are of entire eye capsule, not just pigmented portion.
† P_2 damaged on all transformation & juvenile specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.7 mm
Flexion length: ca. <4.4 mm–6.3 mm
Transformation length: ca. 20–30 mm
Fin development sequence: C_1, D, P_2 & A, C_2, P_1
Pigmentation: *Preflexion*—On snout tip, isthmus, & occiput; between orbits; at P_1 base; 3 peritoneal patches; on myosepta at midlateral line of trunk; on caudal peduncle. *Flexion*—Row on tail ventrally; on epaxial myosepta at shoulder & above anus; on midlateral trunk myosepta; vertical rows on tail myosepta; proximally on D finfold at midbody; proximally on A finfold near midtail; on C base. *Postflexion*—Increasing on head & trunk myosepta; heavy on dorsum & ventrum on caudal peduncle; vertical series on operculum. *Transitional*—On all fins; large blotches forming linearly, associated with the 3 muscle bands. *Juvenile*—Lateral blotches more numerous; body iridescent.
Diagnostic features: 48–52 total vertebrae; D 12–13, usually 12; A 27–31, usually 29; caudal peduncle pigmentation heavy; gill filaments not projecting beyond gill cover.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				54–62 57	50–55 53	52–60 55
BD/BL				17–23 19	16–17 17	17–22 19
HL/BL				25–36 29	23–26 24	24–30 27
HW/HL				28–39 34	33–45 39	33–45 39
SnL/HL				31–41 36	31–35 31	24–28 27
ED/HL*				14–20× 21–25 16×22	17–21× 23–26 18×25	23–25× 29–32 24×31
P_1L/BL				8–9 9	8–10 9	>9–17
P_2L/BL†				8–9 9	>9	>9

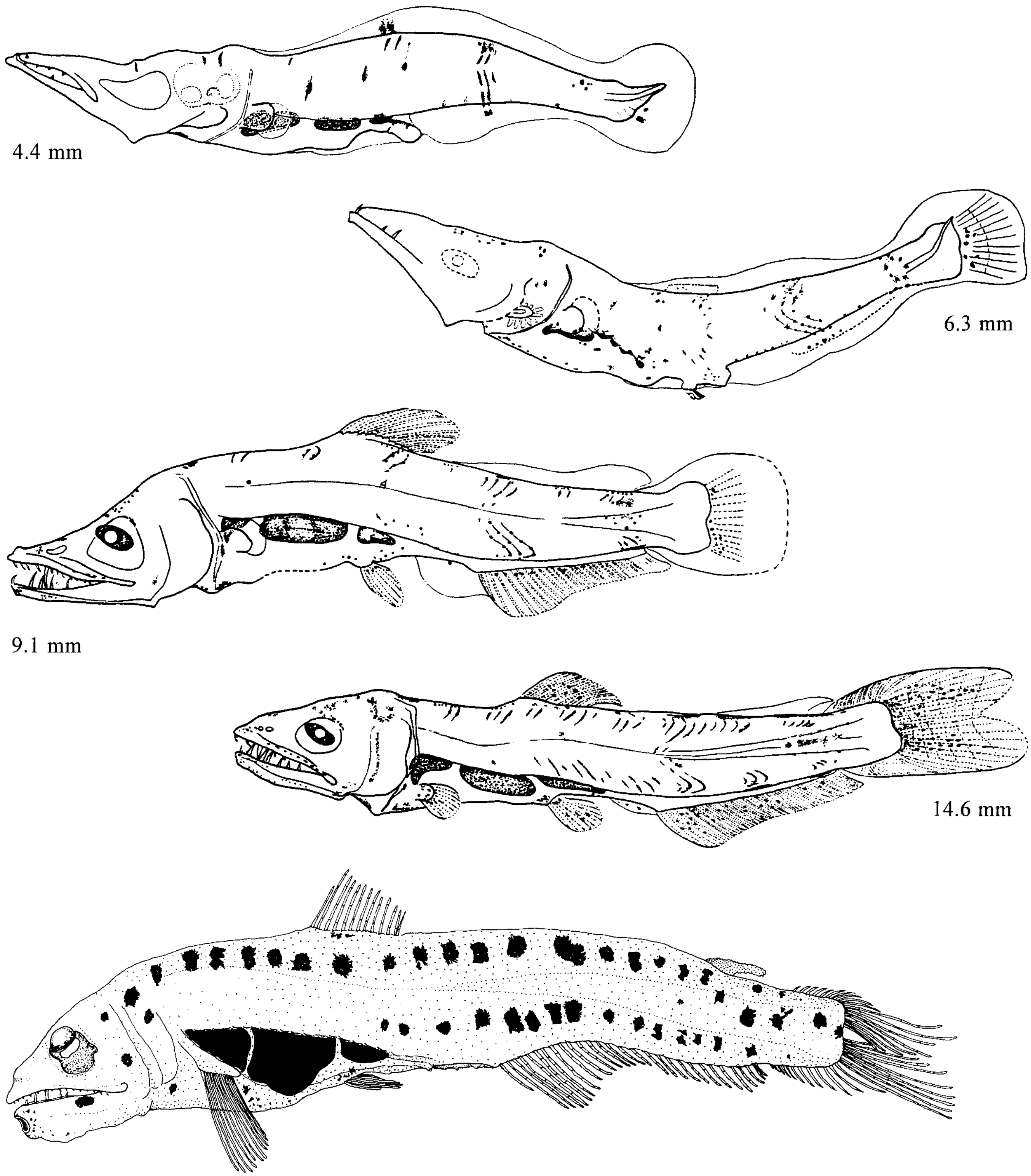


Figure Evermannellidae 2. Flexion larva, 4.4 mm; postflexion larvae, 6.3 mm, 9.1 mm, 14.6 mm (Ozawa 1986c); juvenile, 28.0 mm (Johnson 1982).

ALEPISAURIDAE: Lancetfishes

D. A. Ambrose

The family Alepisauridae includes one genus and two species, *Alepisaurus brevirostris* and *A. ferox* (Okiyama 1984a). *A. brevirostris* is absent from the north Pacific (Francis 1981). Larval *A. ferox* have been collected only south of 29°48′ N and west of 179°04′ E (Boehlert and Mundy 1992); however, adults range in the eastern Pacific from Alaska to Chile. Lancetfishes are large (maximum length ca. 200 cm), pelagic to bathypelagic predators in temperate and tropical seas. They possess a compressed, elongate body covered with pores, a large mouth with pointed jaws and dagger-like teeth, a fleshy keel along each side of the caudal peduncle, a sail-like dorsal fin extending from behind the head almost to the small adipose fin, and a short-based anal fin located far posteriorly. Scales, fin spines, light organs, and a swim bladder are absent. Meristic counts for the family are D 29–49, A 11–19, P_1 12–16, P_2 7–10, and V 47–51 (Okiyama 1984a). The body of adults is mostly iridescent. They are noted for their voracious appetite and many new species have been described from their stomach contents (Fitch and Lavenberg 1968).

Alepisaurids are synchronous hermaphrodites whose eggs are unknown. Larvae have been described for both species: *Alepisaurus brevirostris* as *Alepisaurus* sp., 6.9–17.2 mm (Rofen 1966b) and *A. ferox* , 10.0 mm (Okiyama 1984a) and 6.4 mm (Okiyama 1988f). Larvae are moderately elongate, have a large head (HL 24–43% BL), somewhat oblong eyes until mid-postflexion, prominent canine teeth, and a preanal length that increases from ca. 37% BL in preflexion larvae to ca. 81% BL in transformation specimens. Fine specks of pigment are present on the pectoral fins by preflexion stage; peritoneal pigment forms during the postflexion stage. Unlike the evermannellids, with whom they may be closely related, the alepisaurids do not have distinct peritoneal pigment sections (Johnson 1982). Like the scopelarchids and giganturids, the alepisaurids have a translucent space between the gut and hypaxial musculature, prior to completion of the flexion stage. Transformation is gradual. In *A. ferox* larvae, four preopercular spines are present by the flexion stage and pigment forms near the anal fin origin by the postflexion stage. *A. brevirostris* larvae lack both preopercular spines and pigment at the anal fin origin. Preflexion alepisaurids may be confused with scopelarchids; however, alepisaurids have a more rounded eye.

The following species description is based on detailed examinations of a 5.2 mm preflexion larva, 3 flexion larvae (6.9–8.4 mm), 10 postflexion larvae (6.4–15.5 mm), 5 transformation specimens (15.8–22.3 mm), and 5 juveniles (30.6–52.2 mm) of *A. ferox*. Meristic data were obtained from literature (Fujii 1984d; Okiyama 1984a; Heemstra and Smith 1986; Matarese et al. 1989). Ecological information was obtained from Fitch and Lavenberg (1968) and Eschmeyer et al. (1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–52	50
Precaudal	19–26	23
Caudal	24–31	27
Fins:		
Dorsal spines	0	0
Dorsal rays	30–45	
Anal spines	0	0
Anal rays	13–18	
Pelvic	8–10	
Pectoral	12–15	
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–6	
Lower	16–24	
Branchiostegals	7–8	

LIFE HISTORY

Range: Temperate & tropical waters worldwide; in the eastern Pacific from the Aleutian Islands to Chile

Habitat: Near surface to bathypelagic (1829 m depth)

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Okiyama 1984a, 1988f

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.2 mm (N. Arthur)
Flexion larva, 8.4 mm (N. Arthur)
Transformation specimen, 20.5 mm (N. Arthur)

* Eye off-round through mid-postflexion stage; horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <5 mm
Flexion length: ca. 6–8.5 mm
Transformation length: ca. 16–30 mm
Fin development sequence: C, P_1, A, D, P_2
Pigmentation: *Preflexion*—Fine specks on P_1. *Flexion*—On lower jaw angle. *Postflexion*—Dorsally on head; on gular region, operculum, & peritoneum; patch near A origin; dorsolaterally below Ad; midlaterally on trunk. *Transformation*—Spreading dorsally & laterally along dorsum & tail. *Juvenile*—Body becoming iridescent.
Diagnostic features: Preopercular spines; bony ridges on head; pigment near A origin; peritoneal pigment blotches absent.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			45–49	43–78	62–81	60–66
		37	47	59	68	62
BD/BL			16–20	18–36	26–35	19–26
		17	18	28	30	23
HL/BL			29–33	31–43	35–40	31–35
		24	31	37	37	33
HW/HL			40–46	39–64	45–59	38–55
		52	42	50	51	48
SnL/HL			43–48	35–51	36–43	31–38
		32	44	43	40	35
ED/HL*			18–23×	24–31×	27–33×	23–34×
			16–29	19–35	28–33	23–34
		29×37	20×23	27×27	30×30	27×28
P_1L/BL			12–13	9–24	21–27	20–25
		11	12	14	24	22
P_2L/BL			0–0	0–3	2–5	6–8
		0	0	0.4	4	7

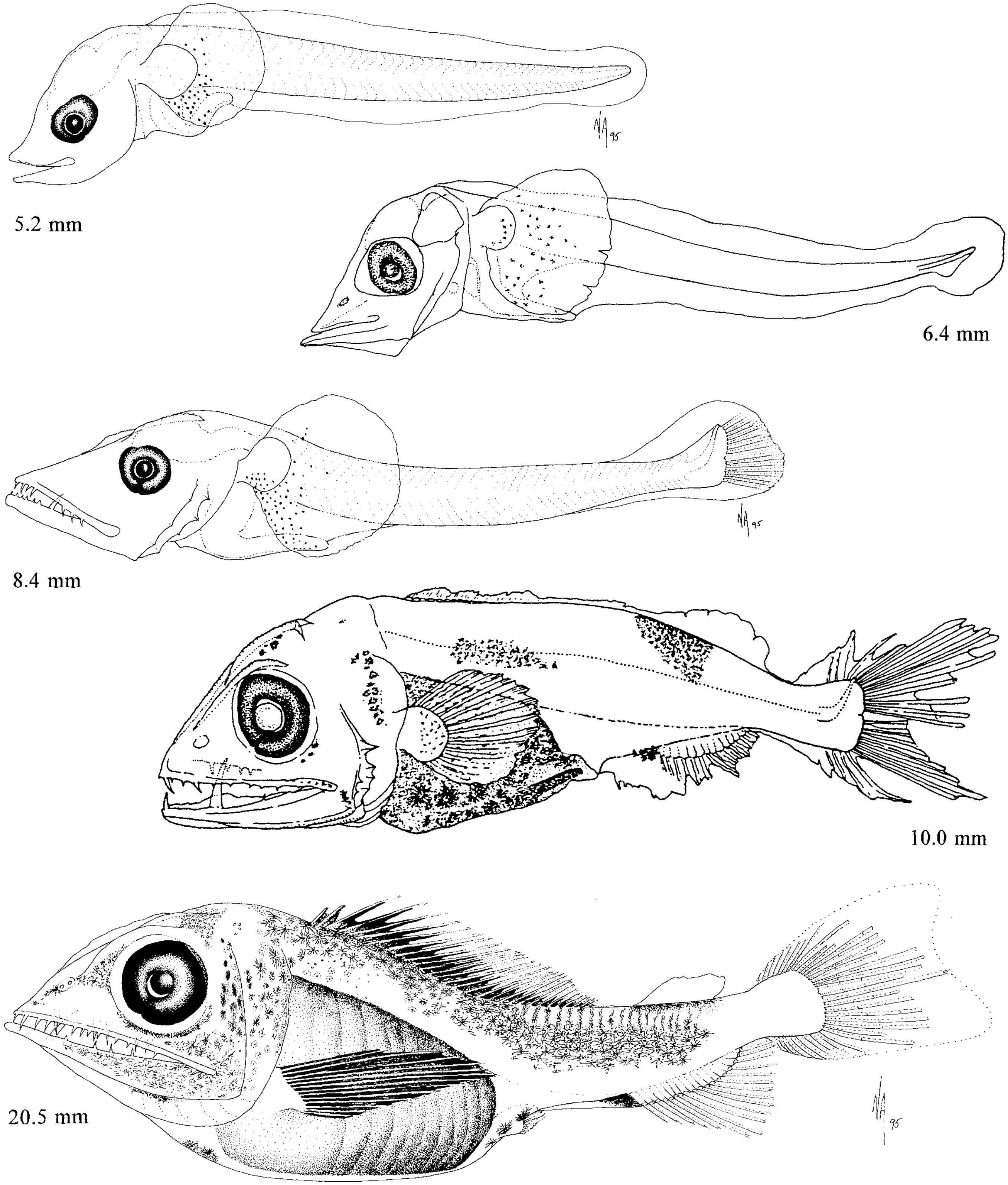


Figure Alepisauridae 1. Preflexion larva, 5.2 mm (CalCOFI 7205, station 20.135); flexion larvae, 6.4 mm (Okiyama 1988f), 8.4 mm (CalCOFI 7210, station 27.135); postflexion larva, 10.0 mm (Okiyama 1984a); transformation specimen, 20.5 mm (SIO 70–310).

MYCTOPHIFORMES: Lanternfishes

H. G. MOSER

Myctophiformes includes two families, Neoscopelidae and Myctophidae, with a total of 35 genera and >240 species (Nelson 1994; Hulley 1994). All are pelagic or benthopelagic fishes that occupy deep-sea habitats. Neoscopelidae is a small family (six species in three genera) consisting of photophore-bearing species (e.g., *Neoscopelus*) that inhabit benthopelagic continental slope waters and structurally reduced forms (*Scopelengys*), lacking photophores, that inhabit deep oceanic midwaters. Myctophids are a highly diverse and speciose (>240 species) family of luminous, primarily midwater, fishes that inhabit all oceans.

Prior to Rosen's (1973) analysis of the interrelationships of euteleost fishes, Myctophiformes was considered a much larger group that included the aulopiforms (Gosline 1971). Rosen (1973) considered them to be ctenosquamates (Myctophiformes + Acanthomorpha), based on numerous synapomorphies, of which the reductive restructuring of the gill arches is the most unequivocal (Johnson 1992). The important place that myctophiforms occupy in teleost evolution has attracted much research interest, resulting in conflicting hypotheses and considerable confusion (Rosen 1985; Stiassny 1986). Johnson (1992) assessed the characters used in previous hypotheses and argued cogently for ctenosquamate monophyly based on the loss of the fifth pharyngobranchial toothplate and the third internal levator muscle in myctophiforms and in acanthomorphs. Monophyly of Myctophiformes is more problematic although Rosen's (1973) hypothesis was corroborated by Stiassny (1986) and tentatively confirmed by Johnson (1992).

Families included: Neoscopelidae
Myctophidae

NEOSCOPELIDAE: Blackchins

H. G. MOSER

The family Neoscopelidae consists of six species in three genera. Only *Scopelengys* is found in the eastern Pacific. Adult *Scopelengys tristis* are taken regularly in deep midwater trawls as far north as southern California; however, larvae are found in the eastern tropical Pacific and only rarely are captured in the southernmost part of the CalCOFI survey area. A second nominal species, *S. clarkei*, inhabits the central water mass west of the CalCOFI survey area (Butler and Ahlstrom 1976). Bekker and Shcherbachev (1990) suggested that the status of the nominal *Scopelengys* species needs review.

Neoscopelids are small to medium in size (<30 cm) with a compressed head and body. Jaws are large, extend to the back of the orbit, and bear villiform teeth. The eyes are small in *Scopelengys* and large in *Neoscopelus*. *Scopelengys* has an elongate body covered with large, highly deciduous cycloid scales. *Neoscopelus* has ventrolateral rows of photophores and light organs on the tongue; *Scopelengys* lacks luminous organs. Fins are large; the dorsal fin origin lies above the pelvic fin and the anal fin origin is well behind the dorsal fin insertion. The large pectorals extend posteriad to the anus or anal fin origin. An adipose fin is present. The benthopelagic *Neoscopelus* is silvery in coloration, well ossified with firm musculature, and has a large gas bladder. In contrast, the bathypelagic *Scopelengys* is weakly ossified, flabby, and lacks a gas bladder (Fitch and Lavenberg 1968; Butler and Ahlstrom 1976; Nafpaktitis 1977; Hulley 1984). The monotypic *Solivomer*, with ctenoid scales, is known only from the Philippines.

Neoscopelids are assumed to be oviparous but planktonic eggs have not been identified. The larvae are deep bodied and robust with a somewhat massive gut that has a strong sigmoid flexure. The head and jaws are large; the jaws bear strong sharp teeth that are enlarged anteriorly. The pectorals are the first fins to develop rays and become elongate, extending posteriad beyond the anus. Larvae of both *Scopelengys* species have a large pigment blotch over the gut. Larvae of *S. tristis* develop a stripe through the eye while *S. clarkei* larvae lack an eye stripe but are pigmented on the lower jaw and posteriorly on the head and nape (Okiyama 1974, 1984a, 1988e; Butler and Ahlstrom 1976). Also, the caudal peduncle is deeper in *S. clarkei* compared to *S. tristis* (Butler and Ahlstrom 1976). Larvae of *S. tristis* resemble larvae of some species of the myctophid genus *Lampanyctus* but have a more posteriad placement of the anal fin, a more massive gut, and lack the Br_2 photophore present in larval myctophids. Larvae of *Neoscopelus* differ from those of *Scopelengys* in having a relatively shorter snout, longer gut, smaller pectoral fins and have preopercular spination (Okiyama 1988e).

The following description of *S. tristis* is based on the literature (Butler and Ahlstrom 1976; Okiyama 1974, 1984a, 1988e) and on detailed examination of 14 larvae (5 preflexion, 3.7–5.6 mm; 3 flexion, 6.9–7.7 mm; 6 postflexion, 8.0–16.4 mm) and 2 juveniles (24.8 and 27.5 mm). Meristic data and ecological information were obtained from the literature (Fitch and Lavenberg 1968; Butler and Ahlstrom 1976; Nafpaktitis 1977; Hulley 1984) and from observations made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–32	31
Precaudal	12–13	13
Caudal	17–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	11
Anal spines	0	0
Anal rays	12–14	13
Pelvic	8	8
Pectoral	14–17	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–9	
Lower	7–8	
Gill rakers:		
Upper	1–2	
Lower	6–9	
Branchiostegals	8	8

LIFE HISTORY

Range: Tropical Pacific, Indian, & Atlantic Oceans; from central California to Chile in the eastern Pacific

Habitat: Bathypelagic

Spawning season: Larvae were captured throughout the year on EASTROPAC cruises

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Butler & Ahlstrom 1976
Okiyama 1974, 1984a, 1988e

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.7 mm (N. Arthur)
Flexion larva, 5.6 mm (N. Arthur)

* P_1 rays broken.
† P_2 rays broken.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length: ca. 6.0–8.0 mm
Transformation length: >17 mm
Fin development sequence: P_1, C_1, D, A, C_2, P_2
Pigmentation: *Preflexion*—Smallest larvae have a blotch above gut & ca. 7 in a postanal median ventral series; by 4.6 mm, an embedded linear blotch in snout & an embedded post-orbital blotch give the appearance of a streak through eye. *Flexion–postflexion*—Postanal series reduced to 1–5, or absent; blotch above gut becomes elongate.
Diagnostic features: Body deep & robust; gut moderate in length, robust, strongly sigmoid; head & jaws large; teeth needle-like, larger at tip of jaws; eyes round & small; P_1 forms early in preflexion stage & becomes large; pigment streak through eye; similar *S. clarkei* lacks eye stripe & has mandibular, posterior head, & nape pigment after flexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–56 53	61–61 61	60–66 64		62–65 63
BD/BL		19–21 21	22–23 23	20–24 22		19–20 20
HL/BL		27–32 29	32–33 32	33–35 34		27–31 29
HW/HL		44–54 49	38–44 41	40–45 42		39–39 39
SnL/HL		26–36 30	32–34 33	36–41 38		36–36 36
ED/HL		24–28 26	20–21 20	14–19 17		13–13 13
P_1L/BL		14–25 19	25–34 30	36–40 38		*
P_2L/BL		0–0 0	0–2 1	2–9 5		†

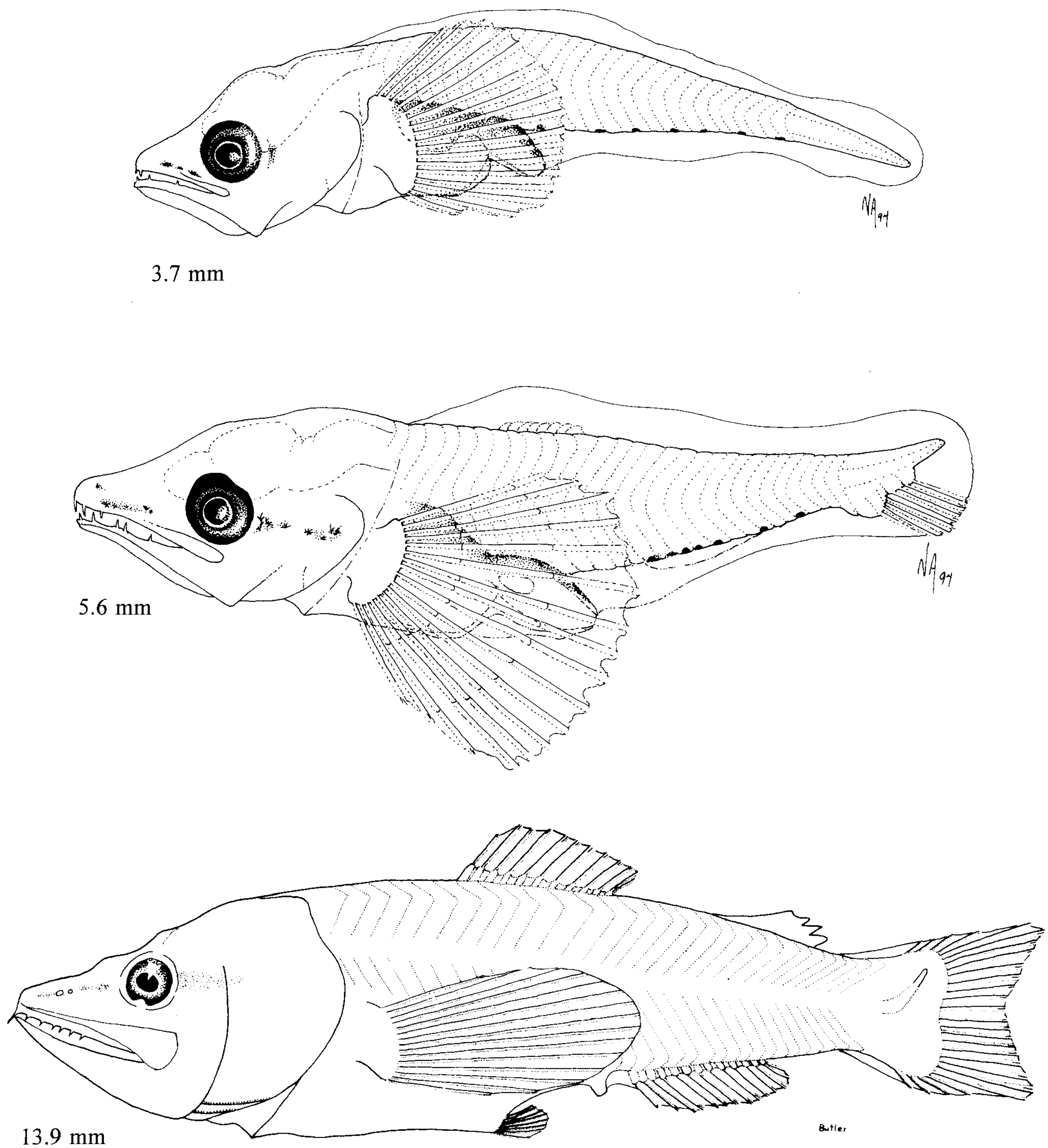


Figure Neoscopelidae 1. Preflexion larva, 3.7 mm (EASTROPAC II, station 47.005); flexion larva, 5.6 mm (EASTROPAC II, station 47.040); postflexion larva, 13.9 mm (Butler and Ahlstrom 1976).

MYCTOPHIDAE: Lanternfishes

H. G. MOSER AND E. H. AHLSTROM[1]

Lanternfishes are the most ubiquitous fishes in the world ocean and may have the greatest biomass of all oceanic fishes. Hulley (1994) suggested their total biomass exceeds 600 million tons but this is likely a conservative estimate. There are at least 80 species representing 23 genera in the California Current and adjacent waters (Wisner 1976). We have identified larvae of approximately 50 species representing all 23 genera in the northeastern Pacific (Table Myctophidae 1). Lanternfish larvae are among the most abundant larvae encountered in CalCOFI samples; *Triphoturus mexicanus* and *Stenobrachius leucopsarus* rank sixth and seventh in total abundance and 11 of the 30 most abundant taxa in the time series are myctophids.

Myctophids are small to medium-size (3–35 cm) deep-sea fishes with a compressed body and head, large eyes, and moderate to large jaws with bands of small, closely set teeth. The mouth is terminal in most species and the maxillary is completely excluded from the gape. There is a single dorsal fin followed by an adipose fin supported by a cartilaginous plate. The anal fin origin is under or slightly posterior to the dorsal fin base; the pelvic fins are abdominal and have eight rays in most species. Pectoral fins range from large and well developed to small and weakly formed or even absent in some species. There is a rudimentary spine at the base of the first dorsal ray, the first anal ray, the upper pectoral ray, and the outermost pelvic ray. Color of live specimens ranges from iridescent blue, green, or silver in shallow-living species to dark brown or black in deep-living species. The body is covered with rounded cycloid scales; a few species have ctenoid scales. A gas bladder is present in juveniles but may become reduced or invested with fatty tissue in adults. Lanternfishes are harvested commercially only off South Africa and in the sub-antarctic; however, their enormous biomass may mark them for much greater commercial exploitation in the future (Nafpaktitis et al. 1977; Hulley 1994; Paxton et al. 1995).

Lanternfishes have a variety of luminous organs, the most prominent of which are the paired rows or groups of photophores on the ventral and lateral regions of the body. Photophores are complex structures consisting of a modified cup-like scale containing photogenic tissue overlain by a scale modified as a lens. Photophores of similar structure are arranged on the head. Myctophid photophores have a fundamental pattern (Figure Myctophidae 1) but most species and genera (to some degree) have a unique arrangement within the basic pattern. This has lead to the hypothesis that photophore pattern may function in intraspecific recognition. Other kinds of luminous organs are: small secondary photophores on the head and body, supra- and infracaudal glands (often sexually dimorphic) of various form and complexity, specialized photophores associated with the eyes, and luminous patches or scales on the bases of fins and elsewhere on the body (Nafpaktitis et al. 1977; Hulley 1994).

Almost all myctophids undergo diel vertical migrations, probably associated with foraging on planktonic crustaceans. At night, many lanternfishes migrate upward to the mixed layer from daytime depths of 300–2000 m. Some species come to the surface where they may be dipnetted or captured by neuston nets. Deep-living species tend to undergo little or no vertical migration. For some species, the degree and pattern of vertical migration is different for juveniles and adults (Nafpaktitis et al. 1977; Hulley 1994). Larvae of myctophids are generally found in the upper mixed layer; however, larvae of the subfamily Myctophinae have deeper distributions (to 500 m for some species) than do those of the Lampanyctinae (Loeb and Nichols 1984; Moser and Smith 1993).

Myctophids are oviparous and presumably all have planktonic eggs; however, their planktonic eggs are collected infrequently. The great disparity between the apparent paucity of planktonic eggs and high larval abundance may be explained by the disintegration of the eggs during capture. Eggs identified by us as myctophids range in diameter from ca. 0.70 mm to 0.90 diameter, have segmented yolk, a moderately large perivitelline space, a single oil globule (ca. 0.1–0.3 mm diameter), and a fragile, wrinkled chorion. It is likely that the thin chorion is broken during the tow and subsequently the embryo is disintegrated and

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passed through the meshes. Similarly, disintegration and extrusion of yolk-sac larvae could explain their near absence from the samples.

Larvae of lanternfishes are among the most taxonomically tractable and extensively studied of all fish larvae. They hatch at ca. 2.0 mm and range in size at transformation from 10 to 30 mm, depending on the species. Myctophid larvae have a vast array of morphological and pigment characters that permit identification of species and are useful in systematic analyses of genera and subfamilies (Moser et al. 1984a; Paxton et al. 1984). Head, gut, and body shape are distinctive for most species and genera have a recognizable morph. Although most species are moderately slender, body shape ranges from highly attenuate to markedly robust or deep-bodied and compressed. Eyes are elliptical in the Myctophinae and round or nearly round in most Lampanyctinae. Many of the narrow-eyed myctophine species have a well developed mass of choroid tissue on the ventral surface of the eye and several genera have stalked eyes. Typically, the gut is slightly sigmoid, extends to the midbody, and has distinctive transverse mucosal folds; however, gut length can range from extremely short (preflexion *Lampanyctus*) to elongate and trailing free from the body (*Myctophum aurolaternatum*). The pectoral fins may be large and distinctly shaped; some species have a higher pectoral ray count in larvae than in adults and some have elongate, ornamented lower pectoral rays. The pelvic fin is usually the last to form, although it is precocious in some species. Usually, the median finfold is well developed and in *Loweina* and *Tarletonbeania* it is voluminous. In all but two genera, the Br_2 photophore develops during the larval period and in many genera (3 in Myctophinae and 11 in Lampanyctinae) other photophores develop during the larval period. Except for the large genus *Diaphus*, most species have a unique melanophore pattern that allows their identification and a recurring pattern of pigment loci can be recognized for most genera (Moser et al. 1984a). Identification of larval *Diaphus* species has proven to be extremely difficult. Two forms of *Diaphus* larvae have been described (Moser et al. 1984a): a slender form with numerous persistent postanal ventral melanophores and a stout form with fewer postanal melanophores that coalesce before flexion. Within these two morphs, few characters are available for distinguishing species. *Diaphus theta* is the most common member of the genus in the northern and central part of the CalCOFI survey area and *D. pacificus* is the most common member in the southern part, south of Punta Eugenia, Baja California Sur; however, a number of other species are reported from the region (see Berry and Perkins 1966; Wisner 1976; Hubbs et al. 1979; Bekker 1983). Among these are: *D. andersoni*, *D. fulgens*, *D. garmani*, *D. trachops*, and a form that is part of the *D. perspicillatus/mollis/fulgens/rafenesquii* species complex (B. Mundy, pers. comm.). The principal distributions of most of these species are to the west or to the south of the core of the California Current where *D. theta* and, to a lesser extent, *D. pacificus* are predominant. Our identifications of larval *D. theta* (a slender form) and *D. pacificus* (a stout form) are based on distribution, relative abundance, and extensive transformation series. Identification of *Diaphus* larvae from peripheral localities of the CalCOFI survey area awaits the discovery of distinguishing larval characters and the resolution of taxonomic problems within the genus.

The following descriptions are based on detailed observations of 11–46 specimens of 41 species and on published literature where applicable (Table Myctophidae 1). Larvae of eight other identified species are captured rarely to the west or south of the regular CalCOFI sampling pattern and are not described separately; however, single larval stages are shown in Figure Myctophidae 2 (*Benthosema fibulatum*, *Lampadena luminosa*, *Myctophum lychnobium*, and *M. spinosum*) and in Figure Myctophidae 3 (*M. asperum*, *M. brachygnathum*, *M. obtusirostrum*, and *M. selenops*). Meristic data were obtained from several literature sources (Moser and Ahlstrom 1970; Wisner 1976; Zahuranec 1980; Moser et al. 1984a) and from counts made during this study. Ecological information was obtained primarily from Wisner (1976), Nafpaktitis et al. (1977), and Hulley (1994).

Zahuranec (1980) revised those species of *Lampanyctus* with reduced or absent pectoral fins and placed 17 species in *Nannobrachium*, a generic name previously used by Günther (1887). Larvae of five *Nannobrachium* species are described in this guide and two of these belong to species new to science (Zahuranec, in press). These two species are referred to by descriptive names (*Nannobrachium* "no pectorals" and *Nannobrachium* "niger") since the use of Zahuranec's (1980) manuscript names would produce *nomina nuda*. The identities of these two species can be ascertained from synonym lists in Zahuranec (1980).

Table Myctophidae 1. Meristic characters for selected myctophid species in the California Current vicinity. All species have 10 superior and 9 inferior principal caudal fin rays.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	P_2	C_2
Lampanyctinae								
Bolinichthys longipes	15–16	18–19	32–35	11–13	13–15	12–14	8	6–7+6–8
Ceratoscopelus townsendi	16–17	20–21	35–38	13–15	13–16	13–15	8	6–7+6–7
Diaphus pacificus	16	16–17	31–33	13–15	11–13	9–10	8	5–7+5–6
D. theta	15–16	18–20	34–36	12–14	12–14	10–12	8	6–8+6–8
Lampadena luminosa	15–17	20–22	35–37	14–15	13–15	15–17	8	8+8
L. urophaos	16	20–22	36–38	14–16	13–14	14–17	8	8–9+8–9
Lampanyctus acanthurus	14–16	19–22	35–37	13–14	16–18	13–15	8	8–10+9–11
L. nobilis	16	21–23	37–39	14–15	17–19	13–14	8	6–7+6–7
L. parvicauda	15–16	19–21	35–38	13–15	17–20	12–15	8	6–7+7–8
L. steinbecki	14–15	19–20	34–36	12–14	16–19	13–15	8	7+6–8
L. tenuiformis	14–16	19–21	35–37	13–14	17–18	13–15	8	7–8+7–8
Lobianchia gemellarii	15–17	18–20	34–35	16–18	13–15	11–13	8	6–7+5–6
Nannobrachium idostigma	13–15	17–19	31–34	11–14	16–20	10–13	8	6–8+6–8
N. "niger"	15–16	20–23	36–38	14–16	16–19	13–16	7–8	6–8+6–8
N. "no pectorals"	13–16	18–21	33–35	12–15	15–19	0	8	6–7+6–7
N. regalis	15–16	20–22	36–39	12–17	17–19	12–15	8	6–8+6–8
N. ritteri	15–16	20–22	35–38	12–16	16–19	10–13	8	7–8+7–8
Notolychnus valdiviae	12–13	16–18	27–31	10–12	12–15	12–15	6	6–8+6–8
Notoscopelus resplendens	16	21–22	35–38	21–24	18–20	11–13	8	11–14+10–14
Parvilux ingens	15–16	21–22	35–38	14–17	15–18	10–13	8	7–9+7–9
Stenobrachius leucopsarus	15–16	20–22	35–38	13–15	14–16	8–10	8	6–8+7–8
Taaningichthys minimus	18–20	20–22	39–41	11–13	11–14	15–17	8	8–10+8–9
Triphoturus mexicanus	15–17	18–19	33–35	13–16	14–17	8–10	8	5–7+6–7
T. nigrescens	15–16	17–19	33–35	13–15	16–18	8–10	8	5–6+5–6
Myctophinae								
Benthosema fibulatum	13	19	31–32	12–14	18–20	14–17	8	8–9+7–8
B. panamense	13–14	18–19	31–33	12–14	19–22	13–16	8	7–9+7–8
B. suborbitale	15	18–19	33–35	12–14	16–19	13–15	8	8+7–8
Centrobranchus nigroocellatus	14–15	22–25	35–40	9–11	16–19	13–17	8	5–7+5–7
Diogenichthys atlanticus	13–14	18–20	31–35	10–12	14–18	12–15	8	8–9+8–9
D. laternatus	12–13	18–20	29–32	10–13	15–17	10–12	8	7–9+7–9
Electrona risso	14–16	17–20	32–34	12–15	18–20	13–16	8	6–8+6–7
Gonichthys tenuiculus	14–16	23–26	38–41	10–12	17–20	11–14	6–8	5–6+5–6
Hygophum atratum	15–17	19–21	35–37	11–14	18–21	12–15	8	6–9+6–9
H. proximum	15–16	18–21	34–37	12–14	18–21	13–15	8	8–9+8–9
H. reinhardtii	16–17	21–23	38–40	13–15	21–25	13–15	8	7–9+7–8
Loweina rara	17–19	19–21	37–39	10–13	13–17	9–13	8	6–7+6–7
Myctophum asperum	15–17	19–22	35–38	10–11	16–17	13–15	8	8–9+8–9
M. aurolaternatum	18–19	25–26	42–46	9–12	21–27	12–16	8	8+7–8
M. brachygnathum	15	20–21	35–36	12–13	18–19	16–18	8	8–9+7–9
M. lychnobium	15–16	22–25	37–39	12–14	17–20	14–17	8	8–9+8–9
M. nitidulum	15–16	21–23	36–39	12–14	18–21	13–16	8	7–9+7–9
M. obtusirostrum	15–16	19–21	35–36	12–13	17–19	17–19	8	8–9+7–8
M. selenops	15–16	19–20	34–35	13	17–19	16–18	8	8+7–8
M. spinosum	15–16	22–24	37–40	12–14	18–20	12–15	8	8–9+8–9
Protomyctophum crockeri	14–16	21–23	36–38	11–13	19–24	13–17	8	7–9+7–8
P. thompsoni	14–16	22–24	37–39	11–13	21–25	14–17	8	7–9+6–8
Symbolophorus californiensis	15–17	22–23	37–40	13–15	19–21	15–20	8	8–10+7–8
S. evermanni	15–16	21–22	36–38	13–16	18–22	13–18	8	8–9+7–9
Tarletonbeania crenularis	17–18	22–24	39–42	11–14	17–20	11–15	8	5–7+5–7

Table Myctophidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the myctophid species descriptions. An "L" indicates literature used in the description.

Species	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Lampanyctinae	7	8	12	4	4
Bolinichthys longipes	3.1–4.8	5.0–6.4	6.7–11.7	10.6–13.0	15.4–20.7
Ceratoscopelus townsendi	11	6	13	6	5
	2.6–6.1	6.2–7.8	7.8–18.3	16.6–20.1	17.7–20.3
Diaphus pacificus	5	3	5	3	3
	2.1–3.9	4.1–4.4	4.6–7.5	8.6–9.6	9.8–10.3
D. theta	7	3	7	3	3
	2.9–5.4	5.6–6.4	6.9–10.5	11.0–13.7	14.7–15.9
Lampadena urophaos	17	6	14	6	3
	2.9–6.7	6.8–8.3	8.6–15.6	17.4–21.0	19.6–22.6
Lampanyctus acanthurus	7	5	12	2	2
	2.5–5.0	5.2–5.9	6.2–14.4	15.0–18.4	25.0–26.9
L. nobilis	5	3	6	0	1
	3.5–5.2	5.2–6.4	6.2–18.3		21.5
L. parvicauda	6	3	8	3	3
	3.5–5.2	5.8–6.6	7.2–13.5	14.5–16.4	25.0–28.1
L. steinbecki	5	4	6	0	0
	3.0–3.9	4.5–5.8	6.1–10.0		
L. tenuiformis	4	3	7	0	0
	3.2–4.2	4.3–4.9	5.0–16.1		
Lobianchia gemellarii	5	3	7	1	3
	2.9–4.5	5.0–5.6	6.2–13.5	11.8	14.7–16.2
Nannobrachium idostigma	9	3	7	0	3
	2.2–5.3	5.3–6.0	6.3–11.7		20.3–22.4
N. "niger"	8	3	5	1	0
	3.3–6.1	6.6–7.3	7.5–13.9	20.7	
N. "no pectorals"	6	3	6	0	0
	3.0–5.3	5.6–6.6	6.5–14.4		
N. regalis	9	11	15	1	2
	3.4–5.8	6.0–7.9	8.1–16.4	21.2	27.4–31.3
N. ritteri	7	4	8	3	3
	3.4–5.8	6.1–7.1	7.2–15.6	15.7–17.6	22.4–26.5
Notolychnus valdiviae	9	8	15	5	3
	2.8–4.4	4.4–6.2	6.2–10.6	10.1–10.8	12.5–13.9
Notoscopelus resplendens	15	7	12	1	2
	2.4–4.9	5.0–6.5	6.8–19.1	21.0	26.1–26.3
Parvilux ingens	3	2	6	0	0
	4.5–6.5	7.6–7.8	10.1–17.6		
Stenobrachius leucopsarus	8	4	9	4	3
	3.1–6.4	6.6–7.9	8.4–16.1	15.7–18.4	19.6–21.0
Taaningichthys minimus	3	3	10	0	0
	4.9–6.8	7.0–8.5	8.8–20.3		
Triphoturus mexicanus	7	5	9	2	3
	2.7–6.1	6.3–7.6	8.0–13.5	12.5–15.4	16.7–17.8
T. nigrescens	6	3	8	1	3
	3.2–5.6	5.6–6.4	6.6–14.0	15.0	16.2–17.8
Myctophinae					
Benthosema panamense	L[a]	L[a]	L[a]	L[a]	0
B. suborbitale	6	4	5	2	4
	2.6–5.0	5.2–6.5	6.6–9.6	9.7–10.8	11.0–16.1
Centrobranchus nigroocellatus	L[a]	L[a]	L[a]	0	L[a]
Diogenichthys atlanticus	L[a]	L[a]	L[a]	L[a]	L[a]
D. laternatus	L[a]	L[a]	L[a]	0	L[a]
Electrona risso	L[a]	L[a]	L[a]	0	L[a]
Gonichthys tenuiculus	L[a]	L[a]	L[a]	0	L[a]

Table Myctophidae 2. Continued.

Species	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Hygophum atratum	L[a]	L[a]	L[a]	L[a]	0
H. proximum	7	4	6	0	3
	2.7–5.8	6.1–7.6	7.7–11.8		12.8–16.2
H. reinhardtii	L[a]	L[a]	L[a]	L[a]	L[a]
Loweina rara	L[a]	L[a]	L[a]	L[a]	0
Myctophum aurolaternatum	7	3	6	2	3
	3.8–10.6	11.7–13.8	15.4–25.8	27.6–29.0	25.9–28.2
M. nitidulum	L[a]	L[a]	L[a]	0	L[a]
Protomyctophum crockeri	L[a]	L[a]	L[a]	L[a]	L[a]
P. thompsoni	L[a]	L[a]	L[a]	0	L[a]
Symbolophorus californiensis	L[a]	L[a]	L[a]	0	L[a]
S. evermanni	6	3	6	0	1
	3.4–6.1	6.1–7.5	7.6–16.9		24.5
Tarletonbeania crenularis	L[a]	L[a]	L[a]	L[a]	L[a]

[a] Moser and Ahlstrom 1970

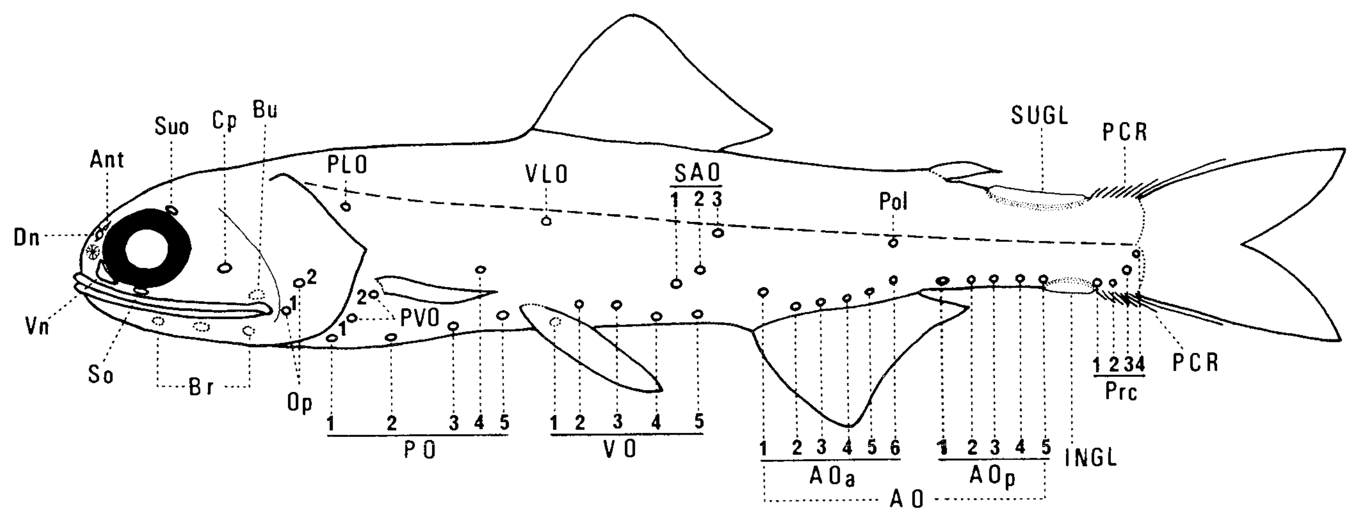


Figure Myctophidae 1. Generalized photophore pattern and terminology for Myctophidae (from Fujii 1984c). Ant—antorbital organ; AO—anal organs; AOa—anterior anal organs; AOp—posterior anal organs; Br—branchiostegal organs; Bu—buccal organ; Cp—cheek organ; Dn—dorsonasal organ; INGL—infracaudal luminous gland; Op—opercular organs; PLO—suprapectoral organ; PO—thoracic organs or pectoral organs; Pol—posterolateral organ; Prc—precaudal organs; PVO—subpectoral organs; SAO—supraanal organs; So—suborbital organ; SUGL—supracaudal luminous gland; Suo—supraorbital organ; VLO—supraventral organ; Vn—ventronasal organ; VO—ventral organs.

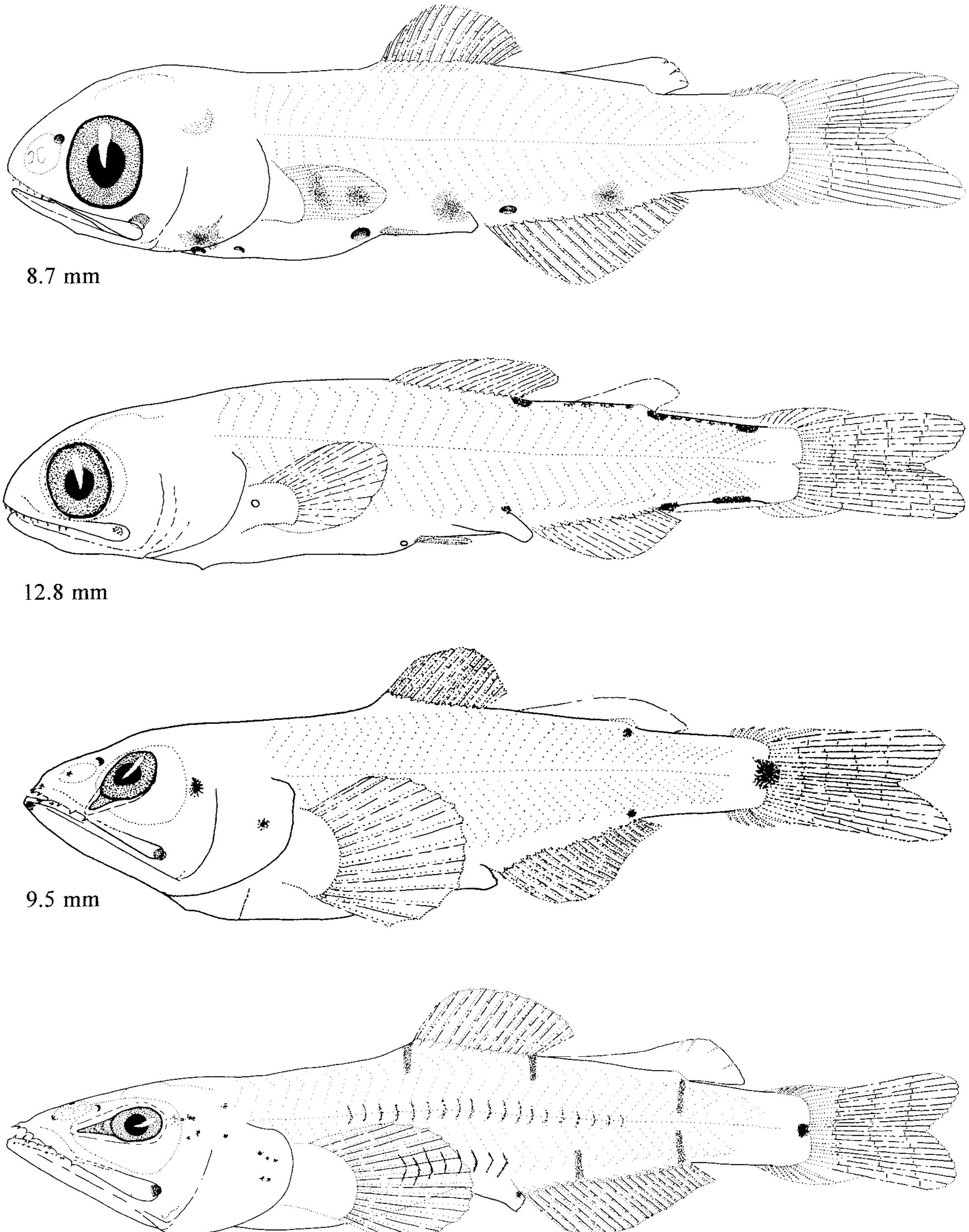


Figure Myctophidae 2. Postflexion myctophid larvae (top to bottom): *Benthosema fibulatum*, 8.7 mm; *Lampadena luminosa*, 12.8 mm; *Myctophum lychnobium*, 9.5 mm; *Myctophum spinosum*, 9.0 mm (Moser and Ahlstrom 1974).

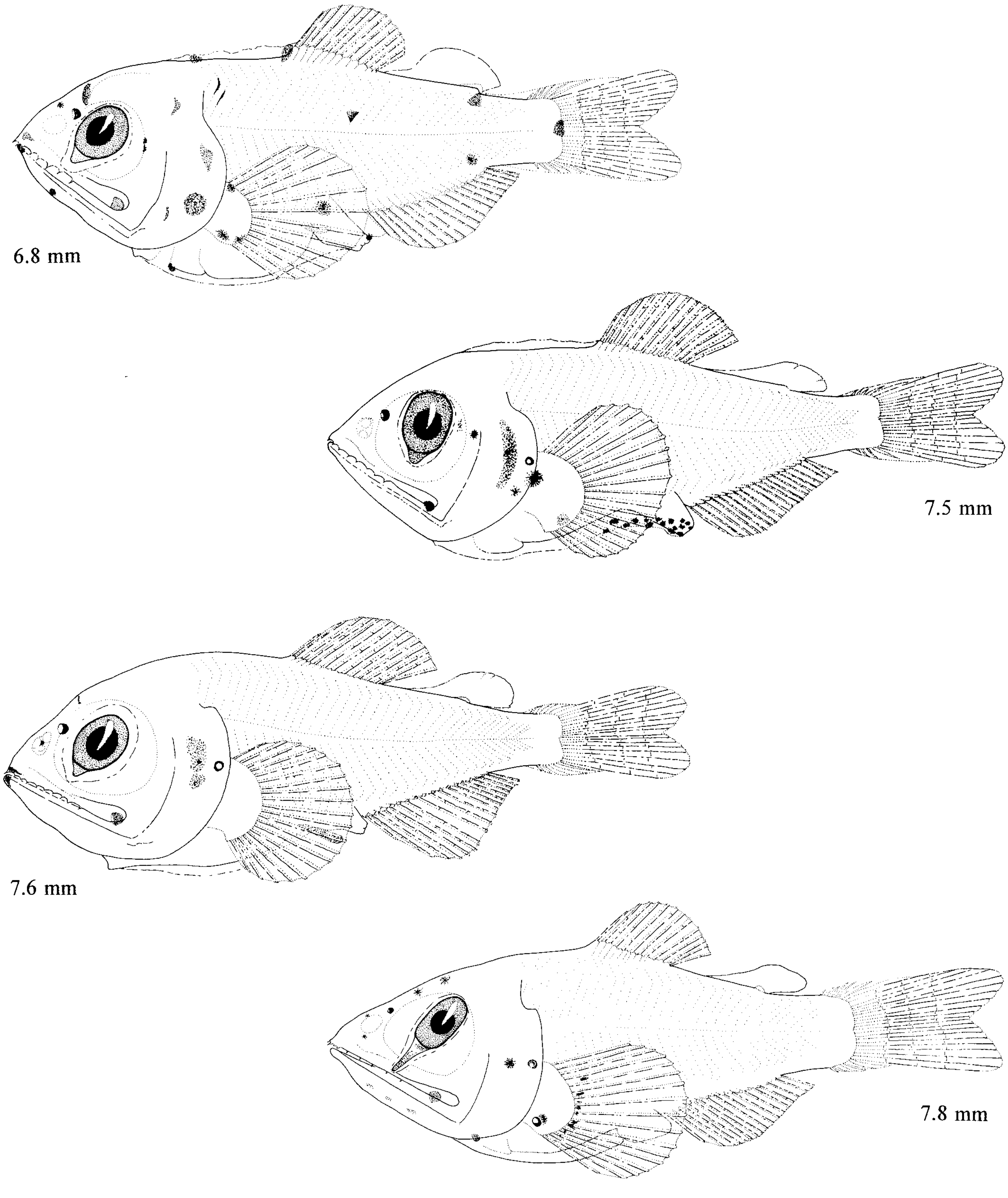


Figure Myctophidae 3. Postflexion *Myctophum* larvae (top to bottom): *M. asperum*, 6.8 mm; *M. brachygnathum*, 7.5 mm; *M. obtusirostrum*, 7.6 mm; *M. selenops*, 7.8 mm (Moser and Ahlstrom 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	32–35	33–34
Precaudal	15–16	16
Caudal	18–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	12–13
Anal spines	0	0
Anal rays	13–15	14
Pelvic	8	8
Pectoral	12–14	12–13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	7
Lower	6–8	7
Gill rakers:		
Upper	4–5	5
Lower	12–15	13–14
Branchiostegals	9	9

LIFE HISTORY

Range: Eastern Pacific from 30° N to 20° S; also in southwest Pacific & in Indian Ocean

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser et al. 1984a
Pertseva-Ostroumova 1964

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.1 mm, 4.7 mm (G. Mattson)
Flexion larva, 5.2 mm (G. Mattson)
Postflexion larva, 10.6 mm (G. Mattson)
Juvenile, 16.6 mm (G. Mattson)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

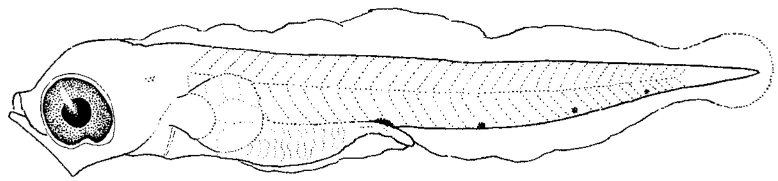
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

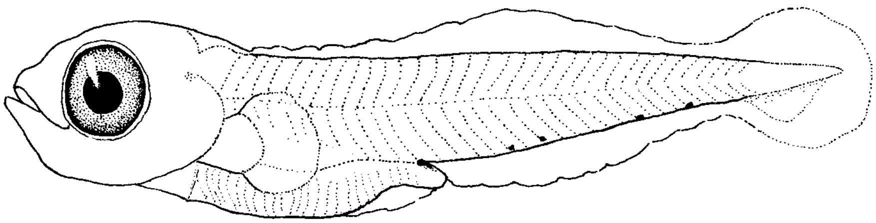
LARVAE
Hatching length: <3.0 mm
Flexion length: ca. 5.0–6.5 mm
Transformation length: ca. 10.5–13.0 mm
Fin development sequence: C_1, D & A & P_1 & C_2, P_2
Pigmentation: *Preflexion*—3–9 (usually 4–6) in median ventral series extending posteriad from above preanal arch of gut; 1 above gas bladder by 4.0 mm; 1 embedded in otic region in larvae as small as 4.4 mm. *Flexion*—By 5.0 mm, postanal series coalesces to 1, occasionally 2, in caudal peduncle region; 1 above preanal arch of gut remains; embedded series of 1–3 above spinal column in caudal peduncle region in larvae as small as 5.3 mm. *Postflexion*—All larvae >7.0 mm have series above spinal column, 1–9 (usually 2–3); 1 or 2 in dorsal midline posterior to cerebellum at ca. 8.0 mm.
Diagnostic features: Moderately slender body; head & jaw size moderate; eyes large & nearly round; snout blunt; gut to midbody with slight sigmoid curvature; pigment sparse but diagnostic (see *Ceratoscopelus townsendi*); Br_2 photophores form at ca. 5.0 mm; Br_1, Op_1, & PO_5 form during transformation; larvae somewhat similar to those of *Ceratoscopelus townsendi* but are stouter, have a larger, more round eye, have embedded pigment in the otic region (lacking in *C. townsendi* larvae <10.5 mm), & lack early developing photophores present in *C. townsendi* larvae.

MORPHOMETRICS (range & mean in %)

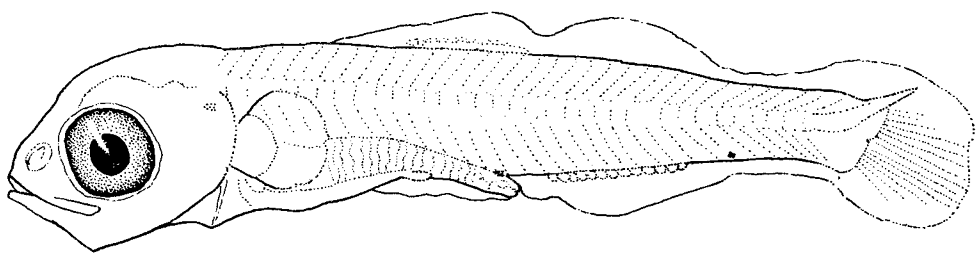
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–58 55	58–62 60	59–63 62	60–62 61	59
BD/BL		14–18 15	18–23 20	19–25 22	20–24 22	21
HL/BL		22–25 24	24–27 25	26–29 27	27–29 29	28
HW/HL		53–66 60	53–62 56	52–62 58	54–62 58	59
SnL/HL		13–26 20	22–26 24	21–24 23	19	17
ED/HL*		35–44× 35–46 39×41	33–38× 36–40 35×38	34–40× 36–43 38×41	31–35× 32–35 33×33	33
P_1L/BL		4–7 6	6–8 7	9–11 10	20	24
P_2L/BL		0–0 0	0–2 0.5	2–10 6	13	12



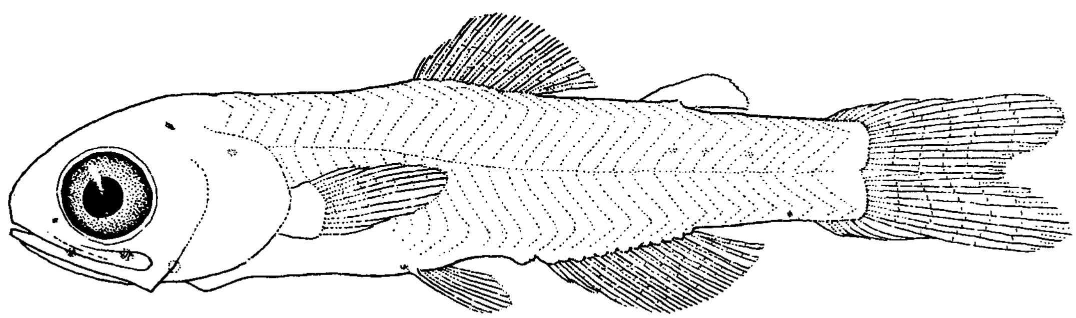
3.1 mm



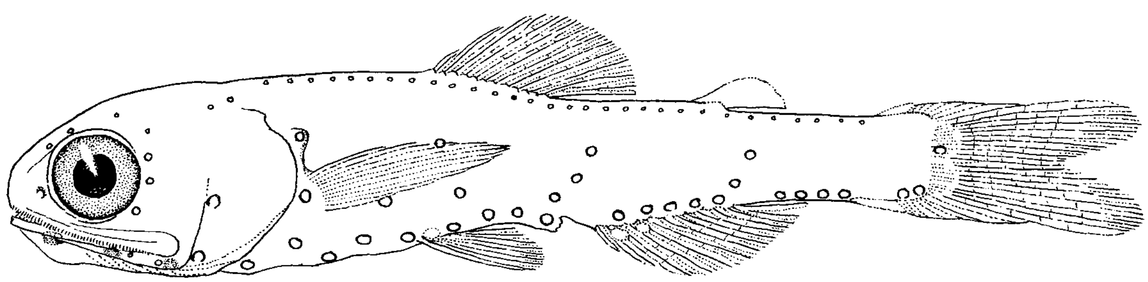
4.7 mm



5.2 mm



10.6 mm



16.6 mm

Figure Myctophidae 4. Preflexion larvae, 3.1 mm (CalCOFI 6611, station 147.60), 4.7 mm (CalCOFI 6207, station 80.160); flexion larva, 5.2 mm (CalCOFI 5011, station 150.80); postflexion larva, 10.6 mm (SIO 60–251); juvenile, 16.6 mm (NORPAC, station 78 Deep).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	36
Precaudal	16–17	16
Caudal	20–21	20
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	13–16	13–14
Pelvic	8	8
Pectoral	13–15	13–14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	6
Lower	6–7	6
Gill rakers:		
Upper	4–5	4
Lower	10–12	11
Branchiostegals	9	9

LIFE HISTORY

Range: Widely distributed in warm to temperate waters of Atlantic, Pacific & Indian Oceans

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout the year in CalCOFI area; highest abundance is in the summer, with a peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Amaoka et al. 1992
Badcock & Araújo 1988
Belyanina 1982a
Matarese et al. 1989
Miller et al. 1979
Moser & Ahlstrom 1974
Moser et al. 1984a
Ozawa 1986b, 1988d
Shiganova 1977

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.1 mm, 5.4 mm (G. Mattson)
Flexion larva, 6.9 mm (G. Mattson)
Postflexion larva, 7.8 mm (G. Mattson)
Transformation specimen, 20.6 mm (G. Mattson)
Juvenile, 20.3 mm (G. Mattson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 6.1–7.8 mm
Transformation length: ca. 17–20 mm
Fin development sequence: C_1, A, D & C_2, P_1, P_2
Pigmentation: *Preflexion*—6–11 dashes (ave. ca. 8) in postanal median ventral series; above developing gas bladder by 5.0 mm; pair on terminal section of gut. *Flexion*—Postanal series coalesces to 1 at A insertion by end of stage; embedded series of 1–4 (usually 2 or 3) above vertebral column in caudal peduncle region. *Postflexion*—Embedded in otic region in some larvae >10.5 mm (present in most larvae >16.0 mm); 1 medially above hindbrain in some larvae >12.5 mm.
Diagnostic features: Moderately slender body; gut to ca. midbody, slightly sigmoid; head relatively small; eyes large, slightly elliptical, with lunate sliver of choroid tissue in larvae >5.0 mm; snout acute, becoming blunted in larvae >14.5 mm; Br_2 photophores form at 7.0 mm, Vn at 7.8 mm, PLO at 8.7 mm, PO_5 at 9.0 mm; upper OP & PO_1 form first during transformation; larvae similar to *Bolinichthys longipes* but more slender, with relatively smaller & narrower eyes, a more acute snout, & distinct larval photophores (lacking in *B. longipes*); lacks pigment on mid-lateral region of gut & on anterior ventral margin of gut (present in *Diaphus theta*, *Stenobrachius leucopsarus*, & *Triphoturus*); lacks hypural melanophore (present in *Diaphus*).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–53 46	55–61 58	58–62 60	60–61 60	60–61 60
BD/BL		10–14 11	13–16 14	14–19 17	18–21 20	19–21 20
HL/BL		16–23 19	23–26 24	24–27 25	28–31 29	31–33 32
HW/HL		55–74 62	52–58 56	46–58 54	45–46 46	41–53 47
SnL/HL		20–25 23	23–25 24	19–27 23	19–21 20	20–22 21
ED/HL*		26–34× 33–45 29×40	28–30× 33–37 29×36	24–32× 27–40 28×33	22–25× 24–25 23×24	23–24× 23–24 23×23
P_1L/BL		5–8 7	7–8 7	8–15 12	†	25–28 27
P_2L/BL		0–0 0	0–1 0.5	2–9 5	‡	14–14 14

* Eye slightly elliptical; horizontal axis is given first, vertical axis second.
† P_1 rays broken.
‡ P_2 rays broken.

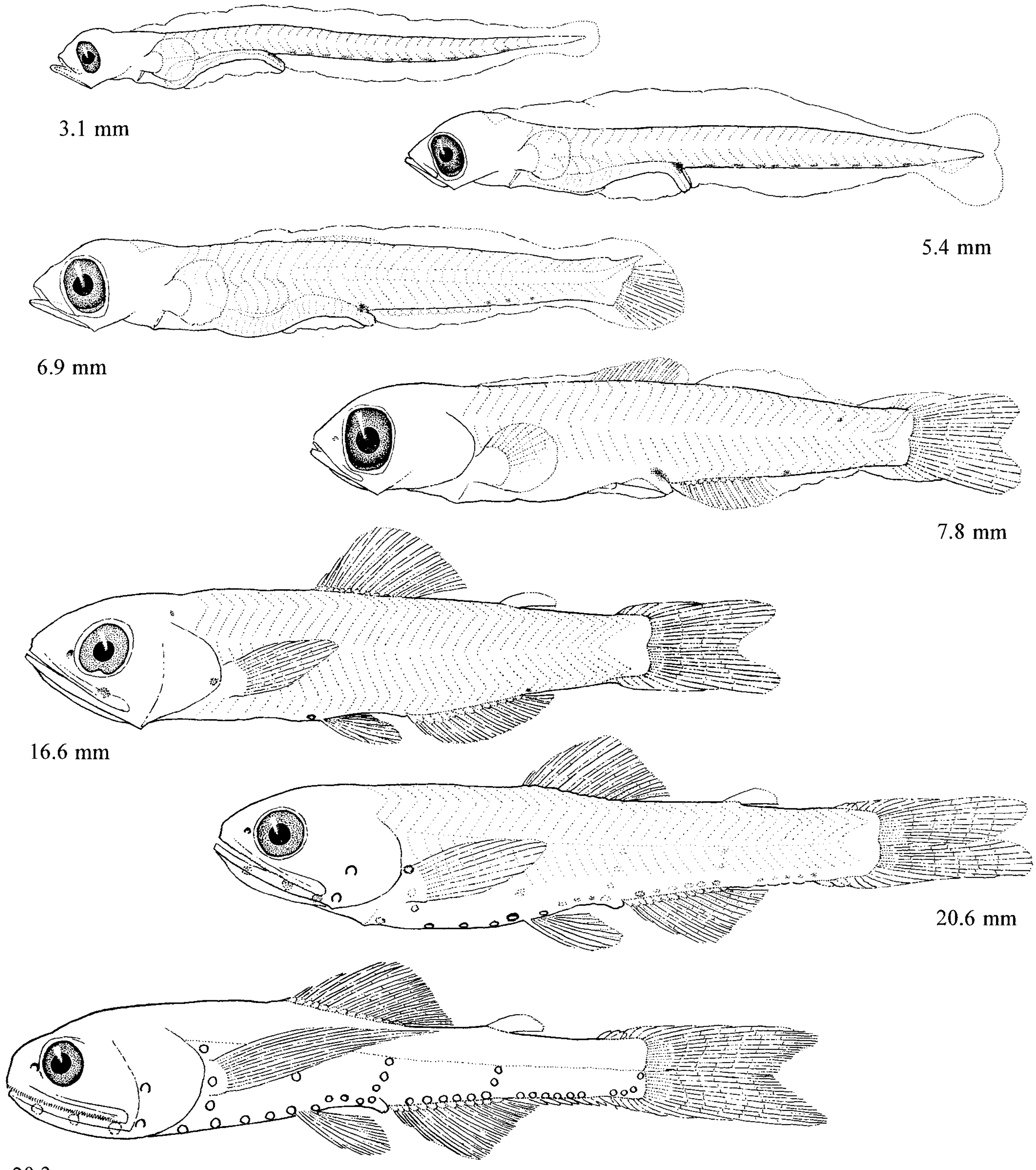


Figure Myctophidae 5. Preflexion larvae, 3.1 mm (CalCOFI 5908, station 93.90), 5.4 mm (CalCOFI 5910, station 100.60); flexion larva, 6.9 mm (CalCOFI 6604, station 103.90); postflexion larvae, 7.8 mm (CalCOFI 6610, station 123.50), 16.6 mm (Moser and Ahlstrom 1974); transformation specimen, 20.6 mm (NORPAC, station 80); juvenile, 20.3 mm (CalCOFI 4907, station 111.58).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–33	32
Precaudal	16	16
Caudal	16–17	16
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	11–13	12
Pelvic	8	8
Pectoral	9–10	10
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–7	6
Lower	5–6	6
Gill rakers:		
Upper	6–8	7
Lower	13–15	14
Branchiostegals		

LIFE HISTORY

Range: Eastern tropical Pacific from ca. 25° N to 15° S

Habitat: Epi- to mesopelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser & Ahlstrom 1974
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.1 mm, 2.8 mm (B. Sumida MacCall)
Late flexion larva, 4.3 mm (B. Sumida MacCall)
Postflexion larva, 7.5 mm (B. Sumida MacCall)
Juvenile, 9.8 mm (B. Sumida MacCall)

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* Identification of *D. pacificus* larvae is based on distribution, relative abundance, meristics & on extensive transformation series; see introduction to family for more detailed explanation.
† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.0 mm
Flexion length: ca. 4.0–4.5 mm
Transformation length: ca. 8.0–10.0 mm
Fin development sequence: C_1, D & A & C_2, P_1, P_2
Pigmentation: *Preflexion*—Initially, up to 7 dashes in postanal median ventral series (coalescing to 1 by 2.8 mm), 1 at future hypural region, 1 anteriorly on ventral margin of gut & a pair on terminal gut section; by 2.8 mm, 1 embedded above developing gas bladder. *Flexion–postflexion*—Same pattern; up to 4 in vertical series at posterior edge of hypural; 1 at A insertion.
Diagnostic features: Deep & compressed, becoming somewhat stout; head relatively large, eyes slightly elliptical with lunate choroid sliver; notochord flexion & transformation at small size; caudal melanophore typical of genus; early coalescense of postanal series; melanophore anteriorly on ventral margin of gut Br_2, PO_1, & PO_5 photophores form by ca. 6.6 mm; lower PVO, PO_2, & PO_3 by ca. 7.5 mm; Br_3, PO_4, upper Op, VLO, VO series, & some AOa the first to form at transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		44–56 50	56–61 58	57–64 60	61–64 62	62–65 64
BD/BL		15–23 19	23–27 25	28–30 29	25–27 26	26–27 27
HL/BL		22–26 24	27–30 29	28–32 30	30–31 31	31–33 32
HW/HL		59–63 61	58–60 59	59–65 62	50–53 52	47–56 52
SnL/HL		22–33 29	23–27 26	27–31 29	23–25 24	21–24 23
ED/HL†		30–39× 38–44	30–32× 34–38	23–34× 27–39	21–23× 23–24	21–23× 22–24
		35×40	31×36	28×32	22×24	22×23
P_1L/BL		5–8 6	6–8 7	7–12 9	13–16 15	 16
P_2L/BL		0–0 0	0.9–1 0.9	3–14 9	15–16 16	18–20 19

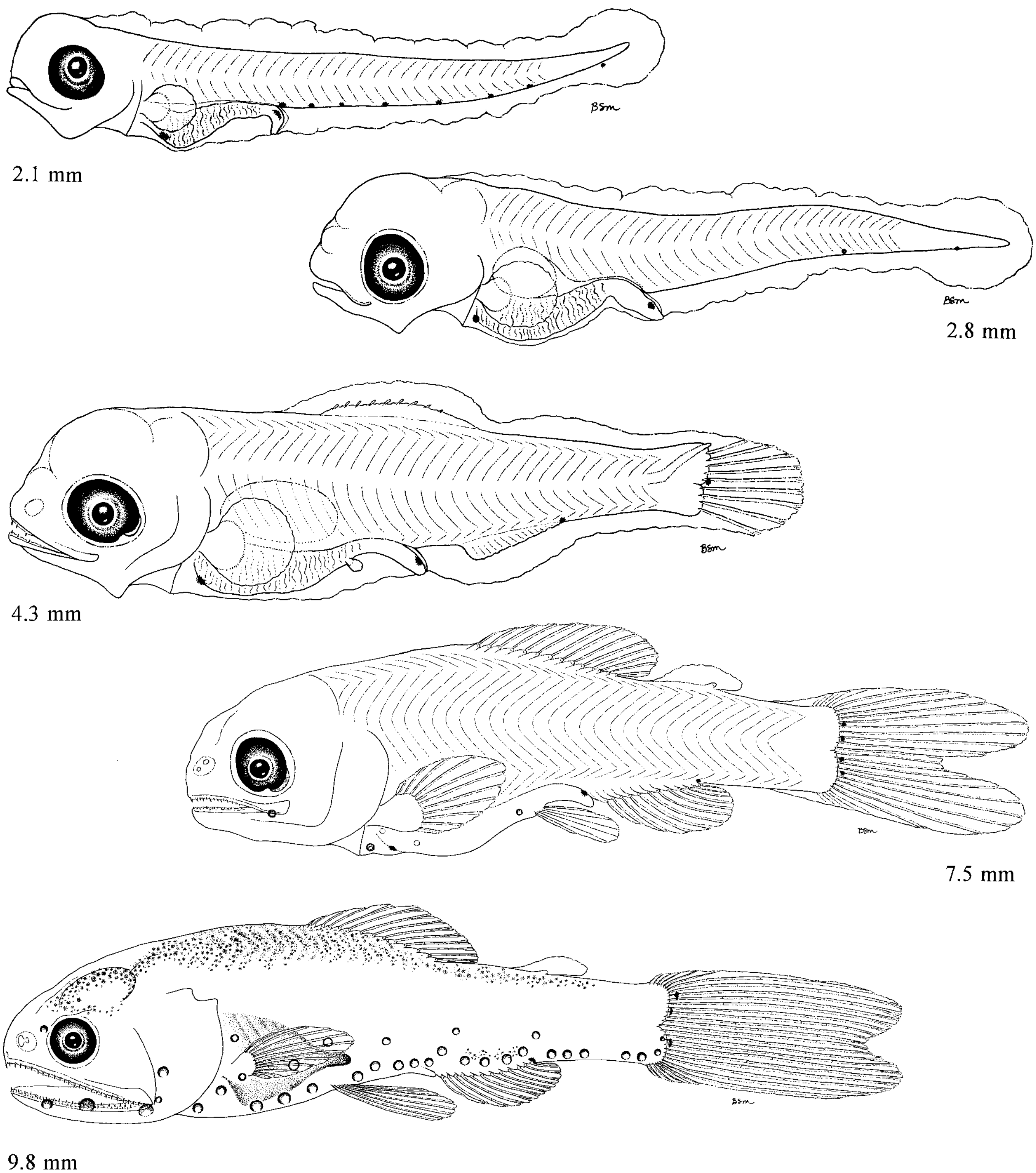

Figure Myctophidae 6. Preflexion larvae, 2.1 mm (EASTROPAC II, station 76.01a), 2.8 mm (CalCOFI 7210, station 157.35); late flexion larva, 4.3 mm (CalCOFI 5612, station 173.G.20); postflexion larva, 7.5 mm (CalCOFI 5612, station 167.G.40); juvenile, 9.8 mm (CalCOFI 7210, station 157.35).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	35
Precaudal	15–16	16
Caudal	18–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	12–14	13
Pelvic	8	8
Pectoral	10–12	10–11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	6–8	7
Gill rakers:		
Upper	6–7	6–7
Lower	14–16	15
Branchiostegals	9	9

LIFE HISTORY

Range: Common in California Current region to 20° S & throughout subarctic-transitional waters westward to northern Japan

Habitat: Epi- to mesopelagic

Spawning season: Larvae present throughout the year in CalCOFI area; highest abundance in the spring–summer, with peak in July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Matarese et al. 1989
Moser & Ahlstrom 1974
Moser et al. 1984a
Pertseva-Ostroumova 1964

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.2 mm, 4.4 mm (B. Sumida MacCall)
Flexion larva, 5.8 mm (B. Sumida MacCall)
Postflexion larvae, 7.8 mm, 8.6 mm (B. Sumida MacCall)
Juvenile, 14.7 mm (B. Sumida MacCall)

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* Identification of *D. theta* larvae is based on distribution, relative abundance, meristics & on extensive transformation series; see introduction to family for more detailed explanation.

† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: ca. 5.5–6.8 mm
Transformation length: ca. 11–14 mm
Fin development sequence: C_1, D & A & C_2, P_1, P_2
Pigmentation: *Preflexion*—Initially, up to 15 dashes in postanal median ventral series, with little coalescence (10–14 dashes) in preflexion larvae; earliest larvae have a pair on terminal gut section, 1 in the caudal region region & 2 lateral gut pairs (1 at ca. midgut & 1 anteriorly); by ca. 4.4 mm, the anterior lateral gut pair has moved anteroventrad; by ca. 5.2 mm, 1 present above the gas bladder. *Flexion*—9–11 in postanal series; anteroventral pair on gut coalesces to 1 on ventral midline. *Postflexion*—Postanal series coalesces to ca. 5–6 embedded blotches; 1–4 in vertical series on posterior hypural edge.
Diagnostic features: Slender body becoming somewhat compressed & less slender with development; head relatively small; snout relatively short; eyes slightly elliptical with lunate choroid tissue; relative eye size increases with development; gut moderate in length, slightly sigmoid; anteroventral pair of melanophores on gut coalesces in ventral midline during flexion stage; postanal pigment series persists throughout larval period (vs. early coalescence in the deep-bodied, big-headed *D. pacificus*); Br_2 photophores form by 6–9 mm; PO_5 by 7.5 mm; PO_1 by 8.2 mm; PO_2, PO_3, VO_1, & AOa_1 by ca. 10.5 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–53 48	48–55 52	56–61 58	61–64 62	60–63 62
BD/BL		10–14 12	13–17 15	19–23 21	25–26 25	24–26 25
HL/BL		15–21 19	21–25 23	23–27 25	27–28 27	27–30 28
HW/HL		50–64 60	54–59 57	53–67 57	52–57 54	47–54 50
SnL/HL		9–28 21	23–25 24	22–27 23	19–20 19	18–21 19
ED/HL†		25–31× 32–41	25–28× 30–34	29–32× 29–37	30–30× 33–35	28–32× 28–32
		27×35	27×32	31×33	30×34	30×30
P_1L/BL		4–8 6	6–8 7	7–11 9	11–12 12	13–16 15
P_2L/BL		0–0 0	0–0.6 0.2	0.6–11 6	12–15 14	16–18 17

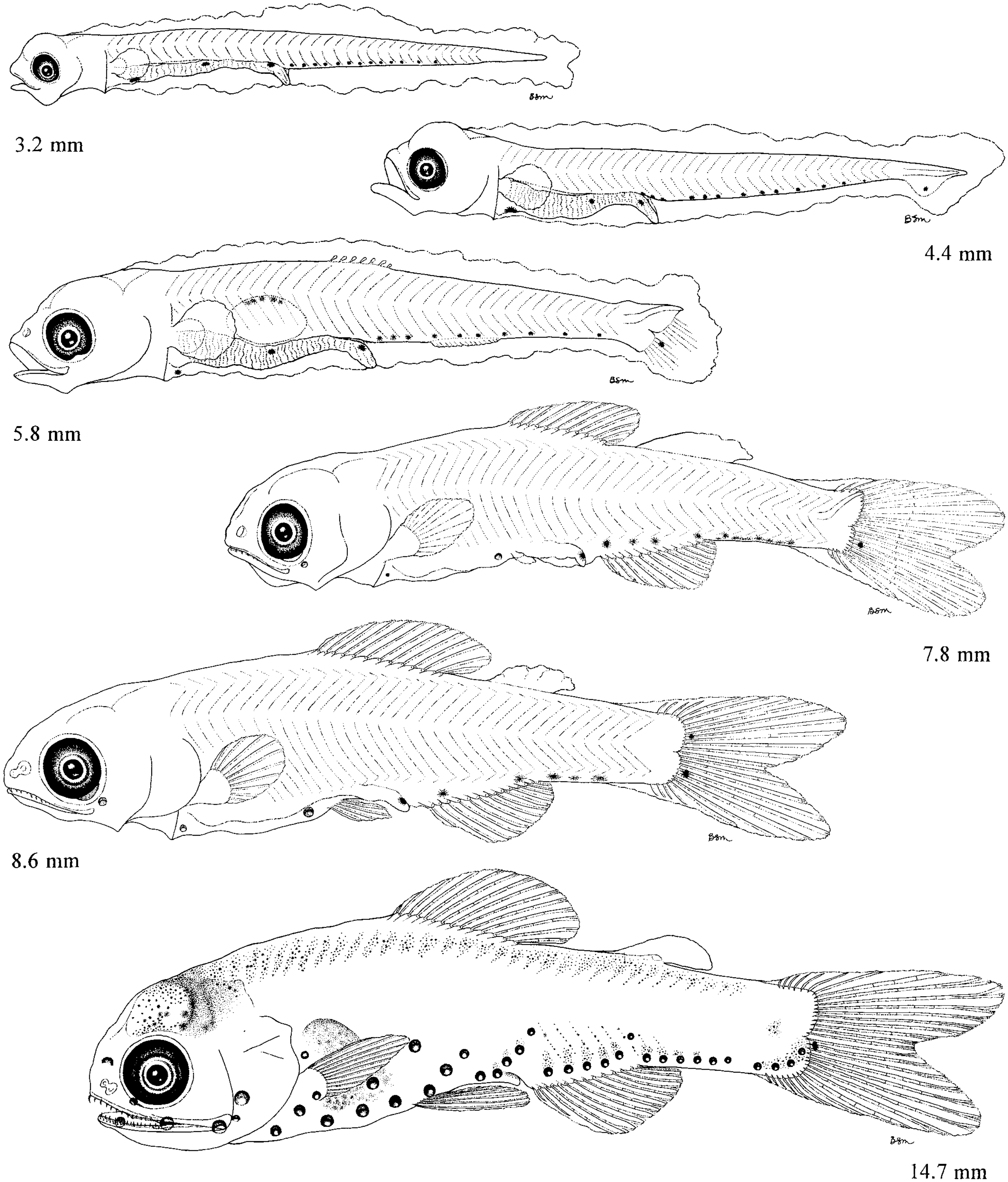

Figure Myctophidae 7. Preflexion larvae, 3.2 mm (CalCOFI, station 5908, station 87.75), 4.4 mm (CalCOFI 5406, station 70.70); flexion larva, 5.8 mm; postflexion larvae, 7.8 mm, 8.6 mm (CalCOFI 4907, station 59.117); juvenile, 14.7 mm (CalCOFI 6608, station 87.70).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	37
Precaudal	16	16
Caudal	20–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	14–16	15
Anal spines	0	0
Anal rays	13–14	13–14
Pelvic	8	8
Pectoral	14–17	15–16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	8
Lower	8–9	9
Gill rakers:		
Upper	3–5	4
Lower	9–11	8–9
Branchiostegals	9–10	9

LIFE HISTORY

Range: Eastern North Pacific between ca. 25° & 42° N; in northwest Pacific at 10°–30° N; in central Pacific at 0°–35° N; off Australia; a subspecies occurs in the subtropical Atlantic

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout the year in CalCOFI area; highest abundance in the summer & fall, with a peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fahay 1983
Matarese et al. 1989
Moser & Ahlstrom 1972
Moser 1981
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.7 mm, 5.6 mm (G. Mattson)
Flexion larva, 6.8 mm (G. Mattson)
Postflexion larva, 8.8 mm (G. Mattson)
Transformation specimen, 20.9 mm (G. Mattson)

* Eye slightly elliptical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.9 mm
Flexion length: ca. 6.8–8.3 mm
Transformation length: ca. 17–21 mm
Fin development sequence: C_1, P_1, A & D & C_2, P_2
Pigmentation: *Preflexion*—Initially, 1 above developing gas bladder, 1 above preanal arch of gut, & 1 on ventral margin midway between anus & notochord tip; at ca. 4.2 mm, 1 on dorsal midline apposing the one at ventral midline; at ca. 6.2–6.5 mm, 1 at future D insertion, 1 embedded just posterior to P_1 base, & 1 embedded ventrolaterally on surface of hindbrain. *Flexion*—At 6.5–7.0 mm, on dorsal midline at nape & D origin, above & below caudal peduncle, pair on A base, & 2 in midline embedded above gut; at 7.0–8.3 mm, on dorsal midline at cerebellum & anterior to Ad, pairs dorsally at Ad & D insertion, & 2 more in embedded midline series above gut. *Postflexion*—Additional midline & paired melanophores along dorsum & postanal ventrum in some specimens.
Diagnostic features: Moderate body depth; gut to midbody, slightly sigmoid; head size moderate; eyes relatively large, slightly elliptical with choroid sliver; distinctive pigment with large, dense melanophores; Br_2 photophores form by 6.5–7.2 mm; PLO by 7.2–8.0 mm; PO_5 by 8.5–9.5 mm; PO_1 & Vn by 13.5 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–63 55	63–66 64	62–67 64	62–63 63	59–60 60
BD/BL		12–17 13	18–22 20	21–27 24	23–26 24	20–21 21
HL/BL		17–25 21	27–29 27	27–31 28	27–29 28	29–33 30
HW/HL		59–88 68	57–63 61	47–65 58	59–64 62	39–51 46
SnL/HL		19–28 22	17–24 21	21–29 23	20–21 21	18–20 19
ED/HL*		29–42× 32–38 32×35	31–37× 35–40 34×37	26–36× 26–40 32×35	25–30× 25–32 28×29	20–25× 20–25 22×23
P_1L/BL		7–8 7	8–12 9	11–14 13	16–17 17	22–23 22
P_2L/BL		0–0 0	0.6–1 1	3–10 6	13–15 13	14–15 15

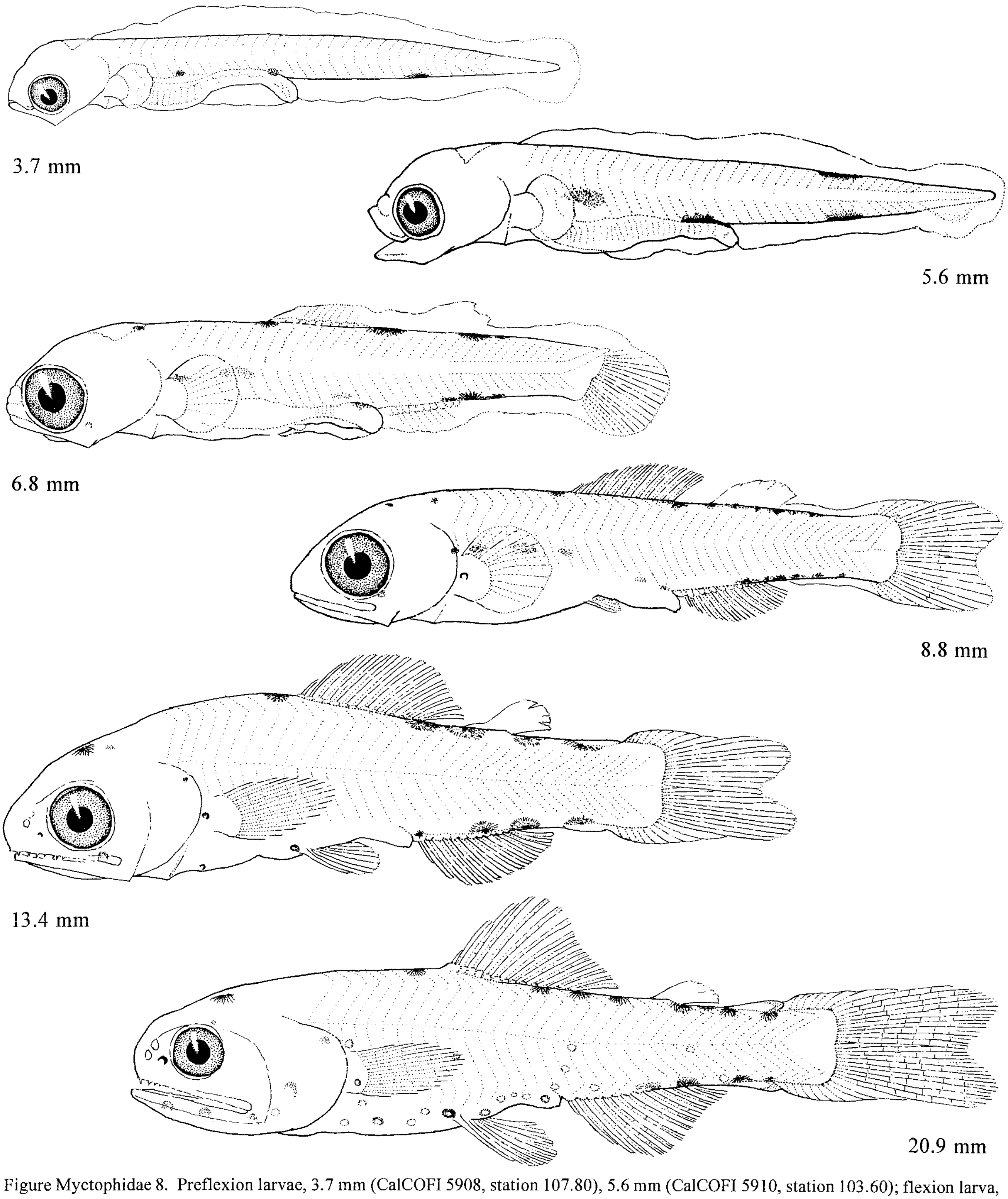

Figure Myctophidae 8. Preflexion larvae, 3.7 mm (CalCOFI 5908, station 107.80), 5.6 mm (CalCOFI 5910, station 103.60); flexion larva, 6.8 mm (CalCOFI 5909, station 120.40); postflexion larvae, 8.8 mm (CalCOFI 6507, station 127.80), 13.4 mm (Moser 1981); transformation specimen, 20.9 mm (CalCOFI 5908, station 107.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–37	36
Precaudal	14–16	15
Caudal	19–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	13–14	13
Anal spines	0	0
Anal rays	16–18	17
Pelvic	8	8
Pectoral	13–15	14–15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–10	9
Lower	9–11	10
Gill rakers:		
Upper	5–6	5
Lower	10–12	11
Branchiostegals		

LIFE HISTORY

Range: North Pacific central water mass between ca. 20° & 35° N, east to the western margin of the California Current

Habitat: Mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.2 mm, 4.2 mm (B. Sumida MacCall)
Flexion larva, 5.2 mm (B. Sumida MacCall)
Postflexion larva, 10.8 mm (B. Sumida MacCall)
Transformation specimen, 25.0 mm (B. Sumida MacCall)

* P_2 rays broken in transformation specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 5.0–6.0 mm
Transformation length: ca. 15.0–18.4 mm
Fin development sequence: C_1, D & A & C_2 & P_2, P_1
Pigmentation: *Preflexion*—1 on dorsal surface of terminal gut section in smallest larvae; by 3.5 mm, 1 above developing gas bladder & 1 at tip of lower jaw; by 4.5 mm, most specimens have 1 in midline above cerebellum, 1 anterior to Ad region, & 1 at upper jaw tip. *Flexion–postflexion*—As above; most larvae >8.0 mm have 1 embedded at cleithrum near upper edge of P_1 base; anterior trunk myosepta outlined by ca. 16.0 mm.
Diagnostic features: Large, deep head with large jaws, armed with strong, curved teeth; largest teeth at jaw tips; large round eyes; body tapered & compressed initially, becoming somewhat robust in postflexion stage; gut short & sharply sigmoid initially; pigment sparse but diagnostic; Br_2 photophores form at ca. 7.0 mm; high procurrent C ray count (8–10+9–11).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–60	64–67	61–68	55–60	55–56
		52	66	65	58	56
BD/BL		15–26	25–31	25–29	19–25	17–19
		22	28	28	22	18
HL/BL		23–33	33–38	28–36	30–33	27–28
		29	35	32	32	27
HW/HL		50–67	46–53	45–57	36–44	42–43
		57	49	51	40	42
SnL/HL		30–43	36–38	29–36	20–24	16–18
		37	37	33	22	17
ED/HL		34–46	32–37	27–35	24–27	21–22
		37	34	32	25	22
P_1L/BL		6–8	9–10	9–13		
		7	10	11	15	35
P_2L/BL		0–1	5–10	11–19	*	9–13
		0.2	8	16		11

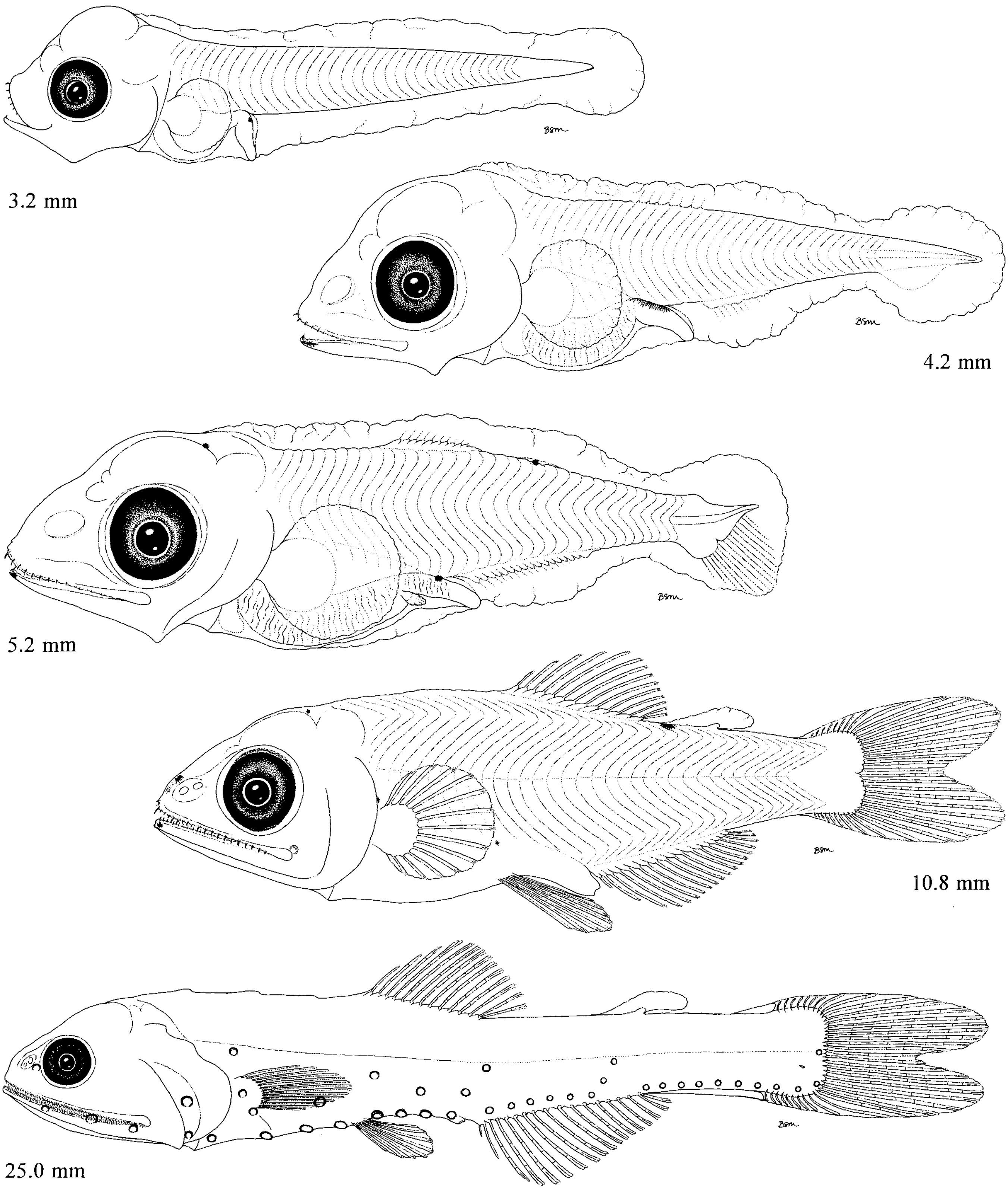

Figure Myctophidae 9. Preflexion larvae, 3.2 mm (Southtow, station 13–76), 4.2 mm (Tasaday XI, station A2); flexion larva, 5.2 mm (Tasaday XI, station A2); postflexion larva, 10.8 mm (Southtow, station A4); transformation specimen, 25.0 mm (Tasaday XI, station A2).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–39	38
Precaudal	16	16
Caudal	21–23	21
Fins:		
Dorsal spines	0	0
Dorsal rays	14–15	14–15
Anal spines	0	0
Anal rays	17–19	18
Pelvic	8	8
Pectoral	13–14	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	6
Lower	6–7	7
Gill rakers:		
Upper	3–4	3
Lower	9–11	10
Branchiostegals		

LIFE HISTORY

Range: Circumglobal in tropics except extreme eastern Pacific Ocean; at western margin of CalCOFI survey area

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Miller et al. 1979
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.5 mm (N. Arthur)
Flexion larva, 6.2 mm (N. Arthur)
Postflexion larva, 9.6 mm (N. Arthur)
Transformation specimen, 18.3 mm (N. Arthur)

* Eye slightly elliptical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.5 mm
Flexion length: ca. 5.0–6.5 mm
Transformation length: ca. 20 mm
Fin development sequence: C_1, D & A & C_2, P_1, P_2
Pigmentation: *Preflexion–postflexion*—1 above & 1 anterior to forebrain; 1 above cerebellum; at lower jaw symphysis; on midline of gular region between urohyal & symphysis, usually 1 in larvae <4.0 mm, 2–4 in larger larvae; blotch above gas bladder; 1 embedded medially anterior to gut mass; beginning at ca. 12 mm, series on myosepta anterior to P_2; in late larvae, myosepta of entire trunk outlined between P_1 & P_2 bases.
Diagnostic features: Large head; large, nearly round eyes; large jaws with prominent teeth & tooth patch at tip of upper jaw; gut short, sigmoid; body sharply tapered in early larvae, robust in late larvae; distinctive pigment pattern with median gular series; Br_2 photophores form at ca. 10 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–54 50	58–61 59	57–64 62	55	
BD/BL		21–25 23	23–28 26	26–32 30	20	
HL/BL		29–33 31	33–34 34	28–39 35	27	
HW/HL		41–58 49	42–44 43	40–50 45	41	
SnL/HL		22–40 36	36–44 39	23–37 31	22	
ED/HL*		29–36× 35–41	31–33× 32–35	25–34× 25–37		
		34×39	32×34	30×32	22	
P_1L/BL		4–10 7	6–8 7	10–11 11	13	
P_2L/BL		0–0 0	0–0 0	0.3–8 5	12	

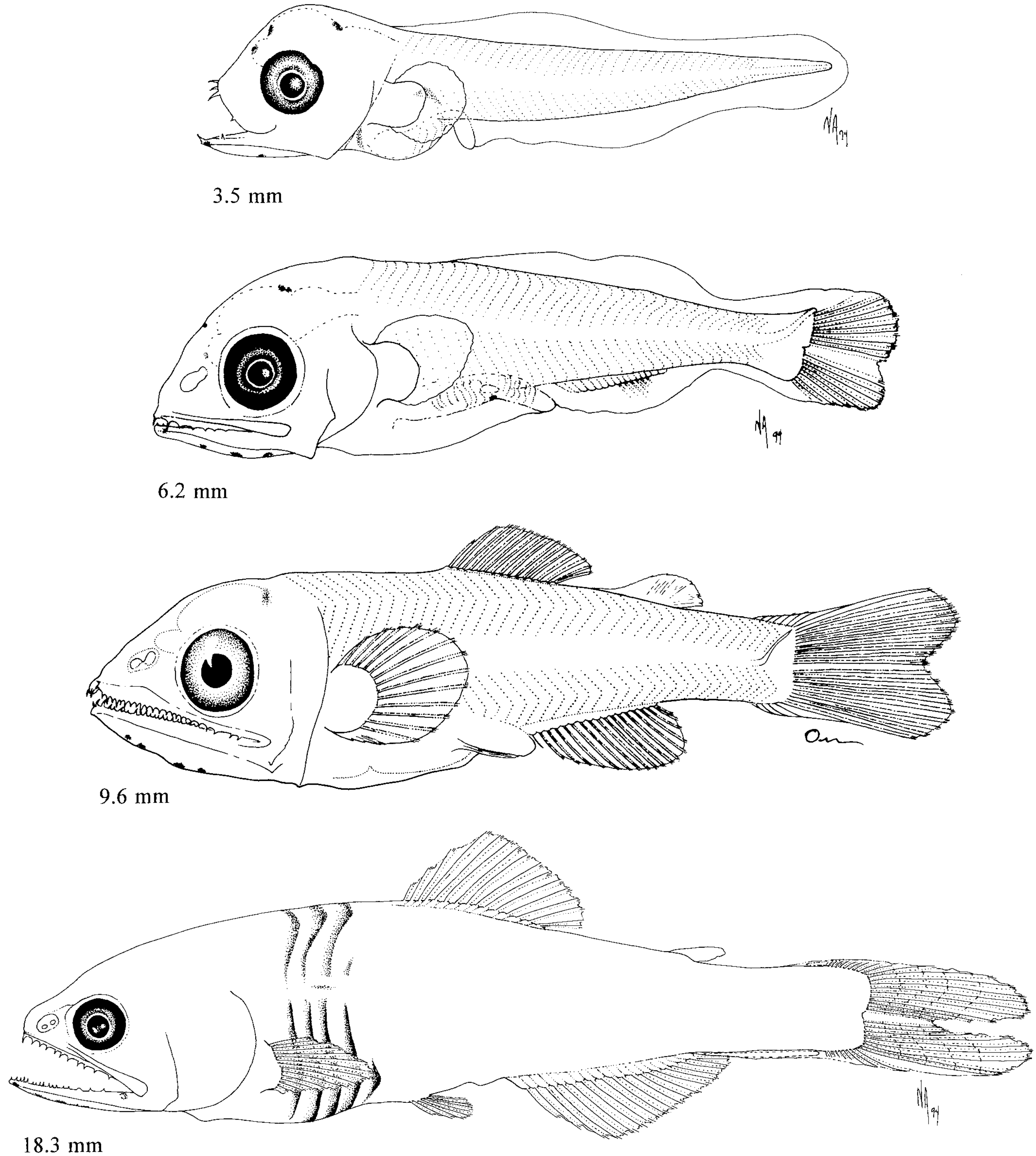

Figure Myctophidae 10. Preflexion larva, 3.5 mm (Cato II, station A7); flexion larva, 6.2 mm (Clarke-Hawaii, station 71–6–17); postflexion larva, 9.6 mm (Moser et al. 1984a); transformation specimen, 18.3 mm (Clarke-Hawaii, station 71–6–5).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	36–37
Precaudal	15–16	16
Caudal	19–21	19–20
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	17–20	18
Pelvic	8	8
Pectoral	12–15	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	7
Lower	7–8	7
Gill rakers:		
Upper	3–4	3
Lower	9–11	10
Branchiostegals		

LIFE HISTORY

Range: Eastern Pacific from ca. 20° N to 15° S & the Gulf of California

Habitat: Mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.7 mm, 4.2 mm (N. Arthur)
Flexion larva, 5.7 mm (N. Arthur)
Transformation specimen, 15.0 mm (N. Arthur)
Juvenile, 25.0 mm (N. Arthur)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: ca. 5.7–7.0 mm
Transformation length: ca. 14.5–16.5 mm
Fin development sequence: C_1, D & A & P_1, C_2, P_2
Pigmentation: *Preflexion–postflexion*—Initially, 1 on ventral midline of gut just posterior to cleithrum, a pair on terminal gut section, ca. 8 in postanal ventral midline series; by ca. 4.0 mm, 1 in midline anterior to forebrain, 1 posterior to each lobe of cerebellum, 1 at dorsum where Ad will form, at lower jaw symphysis, above gas bladder, & 2–5 in postanal ventral series; only 1 at postanal ventral midline with 1 apposing it at Ad base in flexion & postflexion larvae. *Late postflexion*—Beginning at ca. 11 mm, trunk myosepta anterior to P_2 become outlined, initially ventrally & progressing dorsad.
Diagnostic features: In early preflexion larvae the gut is straighter than in other species of the genus; body highly compressed, becoming robust in late postflexion stage; snout somewhat blunt; presence of a postanal pigment series unusual for genus; pigment pattern distinct in flexion–postflexion stages; eye slightly elliptical with lunate choroid sliver; Br_2 photophores form at ca. 11.0 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–54 44	55–59 57	59–63 61	56–60 59	55–57 56
BD/BL		11–22 16	21–26 23	26–31 28	23–26 24	18–20 19
HL/BL		17–26 21	28–29 28	28–31 30	31–35 33	28–30 29
HW/HL		45–60 53	41–42 42	40–55 46	42–44 43	44–45 44
SnL/HL		23–32 26	31–35 33	29–36 34	26–28 27	20–23 22
ED/HL*		31–38× 34–40	28–30× 29–33	20–28× 23–29	22–24	18–20
		34×37	29×31	24×25	23	19
P_1L/BL		4–8 6	8–9 8	10–13 11	8–10 9	9–23 16
P_2L/BL		0–0 0	0–0.6 0.2	2–9 5	8–10 9	6–12 9

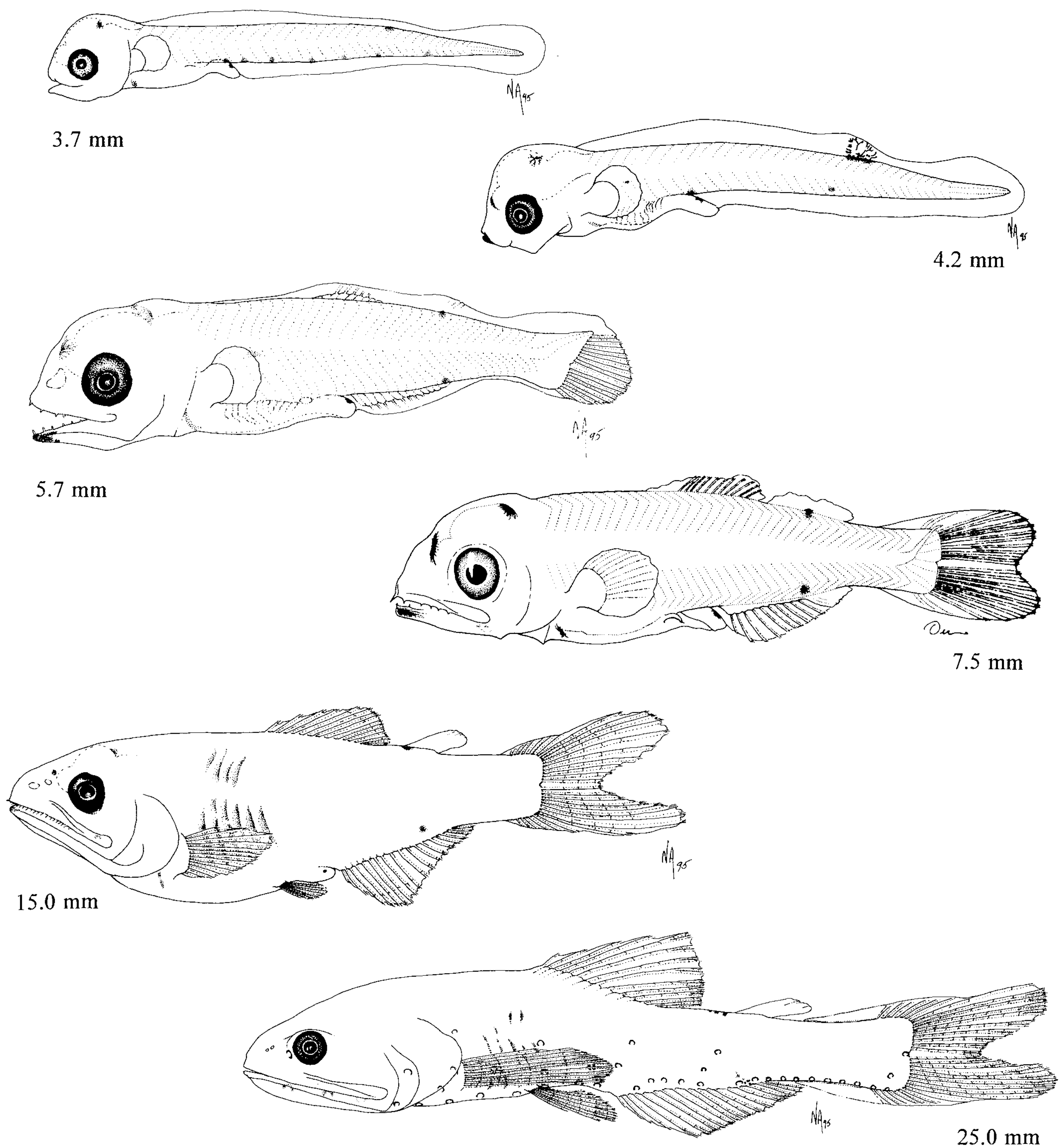

Figure Myctophidae 11. Preflexion larvae, 3.7 mm (CalCOFI 7201, station 137.35), 4.2 mm (CalCOFI 7202, station 150.55); flexion larva, 5.7 mm (EASTROPAC II, station OP.023); postflexion larva, 7.5 mm (Moser et al. 1984a); transformation specimen, 15.0 mm (Scope, station 9–2–C1); juvenile, 25.0 mm (CalCOFI 5205, station 137.50).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	35
Precaudal	14–15	15
Caudal	19–20	20
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	12–13
Anal spines	0	0
Anal rays	16–19	17–18
Pelvic	8	8
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7	7
Lower	6–8	7
Gill rakers:		
Upper	3–4	3–4
Lower	9–11	10
Branchiostegals		

LIFE HISTORY

Range: Widespread in tropical & subtropical waters of the eastern Pacific; possibly in Indian Ocean

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.5 mm (N. Arthur)
Flexion larva, 5.0 mm (N. Arthur)

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* *L. steinbecki* is closely related to *L. tenuiformis* & to a third species, *L. festivus*, reported to occur in the CalCOFI area (Berry & Perkins 1966; Wisner 1976; Bekker 1983). The taxonomic status of these species, particularly the latter two, is unresolved. We identify two distinct larval types as *L. steinbecki* & *L. tenuiformis* based on the distribution & relative abundance of adults & larvae. Confirmation of our identifications awaits the collection of complete transformation series & taxonomic resolution of the species complex.

† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: ca. 4.0–6.0 mm
Transformation length: ca. 20 mm
Fin development sequence: C_1, P_1, D & A, P_2 & C_2
Pigmentation: *Preflexion*—Embedded in otic region; at upper & lower jaw tips; 1 or 2 at lateral midline above P_1 base; on inner surface of P_1 base & adjacent trunk; above gas bladder; by 3.7 mm, on ventral midline below gut, on opercle, on terminal gut section; on some P_1 rays near bases. *Flexion*—Blotch at basibranchial region; embedded in preopercular region; usually 2–3 in lateral midline series; embedded series above spinal column in late flexion stage. *Postflexion*—Lateral to basibranchial region; up to 6 in lateral midline series & 9 in spinal column series; on P_2 in some.
Diagnostic features: Early larvae deep-bodied & strongly tapered, becoming highly robust & stout; head & eyes large; snout blunt; distinct pigment pattern with basibranchial blotch that is absent in putative *L. tenuiformis* larvae; Br_2 photophores form at ca. 5.0 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–60 52	62–71 66	60–70 66		
BD/BL		24–34 28	36–41 39	38–41 40		
HL/BL		29–33 31	34–38 35	32–37 35		
HW/HL		55–64 58	58–75 66	60–81 68		
SnL/HL		34–42 38	30–37 34	25–33 30		
ED/HL†		30–40× 32–46 35×40	41–42× 45–47 42×46	35–48× 37–52 41×44		
P_1L/BL		6–7 7	8–13 11	14–15 15		
P_2L/BL		0–0 0	2–9 5	10–13 12		

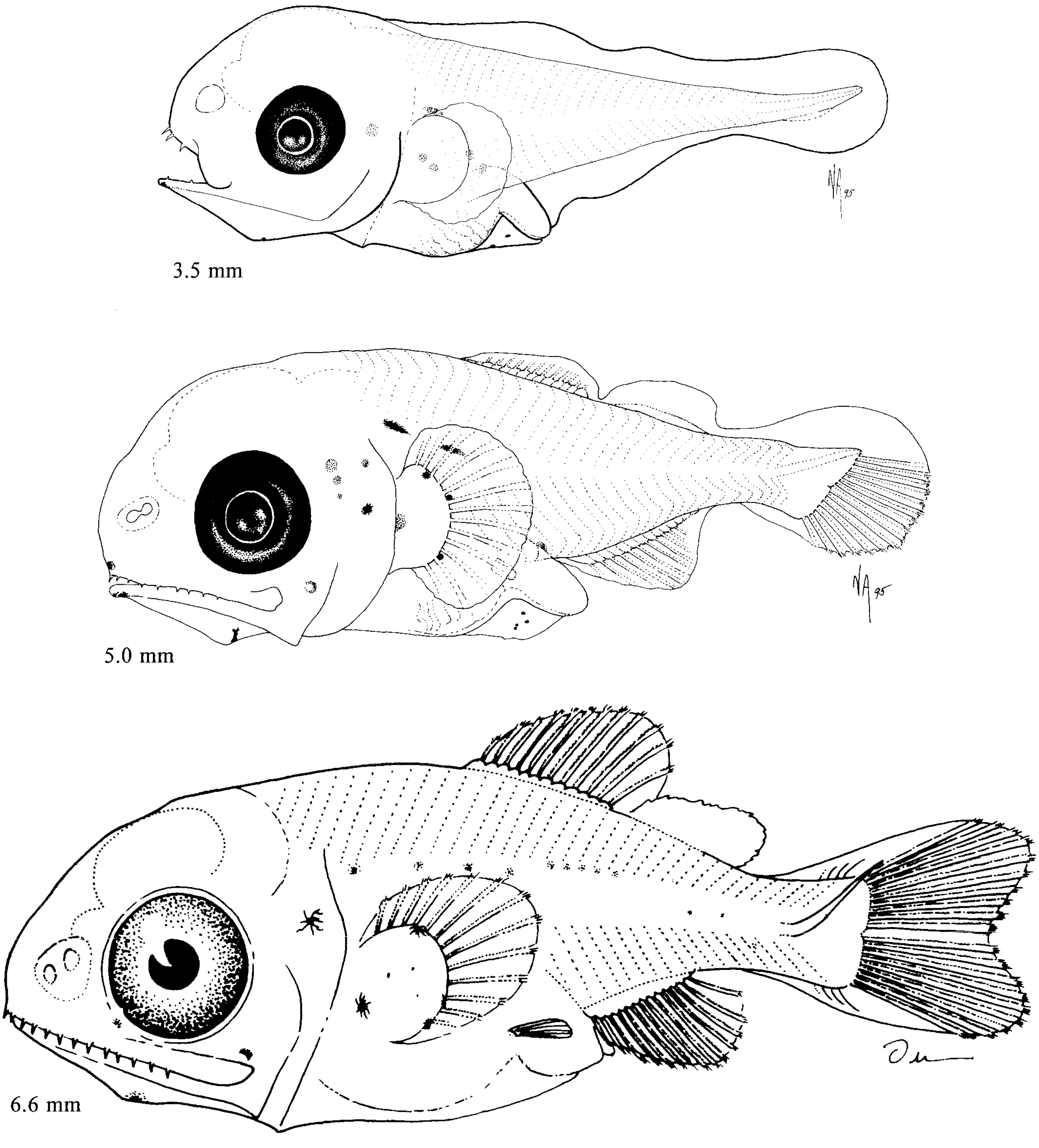

Figure Myctophidae 12. Preflexion larva, 3.5 mm (CalCOFI 6207, station 90.150); flexion larva, 5.0 mm (CalCOFI 6207, station 90.120); postflexion larva, 6.6 mm (Moser et al. 1984a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–37	36
Precaudal	14–16	15
Caudal	19–21	20
Fins:		
Dorsal spines	0	0
Dorsal rays	13–14	13–14
Anal spines	0	0
Anal rays	17–18	17–18
Pelvic	8	8
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–8	7
Lower	7–8	7
Gill rakers:		
Upper	4–5	4
Lower	10–12	10
Branchiostegals		

LIFE HISTORY

Range: Apparently circumglobal in tropics & subtropics; taxonomy unsettled

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (N. Arthur)
Flexion larva, 4.7 mm (N. Arthur)
Postflexion larva, 7.1 mm (N. Arthur)

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* See comments on *L. tenuiformis* species complex in the description of *L. steinbecki* larvae.
† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.0 mm
Flexion length: ca. 4.2–5.0 mm
Transformation length: <20 mm
Fin development sequence: C_1, D & A & P_1, C_2, P_2
Pigmentation: *Preflexion*—Similar to *L. steinbecki. Flexion*—Similar to *L. steinbecki* but none in basibranchial region, usually only 1 on lateral midline, 1 on upper P_1 rays; 1 (large) on finfold just anterior to anus. *Postflexion*—Most pigment embedded & masked; none above spinal column.
Diagnostic features: Early larvae deep-bodied & strongly tapered, becoming stout; head & eye large; snout blunt; body less stout & snout not as blunt as in *L. steinbecki*; flexion & postflexion larvae lack pigment in basibranchial region & above spinal column; prominent melanophore in finfold anterior to anus; Br_2 photophores form at ca. 5.0 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–57 55	61–65 63	57–66 62		
BD/BL		26–31 29	35–40 37	24–38 32		
HL/BL		29–34 32	35–36 35	26–38 32		
HW/HL		50–58 54	48–64 55	48–63 57		
SnL/HL		35–37 36	34–39 36	20–35 29		
ED/HL†		37–40× 39–43 38×41	35–48× 40–52 41×44	26–43× 26–48 38×40		
P_1L/BL		6–8 7	8–9 8	9–14 12		
P_2L/BL		0–0 0	0.9–3 2	3–10 7		

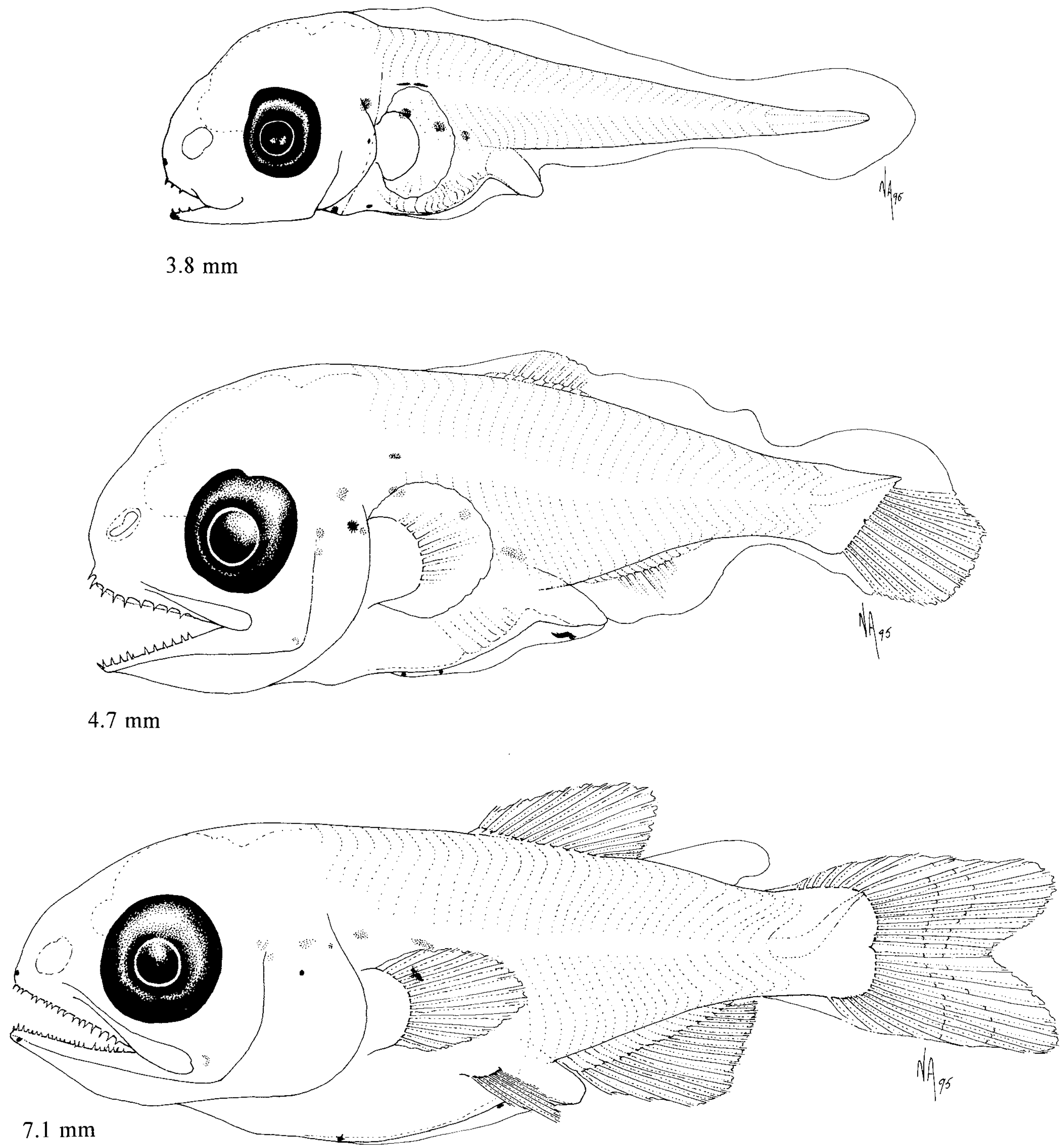

Figure Myctophidae 13. Preflexion larva, 3.8 mm (Clarke-Hawaii, station 71–10–7); flexion larva, 4.7 mm (CalCOFI 7205, station 20.145); postflexion larva, 7.1 mm (CalCOFI 7205, station 24.129).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–35	35
Precaudal	15–17	16
Caudal	18–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	16–18	17
Anal spines	0	0
Anal rays	13–15	14
Pelvic	8	8
Pectoral	11–13	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	6
Lower	5–6	6
Gill rakers:		
Upper	4–6	
Lower	11–15	
Branchiostegals		

LIFE HISTORY

Range: Tropical-subtropical cosmopolite

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fahay 1983
Moser & Ahlstrom 1974
Moser et al. 1984a
Ozawa 1986b, 1988d
Pertseva-Ostroumova 1964, 1974
Sanzo 1931b
Shiganova 1977
Tåning 1918

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.2 mm (N. Arthur)
Late flexion larva, 5.6 mm (N. Arthur)
Transformation specimen, 11.8 mm (N. Arthur)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2 mm
Flexion length: ca. 5.0–6.0 mm
Transformation length: ca. 12–14 mm
Fin development sequence: P_1 C_1, D & A, C_2, P_2
Pigmentation: *Preflexion*—At 3.0–4.0 mm, blotch on lower inner surface of P_1 base, deeply embedded blotch anterior to P_1 base blotch, ventral midline cluster on gut just posterior to cleithral symphysis, pair on terminal section of gut, scattered basally on P_1 rays, & embedded blotch above gas bladder; at >4.0 mm, 1 in midline at A insertion. *Flexion*—Basally A rays; on ventral midline below gut. *Postflexion*—Superficial & embedded on myosepta, beginning at anterior gut region and, by 7.0 mm, on epaxial region above gut; two blotches on basal region of C; some added to inner surface of P_1 base; on P_2 in some specimens.
Diagnostic features: Stout body with deep, broad head, large oval eyes with lunate ventral choroid sliver; bilobed P_1 with upper 5 rays early-forming & upper 4 rays elongate; prominent teeth in small larvae; Br_2 photophores form by 6 mm; PO_1 & PO_5 by 7 mm; VO_1, AOa_1, AOa_2, VLO, & OP by 11 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–56 52	54–58 56	61–65 63	 61	60–62 61
BD/BL		15–24 20	24–29 27	30–38 33	 35	25–27 26
HL/BL		27–33 30	32–33 32	27–38 34	 35	32–33 32
HW/HL		63–71 68	69–72 71	57–76 66	 51	48–52 50
SnL/HL		25–40 35	25–29 28	27–34 30	 23	21–23 22
ED/HL*		25–33× 40–50	32–33× 37–40	21–31× 23–33		21–23
		29×44	32×38	27×30	22	22
P_1L/BL		9–13 10	14–21 18	21–30 27	 18	 15
P_2L/BL		0–0 0	0–0.7 0.2	6–17 11	 16	16–18 17

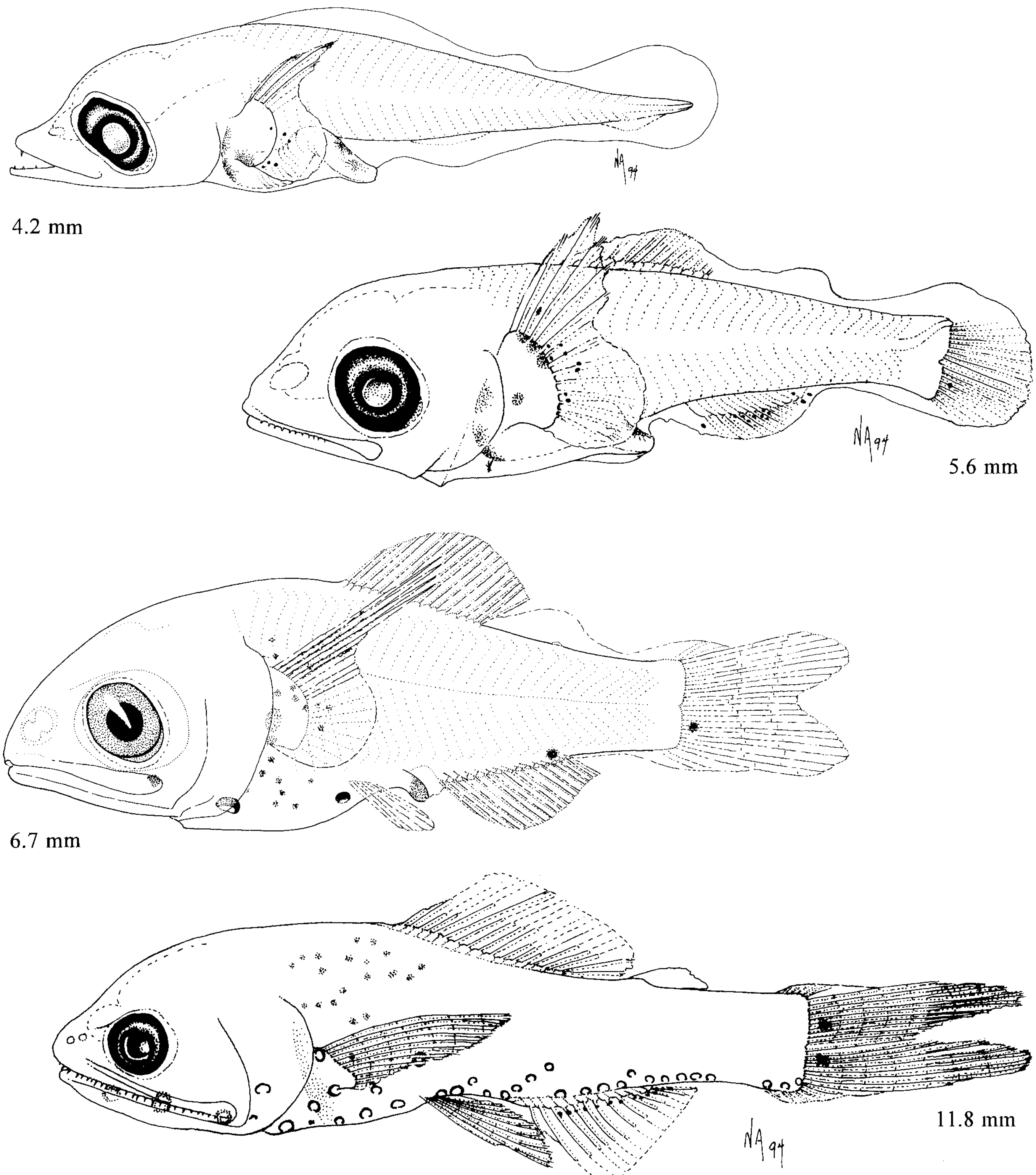

Figure Myctophidae 14. Preflexion larva, 4.2 mm (CalCOFI 7205, station 24.139); late flexion larva, 5.6 mm (CalCOFI 7205, station 24.139); postflexion larva, 6.7 mm (Moser and Ahlstrom 1974); transformation specimen, 11.8 mm (Clarke-Hawaii, station 70–9–6).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–34	32
Precaudal	13–15	14
Caudal	17–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	11–14	13
Anal spines	0	0
Anal rays	16–20	17–18
Pelvic	8	8
Pectoral	10–13	11–12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	6–8	7
Gill rakers:		
Upper	4–5	4
Lower	10–12	11
Branchiostegals	9–11	9

LIFE HISTORY

Range: In Pacific east of 135° W from ca. 33° N to 25° S

Habitat: Epi- to mesopelagic

Spawning season: Larvae captured during all seasons on CalCOFI surveys

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.5 mm, 4.4 mm (G. Mattson)
Flexion larva, 5.5 mm (G. Mattson)
Postflexion larva, 10.8 mm (G. Mattson)
Juvenile, 21.0 mm (G. Mattson)

* Eye slightly elliptical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 5.3–6.3 mm
Transformation length: >11.7 mm, <20 mm
Fin development sequence: C_1 & D & A & P_1 & P_2, C_2
Pigmentation: *Preflexion*—Pair on snout by 2.7 mm; 1 above eye by 3.5 mm; pair on terminal gut section & above gas bladder by 4.0 mm; 1 posterior to eye & at nape (in some specimens) by 4.5 mm. *Flexion*—1 embedded anterior to upper margin of P_1 base; 1 embedded in upper gill arch region; series above gas bladder. *Postflexion*—By ca. 8.6 mm, 1 on preopercle posterior to the one at postorbital region & myosepta becoming outlined in gut region.
Diagnostic features: Head large & compressed; large jaws & moderately large teeth of nearly uniform size; body tapered & compressed becoming stout in postflexion stage; gut short & strongly flexed, becoming straighter & moderate in length; pigment pattern distinct with supra- & postorbital melanophores; no pigment above brain; Br_2 photophores form at ca. 6.3 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–59 45	58–68 62	60–65 63		54–55 55
BD/BL		14–26 19	23–27 25	27–31 29		19–20 20
HL/BL		17–31 24	30–32 31	30–35 32		30–30 30
HW/HL		41–68 55	42–49 46	46–52 50		46–49 48
SnL/HL		26–36 32	34–38 35	33–38 36		21–23 22
ED/HL*		29–41× 33–44	28–34× 32–34	21–30× 22–33		16–18
		36×38	31×33	26×29		18
P_1L/BL		4–12 8	10–12 11	9–13 11		9–10 9
P_2L/BL		0–5 1	5–6 5	7–13 10		11–11 11

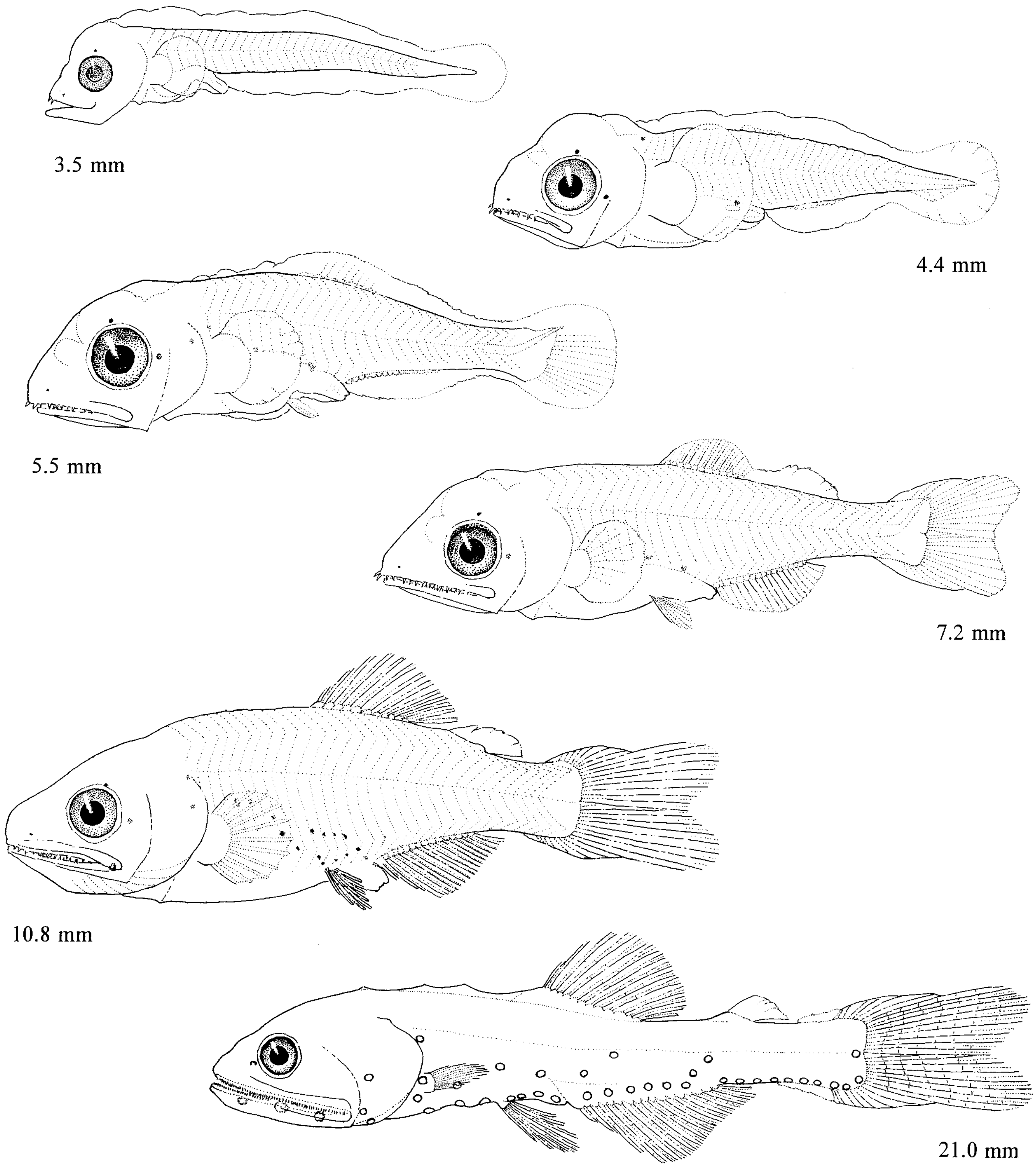

Figure Myctophidae 15. Preflexion larvae, 3.5 mm (CalCOFI 6604, station 137.55), 4.4 mm (CalCOFI 6607, station 130.80); flexion larva, 5.5 mm (CalCOFI 6110, station 130.55); postflexion larvae, 7.2 mm (Moser et al. 1984a), 10.8 mm (CalCOFI 6207, station 130.80); juvenile, 21.0 mm (EASTROPAC I, station 13.167).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	37
Precaudal	15–16	16
Caudal	20–23	21
Fins:		
Dorsal spines	0	0
Dorsal rays	14–16	14
Anal spines	0	0
Anal rays	16–19	18
Pelvic	7–8	
Pectoral	13–16	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	6–8	8
Gill rakers:		
Upper	4–5	4
Lower	10–12	11
Branchiostegals		

LIFE HISTORY

Range: Tropical & subtropical north Pacific; western margin of California Current region

Habitat: Mesopelagic

Spawning season: Larvae captured during all seasons on CalCOFI surveys but most frequently during summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser & Ahlstrom 1974
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.7 mm (N. Arthur)
Head of 3.7 mm preflexion larva, dorsal view (N. Arthur)
Flexion larva, 7.1 mm (N. Arthur)
Transformation specimen, 20.7 mm (N. Arthur)

* See explanation in introduction to family.
† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: ca. 6.2–7.3 mm
Transformation length: ca. 20 mm
Fin development sequence: C_1, D & A & P_1 & P_2 & C_2
Pigmentation: *Preflexion*—In smallest larvae, 1 in midline anterior to forebrain, a pair on anterolateral region of midbrain, a pair near tip of snout, 1 on lower jaw symphysis, 1 embedded anterior to upper margin of P_1 base, 1 on inner surface of P_1 base, & 1 or 2 on ventral midline below anterior region of gut; by 4.0 mm, 1 proximally on lower P_1 blade & 1 above gas bladder. *Flexion*—Some have 1 (minute) at basibranchial region, on posterior lateral region of gut, & on P_2. *Postflexion*—By ca. 9.0 mm, on bases & distal regions of P_1 rays & some have paired series anterior to D. *Transformation*—Trunk myosepta outlined.
Diagnostic features: Stout body with large head; very long snout; jaws large, with large teeth; paired tooth patches at tip of snout with curved canines; anterior & posterior series of preopercular spines; gut short in early preflexion larvae; unique pigment pattern; Br_2 photophores form in early flexion.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		39–61 51	62–68 64	68–75 72	65	
BD/BL		17–28 23	26–32 29	33–42 36	28	
HL/BL		24–39 32	37–41 39	39–45 42	31	
HW/HL		36–51 44	41–41 41	43–56 48	63	
SnL/HL		39–61 50	52–56 53	43–56 51	35	
ED/HL†		24–33× 26–38 29×31	23–25× 27–28 24×28	18–24× 19–27 21×23	19	
P_1L/BL		3–10 7	9–11 10	13–16 14	10	
P_2L/BL		0–0 0	3–6 5	12–26 17	12	

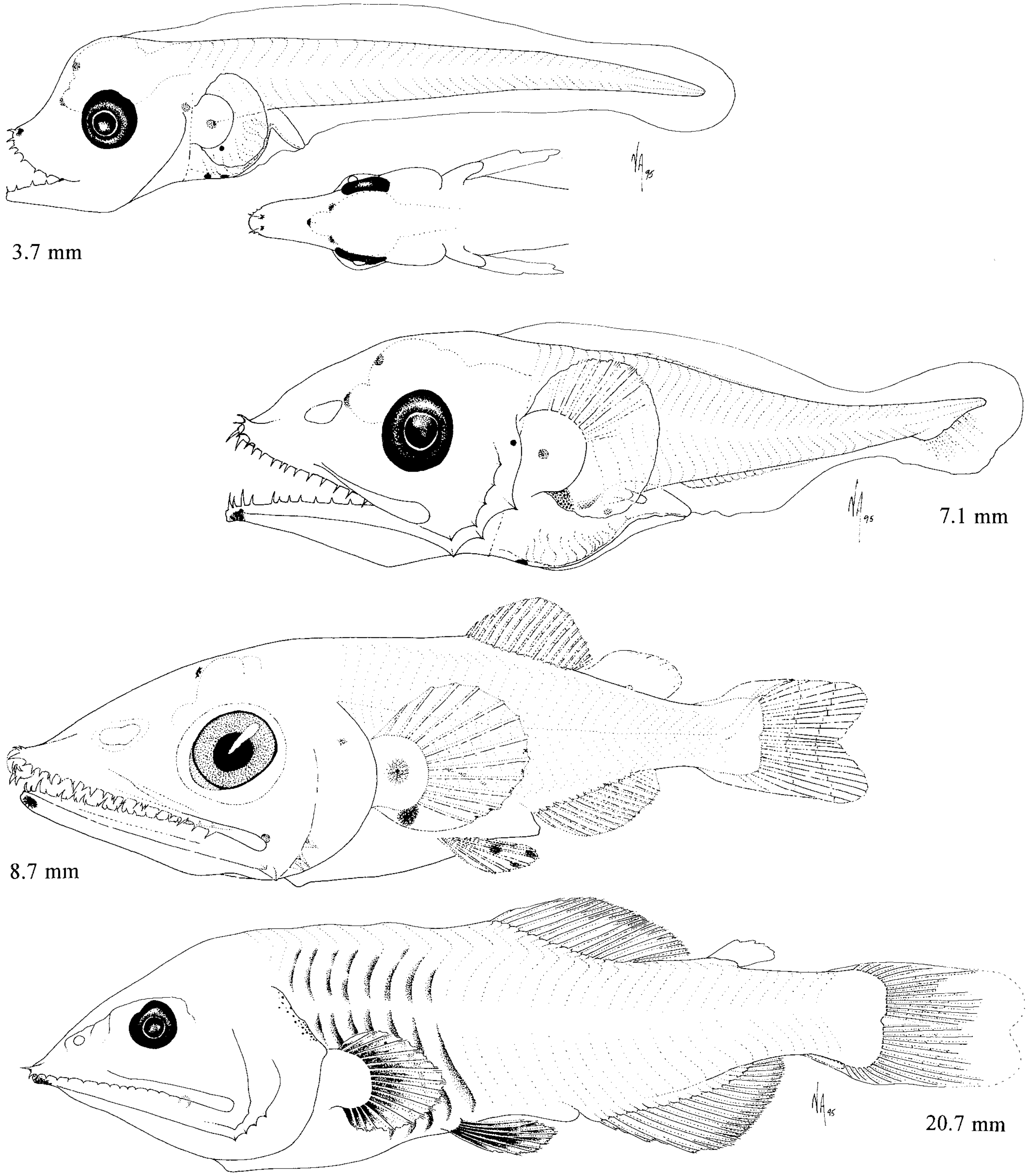

Figure Myctophidae 16. Preflexion larva, 3.7 mm, lateral view and dorsal view of head (CalCOFI 7205, station 27.137); flexion larva, 7.1 mm (CalCOFI 7205, station 21.133); postflexion larva, 8.7 mm (Moser and Ahlstrom 1974); transformation specimen, 20.7 mm (Clarke-Hawaii, station 71–3–4).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	33
Precaudal	13–16	14
Caudal	18–21	19
Fins:		
Dorsal spines	0	0
Dorsal rays	12–15	13
Anal spines	0	0
Anal rays	15–19	17
Pelvic	8	8
Pectoral†	0, 20–21	0
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	6
Lower	6–7	6
Gill rakers:		
Upper	4	4
Lower	11–12	11
Branchiostegals		

LIFE HISTORY

Range: North Pacific central water mass to western margin of California Current region

Habitat: Mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser 1981
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.0 mm (N. Arthur)
Flexion larva, 6.0 mm (N. Arthur)
Head of 6.0 mm flexion larva, dorsal view (N. Arthur)

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* See explanation in introduction to family.
† Larvae with up to 20–21 P_1 rays; P_1 absent in adults.
‡ Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.0 mm
Flexion length: ca. 5.6–6.6 mm
Transformation length: <20 mm
Fin development sequence: P_1, C_1, P_2, D & A & C_2
Pigmentation: *Preflexion*—Between 4.0 & 5.0 mm, on tip of lower jaw, on snout, & peppering on P_1 blade. *Flexion*—By ca. 5.6 mm, peppering on lateral surface of P_1 blade; by ca. 6.0 mm, 1 in midline anterior to forebrain, pair at anterolateral surface of midbrain, pair near tip of snout, 1 embedded in otic region, embedded vertical series developing anterior to P_1 base, & peppering on inner & lateral surfaces of P_1 base. *Postflexion*—By 6.5 mm, on nape, embedded anterior to gut mass, & peppering on P_2; by 7.5 mm, paired series anterior to D (some specimens).
Diagnostic features: Stout body with large head; huge P_1 base & blade; snout relatively long; jaws & teeth large; paired tooth patches on upper jaw; gut short in early larvae; P_1 base & rays peppered with minute melanophores; Br_2 photophores form at ca. 6.5 mm; P_1 lost at transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		37–53 44	54–62 59	60–66 63		
BD/BL		16–25 19	23–28 26	29–35 32		
HL/BL		20–28 25	30–35 33	31–39 36		
HW/HL		43–67 53	46–51 47	46–61 55		
SnL/HL		30–40 36	35–41 39	36–43 40		
ED/HL‡		34–40× 35–43 37×39	29–31× 33–34 30×33	22–30× 24–33 26×29		
P_1L/BL		8–19 12	20–23 22	15–28 22		
P_2L/BL		0–0 0	0–7 4	12–17 15		

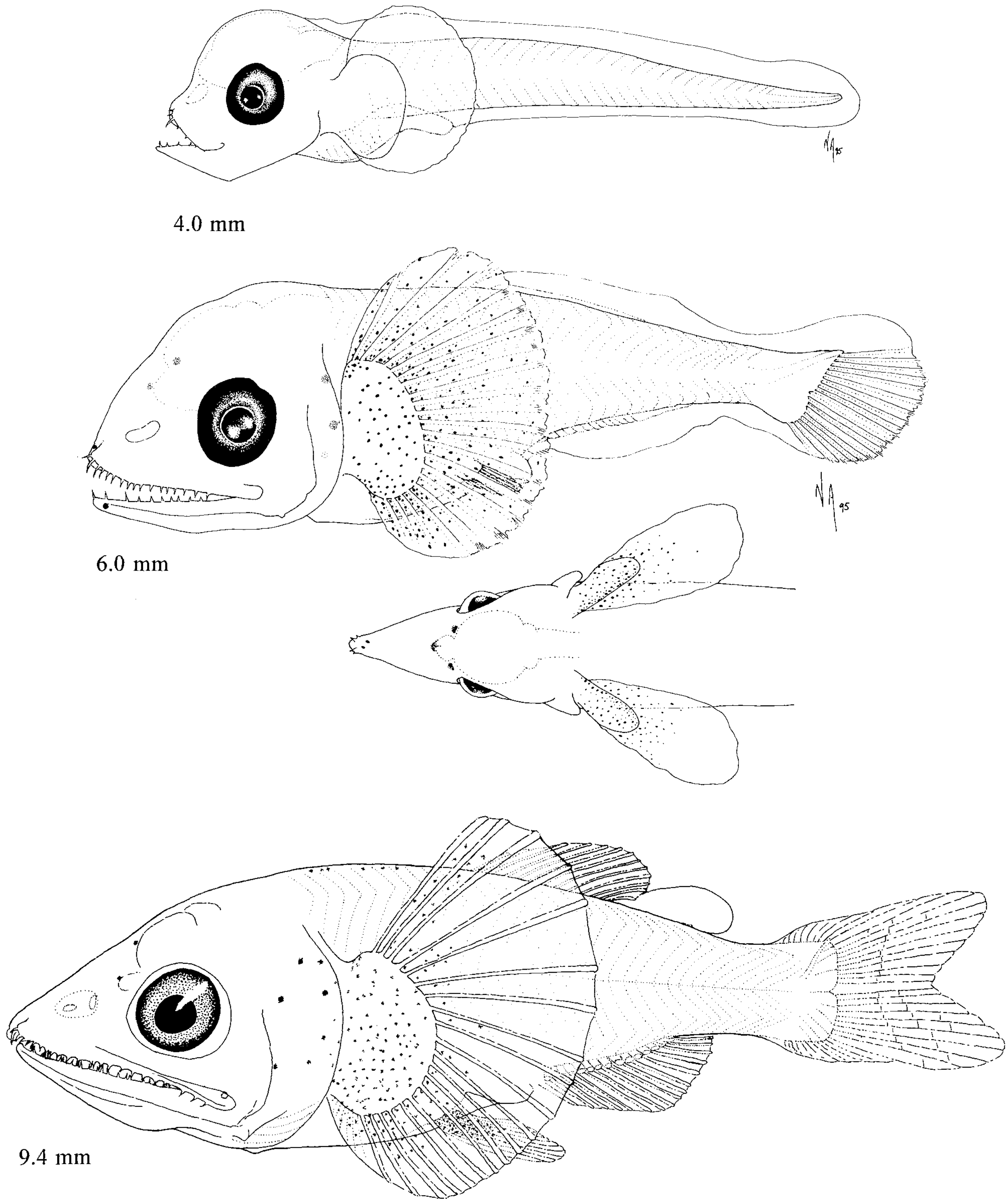


Figure Myctophidae 17. Preflexion larva, 4.0 mm (CalCOFI 7205, station 31.141); flexion larva, 6.0 mm, lateral view and dorsal view of head (CalCOFI 7205, station 24.137); postflexion larva, 9.4 mm (Moser 1981).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–39	36–37
Precaudal	15–16	15
Caudal	20–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	12–17	15
Anal spines	0	0
Anal rays	17–19	18
Pelvic	8	8
Pectoral	12–15	13–14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	6–8	7
Gill rakers:		
Upper	3–5	4
Lower	9–11	10
Branchiostegals	9–11	10

LIFE HISTORY

Range: Subarctic-transitional region of North Pacific, including Bering Sea; southernmost captures at Sagami Bay, Japan & off Bahía Magdalena, Baja California Sur, in the western & eastern Pacific, respectively

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout the year in CalCOFI area; highest abundance in the spring–summer, with peak in July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Amaoka et al. 1992
Matarese et al. 1989
Moser & Ahlstrom 1974
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.8 mm, 5.8 mm (G. Mattson)
Flexion larva, 7.2 mm (G. Mattson)
Head of 9.1 mm flexion larva, dorsal view (G. Mattson)
Postflexion larva, 19.9 mm (G. Mattson)
Juvenile, 28.0 mm (G. Mattson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.2
Flexion length: ca. 6.0–8.0
Transformation length: ca. 20.0 mm
Fin development sequence: C_1, D & A & P_1 & P_2, C_2
Pigmentation: *Preflexion*—By ca. 4.3 mm, 1 in midline anterior to forebrain & 1 anterior to each midbrain lobe (most specimens); by 4.7 mm, at lower jaw tip & above gas bladder; by 5.4 mm, peppering on P_1 blade & 1 at gut above preanal arch of gut; by 5.8 mm, embedded at cleithrum near upper margin of P_1 base; *Flexion*—On snout at tip, on nostril, & just anterior to eye; 1 posterior to orbit; blotch at Ad; series above gut & gas bladder; on inner surface of P_1 base; 1 in midline above cerebellum; peppering on P_2 blades. *Postflexion*—Myosepta becoming outlined in gut region; some develop 1 in midline anterior to D.
Diagnostic features: Initially, head small, body slender, & gut short & strongly sigmoid; beginning at ca. 5.0 mm, head & body become deep & compressed; head large with elongate snout & large jaws armed with large teeth; tooth patch with larger teeth on upper jaw tip; P_1 & P_2 large & pigmented; distinctive pigment pattern with Ad blotch & stripe through eye; Br_2 photophores form at ca. 7.5 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		29–57 41	58–67 62	64–70 68	 59	56–57 56
BD/BL		11–28 18	26–30 27	28–34 31	 23	20–20 20
HL/BL		15–33 22	34–39 36	32–43 39	 33	28–31 30
HW/HL		50–66 60	40–48 45	34–64 44	 40	38–49 44
SnL/HL		22–43 33	42–46 44	34–47 42	 35	23–26 24
ED/HL*		30–40× 33–46	24–29× 27–31	17–23× 19–25		15–15
		36×40	27×29	20×21	15×16	15
P_1L/BL		3–10 8	10–17 13	12–17 14	 11	14–15 14
P_2L/BL		0–0.7 0.1	4–22 12	15–27 20	†	12–13 12

* Eye slightly elliptical; horizontal axis is given first, vertical axis second.
† P_2 rays broken in transformation specimen.

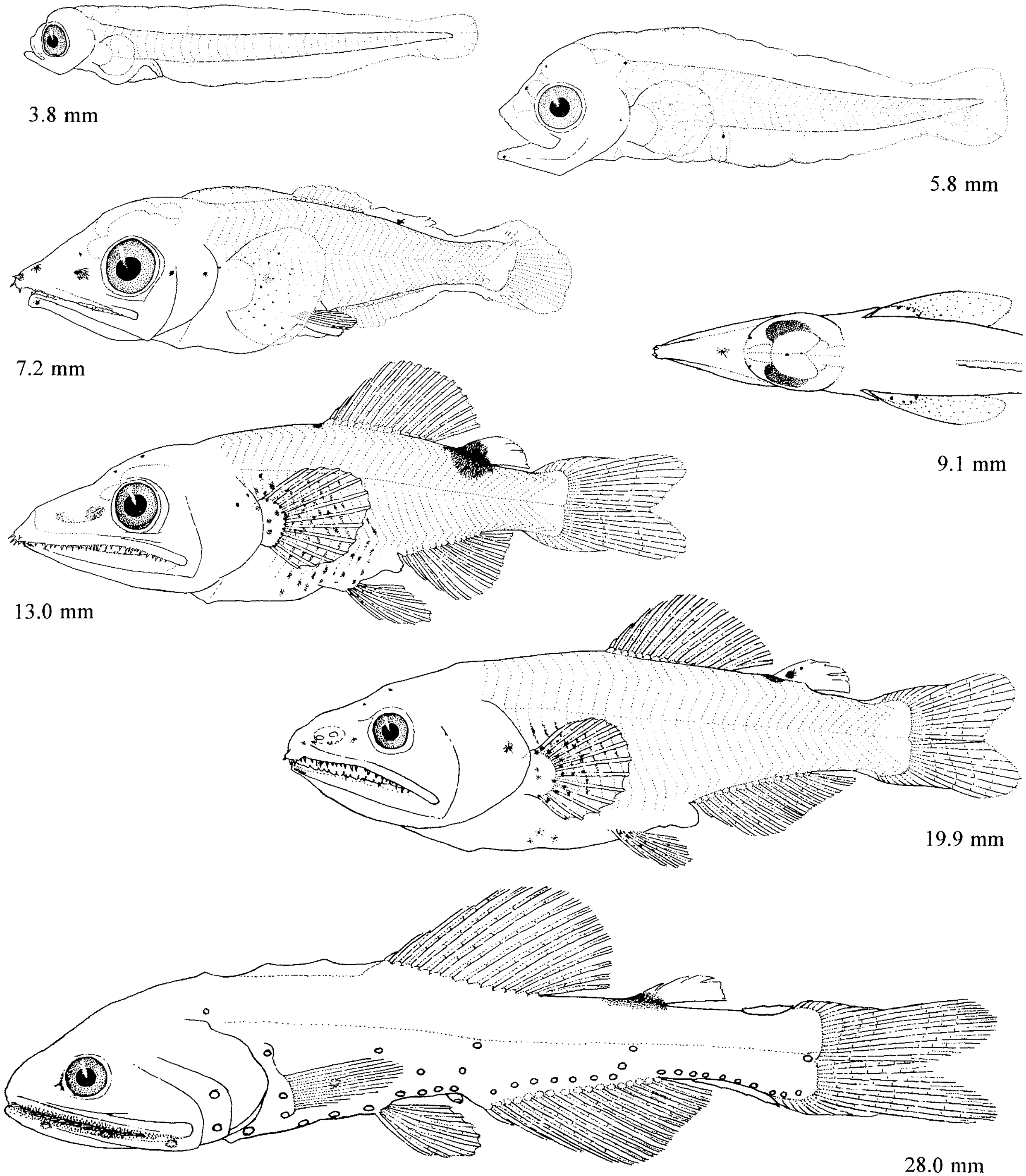


Figure Myctophidae 18. Preflexion larvae, 3.8 mm (CalCOFI 6407, station 77.8.60), 5.8 mm (CalCOFI 6407, station 76.70); flexion larva, 7.2 mm (CalCOFI 4907, station 61.87); head of 9.1 mm postflexion larva, dorsal view (CalCOFI 4908, station 72.56); postflexion larvae, 13.0 mm (Moser and Ahlstrom 1974), 19.9 mm (CalCOFI 6806, station 90.65); juvenile, 28.0 mm (CalCOFI 4911, station 31.65).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	36–37
Precaudal	15–16	15
Caudal	20–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	12–16	14
Anal spines	0	0
Anal rays	16–19	18
Pelvic	8	8
Pectoral	10–13	11–12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–8	7
Lower	7–8	8
Gill rakers:		
Upper	4–5	4
Lower	9–11	10
Branchiostegals		

LIFE HISTORY

Range: Subarctic-Transitional zone of the northeastern Pacific south to ca. Bahía Magdalena, Baja California Sur

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout the year in CalCOFI area; highest abundance in the winter & spring, with a peak in March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Bolin 1939
Matarese et al. 1989
Moser & Ahlstrom 1974
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.7 mm (G. Mattson)
Flexion larva, 7.0 mm (G. Mattson)
Postflexion larva, 7.6 mm (G. Mattson)
Head of 7.6 mm postflexion larva, dorsal view (G. Mattson)
Postflexion larva, 14.4 mm (G. Mattson)
Juvenile, 22.5 mm (G. Mattson)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3 mm
Flexion length: ca. 6.0–7.1 mm
Transformation length: ca. 16.0–18.0 mm
Fin development sequence: C_1, D & A & P_1 & C_2, P_2
Pigmentation: *Preflexion*—At ca. 4.0 mm, 1 in midline anterior to forebrain; by ca. 4.5 mm, 1 embedded in midline below hindbrain & 1 in midline anterior to midbrain; by 5.0 mm, 1 embedded anterior to gut, 1 or more above gas bladder, 1 on inner surface of P_1 base, 1 above terminal gut section, & 1 above nape. *Flexion*—1 at cleithrum anterior to upper P_1 base. *Postflexion*—Myosepta becoming outlined at gut, spreading dorsally & ventrally; 1 anterior to Ad in some specimens; 1 or more on ventral midline below gut; on P_2 rays.
Diagnostic features: Initially, small rounded head, slender body, & short, strongly sigmoid gut; head & body become deep & compressed, gut elongates during preflexion stage; body stout in postflexion stage; eyes relatively large, jaws large with large teeth, especially at upper jaw tip; snout somewhat elongate but blunter than in *N. regalis*; diagnostic pigment, especially on midline of brain; Br_2 photophores form at ca. 7.0 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		29–50 38	53–59 55	58–63 61	55–57 56	53–56 54
BD/BL		11–22 17	23–28 25	28–31 29	21–24 23	18–20 19
HL/BL		15–28 21	27–31 29	27–33 31	29–30 30	27–28 27
HW/HL		49–65 58	50–56 52	47–67 54	43–50 47	39–44 42
SnL/HL		17–33 26	36–39 38	31–42 35	27–33 30	18–21 20
ED/HL†		29–44× 29–46 36×39	36–38× 37–42 37×40	26–35× 29–35 30×32	21–24× 21–24 22×22	20–21× 20–21 21×21
P_1L/BL		6–8 7	7–9 8	8–12 10	9–10 10	9–10 10
P_2L/BL		0–0 0	0–2 0.8	6–10 8	8–10 9	10–11 11

* A closely related species, *L. fernae*, occurs on the northwestern margin of the CalCOFI area (Wisner 1976); we have not identified the larvae of *L. fernae* but presume they are similar to *L. ritteri* larvae.
† Eye slightly oval; horizontal axis is given first, vertical axis second.

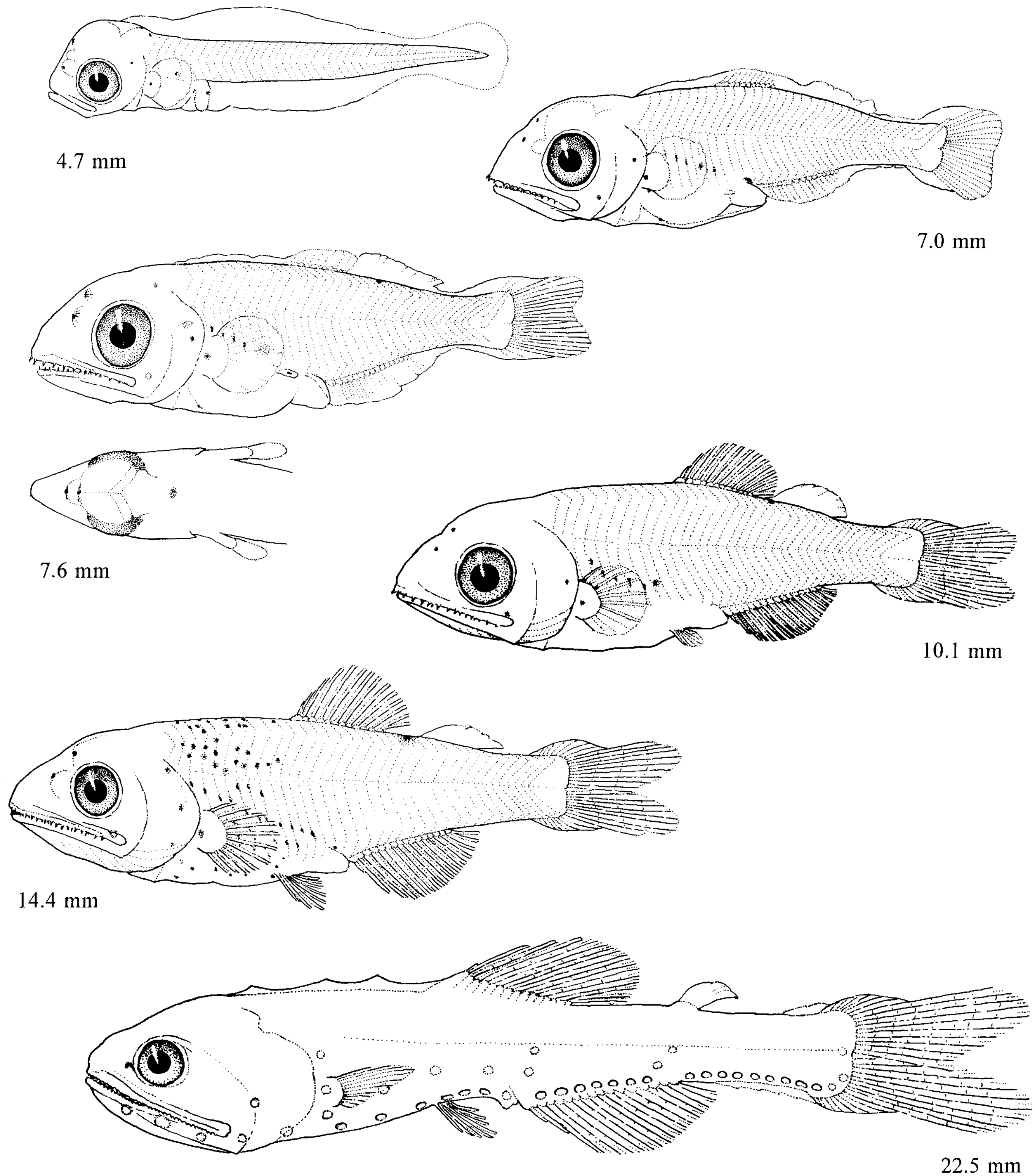


Figure Myctophidae 19. Preflexion larva, 4.7 mm (CalCOFI 6801, station 93.90); flexion larva, 7.0 mm (CalCOFI 6201, station 83.65); postflexion larvae, 7.6 mm, lateral view and dorsal view of head (CalCOFI 6806, station 70.70), 10.1 mm (Moser and Ahlstrom 1974); transformation specimen, 14.4 mm (CalCOFI 6204, station 90.160); juvenile, 22.5 mm (CalCOFI 4909, station 82.67).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27–31	30
Precaudal	12–13	13
Caudal	16–18	17
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	11
Anal spines	0	0
Anal rays	12–15	13–14
Pelvic	6	6
Pectoral	12–15	13–14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	6–8	7
Gill rakers:		
Upper	2	2
Lower	8–9	8
Branchiostegals	9	9

LIFE HISTORY

Range: Circumglobal in tropical & temperate waters

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout year in CalCOFI area; highest abundance in the spring & summer, with a peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fahay 1983
Moser & Ahlstrom 1974
Moser et al. 1984a
Pertseva-Ostroumova 1964
Tåning 1918

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.8 mm (G. Mattson)
Flexion larva, 5.4 mm (G. Mattson)
Postflexion larva, 7.2 mm (G. Mattson)
Transformation specimen, 10.7 mm (G. Mattson)
Juvenile, 9.7 mm (G. Mattson)

* Eye variably oval or trapezoidal, usually narrow with long axis inclined forward; narrow axis is given first, long axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 4.4–6.2 mm
Transformation length: ca. 10.0–10.8 mm
Fin development sequence: C_1, D & A & P_1 & C_2, P_2
Pigmentation: *Preflexion*—By ca. 2.8 mm, 1 laterally on midgut just anterior to preanal arch of gut; by ca. 3.2 mm, 1–4 (usually 1) ventral midline postanal dashes; by ca. 3.8 mm, 1 above developing gas bladder & pair on terminal gut section. *Flexion*—Usually 2 or 3 on lateral gut; by ca. 5.0 mm, 1 or a streak at mid-hypural margin. *Postflexion*—2–7 (usually 3 or 4) in postanal ventral midline series, displaced to either side of A base; up to 3 laterally on gut in largest larvae. *Transformation*—Blotch laterally on gut.
Diagnostic features: Low total vertebral count (27–31); uniquely low P_2 ray count (6); slender body; gut short, larger anterior section tapers gradually, slight sigmoid curvature; head moderate in size, initially somewhat rounded; snout becomes somewhat elongate & blunt at tip; eyes narrow, becoming irregularly oval; a crescent of choroid-like tissue on dorsal surface of eye by 4.0 mm & on ventral surface by ca. 6.0 mm; teeth minute; pigment sparse but diagnostic, particularly the mid-hypural streak; the pineal organ in the interorbital region is visible in late postflexion larvae; transforms at small size; Dn, Br_2, PVO_1, PVO_2, VLO, & PO_{1-5} photophores form first; Br_2 form in adult position below eye.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–43 41	40–44 42	44–53 48	51–52 51	51–52 52
BD/BL		11–15 13	13–16 15	16–23 19	21–22 22	19–20 19
HL/BL		18–22 20	21–26 23	25–31 27	27–28 28	27–29 28
HW/HL		47–62 54	50–56 53	44–55 48	48–55 51	46–49 47
SnL/HL		23–36 32	34–40 36	32–39 36	27–34 30	22–25 23
ED/HL*		21–29× 30–49 25×42	24–29× 36–42 26×39	18–25× 27–38 23×33	21–22× 22–29 21×26	19–20× 20–22 19×21
P_1L/BL		5–7 6	5–8 7	7–16 12	18–20 19	16–19 18
P_2L/BL		0–0 0	0–0 0	0.9–8 5	8–9 8	7–9 8

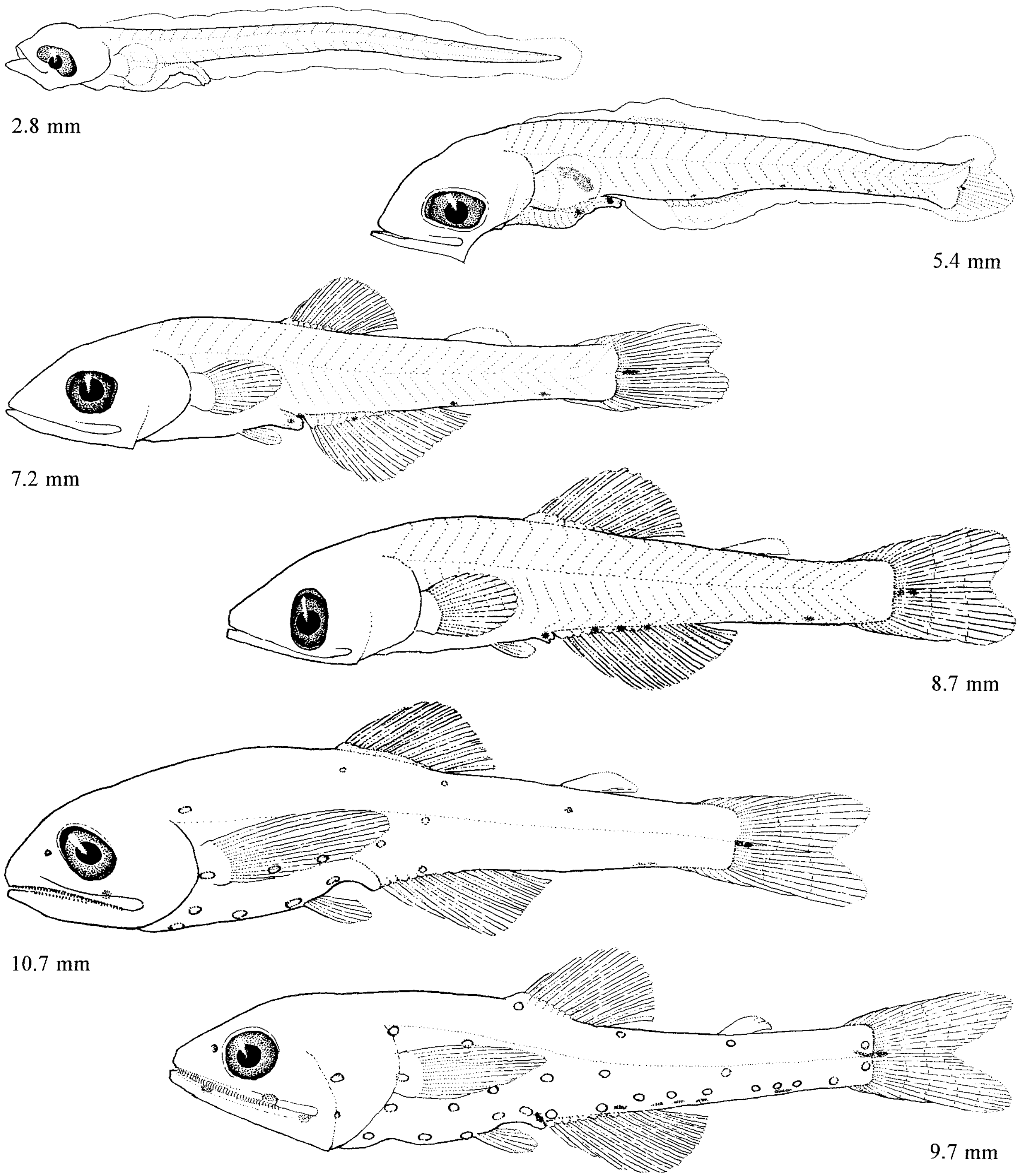


Figure Myctophidae 20. Preflexion larva, 2.8 mm (CalCOFI 6501, station 80.160); flexion larva, 5.4 mm (NORPAC, station 91); postflexion larvae, 7.2 mm (CalCOFI 6201, station 80.200), 8.7 mm (Moser et al. 1984a); transformation specimen, 10.7 mm (EASTROPAC I, station 12.084); juvenile, 9.7 mm (CalCOFI 6607, station 110.60).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	37–38
Precaudal	16	16
Caudal	21–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	21–24	22–23
Anal spines	0	0
Anal rays	18–20	19
Pelvic	8	8
Pectoral	11–13	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	11–14	12
Lower	10–14	13
Gill rakers:		
Upper	6–7	6
Lower	13–15	14
Branchiostegals	9–10	10

LIFE HISTORY

Range: Worldwide in tropical to temperate waters; in eastern Pacific from central California to Chile

Habitat: Epi- to mesopelagic

Spawning season: Larvae most abundant in summer & fall in CalCOFI area, with peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Badcock & Merrett 1976
Fahay 1983
Matarese et al. 1989
Moser 1981
Moser & Ahlstrom 1972, 1974
Moser et al. 1984a
Ozawa 1986b, 1988d

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.1 mm, 4.8 mm (G. Mattson)
Postflexion larvae, 6.5 mm, 16.2 mm (G. Mattson)
Transformation specimen, 21.0 mm (G. Mattson)
Juvenile, 26.3 mm (G. Mattson)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.4 mm
Flexion length: ca. 5.0–6.5 mm
Transformation length: ca. 20.0 mm
Fin development sequence: C_1, D & A & C_2, P_1 & P_2
Pigmentation: *Preflexion*—Initially, at jaw tips & cleithrum; at ca. 3.0 mm, embedded above developing gas bladder & in otic region; at ca. 3.8–4.0 mm, 2 in tandem above terminal gut section & pair above cerebellum; between 4.8 & 5.0 mm, 1 in midline at nape, 1 anterior to midbrain, 1 ventrolaterally on trunk above midgut, 1 or more dashes on lateral midline at midbody, beginning of a series on each side of D base, & beginning of a midline series on A base. *Flexion*—Transverse pair above midbrain in some larvae & beginning of series on hypaxial region above A base in some larvae. *Postflexion*—Paired series on dorsum extends to Ad in some larvae; by ca. 8.5 mm, 1 at angle of jaw in some; by ca. 9.5 mm, some have 1 or more in gular region & anterior to forebrain; by ca. 12.5 mm, on P_2 & A rays & hypural margin; by 14.5 mm, on edge of branchiostegal membrane.
Diagnostic features: High D ray count (21–24); high procurrent C ray count (11–14 + 10–14); initially slender, with short, strongly sigmoid gut; head & body become deep & compressed; snout acute in preflexion stage, becoming bulbous; eyes large, nearly round; teeth well developed; anteriorly hooked teeth on posterior part of lower jaw; complex pigment pattern; Br_2 photophores form at 4.2 mm; PO_5 at 6.2; Vn at 9.2; PLO at 16.2 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–58	56–60	58–63		57–57
		44	58	61	59	57
BD/BL		19–26	24–29	24–28		19–21
		22	26	26	24	20
HL/BL		23–31	30–34	28–32		30–30
		27	31	30	29	30
HW/HL		49–69	48–53	43–60		39–41
		57	51	49	53	40
SnL/HL		33–37	29–37	21–29		17–17
		35	33	25	19	17
ED/HL*		29–40×	35–37×	28–40×		25–25
		35–45	39–43	28–41		
		35×41	36×41	36×37	28	25
P_1L/BL		6–8	7–8	6–11		12–13
		7	8	10	12	12
P_2L/BL		0–0	0–5	6–15		13–14
		0	2	12	14	13

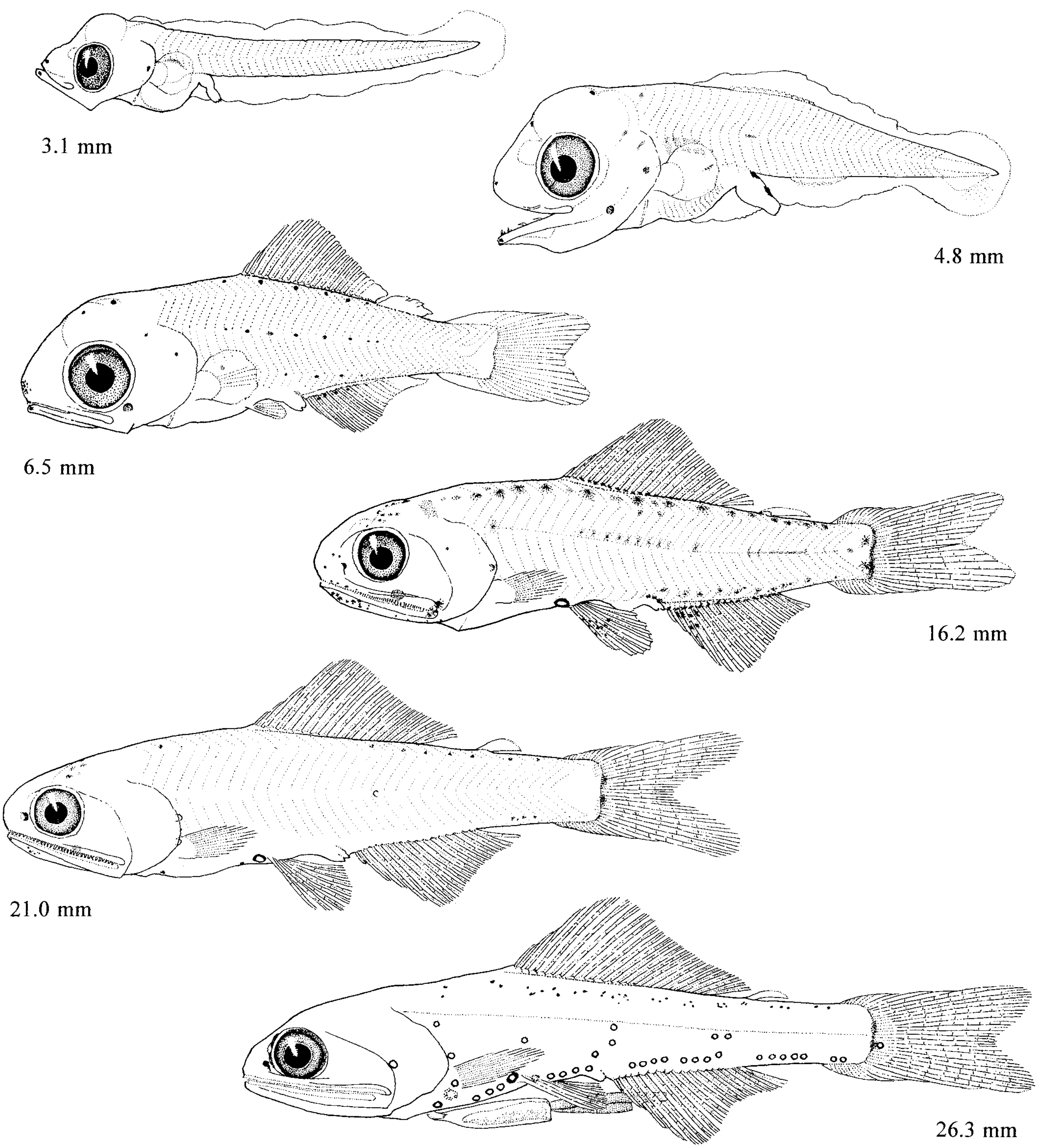


Figure Myctophidae 21. Preflexion larvae, 3.1 mm (CalCOFI 6304, station 120.120), 4.8 mm (CalCOFI 6107, station 90.70); postflexion larvae, 6.5 mm (CalCOFI 6610, station 113.45), 16.2 mm (LACM 9567–6); transformation specimen, 21.0 mm (CalCOFI 6207, station 90.110); juvenile, 26.3 mm, parasitic copepod attached to ventrum (CalCOFI 6208, station 90.150).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	37
Precaudal	15–16	15
Caudal	21–22	22
Fins:		
Dorsal spines	0	0
Dorsal rays	14–17	16
Anal spines	0	0
Anal rays	15–18	17
Pelvic	8	8
Pectoral	10–13	12
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	7–9	8
Gill rakers:		
Upper	4–6	5
Lower	11–15	12
Branchiostegals		

LIFE HISTORY

Range: California Current region from central Baja California north to Cape Mendocino, California, & westward in transition zone to ca. 145° W

Habitat: Mesopelagic

Spawning season: Larvae captured during spring & summer in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Matarese et al. 1989
Moser & Ahlstrom 1974
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 4.5 mm, 6.5 mm (N. Arthur)
Flexion larva, 7.8 mm (N. Arthur)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 6.6–7.8 mm
Transformation length: >17 mm
Fin development sequence: C_1, P_1, C_2, A, D, P_2
Pigmentation: *Preflexion*—By 5.6 mm, 1 midventral to hindbrain; by 6.5 mm, 1 or more above gas bladder. *Flexion*—By end of stage, 1 in midline anterior to midbrain, 1 in midline posterior to cerebellum, & 1 embedded anterior to gut. *Postflexion*—Apposing midline pair on caudal peduncle, dorsal slightly posterior to ventral; largest specimens may have 1 or 2 on dorsal midline of caudal peduncle; myosepta becoming outlined in gut region in late postflexion stage.
Diagnostic features: Gut short in preflexion stage, becoming longer in subsequent stages; extremely large, nearly round eye (EL 38%–54% HL); distinct pigment pattern, with apposing caudal peduncle melanophores in postflexion stage; Br_2 photophores form in postflexion larvae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–42 39	45–50 47	52–58 55		
BD/BL		15–20 18	22–22 22	21–22 21		
HL/BL		16–25 21	26–28 27	25–27 26		
HW/HL		56–73 64	55–57 56	47–57 53		
SnL/HL		24–28 26	26–27 26	24–27 26		
ED/HL*		41–46× 46–54 43×50	40–45× 47–48 42×47	37–46× 38–46 41×42		
P_1L/BL		4–4 4	5–6 6	7–10 8		
P_2L/BL		0–0 0	0–0 0	0–7 3		

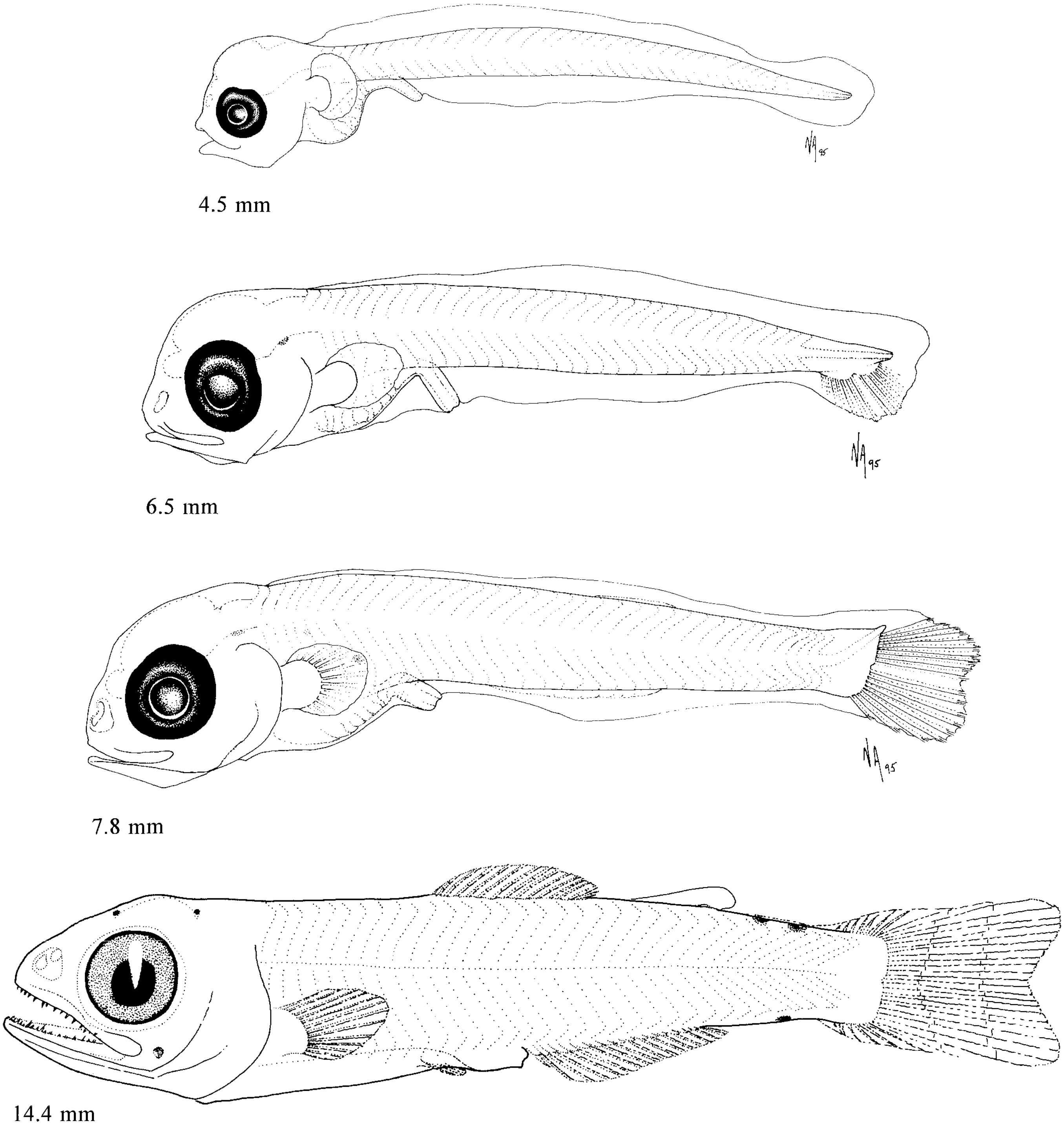


Figure Myctophidae 22. Preflexion larvae, 4.5 mm, 6.5 mm (CalCOFI 7205, station 31.131); flexion larva 7.8 mm (CalCOFI 9008, station 83.110); postflexion larva, 14.4 mm (Moser and Ahlstrom 1974).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	36
Precaudal	15–16	15
Caudal	20–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	14–16	15
Pelvic	8	8
Pectoral	8–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	7–8	8
Gill rakers:		
Upper	5–6	5
Lower	12–14	13
Branchiostegals	9–10	9

LIFE HISTORY

Range: North Pacific from ca. 29° N in California Current to Gulf of Alaska & westward to Japan

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout the year in CalCOFI area; highest abundance in winter–spring, with peak in March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965, 1972a
Fast 1960
Matarese et al. 1989
Moser & Ahlstrom 1974
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.7 mm (N. Arthur)
Juvenile, 21.0 mm (N. Arthur)

* A closely related northern species, *S. nannochir*, extends into the northern part of the CalCOFI area (Wisner 1976); we have not identified *S. nannochir* larvae but presume they are similar to *S. leucopsarus* larvae.

† Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.0 mm
Flexion length: 6.5–8.0 mm
Transformation length: 16–19 mm
Fin development sequence: C_1, A & D & C_2, P_1, P_2
Pigmentation: *Preflexion*—Postanal ventral midline series with 19–22; lateral pairs on gut at terminal section, at midgut, & just posterior to P_1 base; embedded above gas bladder at ca. 6.0 mm; at end of stage, anterior gut pair migrates anteroventrad & coalesces in the midline below the P_1 base & postanal series begins to coalesce. *Flexion*—Postanal series coalesces to 1–3 at end of stage, the one at A insertion not embedded; 1 at midline of hindbrain & 1–2 at nape. *Postflexion*—1 (minute) embedded in otic region by 8.0 mm; in some larvae >10 mm, 1–6 in paired series on dorsum anterior to D in alternating arrangement, 1 or more at D insertion, Ad origin & insertion, & a series on lateral midline anterior to D. *Transformation*—Paired series on dorsum & lateral midline augmented.
Diagnostic features: Similar to *Triphoturus mexicanus* but gut slightly shorter, eye wider, more postanal melanophores (19–22 vs. 11–14), & Br_2 photophores form early (ca. 6.8 mm); *Diaphus theta* have <17 postanal midline melanophores prior to flexion stage & have hypural pigment at >4.4 mm; Vn, PO_1,PO_5 form in late larvae; Op & Br_1 form early in transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–49 44	53–57 54	56–60 58	54–58 56	55–56 56
BD/BL		8–13 11	14–19 16	17–24 22	21–23 22	19–21 20
HL/BL		16–21 18	21–23 22	23–27 25	26–28 28	27–30 29
HW/HL		46–61 55	56–65 60	50–60 56	40–49 45	40–48 43
SnL/HL		14–28 21	23–28 24	23–26 24	19–28 24	20–23 21
ED/HL†		27–30× 32–39	29–37× 35–41	23–33× 27–40	23–28	22–25
		28×35	34×37	28×34	25	24
P_1L/BL		3–7 5	6–8 7	6–11 9	7–10 8	7–8 7
P_2L/BL		0–0 0	0–0.5 0.3	1–9 6	8–10 9	10–11 10

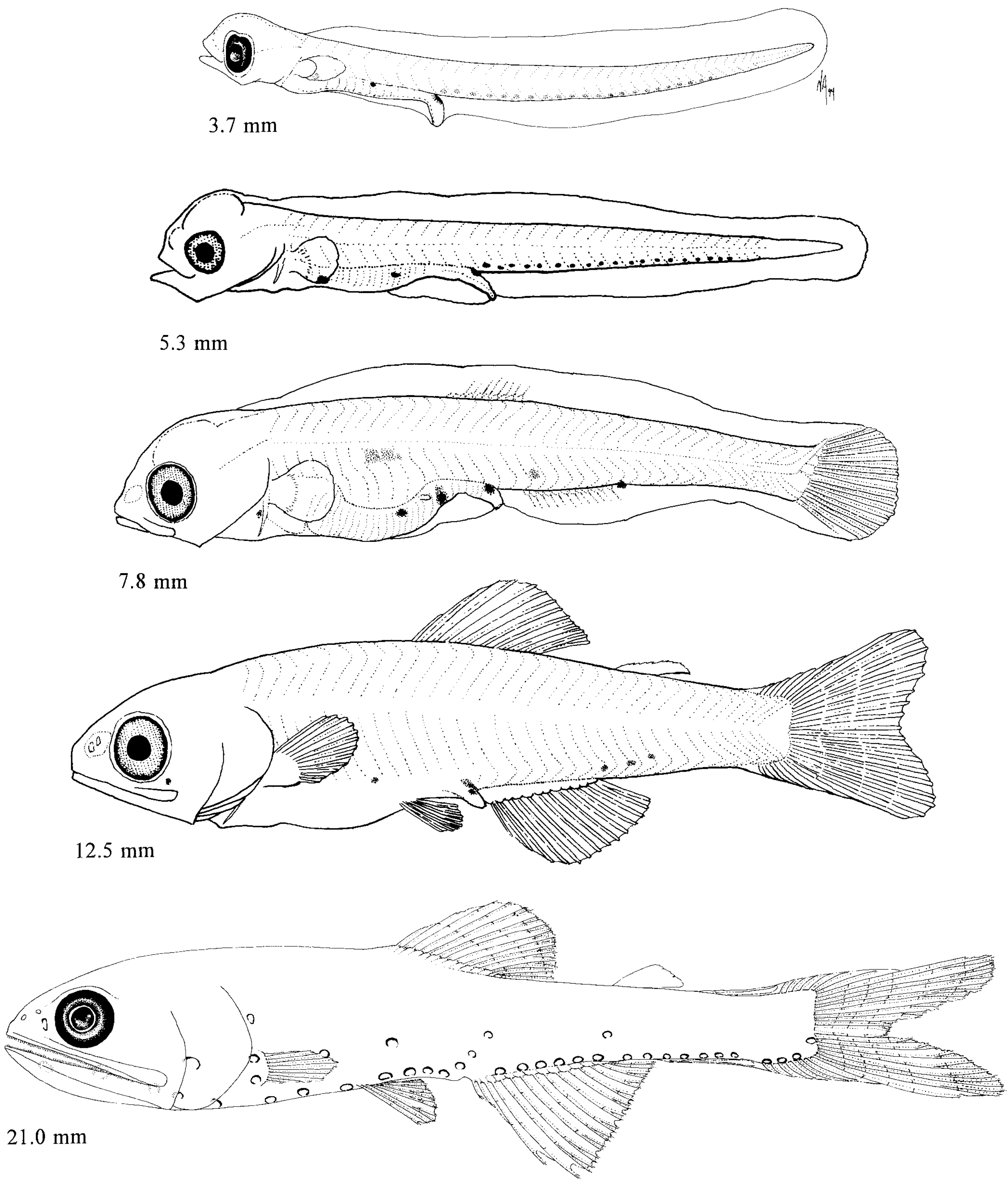


Figure Myctophidae 23. Preflexion larvae, 3.7 mm (CalCOFI 6501, station 73.51), 5.3 mm; flexion larva, 7.8 mm; postflexion larva, 12.5 mm (Ahlstrom 1972a); juvenile, 21.0 mm (CalCOFI 6608, station 90.28).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	40
Precaudal	18–20	19
Caudal	20–22	21
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	12
Anal spines	0	0
Anal rays	11–14	13
Pelvic	8	8
Pectoral	15–17	16–17
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–10	9
Lower	8–9	8
Gill rakers:		
Upper	4–5	4–5
Lower	11–14	12–13
Branchiostegals		

LIFE HISTORY

Range: Worldwide in northern & southern subtropics

Habitat: Epi- to mesopelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & neustonic larvae

LITERATURE

Fahay 1983
Matarese et al. 1989
Moser & Ahlstrom 1972
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.9 mm (B. Sumida MacCall)
Flexion larva, 7.2 mm (B. Sumida MacCall)
Postflexion larva, 16.9 mm (B. Sumida MacCall)
Juvenile, 21.5 mm (B. Sumida MacCall)

* Two other *Taaningichthys* species, *T. bathyphilus* & *T. paurolychnus* occur in the CalCOFI area; we have not identified their larvae but their lower total vertebral counts (35–36) would distinguish them from *T. minimus* (39–41).

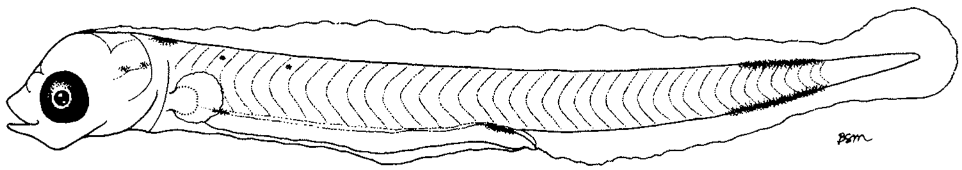
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

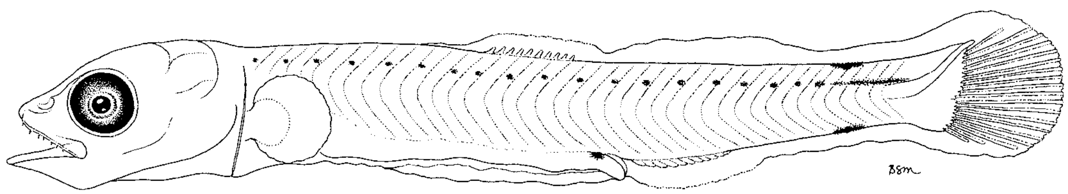
LARVAE
Hatching length: <4.9 mm
Flexion length: ca. 7.0–8.5
Transformation length: ca. 21.0 mm
Fin development sequence: C_1, D & A, C_2, P_1, P_2
Pigmentation: *Preflexion*—By 4.9 mm, elongate apposing median blotches in future caudal peduncle region, 1 above terminal gut section, 1 above gas bladder, 1 at nape, 1 embedded in otic region, 1 or more embedded above anterior spinal column; by 6.1 mm, 1 in midline above cerebellum & 1 above medulla; by 6.8 mm, embedded series extends full length of spinal column. *Postflexion*—By ca. 10.0 mm, beginning of paired series on each side of D, median spot at A insertion, & series on hypural margin; in late postflexion stage, paired series extends from D origin to C & paired ventral series at A & posterior caudal peduncle.
Diagnostic features: High total vertebral count (39–41); slender body; gut relatively long, slender & straight; head relatively small; eyes round; distinct pigmentation, particularly in caudal peduncle region & embedded above spinal column.

MORPHOMETRICS (range & mean in %)

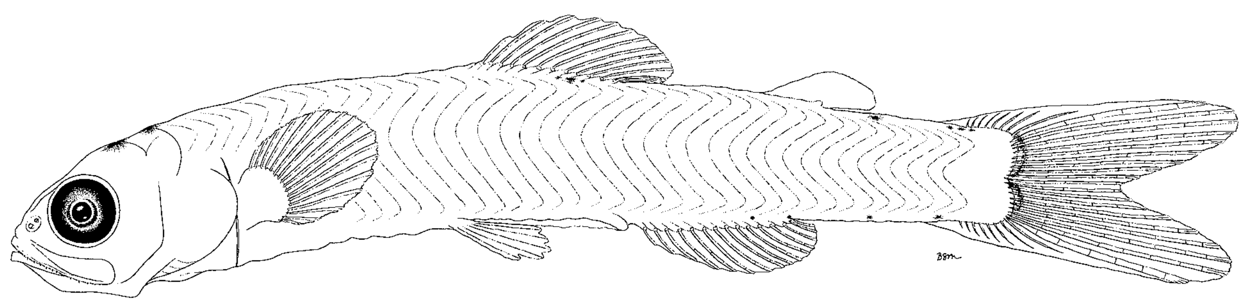
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		59–62 60	63–66 65	60–65 63		
BD/BL		9–12 11	13–15 14	13–18 15		
HL/BL		18–22 20	23–24 23	21–26 23		
HW/HL		51–53 52	47–58 52	46–56 51		
SnL/HL		20–27 24	21–26 24	21–26 23		
ED/HL		28–31 30	27–28 28	26–29 27		
P_1L/BL		3–4 4	4	4–14 9		
P_2L/BL		0–0 0	0–0 0	0.8–10 5		



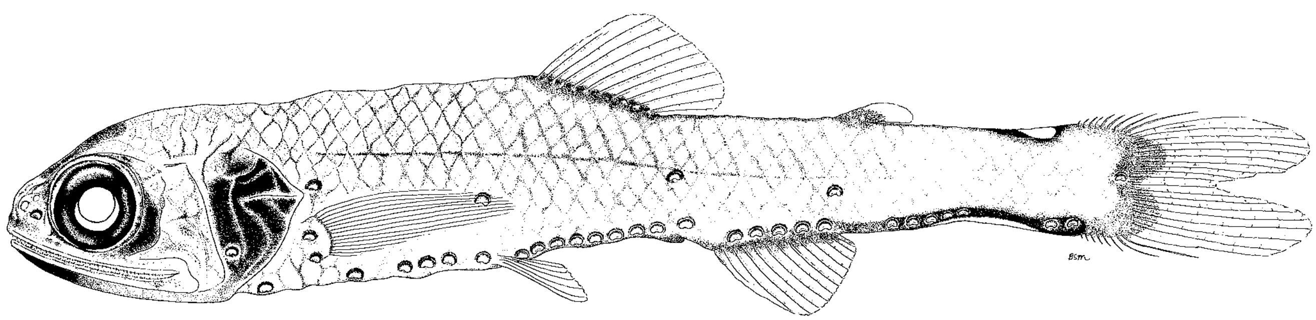
4.9 mm



7.2 mm



16.9 mm



21.5 mm

Figure Myctophidae 24. Preflexion larva, 4.9 mm (CalCOFI 7205, station 20.141); flexion larva, 7.2 mm (CFRD Ref. Coll., Hawaii Inst. Mar. Biol., Miller Neuston Net Series 3); postflexion larva, 16.9 mm (CalCOFI 7205, station 27.133); juvenile, 21.5 mm (SIO 63–544).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	34
Precaudal	15–17	16
Caudal	18–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	13–16	14
Anal spines	0	0
Anal rays	14–17	15–16
Pelvic	8	8
Pectoral	8–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–7	6
Lower	6–7	6
Gill rakers:		
Upper	3–5	5
Lower	10–14	12
Branchiostegals	8–11	10

LIFE HISTORY

Range: Eastern Pacific; northern population from San Francisco, California to southern Mexico, including Gulf of California, westward to 127° W; southern population from Guatemala to Chile

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout the year in CalCOFI area; abundant from spring to fall, with August–September peak

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965, 1972a
Moser et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.6 mm (N. Arthur)
Juvenile, 16.7 mm (N. Arthur)

* Eye oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.0 mm
Flexion length: 6.3–8.0 mm
Transformation length: ca. 12.5–15.4 mm
Fin development sequence: C_1, A, C_2, D, P_1, P_2
Pigmentation: *Preflexion*—At 2.0–3.5 mm, 11–14 in postanal ventral midline series, ventrolateral pair on gut just posterior to P_1 base, 1 or 2 pairs on midlateral gut, pair on terminal gut section, & some along ventral margin of finfold; 1 just posterior to Ad locus in most larvae >3.7 mm; anterior pair on gut coalesces to 1 on ventral midline in most larvae >4.0 mm; embedded above gas bladder by 4.3 mm; postanal series reduced to 1 or 2 by end of stage. *Flexion*—At lower jaw symphysis; lateral gut pair(s) coalesced & embedded above gut. *Postflexion*—By 9.0 mm, at angle of lower jaw, delicate series at base of inferior procurrent caudal rays, & 1 at A insertion; by 10.5 mm, embedded anterior to P_1 base.
Diagnostic features: Moderately slender; gut length moderate, slightly sigmoid; eye elliptical with lunate mass of choroid tissue; Br_2 photophores & caudal luminous glands form in late larvae; ventral finfold pigment present throughout larval period; lacks midlateral pigment series (present in *T. nigrescens*); fewer postanal ventral midline melanophores than in *Stenobrachius leucopsarus* (11–14 vs. 19–22); *S. leucopsarus* & *Diaphus theta* lack ventral finfold pigment.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		44–61 55	62–66 64	61–66 64	60–61 61	56–59 58
BD/BL		9–15 12	16–18 18	17–21 19	21–22 21	17–19 18
HL/BL		19–25 21	24–27 25	25–29 27	31–34 32	29–30 29
HW/HL		46–55 51	49–53 51	46–52 49	40–41 41	40–42 41
SnL/HL		15–28 22	22–28 26	24–30 27	23–23 23	21–24 22
ED/HL*		21–28× 28–36 24×33	21–25× 26–28 24×27	17–26× 20–31 20×25	15–18× 15–16 16×16	16–19× 16–18 17×17
P_1L/BL		3–6 5	8–9 9	8–12 10	 8	8–10 9
P_2L/BL		0–0 0	0–0.6 0.3	1–6 4	9–10 9	10–11 10

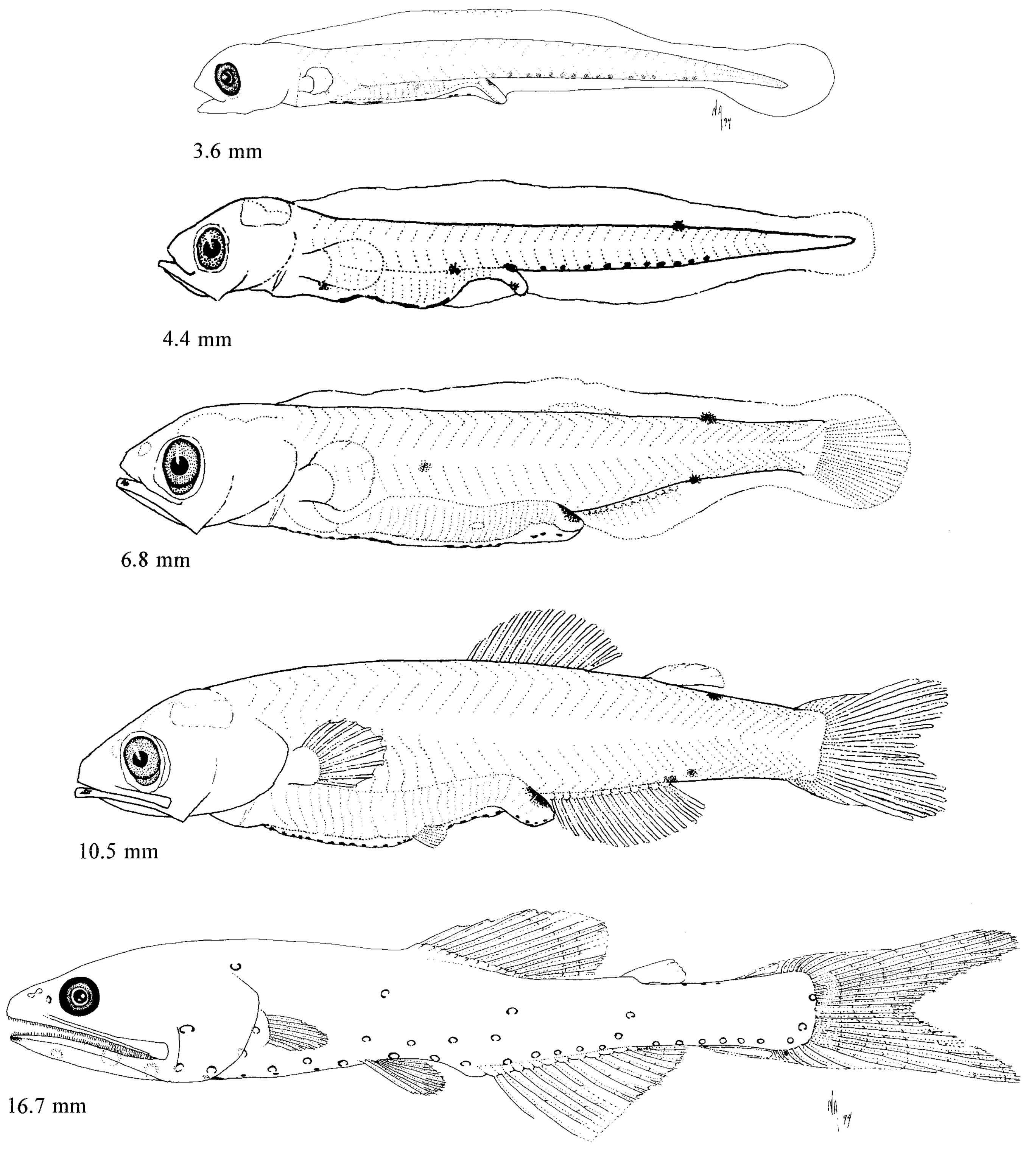


Figure Myctophidae 25. Preflexion larvae, 3.6 mm (CalCOFI 5904, station 100.75), 4.4 mm; flexion larva, 6.8 mm; postflexion larva, 10.5 mm (Ahlstrom 1972a); juvenile, 16.7 mm (CalCOFI 6610, station 97.35).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	34
Precaudal	15–16	16
Caudal	17–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	16–18	17
Pelvic	8	8
Pectoral	8–10	9
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–6	6
Lower	5–6	6
Gill rakers:		
Upper	2–4	3
Lower	7–11	9
Branchiostegals		

LIFE HISTORY

Range: Widespread across tropical & subtropical Pacific & Indian Oceans

Habitat: Mesopelagic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser 1981
Moser et al. 1984a
Ozawa 1986b, 1988d

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.1 mm (N. Arthur)
Flexion larva, 5.6 mm (N. Arthur)
Juvenile, 16.2 mm (N. Arthur)

* Eye oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2 mm
Flexion length: 5.5–6.5 mm
Transformation length: ca. 15 mm
Fin development sequence: C_1, A, D, P_1, C_2, P_2
Pigmentation: *Preflexion*—At 3.0–4.5 mm, up to 11 dashes on lateral midline, 1 embedded at P_1 base, ca. 7 embedded ventral median postanal dashes, on margin of ventral finfold, & pair on terminal gut section & laterally on midgut; at 4.5–5.5 mm, 1 in midline at cleithral symphysis, 1 at lower jaw symphysis, midlateral series reduced to 2–6, & postanal series reduced to 2–4. *Flexion*—Pair at midlateral gut; delicate series along bases of A rays; one at A insertion & 1 or 2 on ventral margin of caudal peduncle. *Postflexion*—Vertical series at base of C rays; by 10 mm, 1 or 2 above caudal peduncle & at Ad base.
Diagnostic features: Moderately slender; gut moderate in length, slightly sigmoid; eye slightly elliptical with lunate ventral choroid tissue; lateral midline & ventral finfold pigmentation; photophores form at transformation; caudal luminous glands form in late larvae; *T. mexicanus* similar but lacks lateral midline pigment.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–62	61–64	56–64		55–57
		58	63	61	57	56
BD/BL		12–18	17–21	19–22		17–18
		15	19	20	18	17
HL/BL		21–26	27–29	24–30		27–28
		23	28	27	28	27
HW/HL		53–62	53–55	50–59		36–40
		57	54	55	41	38
SnL/HL		18–29	28–32	25–31		20–20
		25	30	29	19	20
ED/HL*		22–30×	22–25×	18–26×		16–16×
		29–36	26–29	22–28		17–18
		25×32	23×28	22×26	15×18	16×17
P_1L/BL		6–8	9–10	7–11		
		7	9	9	6	5
P_2L/BL		0–0	0.4–0.7	1–6		7–9
		0	0.6	3	9	8

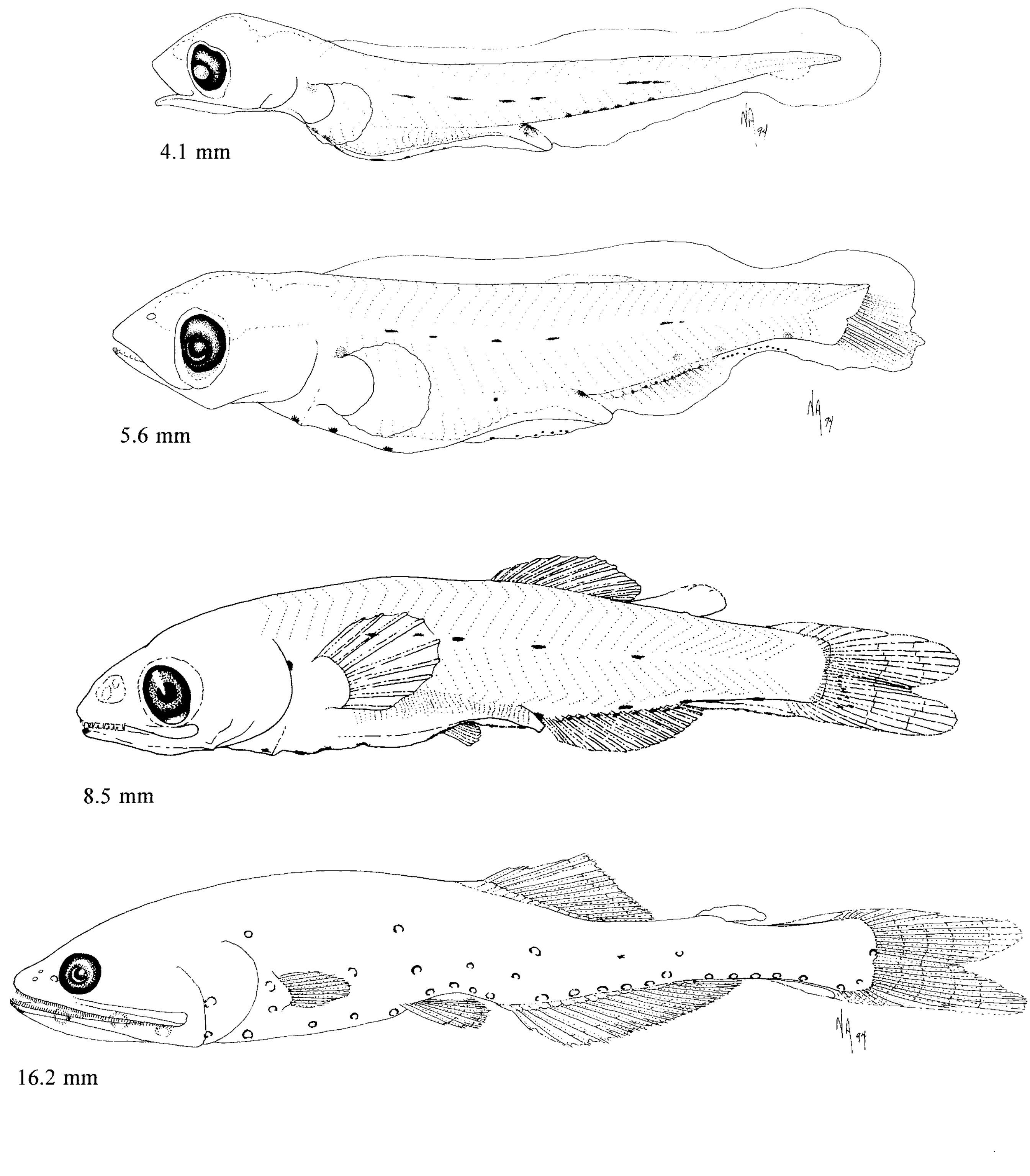


Figure Myctophidae 26. Preflexion larva, 4.1 mm (NORPAC, station 78 Deep); flexion larva 5.6 mm (CalCOFI 5009, station 70.280); postflexion larva, 8.5 mm (Moser 1981); juvenile, 16.2 mm (Cato II, station A5).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–33	32
Precaudal	13–14	14
Caudal	18–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	19–22	21
Pelvic	8	8
Pectoral	13–16	14–15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	7–8	7
Gill rakers:		
Upper	8–10	9
Lower	17–21	19
Branchiostegals	8	8

LIFE HISTORY

Range: Subtropical-tropical northeastern Pacific between 28° N & 10° N, including Gulf of California

Habitat: Epi- to mesopelagic near coast; forms dense aggregations at surface at night

Spawning season: The few occurrences in CalCOFI region were throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser & Ahlstrom 1970
Moser et al. 1984a

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* Calculations based on data in Moser & Ahlstrom (1970).
† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 4.1–5.8 mm
Transformation length: ca. 10.5–12.3 mm
Fin development sequence: C_1, C_2 & P_1 & A, D, P_2
Pigmentation: *Preflexion*—By 2.5 mm, ventrolateral pair of elongate dashes at cleithrum; dorsolateral pair on terminal gut section, 2 pairs on lateral midgut, & 5–9 in postanal median ventral series; by 3.0 mm, 1 on lower jaw tip; by 4.0 mm, some have only a single lateral gut pair & postanal series coalesced to 1. *Flexion*—Patch forms above bladder & cleithral dash angles dorsad along cleithrum; by ca. 5.0 mm, anterior to P_1 base, anterior to each nostril, in ceratohyal region, embedded on ventrolateral surface of hindbrain, & 1 to several in vertical series on posterior edge of hypurals. *Postflexion*—By ca. 6.0 mm, a series on A base (in some); by ca. 7.7 mm, 1 medially above cerebellum; by 8.0 mm, a series embedded along haemal spines.
Diagnostic features: Moderately stout body; gut to ca. midbody, slightly sigmoid; head moderate in size, rounded; snout blunt in postflexion stage; eye elliptical, wider after preflexion stage; lunate choroid tissue; postanal series coalesces to 1 melanophore; Br_2 & Dn photophores forming at ca. 4.0 mm; PO_5 in 6 mm larvae; PVO_1 & upper Op in 7 mm larvae; PO_1; VO_1, & AO_1 in 8 mm larvae.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–53 51	54–62 58	55–61 58	 57	
BD/BL		14–17 16	19–23 21	21–25 23	 25	
HL/BL		21–24 23	27–33 30	28–31 30	 32	
HW/HL		61–78 71	59–68 62	52–63 57	 53	
SnL/HL						
ED/HL†		24–30× 35–43 28×39	26–29× 32–38 27×35	25–29× 27–34 27×31	 29	
P_1L/BL						
P_2L/BL						
CL/HL		0–3 0.7	3–6 4	3–5 4	 0	

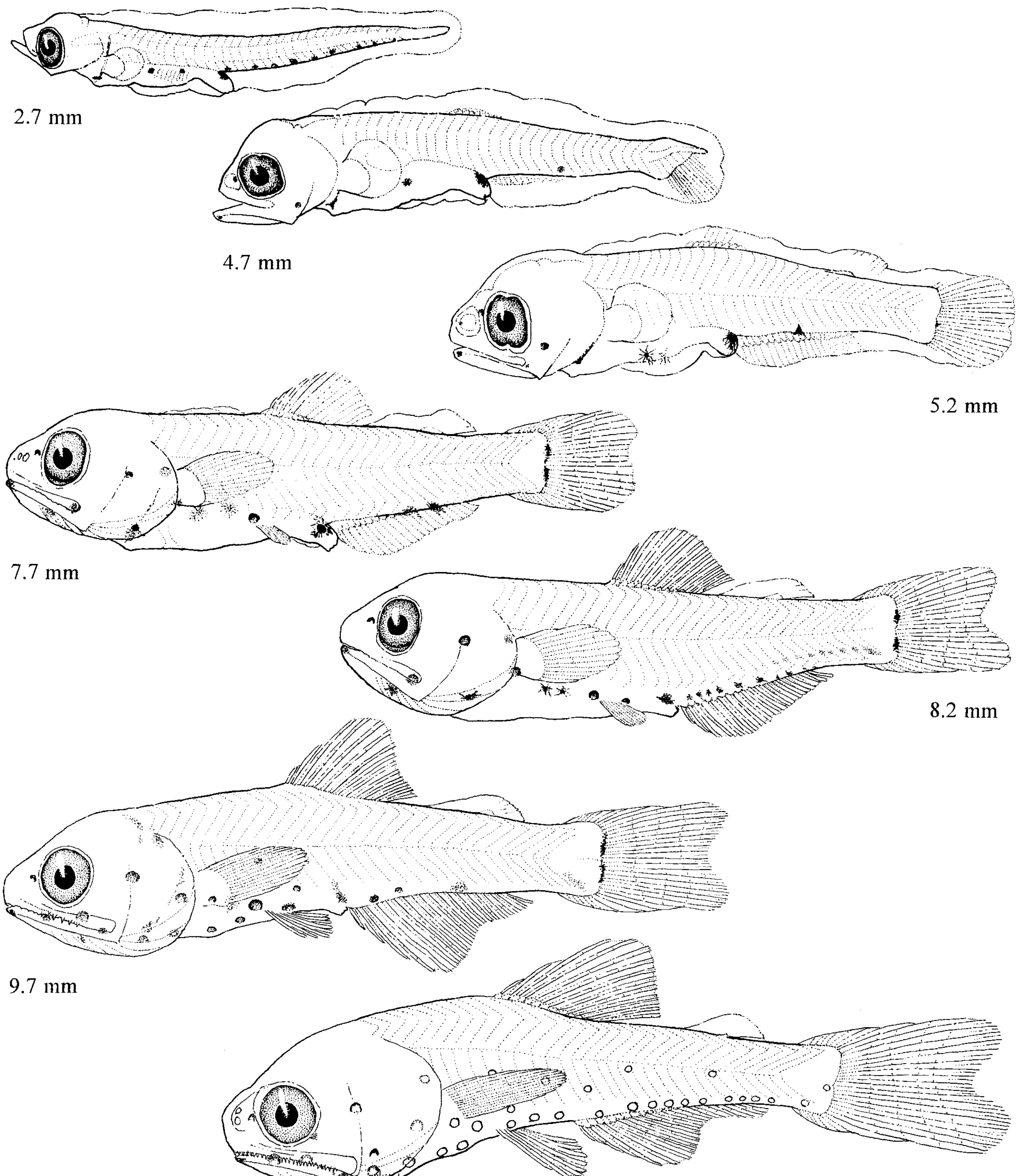

Figure Myctophidae 27. Preflexion larva, 2.7 mm; flexion larva, 4.7 mm; postflexion larvae, 5.2 mm, 7.7 mm, 8.2 mm; transformation specimen, 9.7 mm; juvenile, 11.8 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	34
Precaudal	15	15
Caudal	18–19	19
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	16–19	17
Pelvic	8	8
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8	8
Lower	7–8	7
Gill rakers:		
Upper	3–4	3
Lower	10–11	11
Branchiostegals		

LIFE HISTORY

Range: Warm water; apparently circumglobal, except central & eastern equatorial Pacific Ocean

Habitat: Epi- to mesopelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Badcock & Merrett 1976
Fahay 1983
Moser & Ahlstrom 1974
Moser et al. 1984a
Ozawa 1986b, 1988d
Pertseva-Ostroumova 1964, 1974
Shiganova 1977

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.5 mm (N. Arthur)
Flexion larva, 6.5 mm (N. Arthur)
Postflexion larva, 7.3 mm (N. Arthur)
Transformation specimen, 9.7 mm (N. Arthur)
Juvenile, 14.5 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.0 mm
Flexion length: 5.2–6.5 mm
Transformation length: ca. 10.0 mm
Fin development seqnence: P_1, C_1, A, C_2, D, P_2
Pigmentation: *Preflexion*—Pair just anterior to cleithral symphysis at ca. 4 mm, later coalesces in midline. *Flexion*—at lower jaw symphysis by ca. 5.5 mm; two embedded blotches anterior to P_1 base, one near top & the other near bottom of fin base.
Diagnostic featnres: Short, deep body; narrow eyes with lunate mass of choroid tissue on ventral surface; gut short, terminal section deflected acutely ventrad, Sn-A <50% BL in preflexion & flexion stages; middle Br photophore forms at ca. 5.0 mm; first & second PO's form at ca. 9 mm; pigment scanty; embedded blotches anterior to P_1 base; similar to *Electrona risso* which has relatively longer gut & pigment on P_1 rays but lacks blotches anterior to P_1 base.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–46 44	46–50 48	49–53 52	51–55 53	55–58 56
BD/BL		15–19 17	19–27 23	24–31 29	25–27 26	24–26 25
HL/BL		23–25 24	23–26 25	25–27 27	28–29 28	26–28 27
HW/HL		60–68 63	66–80 72	68–85 75	50–57 54	55–57 56
SnL/HL		23–36 31	28–40 33	25–33 30	22–24 23	18–23 20
ED/HL*		18–23× 42–52 20×46	17–25× 41–48 21×45	19–25× 33–42 22×39	23–30× 32–33 26×33	28–49× 31–49 38×39
P_1L/BL		4–6 5	6–11 9	11–15 13	19	32
P_2L/BL		0–0 0	0–0 0	0.3–4 2	8–9 9	13

* Eye elliptical, narrow; horizontal axis is given first, vertical axis second.

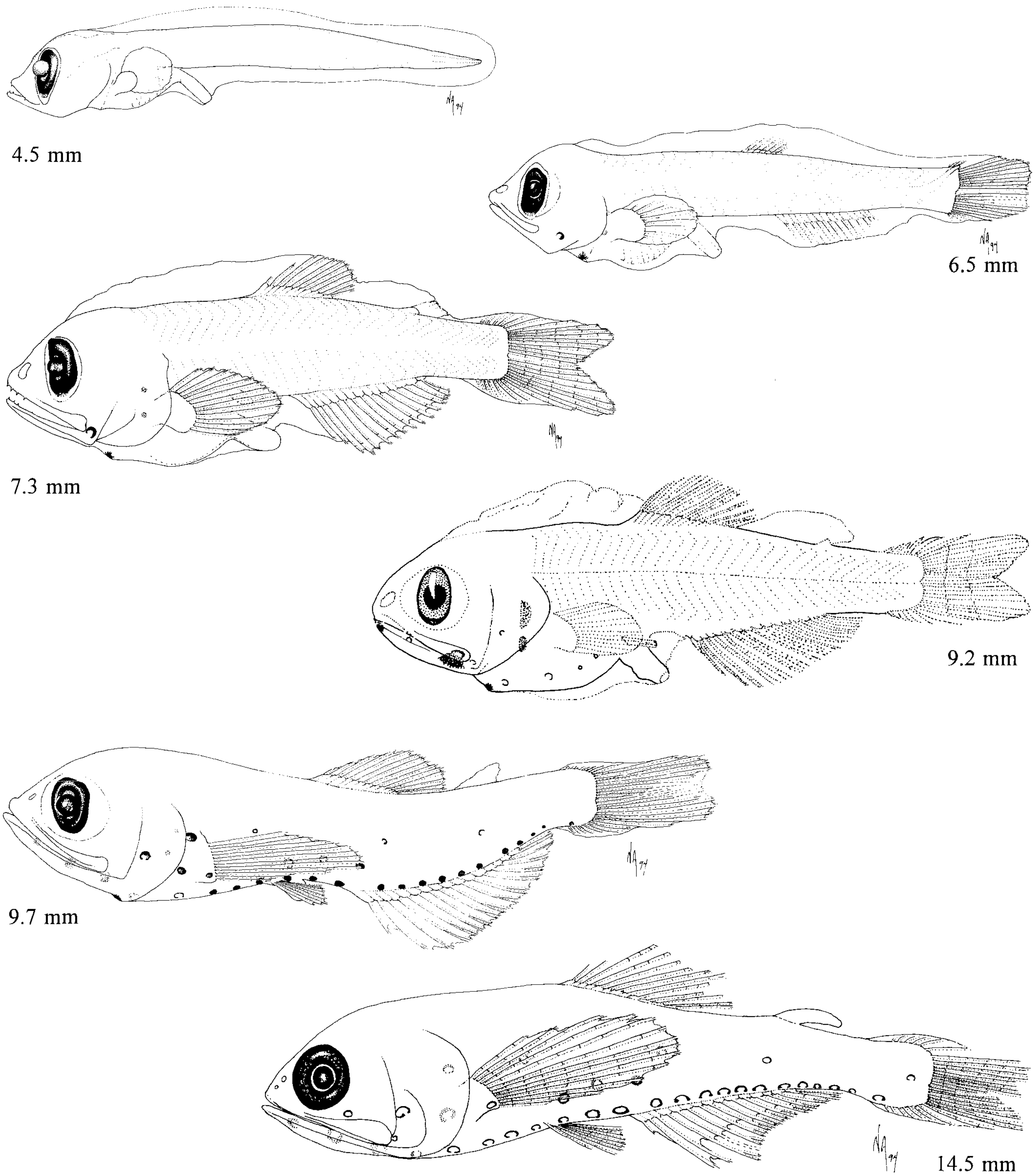

Figure Myctophidae 28. Preflexion larva, 4.5 mm; flexion larva, 6.5 mm (CalCOFI 7205, station 31.141); postflexion larvae, 7.3 mm (Clarke-Hawaii, station 71–6–29), 9.2 mm (Moser and Ahlstrom 1974); transformation specimen, 9.7 mm (CalCOFI 7210, station 31.141); juvenile, 14.5 mm (CalCOFI 7210, station 31.145).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–40	38
Precaudal	14–15	14–15
Caudal	22–25	24
Fins:		
Dorsal spines	0	0
Dorsal rays	9–11	10
Anal spines	0	0
Anal rays	16–19	18
Pelvic	8	8
Pectoral	13–17	14–15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–7	6
Lower	5–7	6
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	7–8	7

LIFE HISTORY

Range: Warm-water cosmopolite; apparently absent from low oxygen waters of eastern tropical Pacific

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser & Ahlstrom 1970, 1974
Moser et al. 1984a
Pertseva-Ostroumova 1964, 1974

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* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, very narrow; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 5.4–6.3 mm
Transformation length: ca. 12 mm
Fin development sequence: C_1 & P_1, C_2 & D & A, P_2
Pigmentation: *Preflexion*—At <4.0 mm, anterodorsal to P_1 base, on trunk near axilla, on upper & lower jaw tips, posterior margin of orbit, anteromedial to mid- & forebrain, & lateral to terminal gut; all but postorbital pigment lost by end of stage. *Flexion*—By ca. 6.0 mm, series outline Br rays, & patch on ventral surface of liver. *Postflexion*—On largest larvae, on posteroventral margin of orbit & posteriorly on upper & lower jaws.
Diagnostic features: Initially moderately slender, becoming deep-bodied & highly compressed; head large with narrow elliptical eyes; conical choroid tissue extremely elongate, unpigmented; terminal gut section only slightly deflected; snout becomes bulbous; large finfolds; early pigment, except postorbital, lost; pigment on branchiostegal membrane & liver forms in postflexion stage; Br_2 photophores form at ca. 5.0 mm; lack of pigment on tail distinguishes *C. nigrocellatus* from those of *C. andreae*.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–65 56	63–66 64	68–70 69		57
BD/BL		12–29 21	28–36 32	31–38 35		19
HL/BL		25–31 28	29–32 31	32–32 32		26
HW/HL		40–50 45	40–48 44	41–47 44		48
SnL/HL						
ED/HL†		14–17× 29–40 16×33	14–16× 26–31 14×29	12–14× 20–27 13×23		20×21
P_1L/BL						
P_2L/BL						
CL/HL		7–28 20	21–32 26	22–31 27		0

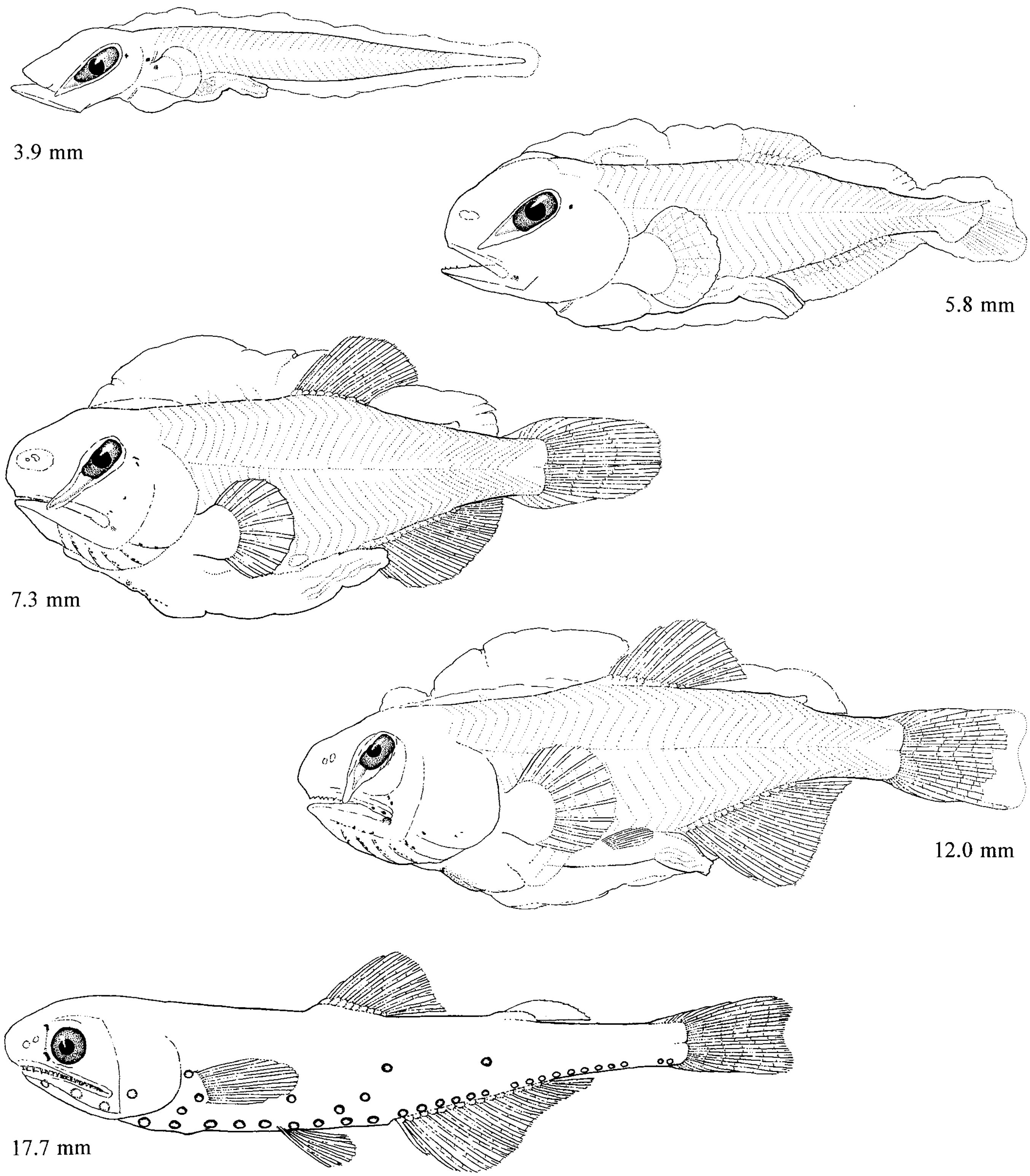

Figure Myctophidae 29. Preflexion larva, 3.9 mm; flexion larva, 5.8 mm; postflexion larvae, 7.3 mm, 12.0 mm; juvenile, 17.7 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–35	33
Precaudal	13–14	14
Caudal	18–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	11
Anal spines	0	0
Anal rays	14–18	16
Pelvic	8	8
Pectoral	12–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	8
Lower	8–9	8
Gill rakers:		
Upper	2	2
Lower	11–13	12
Branchiostegals	6–8	7

LIFE HISTORY

Range: Unevenly distributed warm-water cosmopolite; extends into California Current region from central water mass

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout year in CalCOFI area, with abundance peaks in April & November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Fahay 1983
Moser & Ahlstrom 1970
Moser et al. 1984a
Olivar & Fortuño 1991
Ozawa 1986b, 1988d
Pertseva-Ostroumova 1974
Shiganova 1977
Tåning 1918

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, very narrow in small larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.9 mm
Flexion length: ca. 6.0–6.9 mm
Transformation length: ca. 13.5–14.5 mm
Fin development sequence: C_1, C_2 & P_1 & A, D & P_2
Pigmentation: *Preflexion*—By ca. 3.0 mm, ventrolateral pair just posterior to cleithrum, dorsolateral pair on terminal gut, 2 pairs on lateral midgut, & ca. 3 in postanal series at ventral margin; 1 laterally above preanal arch of gut; at ca. 5.0 mm, first of 3 on dorsal surface of symphyseal barbel; 1 or 2 laterally on gut & up to 4 more postanally by end of stage. *Flexion*—1 (large) at base of rays on C; pair embedded below & pair above hindbrain; 1 on anterior part of P_1 base. *Postflexion*—At ca. 7.0 mm, paired series begin to form at bases of A rays; up to 6 laterally on gut & 12 in postanal ventral midline in largest larvae; 1 posterior to D & one posterior to Ad in largest larvae.
Diagnostic features: Moderately slender body, becoming somewhat compressed; gut to midbody, slightly sigmoid; head size moderate; snout acute, becoming relatively shorter; eye elliptical, becoming wider in later stages, no ventral choroid tissue, although the scleral envelope may extend ventrad from the eye through the early postflexion stage; symphyseal barbel forms at ca. 5.0 mm; melanophore on trunk above preanal arch of gut; Br_2 photophores form at ca. 6.0 mm; PO_2 at ca. 7.0 mm; PO_5 at ca. 8.5 mm; AOa_1 at ca. 11.0 mm.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–56 53	57–60 58	56–62 58	56	60
BD/BL		11–13 12	16–18 17	17–27 23	26	25
HL/BL		21–25 22	27–29 28	28–33 30	28	29
HW/HL		48–60 55	53–56 55	47–64 55	63	59
SnL/HL						
ED/HL†		12–18× 33–40 14×37	18–21× 36–39 19×37	21–30× 34–37 26×36	28×35	39
P_1L/BL						
P_2L/BL						
BbL/HL		6–22 13	20–31 24	13–33 22	0	0

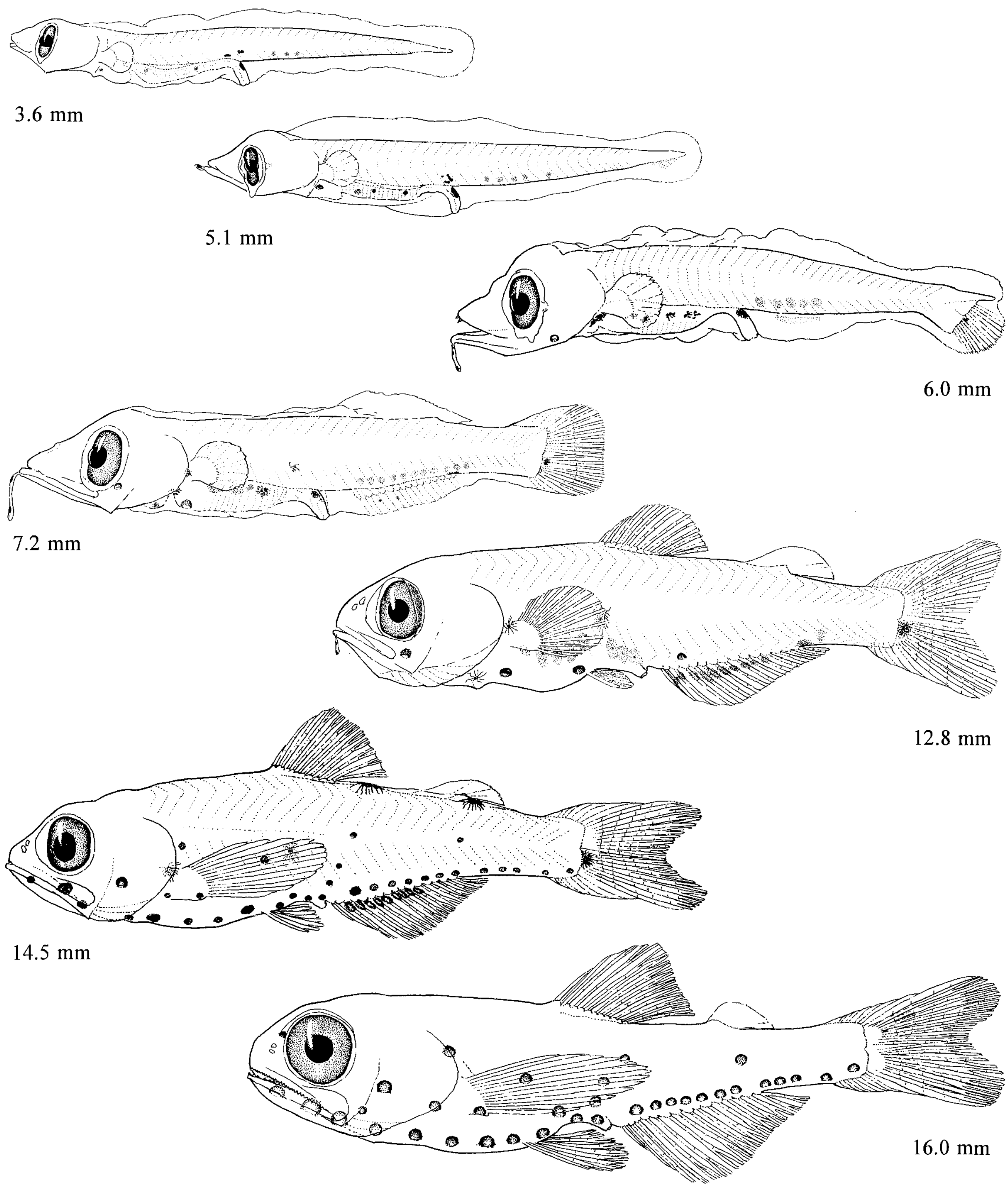

Figure Myctophidae 30. Preflexion larvae, 3.6 mm, 5.1 mm; flexion larva, 6.0 mm; postflexion larvae, 7.2 mm, 12.8 mm; transformation specimen, 14.5 mm; juvenile, 16.0 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–32	31
Precaudal	12–13	12
Caudal	18–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	10–13	11–12
Anal spines	0	0
Anal rays	15–17	16
Pelvic	8	8
Pectoral	10–12	11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	7–9	8
Gill rakers:		
Upper	3–4	3
Lower	10–11	10–11
Branchiostegals	7	7

LIFE HISTORY

Range: Eastern Pacific from ca. Point Conception, California to ca. 33° S; common in eastern tropical Pacific waters with low oxygen minimum

Habitat: Epi- to mesopelagic

Spawning season: Larvae present year-round in CalCOFI area; most abundant during February–April & August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Castillo 1979
Moser & Ahlstrom 1970
Moser et al. 1984a
Ozawa 1986b, 1988d

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, very narrow in small larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.9 mm
Flexion length: ca. 5.2–6.1 mm
Transformation length: ca. 10.5–12.3 mm
Fin development sequence: C_1, C_2, P_1, A, D & P_2
Pigmentation: *Preflexion*—By ca. 3.0 mm, ventrolateral pair just posterior to cleithrum, dorsolateral pair on terminus of gut, 2 pairs on lateral midgut, & 3–5 in postanal median ventral series; at ca. 4.5 mm, on anterior margin of lower jaw. *Flexion*—5–9 in postanal series, becoming embedded. *Postflexion*—By ca. 7.0 mm, 10–12 in postanal series, 1 (large) on anterior region on P_1 base, pair on isthmus on each side of urohyal region, ventrolateral & dorsolateral pairs on hindbrain, 1 (large) at base of lower C rays, & beginning of paired series on each side of A base; in larvae >7.7 mm, 1 or 2 more laterally on gut (some specimens); 11–12 in postanal series.
Diagnostic features: Morphology similar to *D. atlanticus*; lacks barbel but has pigment at tip of lower jaw; lacks large melanophore on trunk above preanal arch of gut that is present in *D. atlanticus*; Br_2 photophores form at ca. 4.5 mm; PO_5 the only other pair to develop in larvae.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–53 51	52–54 53	53–58 56		59
BD/BL		10–14 11	14–16 15	17–26 23		26
HL/BL		17–24 20	23–28 26	27–32 29		30
HW/HL		61–68 63	57–65 60	50–64 56		50
SnL/HL						
ED/HL†		15–22× 34–44 19×39	21–21× 35–38 21×36	21–26× 29–38 24×33		32
P_1L/BL						
P_2L/BL						

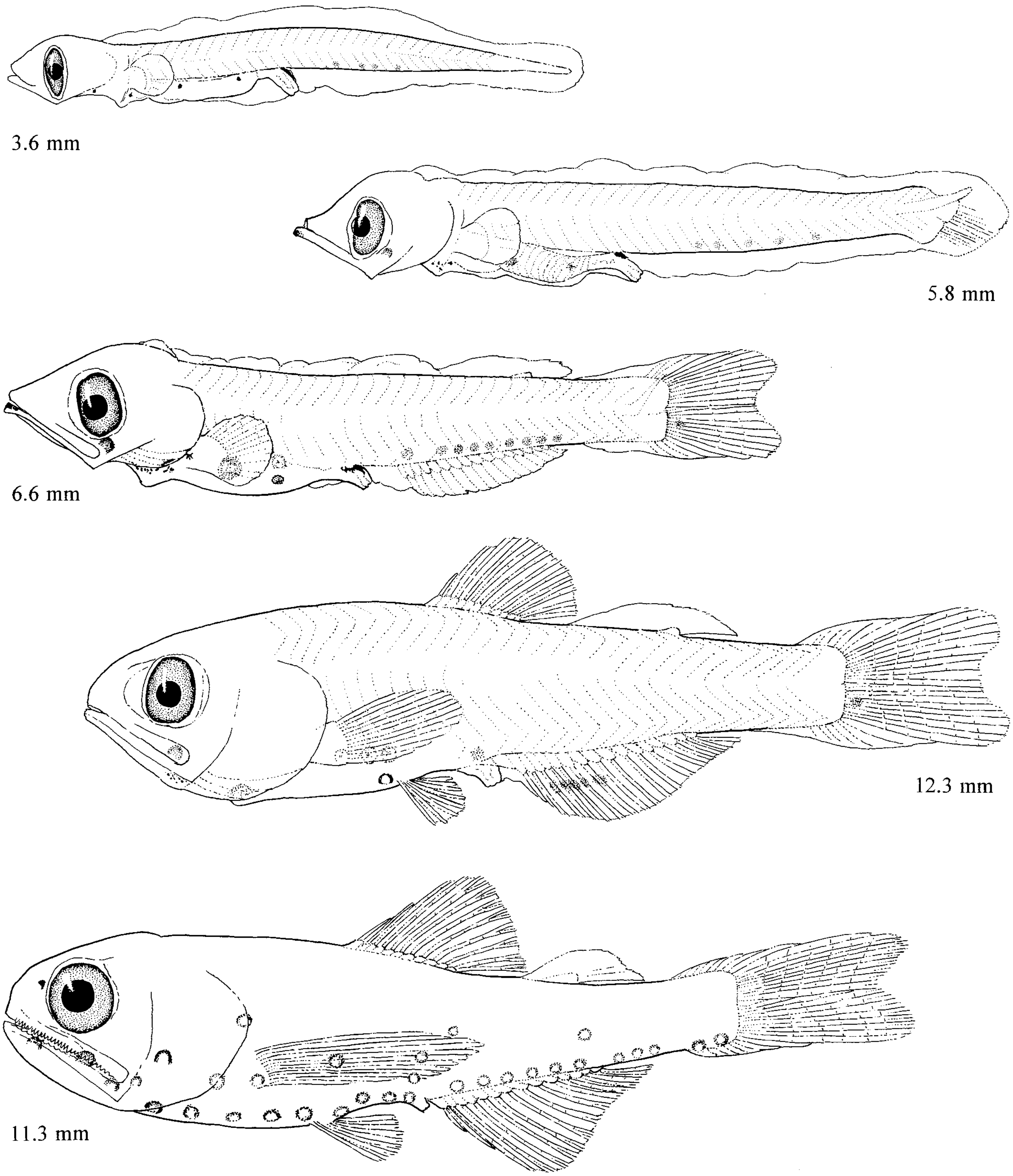

Figure Myctophidae 31. Preflexion larva, 3.6 mm; flexion larva, 5.8 mm; postflexion larvae, 6.6 mm, 12.3 mm; juvenile, 11.3 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	32–34	33
Precaudal	14–16	15
Caudal	17–20	17
Fins:		
Dorsal spines	0	0
Dorsal rays	12–15	14
Anal spines	0	0
Anal rays	18–20	19
Pelvic	8	8
Pectoral	13–16	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–8	7
Lower	6–7	6
Gill rakers:		
Upper	8–9	
Lower	18–21	
Branchiostegals	7–9	8

LIFE HISTORY

Range: Recorded from disjunct localities in the Atlantic, Pacific, Indian, & Southern Oceans; enters California Current region from central water mass

Habitat: Epi- to mesopelagic

Spawning season: Larvae present during all seasons in CalCOFI surveys

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Dekhnik & Sinyukova 1966
Fahay 1983
Matarese et al. 1989
Moser & Ahlstrom 1970
Moser et al. 1984a

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: < 3.8 mm
Flexion length: ca. 6.0–7.0 mm
Transformation length: ca. 9.5–10.0 mm
Fin development sequence: C_1, C_2, A, D & P_2
Pigmentation: *Preflexion*—None. *Flexion*—By ca. 6.0 mm, a pair at lower jaw tip & a patch on P_1 blade; by 7.0 mm, above developing gas bladder. *Postflexion*—Some larvae >9.0 mm have 1 on each side of foregut.
Diagnostic features: Stout; gut slightly sigmoid, extends to ca. midbody; foregut relatively thick, becoming somewhat saccular; head large & broad; eye large but narrow; pigment scanty; transforms at small size (ca. 10.0 mm); Br_2 photophores begin to form at ca. 5.8 mm; PO series the first to form at transformation; similar to *Benthosema suborbitale* which has cleithral pigment, a shorter gut, & lacks pigment on P_1 rays.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–55 52	53–58 56	57–62 59		58–60 59
BD/BL		16–19 17	19–21 20	19–30 24		29–31 31
HL/BL		26–29 27	27–29 28	28–33 30		32–34 33
HW/HL		58–67 64	68–72 70	61–72 66		53–58 55
SnL/HL						
ED/HL†		7–13× 15–16 11×15	16–19× 35–42 18×38	18–27× 33–41 22×38		35–46× 38–49 41×44
P_1L/BL						
P_2L/BL						

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, narrow; horizontal axis is given first, vertical axis second.

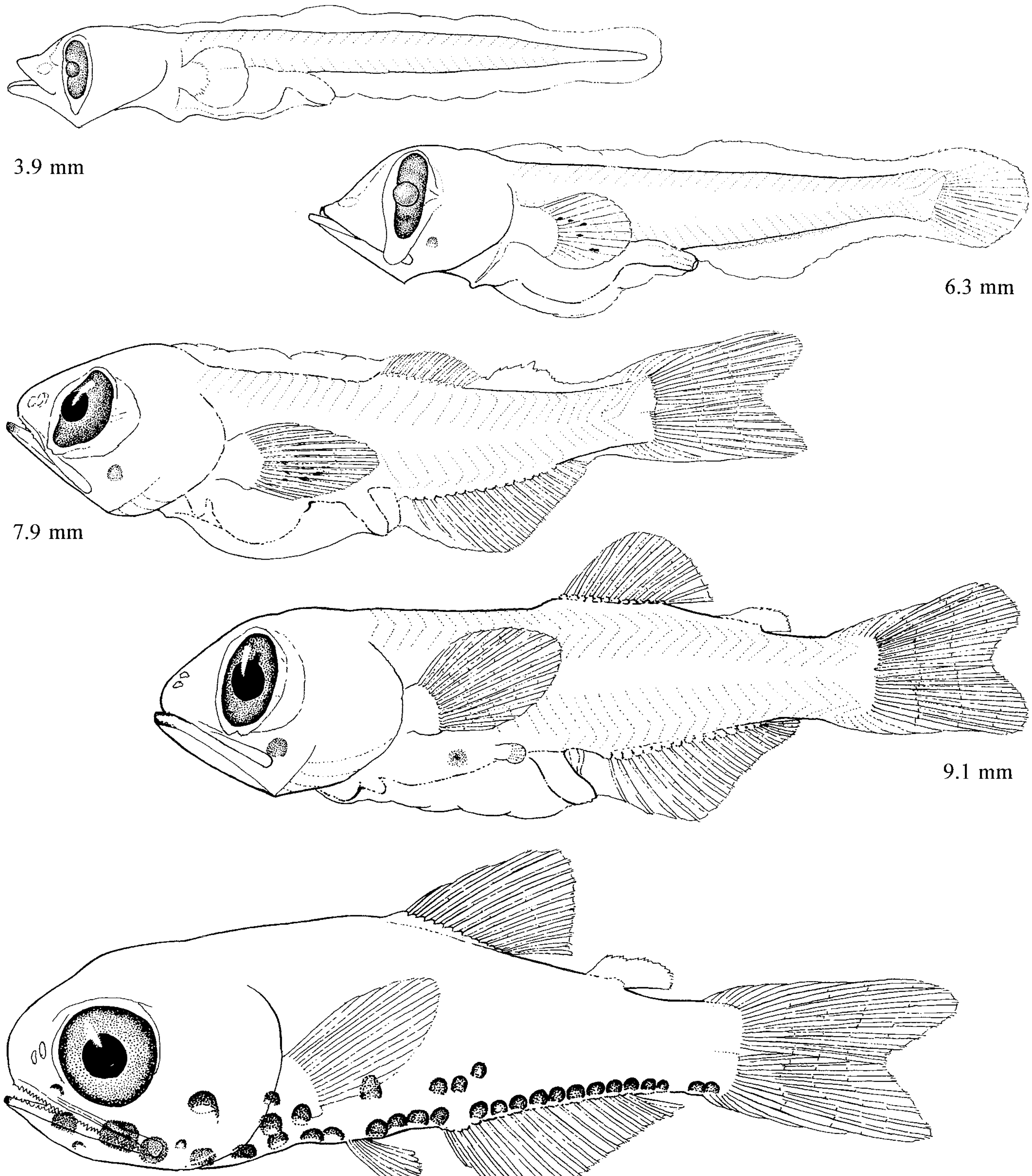

Figure Myctophidae 32. Preflexion larva, 3.9 mm; flexion larva, 6.3 mm; postflexion larvae, 7.9 mm, 9.1 mm; juvenile, 9.9 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–41	39
Precaudal	14–16	15
Caudal	23–26	24
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	11
Anal spines	0	0
Anal rays	17–20	18
Pelvic	6–8	7
Pectoral	11–14	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–6	5
Lower	5–6	5
Gill rakers:		
Upper	4–6	5
Lower	8–12	10
Branchiostegals	8–9	9

LIFE HISTORY

Range: Eastern Pacific between ca. 32° N & 22° S

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae occur throughout the year in CalCOFI area, with highest abundance from December to May

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Castillo 1979
Moser & Ahlstrom 1970, 1974
Moser et al. 1984a

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical to oval, very narrow in small larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 5.2–6.9 mm
Transformation length: ca. 11.5–14.0 mm
Fin development sequence: C_1 & P_1, C_2 & D & A, P_2
Pigmentation: *Preflexion*—By 3.0 mm, 1 at mid-postanal ventral margin, a pair on gut lateral to preanal arch, & a blotch embedded anterior to gut; 3 on midline of brain (posterior to cerebellum, posterior to optic lobes, & anterior to forebrain), & at tips of upper & lower jaws; by end of stage, 3 (on) at dorsal midline (1 opposing the blotch at postanal ventral margin, 1 above preanal arch of gut & 1 between these), a second at postanal ventral margin anterior to first, peppering on margin of dorsal & ventral finfold, upper jaw augmented, & one at lower jaw lost. *Flexion*—Above nostril; embedded in otic region; peppering on P_1 blade; on head anterodorsal to P_1 base; beginning of series on each side of A base; 1 on dorsal midline anterior to D base & 1 at D insertion; opposing postanal blotches form a heavy bar. *Postflexion*—At nape; on posterior margin of orbit; on branchiostegal membrane; at gular region; on liver; a lateral gut series; on A rays.
Diagnostic features: Initially slender, becoming deep-bodied & highly compressed; gut sigmoid with terminal section deflected sharply ventrad; large head & jaws with relatively small oval eye; elongate conical choroid tissue pigmented at tip; large median finfold; Br_2 photophores form at ca. 6.5 mm; Br_1, Br_2, upper Op the first to form at transformation.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–53 49	54–64 59	57–66 62		50
BD/BL		12–19 15	21–32 26	29–34 33		22
HL/BL		22–27 25	29–36 33	31–37 35		29
HW/HL		41–52 48	34–44 39	36–42 38		42
SnL/HL						
ED/HL†		17–22× 29–39 19×34	14–18× 21–27 15×24	13–15× 18–21 14×19		20×22
P_1L/BL						
P_2L/BL						
CL/HL		5–19 11	18–21 19	8–18 16		0

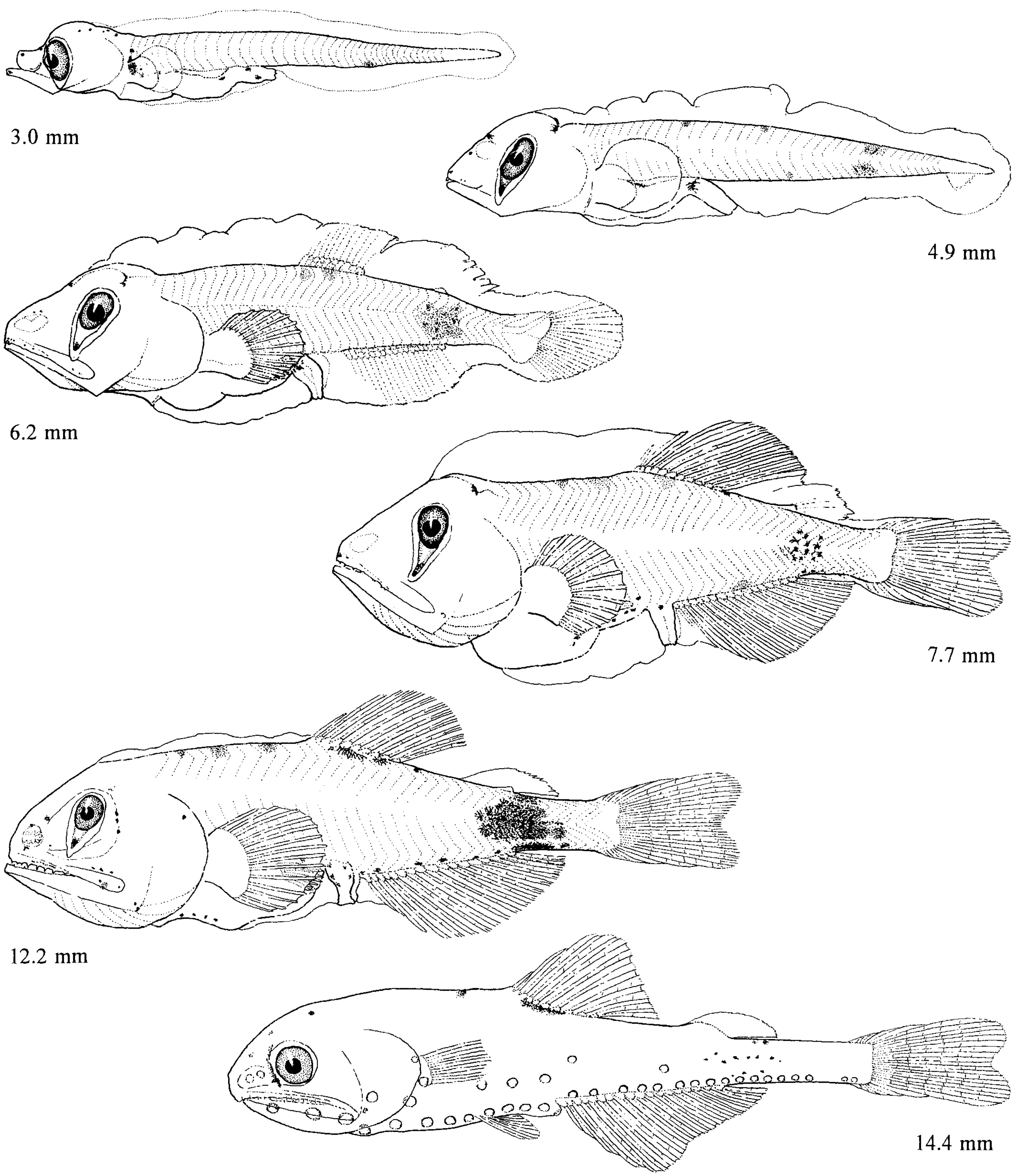

Figure Myctophidae 33. Preflexion larvae, 3.0 mm, 4.9 mm; flexion larva, 6.2 mm; postflexion larvae, 7.7 mm, 12.2 mm; juvenile, 14.4 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–37	36
Precaudal	15–17	16
Caudal	19–21	20
Fins:		
Dorsal spines	0	0
Dorsal rays	11–14	12–13
Anal spines	0	0
Anal rays	18–21	19–20
Pelvic	8	8
Pectoral	12–15	13–14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–9	8
Lower	6–9	8
Gill rakers:		
Upper	4–6	4–5
Lower	14–17	15–16
Branchiostegals	8–9	9

LIFE HISTORY

Range: Eastern Pacific from ca. 30° N to 30° S; widely distributed in eastern tropical Pacific waters with low oxygen minimum

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae present throughout year in CalCOFI area, with peak abundance in November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser & Ahlstrom 1970
Moser et al. 1984a

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, very narrow; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.4 mm
Flexion length: ca. 7.8–9.7 mm
Transformation length: ca. 11.8–14.5 mm
Fin development sequence: C_1, P_1, C_2 & A, D, P_2
Pigmentation: *Preflexion*—By 3.0 mm, ventrolateral pair just posterior to cleithrum, dorsolateral pair on terminus of gut, 2 lateral gut pairs, 2 in tandem on isthmus, 2 widely-spaced on postanal ventral margin, & 1 at dorsal margin; by 5.0 mm, 1 at lower jaw tip; 1 at hypural anlagen; some on ventral finfold; by end of stage, posterior dash on isthmus divided into pair, 1–3 more on lateral gut, & a postanal pair extending upward in myosepta on each side from ventral margin. *Flexion*—1 or 2 more median dashes on isthmus; 1 on opercle; up to 8 laterally on gut; beginning of series on A base. *Postflexion*—Up to 3 postanal myoseptum dashes; up to 8 laterally on gut; up to 15 on A base.
Diagnostic features: Very slender body; gut elongate, thin, & nearly straight; head flattened; narrow, elliptical eyes on short stalks; conical ventral choroid tissue; isthmus pigment typical of genus; lower jaw melanophore present (absent in *H. reinhardtii* larvae in CalCOFI area); fewer (up to 3) postanal myosepta dashes compared with *H. reinhardtii* (up to 10); Br_1, PO_1, PO_5, VO_4 photophores the first to appear at transformation; lower total vertebral count (35–37) & fewer A rays (18–21) compared with *H. reinhardtii* (38–40 & 21–25).

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		54–63 61	62–66 65	66–67 66	52–60 55	
BD/BL		9–14 10	9–10 9	10–16 12	19–22 21	
HL/BL		19–27 23	23–25 24	25–29 26	26–29 27	
HW/HL		47–58 53	42–48 45	35–44 40	47–56 53	
SnL/HL						
ED/HL†		11–22× 22–44 14×29	11–13× 21–23 12×22	11–13× 20–22 12×21	18–34× 22–34 29×30	
P_1L/BL						
P_2L/BL						
CL/HL		0–27 5	7–8 8	0–8 6	0–4 1	

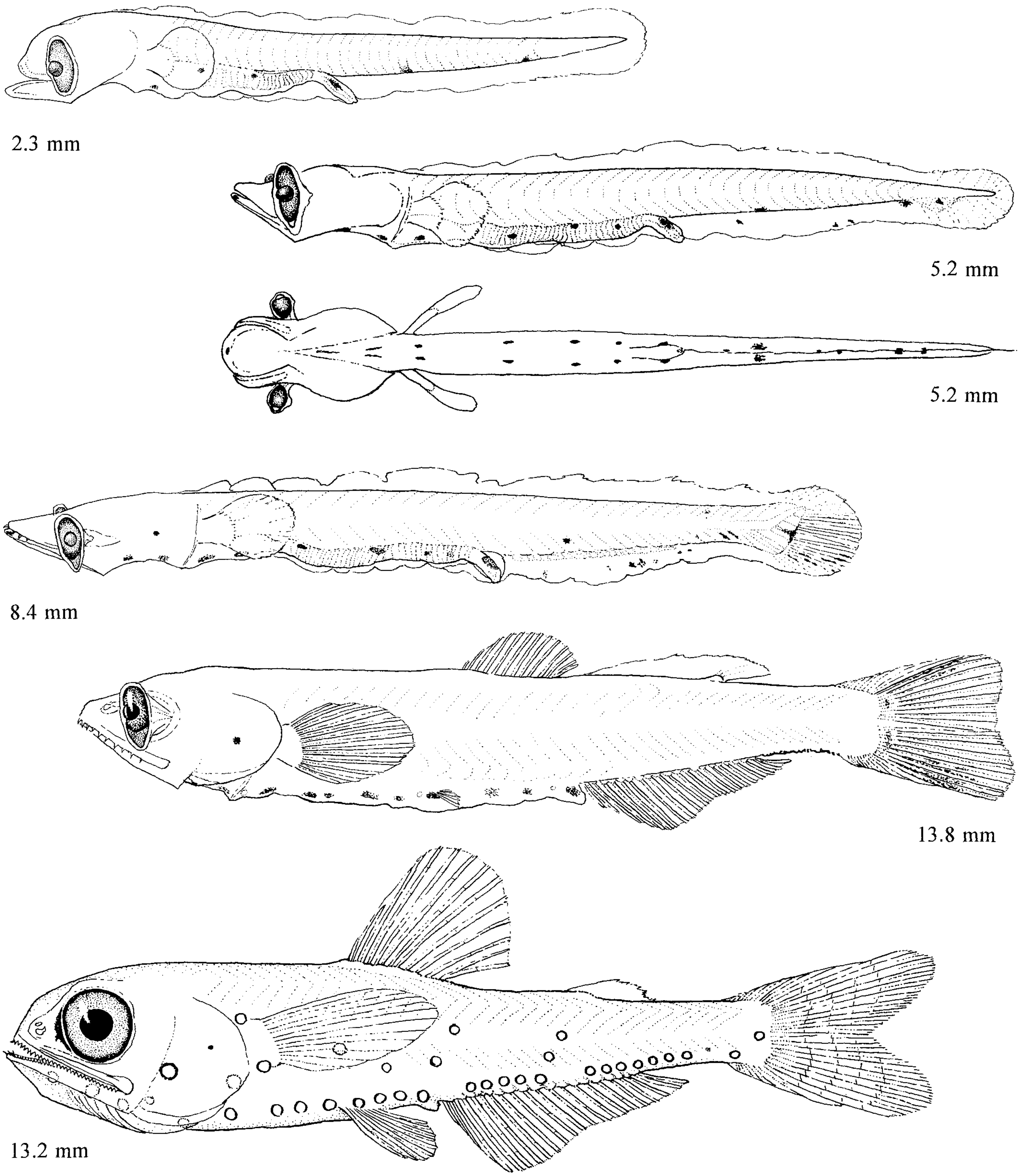

Figure Myctophidae 34. Preflexion larvae, 2.3 mm, 5.2 mm (lateral and ventral views); flexion larva, 8.4 mm; postflexion larva, 13.8 mm; juvenile, 13.2 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–37	36
Precaudal	15–16	15–16
Caudal	18–21	21
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	18–21	19–20
Pelvic	8	8
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	8–9
Lower	8–9	8–9
Gill rakers:		
Upper	4–5	4–5
Lower	12–15	13
Branchiostegals		

LIFE HISTORY

Range: Widespread in tropical & subtropical Pacific & Indian Oceans

Habitat: Epi- to mesopelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Miller et al. 1979
Moser & Ahlstrom 1974
Moser et al. 1984a
Olivar & Fortuño 1991
Ozawa 1986b, 1988d
Pertseva-Ostroumova 1974

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.3 mm, 4.7 mm (N. Arthur)
Flexion larva, 6.3 mm, lateral view (N. Arthur)
Flexion larva, 6.3 mm, ventral view (N. Arthur)
Juvenile, 12.8 mm (N. Arthur)

* Eye elliptical, very narrow in small larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2 mm
Flexion length: 6.1–7.6 mm
Transformation length: ca. 12 mm
Fin development sequence: C_1, P_1, A & C_2, D, P_2
Pigmentation: *Preflexion*—By 3.0 mm, ventrolateral pair on gut posterior to cleithral junction, 1 or 2 lateral pairs along gut, & pair on terminal section of gut; between 3.0–4.0 mm, pair on hypaxial region just posterior to anus, 1 or more in dorsal & ventral finfolds (some specimens), & pair on isthmus just anterior to cleithral symphysis; by 6.0 mm, a median embedded dash on isthmus. *Flexion*—None on hypaxial region or mid-lateral gut. *Postflexion*—By 8.0 mm, another median embedded dash on isthmus.
Diagnostic features: Moderately deep, compressed head & body; moderately narrow eyes with conical ventral choroid tissue; gut slightly sigmoid; sparse pigment; pigment dashes on isthmus & at cleithral symphysis; Br_2 photophores appear at ca. 6.7 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		57–63 61	61–64 62	57–63 61		53–57 55
BD/BL		12–14 13	14–17 16	18–27 23		21–26 23
HL/BL		21–24 23	25–26 25	22–28 25		28–29 29
HW/HL		57–65 61	55–63 59	55–73 61		49–51 51
SnL/HL		20–29 24	30–33 31	29–35 31		14–18 16
ED/HL*		14–17× 30–38 15×33	19–20× 29–33 19×31	21–29× 31–40 25×35		37–38× 37–43 38×39
P_1L/BL		4–7 5	7–8 7	10–12 11		26
P_2L/BL		0–0 0	0–0 0	0–2 0.5		10

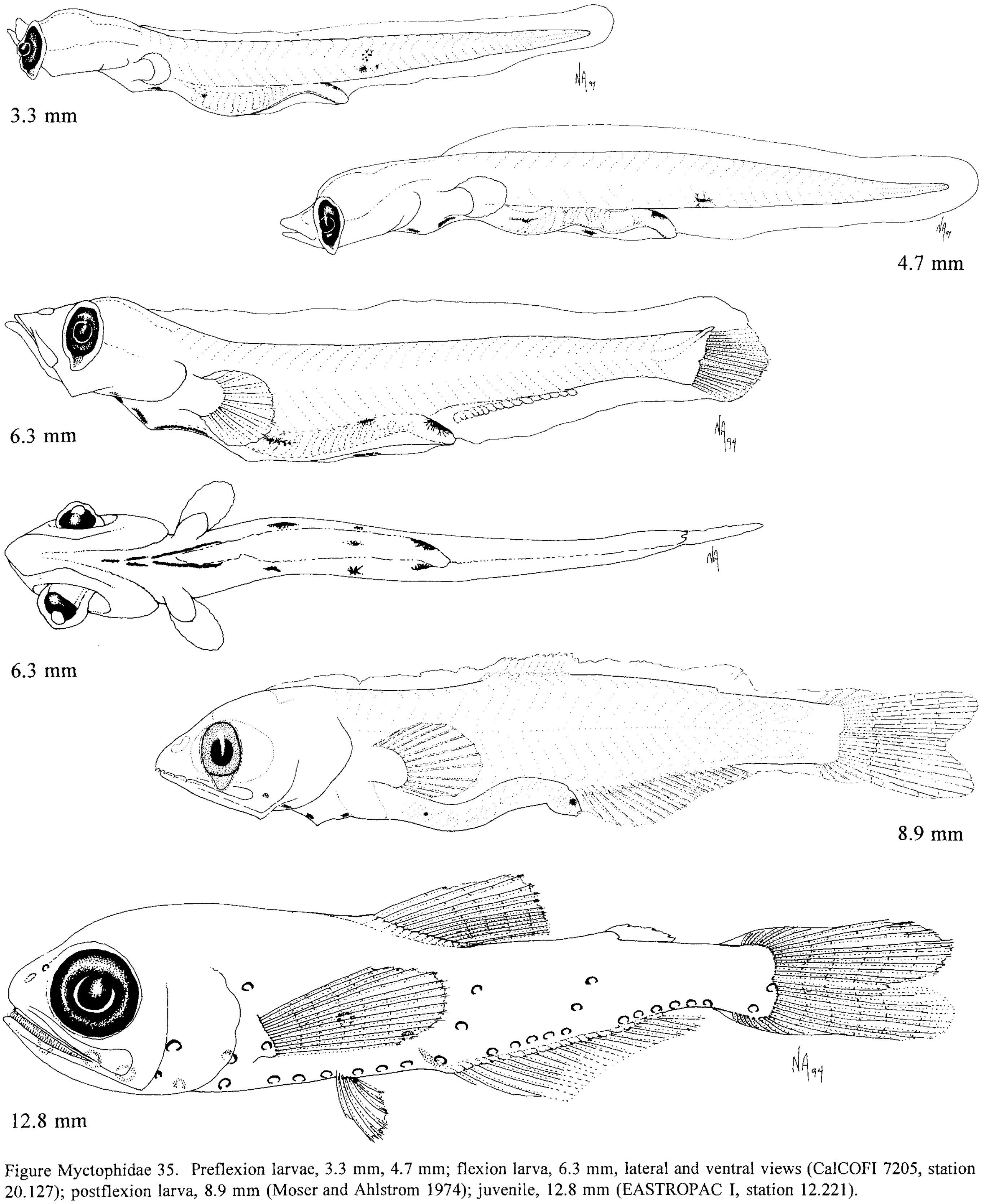

Figure Myctophidae 35. Preflexion larvae, 3.3 mm, 4.7 mm; flexion larva, 6.3 mm, lateral and ventral views (CalCOFI 7205, station 20.127); postflexion larva, 8.9 mm (Moser and Ahlstrom 1974); juvenile, 12.8 mm (EASTROPAC I, station 12.221).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–40	39
Precaudal	16–17	17
Caudal	21–23	22
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14–15
Anal spines	0	0
Anal rays	21–25	22–23
Pelvic	8	8
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	7–8	8
Gill rakers:		
Upper	4–5	4
Lower	13–15	14
Branchiostegals	8–9	9

LIFE HISTORY

Range: Northern & southern subtropical Atlantic & Pacific Oceans; intrudes eastward from central water mass into CalCOFI area

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae occur throughout the year in CalCOFI area; highest abundance in the summer & fall, with peaks in August & November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fahay 1983
Moser & Ahlstrom 1970, 1974
Moser et al. 1984a
Olivar & Fortuño 1991
Ozawa 1986b, 1988d
Shiganova 1977

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, very narrow; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.4 mm
Flexion length: ca. 8.8–10.3 mm
Transformation length: ca. 14.9–16.4 mm
Fin development sequence: C_1, C_2 & P_1, A, D & P_2
Pigmentation: *Preflexion*—Similar to pattern of *H. atratum* except none at lower jaw tip (most specimens), & by end of stage, 1–4 more in postanal series outlining hypaxial myosepta. *Flexion*—7–12 in postanal series. *Postflexion*—5–10 in postanal series.
Diagnostic features: Nearly identical in morphology to *H. atratum*; undergoes notochord flexion & transformation at slightly larger size; higher total vertebral count (38–40 vs. 35–37 in *H. atratum*); lower jaw pigment present in *H. atratum* is not present in most *H. reinhardtii* from CalCOFI region; more melanophores in postanal myosepta pigment series (maximum of 12 vs. maximum of 4 in *H. atratum*); higher A ray count (21–25) than in *H. atratum* (18–21).

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		55–63 59	60–65 62	62–67 64	58–60 59	53
BD/BL		7–10 9	7–8 7	8–15 11	19–21 20	20
HL/BL		21–27 23	23–24 23	24–25 25	24–24 24	26
HW/HL		47–60 51	42–45 43	39–48 42	54–60 57	62
SnL/HL						
ED/HL†		8–15× 22–36 10×26	9–9× 20–21 9×20	9–16× 19–25 13×22	25–27× 31–32 26×32	43
P_1L/BL						
P_2L/BL						
CL/HL		4–9 7	6–9 8	7–9 8	0–4 2	0

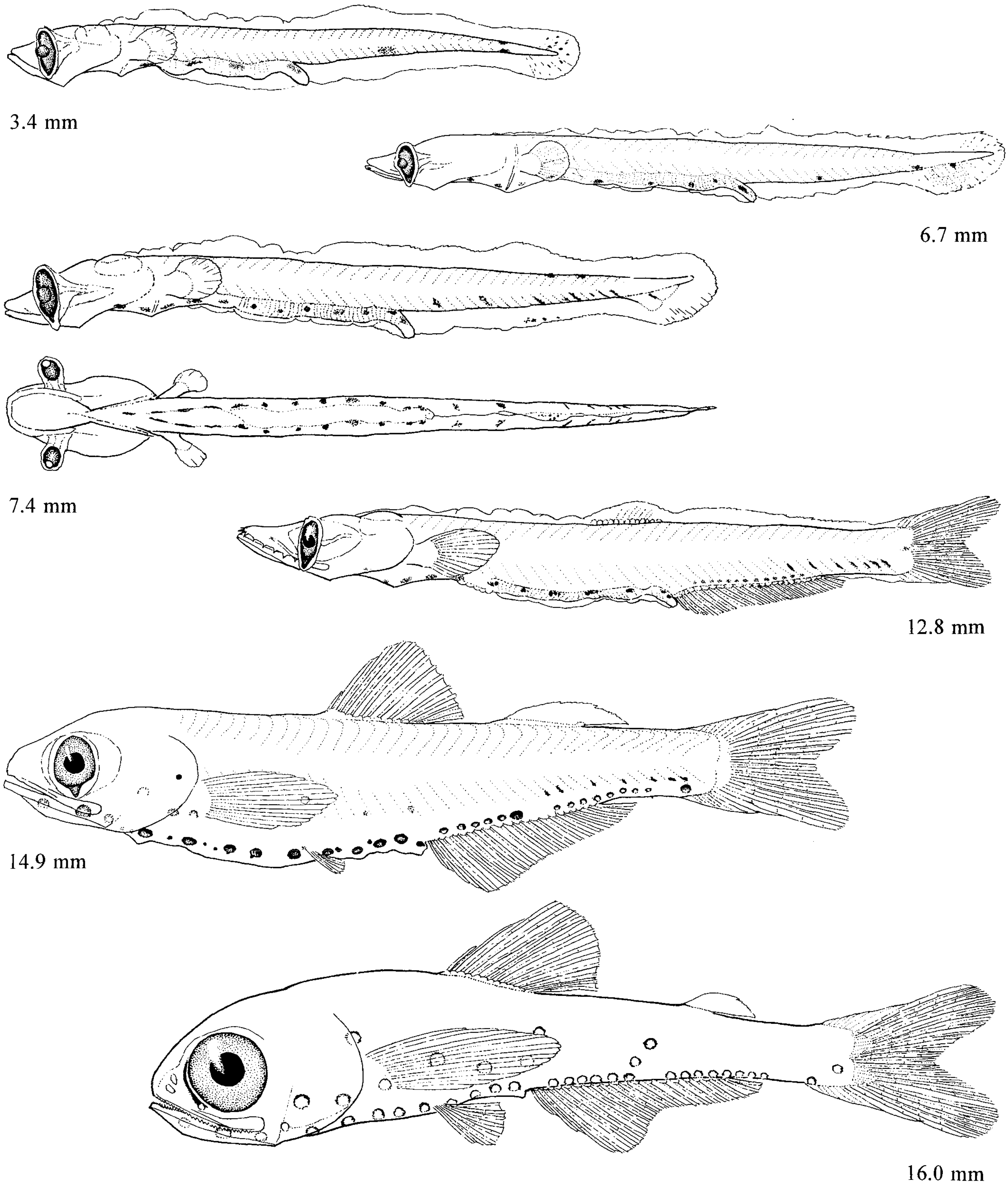

Figure Myctophidae 36. Preflexion larvae, 3.4 mm, 6.7 mm; flexion larva, 7.4 mm, lateral and ventral views; postflexion larva, 12.8 mm; transformation specimen, 14.9 mm; juvenile, 16.0 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–39	38
Precaudal	17–19	18
Caudal	19–21	21
Fins:		
Dorsal spines	0	0
Dorsal rays	10–13	11
Anal spines	0	0
Anal rays	13–17	15
Pelvic	8	8
Pectoral	9–13	10–11
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	6–7	6
Lower	6–7	6
Gill rakers:		
Upper	2	2
Lower	6–7	7
Branchiostegals	8–9	8

LIFE HISTORY

Range: Tropical-subtropical regions of Pacific, Atlantic, & Indian Oceans; in eastern Pacific from ca. 30° N to 30° S

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae present throughout year in CalCOFI area; highest abundance in March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fahay 1983
Matarese et al. 1989
Moser & Ahlstrom 1970, 1974
Moser et al. 1984a
Olivar & Fortuño 1991

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.8 mm
Flexion length: ca. 8.4–10.8 mm
Transformation length: ca. 20.0–21.0 mm
Fin development sequence: P_1, C_1, A, D & C_2, P_2
Pigmentation: *Preflexion*—By 4.0 mm; a heavy transverse bar between fore- & midbrain, an embedded blotch anterior to P_1 base, a blotch embedded above midgut, a blotch on dorsal surface of terminal section of gut, apposing dorsal & ventral blotches in mid-postanal region, & another more anterior dorsal blotch; by 6.0 mm, a median blotch embedded in isthmus, an embedded melanophore at nape, & a blotch on spatulate swellings of elongate lower P_1 ray; by end of stage, embedded blotches at P_1 base & isthmus expanded toward each other to outline ventral border of gill cavity & postanal blotches lost in some specimens. *Postflexion*—Numerous (large) blotches in voluminous finfold; several embedded in postanal hypaxial myosepta; several on P_1 base.
Diagnostic features: Compressed body with voluminous dorsal & ventral finfolds; large head; relatively wide oval eyes; no ventral choroid tissue; elongate gut with large terminal section; large P_1 with elongate ornamented lower ray; D & A far posteriad; distinctive pigment pattern, including transverse bar between fore- & midbrain (lacking in *Tarletonbeania crenularis*).

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		54–66 59	66–74 70	73–81 77	59	
BD/BL		13–17 15	19–23 20	23–30 26	26	
HL/BL		22–30 26	29–32 30	28–34 32	28	
HW/HL		48–60 53	41–48 44	35–52 44	39	
SnL/HL						
ED/HL†		20–23× 29–37 22×33	19–20× 25–30 20×28	19–23× 23–32 20×27	21	
P_1L/BL						
P_2L/BL						

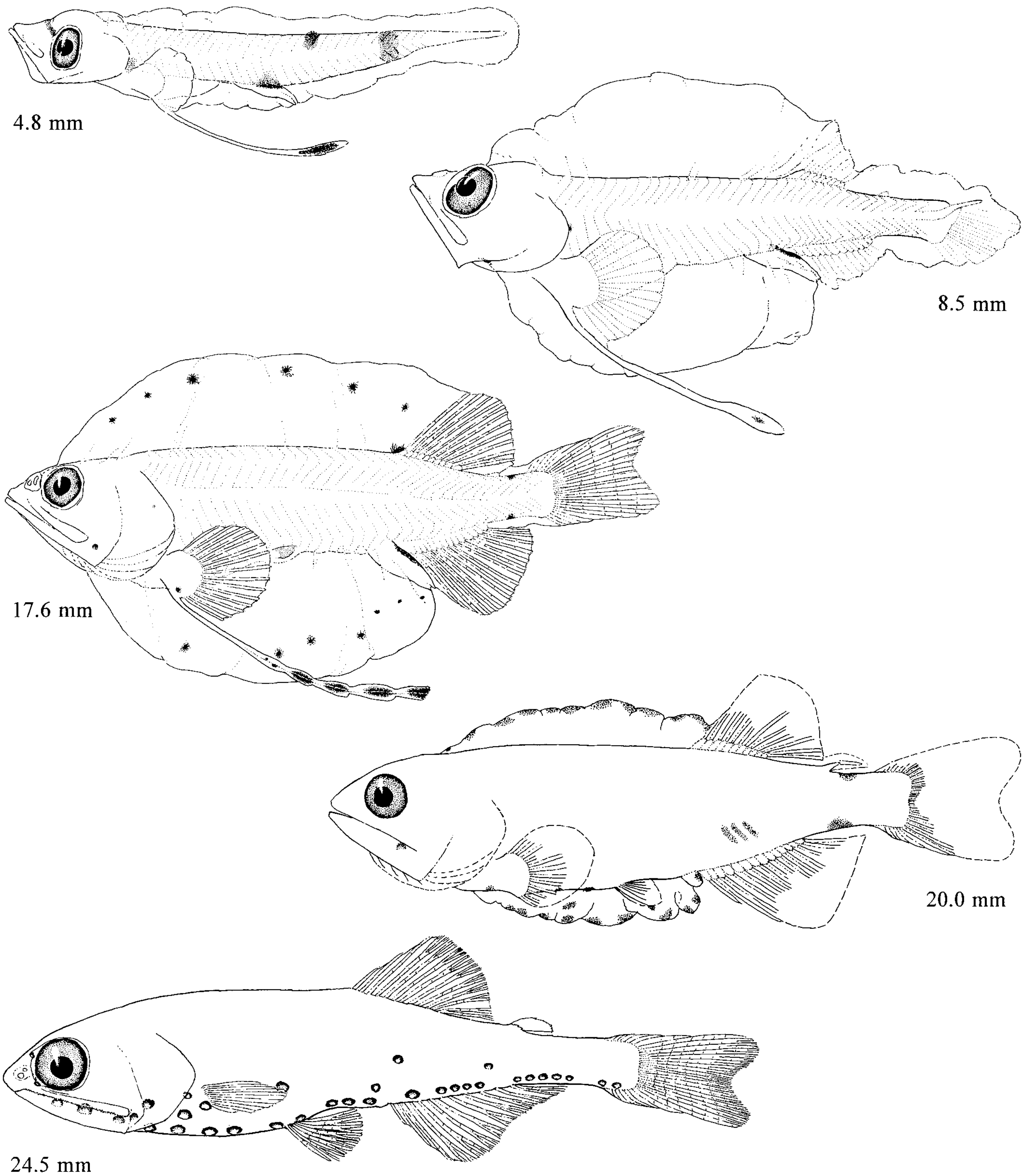

Figure Myctophidae 37. Preflexion larva, 4.8 mm; flexion larva, 8.5 mm; postflexion larva, 17.6 mm; transformation specimen, 20.0 mm; juvenile, 24.5 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	42–46	43–44
Precaudal	18–19	18
Caudal	25–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	9–12	11
Anal spines	0	0
Anal rays	21–27	24
Pelvic	8	8
Pectoral	12–16	13–15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8	8
Lower	7–8	7–8
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Tropical-subtropical Pacific & Indian Oceans; in eastern Pacific between 25° N & 17° S

Habitat: Epi- to mesopelagic; at surface to 300 m depth at night

Spawning season: Larvae collected January–April & September–November in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser & Ahlstrom 1974
Moser et al. 1984a
Ozawa 1986b, 1988d

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 4.0 mm, 5.8 mm (B. Sumida MacCall)
Flexion larva, 12.5 mm (B. Sumida MacCall)
Postflexion larva, 25.8 mm (B. Sumida MacCall)
Juvenile, 25.9 mm (B. Sumida MacCall)

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* Eye elliptical; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: ca. 11.7–13.8 mm
Transformation length: ca. 27–30 mm
Fin development sequence: C_1, P_1 & C_2 & A, D, P_2
Pigmentation: *Preflexion*—By 4.0 mm, 2 (apposing) on dorsum & ventrum near notochord tip, 4–6 laterally on gut, 2–6 paired dashes on isthmus, 2–4 paired ventrolateral dashes just posterior to cleithrum, 1 to several on terminal section of gut, on tip & lateral surface of lower jaw, 2–3 postanally at ventral margin, & several on lower edge of gill cover; by 6.0 mm, 3–4 dashes on isthmus, 2–5 at postanal ventral margin, several on ventral finfold; by end of preflexion, 7–10 laterally on gut, 2–3 on lateral margins of midbrain, apposing blotches at notochord tip (dispersed to hypural region). *Flexion*—6–9 at postanal ventral margin, series on anterior margin of upper jaw; series on A rays; peppering on trailing gut. *Postflexion*—Postanal & lateral gut series augmented, peppering basally & on upper & lower regions of C; series on branchiostegal rays; on finfold anterior to C.
Diagnostic features: High total vertebral count (42–46); slender body & gut; gut becomes trailing at flexion stage; head flattened; elliptical eyes on moderately long stalks; D forms at margin of finfold; distinctive pigment pattern; attains large size (up to ca. 30 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–71 60	65–114 89	103–133 119	86–116 101	53–54 54
BD/BL		6–9 7	6–8 7	6–11 8	12–13 12	19–20 19
HL/BL		20–26 23	19–23 22	20–22 21	21–21 21	26–27 27
HW/HL		39–54 55	38–43 41	37–44 40	47–48 48	41–47 43
SnL/HL		20–27 22	20–27 23	18–26 23	18–22 20	14–18 16
ED/HL*		11–19× 15–30	12–15× 18–21	12–14× 17–19	14–15× 17–18	27–30
		14×22	13×19	13×18	14×18	29
P_1L/BL		3–5 4	4–5 4	6–8 7	 9	16–17 16
P_2L/BL		0–0 0	0–0 0	0.5–2 0.8	 2	10–11 11
ESL/HL		24–63 52	53–64 58	31–59 46	22–25 24	0–0 0

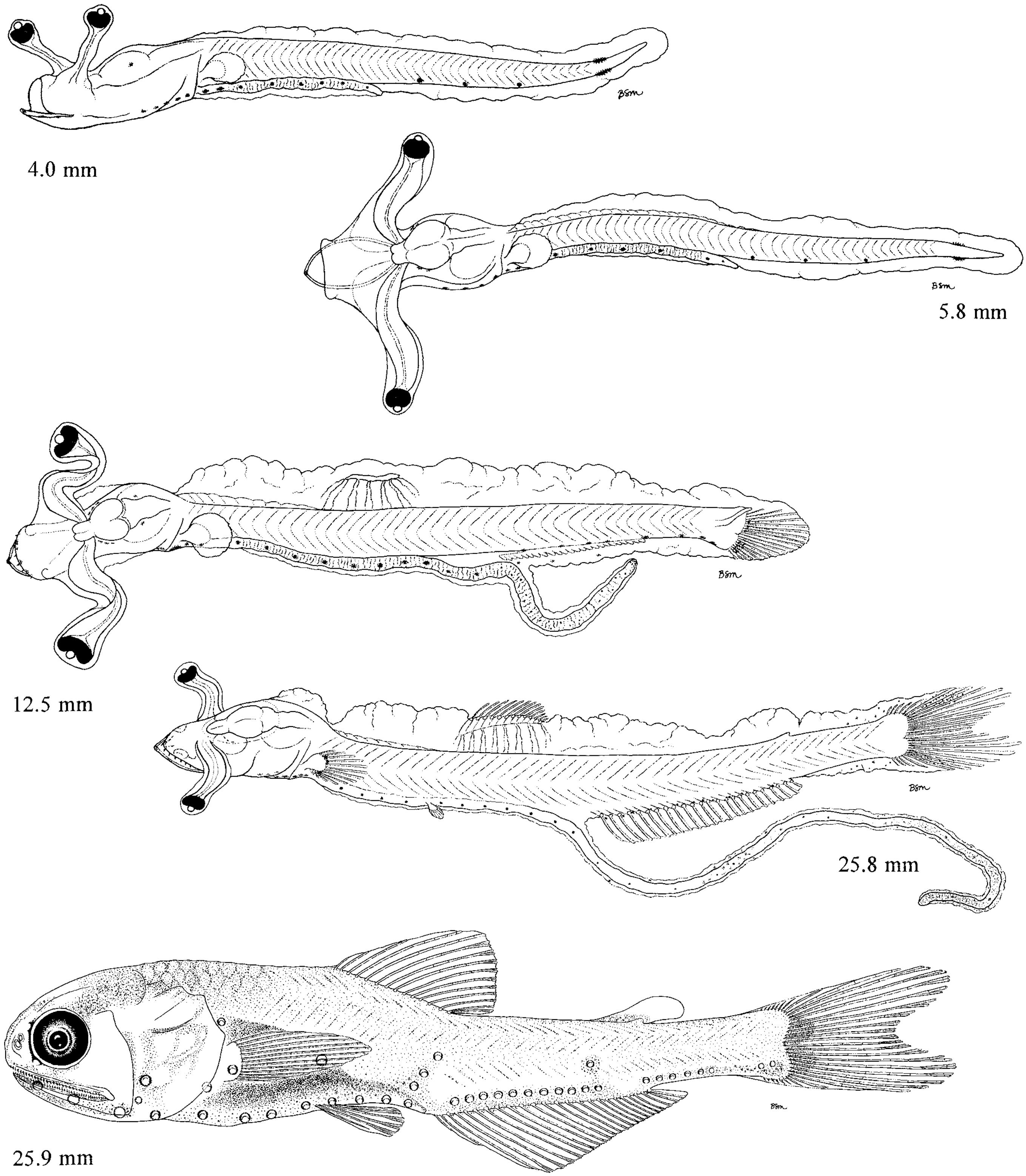

Figure Myctophidae 38. Preflexion larvae, 4.0 mm (EASTROPAC II, station 47.005), 5.8 mm (CalCOFI 7210, station 157.45); flexion larva, 12.5 mm (CalCOFI 7210, station 157.50); postflexion larva, 25.8 mm (EASTROPAC II, station 46.187); juvenile, 25.9 mm (EASTROPAC I, station 12.018).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–39	38
Precaudal	15–16	15
Caudal	21–23	21–22
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	18–21	19
Pelvic	8	8
Pectoral	13–16	14–15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	7–9	7
Gill rakers:		
Upper	5–8	6
Lower	13–19	16
Branchiostegals	9–10	9

LIFE HISTORY

Range: Tropical-subtropical in Pacific, Atlantic & Indian Oceans; in Pacific between ca. 32° N & 31° S

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae present throughout the year in CalCOFI area; highest abundance in the late summer & fall, with peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Castillo 1979
Fahay 1983
Moser & Ahlstrom 1970, 1974
Moser et al. 1984a
Olivar & Fortuño 1991
Ozawa 1986b, 1988d

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* Calculations based on data in Moser & Ahlstrom (1970).
† Eye somewhat oval, very narrow in small larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.1 mm
Flexion length: ca. 6.5–7.0 mm
Transformation length: ca. 11 mm
Fin development sequence: P_1, C_1 & P_2, C_2 & A, D
Pigmentation: *Preflexion*—In larvae <4.0 mm, on tip of lower jaw, 1 ca. midway along postanal ventral midline, 2 pairs on anterior ventral surface of gut, a dorsolateral pair on terminal section of gut, ca. 4 (ring-like) on medial surface of P_1 base, & peppering on P_1 blade; at ca. 4.0 mm, series on isthmus & upper & lower jaws, 1 on nostril, at posterior region of orbit, ventrolaterally on hindbrain, on opercle, & on dorsal midline slightly posterior to the one on ventral margin; by 6.0 mm, 1 on head above P_1 base, a series ventrally on cleithrum, a series associated with each branchiostegal ray, 2 pairs on ventral surface of terminal section of gut, & 1 at A insertion. *Flexion*—One more on nostril, 1 or more in midline above brain; most series augmented. *Postflexion*—Beginning of vertical series at posterior hypural margin.
Diagnostic features: Stout body with broad massive head & robust gut; eyes oval on short stalks; conical ventral choroid tissue; P_1 precocious with large fan-shaped base & blade; P_2 forms early; complex & highly distinctive pigmentation; Br_2 photophores form at ca. 7.0 mm.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–57 54	59–68 63	62–67 65		51–54 53
BD/BL		14–19 17	20–27 22	24–30 27		20–21 21
HL/BL		24–33 29	32–37 35	33–37 35		27–28 27
HW/HL		60–78 67	56–68 63	56–64 60		49–54 51
SnL/HL						
ED/HL†		14–18× 24–37 15×30	13–15× 23–26 14×24	13–16× 21–24 15×23		22–31 27
P_1L/BL						
P_2L/BL						
CL/HL		4–9 6	8–11 9	7–13 10		0–0 0

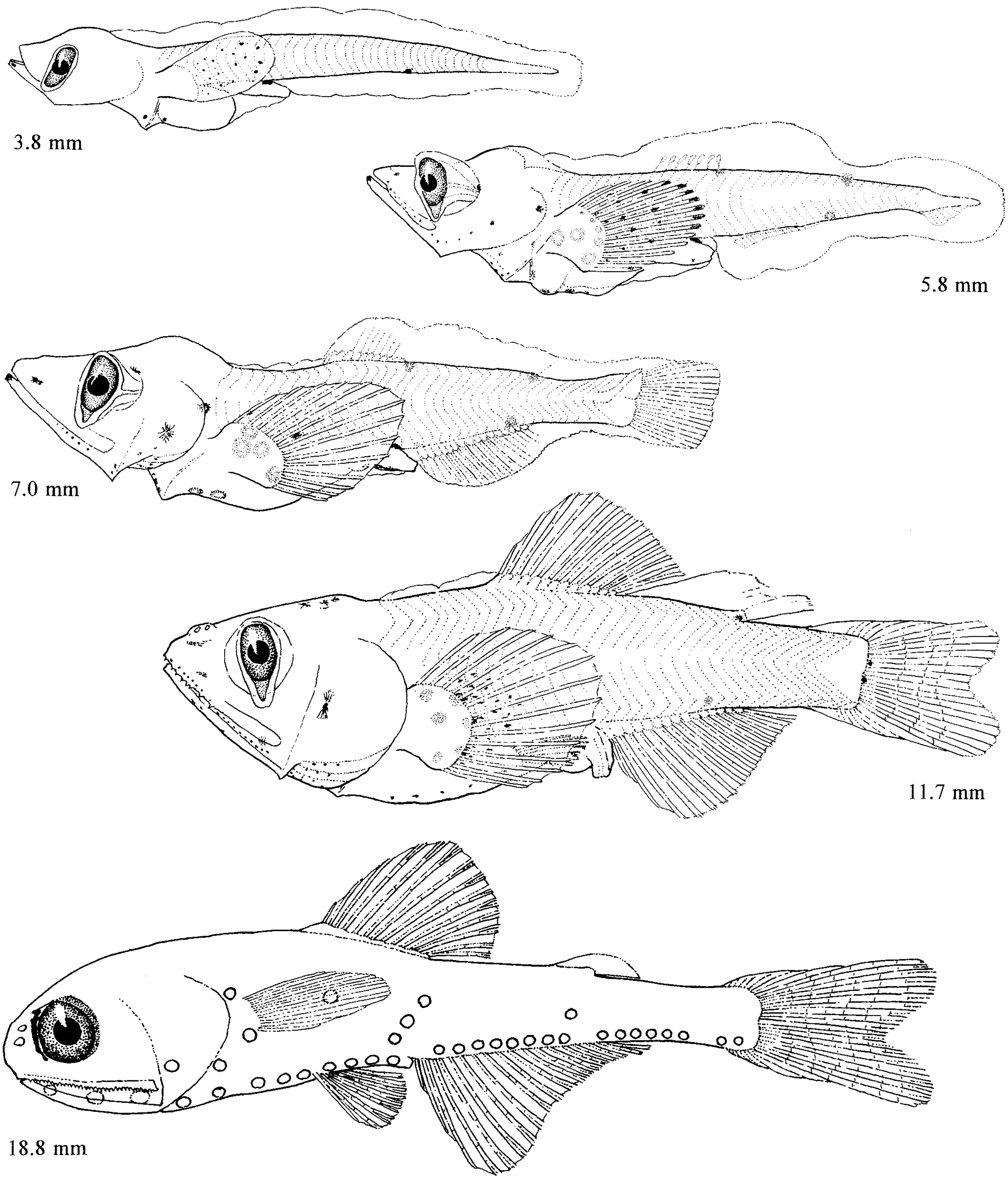

Figure Myctophidae 39. Preflexion larvae, 3.8 mm, 5.8 mm; flexion larva, 7.0 mm; postflexion larva, 11.7 mm; juvenile, 18.8 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	37
Precaudal	14–16	15
Caudal	21–23	22
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	12
Anal spines	0	0
Anal rays	19–24	21–22
Pelvic	8	8
Pectoral	13–17	15–16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	7–8	7
Gill rakers:		
Upper	4–6	5
Lower	14–18	16
Branchiostegals	8–9	9

LIFE HISTORY

Range: Subarctic North Pacific & widespread in California Current, south to 25° N; westward across transition zone to northern Japan

Habitat: Epi- to mesopelagic

Spawning season: Larvae occur throughout year in CalCOFI area; highest abundance in the winter, with peak in December

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Matarese et al. 1989
Moser & Ahlstrom 1970
Moser et al. 1984a
Ozawa 1988d

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: < 3.8 mm
Flexion length: ca. 7.2–8.8 mm
Transformation length: ca. 15.2–17.6 mm
Fin development sequence: C_1, C_2; P_1; A; P_2; D
Pigmentation: *Preflexion*—By ca. 5.0 mm, 1 (large) on each side of midgut. *Flexion–postflexion*—The one at gut enlarges & is more anterior; by ca. 10.0 mm, patch above gas bladder.
Diagnostic features: Slender body; short gut; foregut somewhat conical; head relatively small in preflexion & flexion stages; pointed snout; moderately narrow elliptical eye, lacks ventral choroid tissue; pigment scanty, only laterally on gut & patch above gas bladder; Br_2 photophores form at ca. 8.0 mm; PO series, Br_3 & upper OP the first to form at transformation.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–39 37	34–39 36	35–52 41	57	51
BD/BL		7–12 10	11–13 12	12–20 15	24	26
HL/BL		17–20 18	17–19 18	19–25 21	29	31
HW/HL		50–61 55	59–65 62	52–67 59	50	49
SnL/HL						
ED/HL†		18–23× 40–46	20–23× 41–46	21–29× 38–44		
		19×43	21×43	25×42	28×39	28
P_1L/BL						
P_2L/BL						

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical to oval, very narrow in small larvae; horizontal axis is given first, vertical axis second.

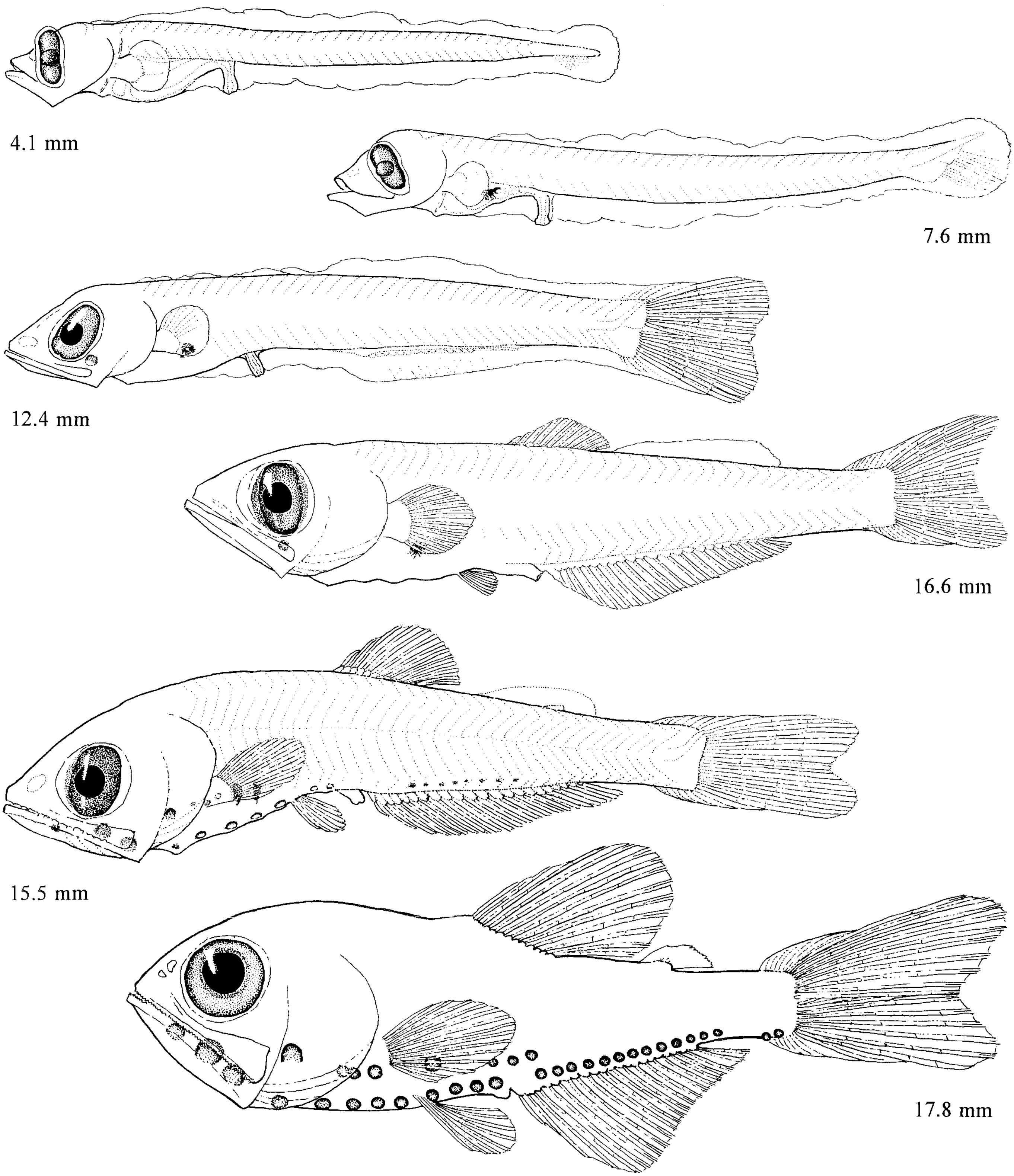

Figure Myctophidae 40. Preflexion larva, 4.1 mm; flexion larva, 7.6 mm; postflexion larvae, 12.4 mm, 16.6 mm; transformation specimen, 15.5 mm; juvenile, 17.8 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–39	38
Precaudal	14–16	15
Caudal	22–24	23
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	12
Anal spines	0	0
Anal rays	21–25	23
Pelvic	8	8
Pectoral	14–17	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	7–9	8
Lower	6–8	7
Gill rakers:		
Upper	3–4	4
Lower	13–16	14
Branchiostegals	8–9	9

LIFE HISTORY

Range: Subarctic-transitional zone of North Pacific, including Bering Sea; in California Current south to ca. 38° N

Habitat: Epi- to mesopelagic

Spawning season: Larvae collected January–February, May, & October in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Matarese et al. 1989
Moser & Ahlstrom 1970
Moser et al. 1984a
Ozawa 1988d
Pertseva-Ostroumova 1964, 1967

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye elliptical, narrow; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.8 mm
Flexion length: ca. 7.9–9.9 mm
Transformation length: ca. 17.2–18.8 mm
Fin development sequence: C_1, C_2, P_1, A, D & P_2
Pigmentation: *Preflexion*—10–14 in median ventral postanal series. *Flexion*—Postanal series coalesced to 6–11; 1–3 laterally on foregut. *Postflexion*—Postanal series reduced from a maximum of 9 at beginning of postflexion stage to none by 17.0 mm; above gas bladder by ca. 13.0 mm; beginning at ca. 13.5 mm, 1–4 embedded in vertical series in lateral hypural region.
Diagnostic features: Morphology similar to *P. crockeri* but pigmentation different; postanal series present (absent in *P. crockeri*); 1–3 lateral gut melanophores (no more than 1 in *P. crockeri*); Br_2 photophores appear at ca. 8.5 mm; PO series & upper OP photophores the first to form at transformation.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–43 40	36–40 38	35–48 41		52–52 52
BD/BL		8–13 10	12–13 13	12–20 15		26–27 26
HL/BL		17–21 19	18–21 20	19–26 21		28–29 29
HW/HL						
SnL/HL		52–62 58	55–65 59	54–64 58		54–54 54
ED/HL†		20–22× 41–44 21×42	20–24× 37–42 22×39	21–28× 37–42 23×40		42–44× 46–46 43×46
P_1L/BL						
P_2L/BL						

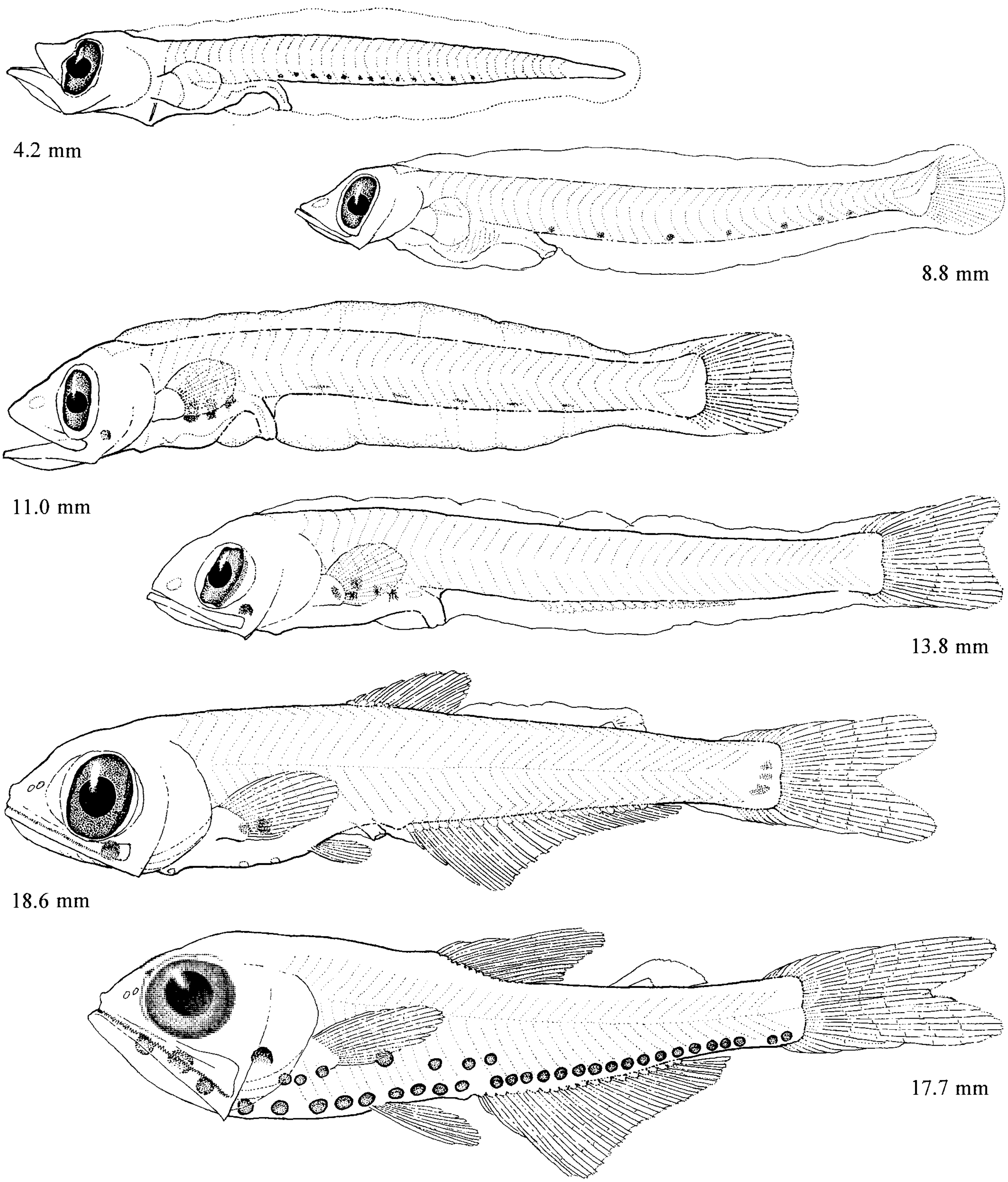

Figure Myctophidae 41. Preflexion larva, 4.2 mm; flexion larva, 8.8 mm; postflexion larvae, 11.0 mm, 13.8 mm; transformation specimen, 18.6 mm; juvenile, 17.7 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–40	39
Precaudal	15–17	16
Caudal	22–23	22–23
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	19–21	20
Pelvic	8	8
Pectoral	15–20	17–18
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–10	9
Lower	7–8	7
Gill rakers:		
Upper	6–7	6
Lower	15–17	16
Branchiostegals	9–10	9

LIFE HISTORY

Range: North Pacific; California Current to ca. 25° S; westward across the transition zone to Japan

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae present throughout the year in CalCOFI area; highest abundance in spring–early summer, with peak in April–May

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Matarese et al. 1989
Moser & Ahlstrom 1970, 1974
Moser et al. 1984a
Ozawa 1988d
Pertseva-Ostroumova 1964, 1974

* Calculations based on data in Moser & Ahlstrom (1970).

† Eye elliptical to oval, very narrow in small larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: ca. 8.5–10.0 mm
Transformation length: ca. 24 mm
Fin development sequence: P_1, C_1 & P_2, C_2 & A, D
Pigmentation: *Preflexion*—By ca. 4.0 mm, ventrolateral pair just anterior to cleithra, 3–4 pairs laterally on gut, 2 dorsolateral pairs on terminal section of gut, up to 11 in a ventral median series extending from above preanal arch of gut to mid-postanal region; by 5.0 mm, a pair on anterior edge of lower jaw & peppering on P_2; by 7.0 mm, up to 3 pairs on isthmus, cleithral pair lie vertically on cleithra, pair on ventrolateral region of hindbrain, pair at lower jaw tip (some specimens), series outlining dorsal margin of P_1 base, & some distally on P_1 rays; by end of stage, lateral gut & postanal series lost. *Flexion–postflexion*—By ca. 8.0 mm, series along ventral margin of P_1 base; bar on P_1 blade.
Diagnostic features: Early preflexion larvae slender, becoming somewhat robust in postflexion stage; gut moderately long, nearly straight; head large, flattened; eyes elliptical & slightly stalked; conical choroid tissue; paired fins large, precocious, distinctively pigmented; P_1 base aliform; much of early pigmentation lost; Br_2 photophores form at ca. 9.0 mm; PO_1 & PO_5 first to form at transformation.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–65 58	63–66 64	62–67 64	57	
BD/BL		8–13 11	13–17 15	16–23 19	20	
HL/BL		18–28 24	28–30 29	24–32 28	29	
HW/HL		55–67 61	56–60 59	52–64 58	44	
SnL/HL						
ED/HL†		13–16× 25–39 14×30	16–17× 25–27 17×26	17–26× 22–33 20×26	21	
P_1L/BL						
P_2L/BL						
CL/HL		6–10 8	7–8 7	4–9 7	2	

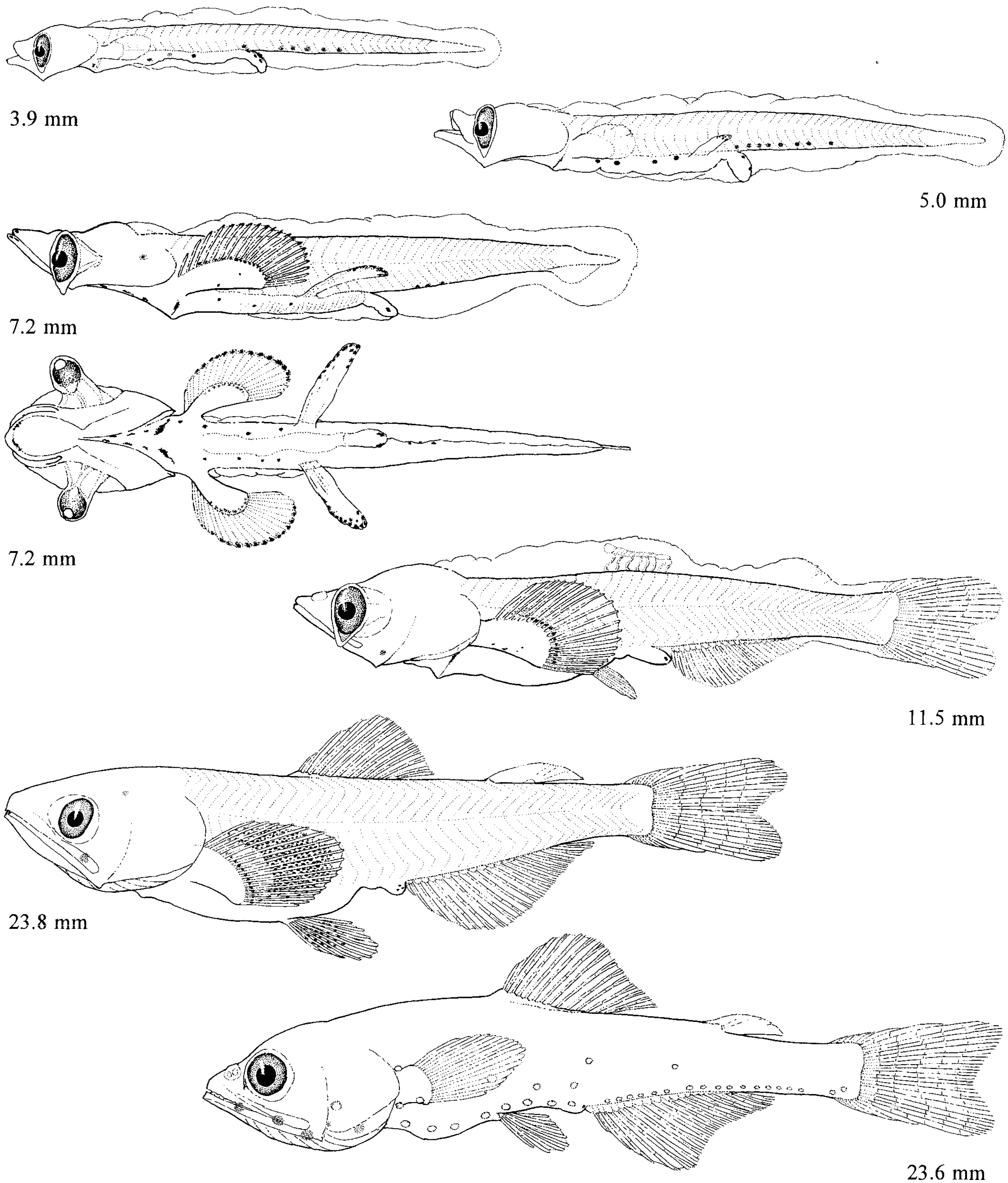

Figure Myctophidae 42. Preflexion larvae, 3.9 mm, 5.0 mm, 7.2 mm (lateral and ventral views); postflexion larvae, 11.5 mm, 23.8 mm; juvenile, 23.6 mm (Moser and Ahlstrom 1970).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	37
Precaudal	15–16	15
Caudal	21–22	21–22
Fins:		
Dorsal spines	0	0
Dorsal rays	13–16	15
Anal spines	0	0
Anal rays	18–22	19
Pelvic	8	8
Pectoral	13–18	15–16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	8–9	9
Lower	7–9	8
Gill rakers:		
Upper	5–7	6
Lower	14–17	15–16
Branchiostegals		

LIFE HISTORY

Range: Tropical Pacific & Indian Ocean; apparently, a species complex

Habitat: Epi- & mesopelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Olivar & Beckley 1994
Ozawa 1986b, 1988d
Pertseva-Ostroumova 1964, 1974

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.8 mm, 5.2 mm (N. Arthur)
Late flexion larva, 7.5 mm, lateral view (N. Arthur)
Late flexion larva, 7.5 mm, ventral view (N. Arthur)
Postflexion larva, 20.0 mm (N. Arthur)
Juvenile, 24.5 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3 mm
Flexion length: 6.1–7.5 mm
Transformation length: ca. 20 mm
Fin development sequence: P_1, C_1, A & C_2, D, P_2
Pigmentation: *Preflexion*—By 3 mm, up to 2 on postanal ventral margin, pair on terminal section of gut, 0–2 pairs along gut (sometimes missing on one side), & pair at cleithral symphysis; by 5 mm, pair at lower jaw symphysis & some have pair on isthmus. *Flexion–postflexion*—Series basally on P_1 rays; lacking on postanal & gut regions.
Diagnostic features: Aliform P_1 base; head large, flattened; slightly stalked eyes in preflexion to early postflexion stages; narrow elliptical eyes in preflexion stage, becoming oval in postflexion stage; conical ventral choroid tissue; pigment sparse; Br_2 photophores form at ca. 7.0 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		56–62 59	62–64 63	59–64 62		48–59 55
BD/BL		12–13 12	13–17 15	16–23 20		17–20 19
HL/BL		26–29 28	28–29 28	27–29 28		25–30 28
HW/HL		61–70 65	67–71 69	56–67 62		43–44 44
SnL/HL		15–35 25	29–35 33	23–33 28		16–21 19
ED/HL†		12–14× 28–31	14–15× 32–32	17–22× 27–32		22–26
		13×30	14×32	20×30		24
P_1L/BL		6–10 8	11–12 11	12–16 15		13
P_2L/BL		0–0 0	0–0 0	0.9–10 5		11–13 12

* All larvae appear to be a single type, putatively *S. evermanni*; another undescribed *Symbolophorus* species extends into the CalCOFI area from the equatorial North Pacific (Gago 1993) & its larvae may be similar to those of *S. evermanni.*

† Eye elliptical, very narrow in small larvae; horizontal axis is given first, vertical axis second.

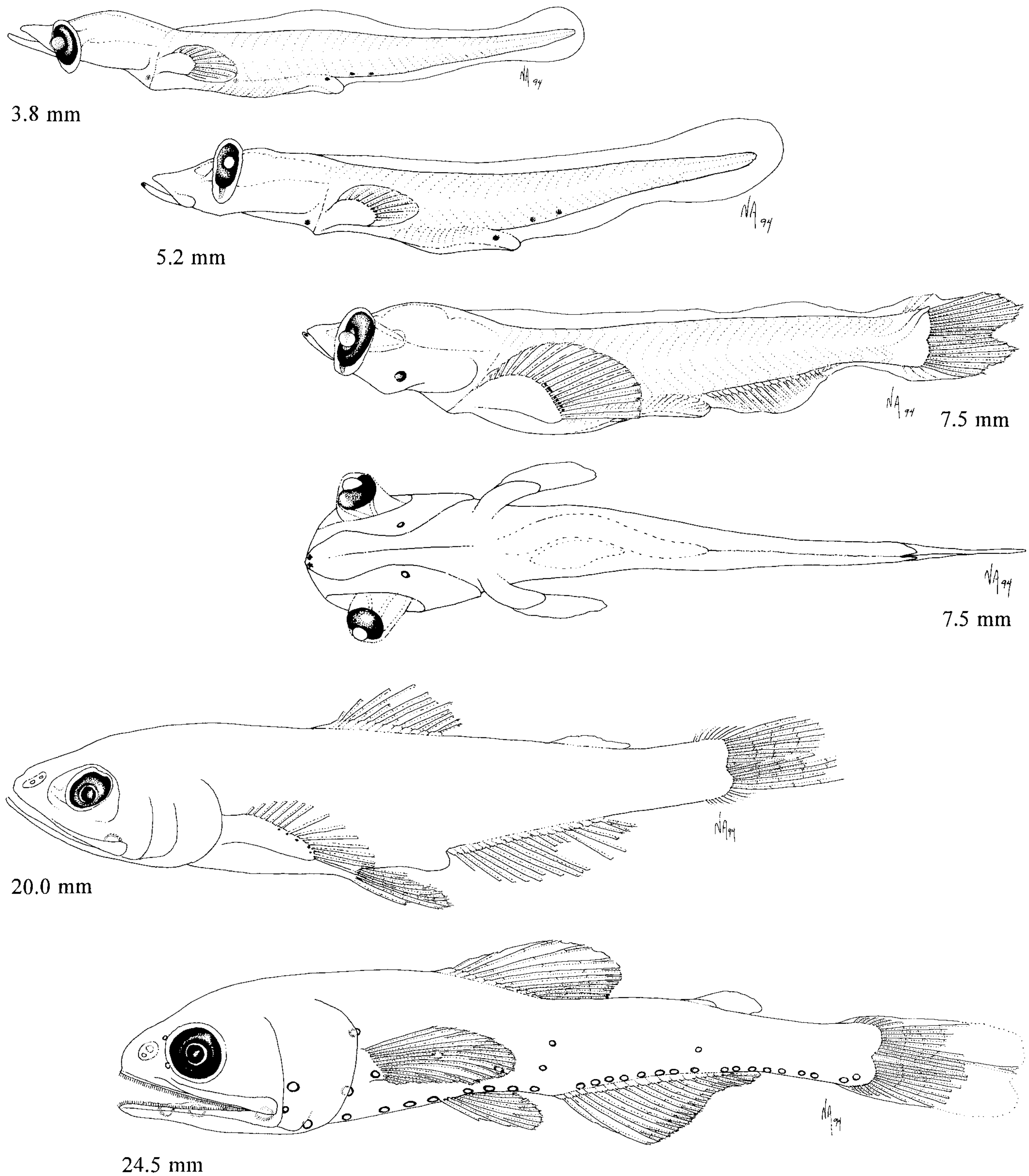

Figure Myctophidae 43. Preflexion larvae, 3.8 mm, 5.2 mm (CalCOFI 7205, station 24.137); late flexion larva, 7.5 mm, lateral and ventral views (CalCOFI 7205, station 24.137); postflexion larva, 20.0 mm (CalCOFI 7205, station 31.135); juvenile, 24.5 mm (EASTROPAC I, station 11.098).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–42	41
Precaudal	17–18	17
Caudal	22–24	24
Fins:		
Dorsal spines	0	0
Dorsal rays	11–14	12–13
Anal spines	0	0
Anal rays	17–20	18
Pelvic	8	8
Pectoral	11–15	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–7	6
Lower	5–7	6
Gill rakers:		
Upper	4–7	6
Lower	10–12	11
Branchiostegals	8–9	8

LIFE HISTORY

Range: Northeast Pacific; south in California Current to ca. 28° N; in Gulf of Alaska & Bering Sea

Habitat: Epi- to mesopelagic; at surface at night

Spawning season: Larvae occur throughout the year in CalCOFI area, with highest abundance in February–March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Bolin 1939
Matarese et al. 1989
Moser & Ahlstrom 1970, 1974
Moser et al. 1984a
Pertseva-Ostroumova 1964, 1974

* Calculations based on data in Moser & Ahlstrom (1970).
† Eye oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: ca. 7.8–10.5 mm
Transformation length: ca. 19.3–21.7 mm
Fin development sequence: P_1, C_1, D & A, C_2, P_2
Pigmentation: *Preflexion*—By ca. 3.0 mm, dorsal & ventral apposing blotches posteriad on tail, blotch on dorsal surface of terminal gut section, embedded blotch above foregut, & one anterior to gut; ventral postanal blotch & embedded blotch above foregut lacking in most larvae >5.0 mm; by ca. 7.0 mm, peppering on P_1 blade & large melanophores on voluminous median finfold. *Flexion*—By ca. 9.0 mm, beginning of 2 pairs of rows on ventral surface of foregut & some (single) at nape; on midbrain & forebrain; transverse pair at cerebellum.
Diagnostic features: Morphology similar to larvae of *Loweina rara*; D origin not as far posteriad as in *L. rara*; choroid tissue present on ventral surface of eye (absent in *L. rara*); peppering on P_1 rays (absent in *L. rara*); median & paired melanophores above brain (transverse bar in *L. rara*); higher counts for total vertebrae (39–42 vs. 37–39) & A rays (17–20 vs. 13–17) compared with *L. rara*; Br_2 photophores form at ca. 10.0 mm.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		49–60 54	60–65 63	65–72 67	54–54 54	57
BD/BL		8–16 13	18–22 20	21–29 26	22–23 22	20
HL/BL		18–25 21	23–29 26	26–31 28	30–30 30	29
HW/HL		53–69 59	48–61 54	44–64 51	39–40 40	43
SnL/HL						
ED/HL†		19–30× 25–36 23×31	22–23× 26–32 22×29	17–21× 21–30 19×25	22–23 22	24
P_1L/BL						
P_2L/BL						
CTL/HL		0–4 2	3–9 7	7–9 8	0–0 0	0

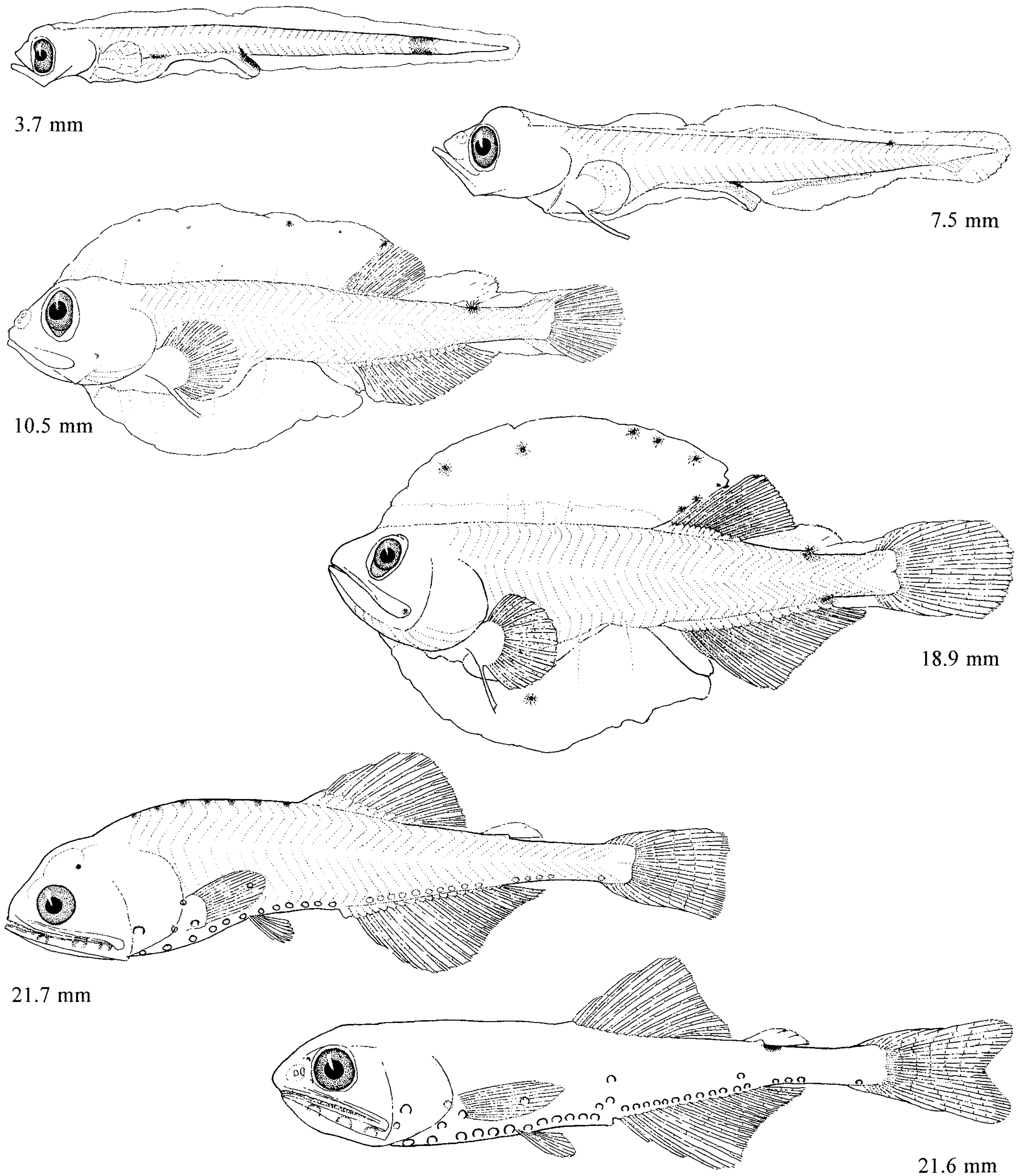

Figure Myctophidae 44. Preflexion larvae, 3.7 mm, 7.5 mm; flexion larva, 10.5 mm; postflexion larva, 18.9 mm; transformation specimen, 21.7 mm; juvenile, 21.6 mm (Moser and Ahlstrom 1970).

GADIFORMES

D. A. Ambrose

Gadiform classification presently is a topic of intense investigation; the absence of consensus among systematists is documented in Cohen (1989). Nelson (1994) included twelve families and about 482 species in the order. Gadiformes contains many important commercial fishes that comprise over one quarter of the world's marine fish catch (Nelson 1994). They are predominantly marine benthopelagic fishes of cool waters. More than half of all gadiform species live in the deep sea beyond commercial fishing depth; many are small, apparently rare, or are widely dispersed (Cohen et al. 1990). One species is confined to freshwater and another has some freshwater populations (Nelson 1994). Gadiforms range from moderately to very elongate and slightly to strongly compressed with a relatively high vertebral count. Most have a short preanal length (ca. <50% BL); long-based dorsal and anal fins, usually multiple; pelvic fins, when present, inserted below or in front of the pectorals and with up to 11 rays; no true spines in the fins (spine-like rays may occur anteriorly in the first dorsal fin); the premaxilla forming the entire margin of the upper jaw; and the branchiostegal rays numbering 6–8. Mental barbels are found in most gadids, macourids, and morids. Despite its absence in over a third of all gadiforms, the distinctive caudal skeleton (isocercal tail) has received much attention. The presence of "X" and "Y" elements (usually bones) has been interpreted as synapomorphic for Gadiformes (Markle 1989). The "X" and "Y" bones are located anterior to the neural spine of the first pre-ural vertebra and the parahypural (Monod 1968). Additional apomorphic features are given in Markle (1989).

Early life history characteristics of gadiform fishes have been summarized by Fahay and Markle (1984). Gadiform fishes are oviparous, spawning spherical to oval eggs, usually with an oil globule. The gut coils early in ontogeny and this, combined with the rounded head, contributes to an overall tadpole-like appearance of the larvae. In yolk-sac and first-feeding gadiform larvae the anus exits laterally through the finfold rather than medially, as is usual in other teleost larvae. Some forms with a caudal fin also differ from the usual pattern in developing some secondary caudal rays before some primary rays. The pelvic fins typically are the first fins to form; however, they form second in the merlucciids and last in gadines (cods and haddock). The features of body shape, anus morphology, and pelvic fin development in combination with specific familial characters appear to be most useful for initial identification.

Gadiformes are represented by 16 genera in 6 families in the California Current vicinity. The Gadidae are not included in this guide because few *Gadus macrocephalus* and *Microgadus proximus* larvae have been collected in CalCOFI surveys and their early life history stages are well known (Dunn and Matarese 1984; Matarese et al. 1989). Melononid larvae have not been collected in CalCOFI tows and also are excluded from this guide (see Matarese et al. 1989).

Families included: Bregmacerotidae
Macrouridae
Moridae
Merlucciidae

GADIFORMES

D. A. AMBROSE

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Families included: Bregmacerotidae
Macrouridae
Moridae
Merlucciidae

BREGMACEROTIDAE: Codlets

E. G. STEVENS[1] AND H. G. MOSER

Bregmacerotidae contains approximately 12 species in the monotypic genus *Bregmaceros* (Houde 1984a; Nelson 1994). Larvae of two species occur in the CalCOFI survey pattern south of Punta Eugenia, Baja California Sur. One of these, *B. bathymaster*, is a neritic species whose distribution extends into the Gulf of California and southward to the Gulf of Panama. Larvae of the other species, called *Bregmaceros* sp. in this guide, have a unique pigment pattern and represent an undescribed species that apparently is endemic to the eastern tropical Pacific. Two other species, *B. atlanticus* and *B. macclellandi*, inhabit tropical waters south of the CalCOFI area (Houde 1984a). Houde (1984a) summarized characteristics of *Bregmaceros* larvae and discussed the taxonomic confusion within the family.

Codlets are small (<12 cm), slender, planktivorous, pelagic fishes of tropical and subtropical seas. Some species are restricted to coastal regions and may enter estuaries, whereas others have oceanic distributions. Codlets are easily recognized by their unusual fins. The first dorsal fin consists of an elongate occipital ray. The second dorsal fin and the anal fin are long-based and strongly lobed. The caudal fin is well developed and separate from the dorsal and anal fins. Pelvic fins are jugular and have 5–7 rays; the outer three rays are separate, thick, and elongate, extending well past the origin of the anal fin. The lateral line extends along the dorsal margin of the body. Scales are relatively large. Most species are epipelagic; however, some are reported to be mesopelagic and undergo diurnal vertical migrations. One species is harvested commercially (Cohen et al. 1990; Nelson 1994).

Bregmacerotids become mature at a relatively small size (typically <30 mm). Their planktonic eggs are reported to be small (<1.0 mm), with a smooth chorion, homogeneous yolk, a single oil globule, and narrow perivitelline space (Houde 1984a). Judging from the small size at hatching (ca. 1.5 mm), codlet eggs may be smaller than reported, possibly <0.7 mm. Larvae are similar to many other gadiforms that have a robust head, large jaws, massive coiled gut, and a strongly tapered tail. Pigment patterns of early preflexion larvae (<3.0 mm) are diagnostic for species and form three general groups: 1) those with scant or moderate head pigment, with a ventral postanal series present or lacking, 2) those with heavy head pigment and large dorsal and ventral postanal blotches, and 3) those with moderate head pigment and a bar at the midpoint of the tail. For those species which develop the occipital ray at a very small size, e.g., *B. macclellandi*, the occurrence of the ray can be diagnostic for early stage larvae, especially when combined with pigment patterns. Pigmentation is transitional in 3.0–6.0 mm larvae and species are difficult to identify at this stage (Houde 1984a). Larger larvae may be identified by specific pigment patterns, meristics, and the size at development of the occipital ray.

The following description of *B. bathymaster* is based on detailed observations of 39 specimens (5 yolk-sac, 1.8–2.2 mm; 10 preflexion, 2.3–4.2 mm; 6 flexion, 4.5–5.1 mm; 10 postflexion, 5.0–12.6 mm; 5 transformation, 14.6–24.4 mm; 3 juvenile/adults, 32.0–41.0 mm), and on the literature. *Bregmaceros* sp. is described from detailed observations of 32 specimens (4 yolk-sac, 1.9–2.2 mm; 12 preflexion, 2.3–4.6 mm; 5 flexion, 4.3–6.0 mm; 11 postflexion, 6.2–14.0 mm). Meristic data were obtained from several literature sources (D'Ancona and Cavinato 1965; Belyanina 1974; Houde 1984a; Fahay and Markle 1984) and from original counts made during this study. Ecological information was obtained primarily from Houde (1984a).

[1] Formerly, at La Jolla Laboratory, National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–51	49
Precaudal	13–15	14
Caudal	34–36	35
Fins:		
Dorsal spines	0	0
Dorsal rays	44–51	49
Anal spines	0	0
Anal rays	45–52	48
Pelvic	6	6
Pectoral	17–19	18
Caudal:		
Total	32–36	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Tropical-subtropical eastern Pacific

Habitat: Coastal; neritic

Spawning season: Larvae captured throughout year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

D'Ancona & Cavinato 1965
Houde 1981, 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 4.2 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <1.8 mm
Flexion length: 4.3 mm through 5.0–5.1 mm
Transformation length: ca. 14–24; gradual
Fin development sequence: C, D, A, P_2, P_1
Pigmentation: *Preflexion*—At <2.0 mm, shield above developing gas bladder, 5–8 in postanal ventral midline series, 1 at angle of jaw, a series on ventral surface of gut, & a blotch above preanal arch of gut; by 3.0 mm, postanal series reduced in most larvae; by end of stage, postanal series lacking. *Flexion*—1 at nape; 1 embedded in otic region; pair at tip of snout; ventral gut series lacking; by end of stage, some larvae have 1 at hypural margin & an embedded blotch above posterior spinal column. *Postflexion*—Usually a pair above anterior midbrain & above cerebellum; blotches added above spinal column; by 12.0 mm, augmentation above brain, nape, at hypural margin, & spinal column; shield around stomach; beginning of juvenile pigment series dorsally & ventrally on tail.
Diagnostic features: In preflexion stage, head more compressed & snout longer than in *Bregmaceros* sp.; postanal ventral pigment series lost early, then pattern sparse but distinctive; occipital ray forms later (during early postflexion stage, at ca. 5.0 mm) than in *Bregmaceros* sp. (during flexion stage, at ca. 4.0 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	42–46 45	43–48 45	41–47 44	36–46 39	32–38 37	36–37 36
BD/BL	24–29 27	25–31 28	25–29 27	14–36 21	15–16 15	15–17 16
HL/BL	20–28 23	20–27 24	23–27 25	17–26 22	15–19 17	16–18 17
HW/HL	48–114 76	45–72 65	53–66 60	48–69 57	64–73 69	62–77 71
SnL/HL	20–32 25	23–36 31	25–29 27	22–34 25	17–28 22	16–21 19
ED/HL	40–54 48	38–52 43	28–38 34	25–36 29	24–28 26	29–30 29
P_1L/BL	6–14 10	5–11 6	4–10 8	6–10 7	10–14 12	13–14 13
P_2L/BL	0–0 0	0–4 0.4	3–7 5	8–34 20	37–47 43	51–54 52
ORL/BL	0–0 0	0–0 0	0–0 0	2–10 6	11–26 17	21–23 22

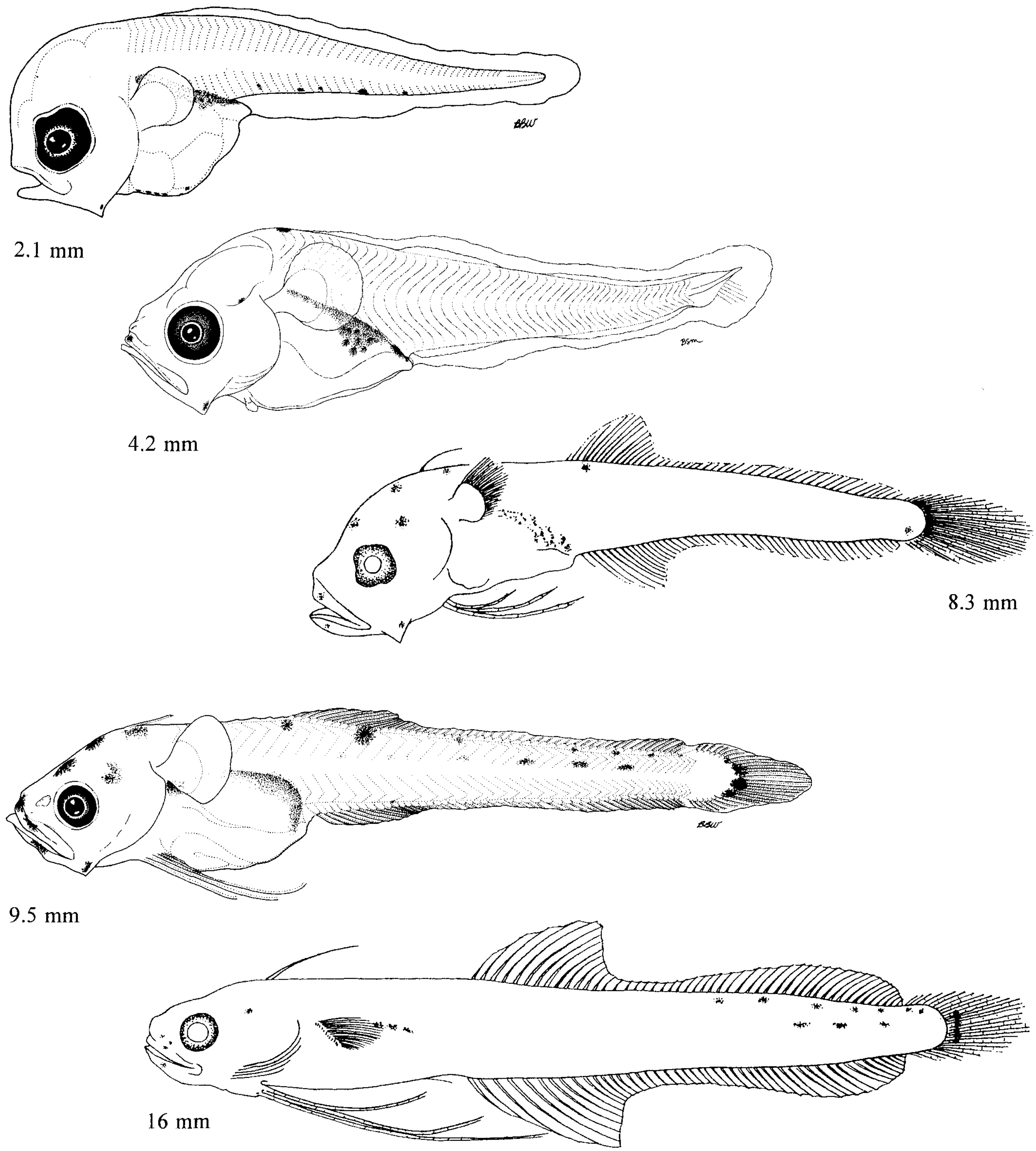


Figure Bregmacerotidae 1. Preflexion larva, 2.1 mm (Houde 1984a); flexion larva, 4.2 mm (CalCOFI 5612, station 151G.130); postflexion larvae, 8.3 mm (D'Ancona and Cavinato 1965), 9.5 mm (Houde 1984a); transformation specimen, 16 mm (D'Ancona and Cavinato 1965).

MERISTICS

	Range	Mode
Vertebrae:		
Total	52–54	53
Precaudal	13–15	15
Caudal	37–41	38
Fins:		
Dorsal spines	0	0
Dorsal rays	49–53	
Anal spines	0	0
Anal rays	50–60	53–54
Pelvic	6	6
Pectoral	18–20	
Caudal:		
Total	34–36	36
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Northeastern tropical-subtropical Pacific

Habitat: Coastal to offshore

Spawning season: Larvae captured primarily during fall & winter

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.2 mm (B. Sumida MacCall)
Preflexion larva, 2.2 mm, 3.5 mm (B. Sumida MacCall)
Flexion larva, 4.3 mm (B. Sumida MacCall)
Postflexion larva, 7.2 mm (B. Sumida MacCall)
Transformation specimen, 14.0 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <1.9 mm
Flexion length: 4.3–4.6 mm through ca. 6.0 mm
Transformation length: begins at ca. 14 mm, gradual
Fin development sequence: C, A, D, P_2, P_1
Pigmentation: *Preflexion*—At <2.0 mm, postanal ventral blotch at myomere 25–29, many scattered above & on anterior & ventral surfaces of gut mass, a blotch covering anterior region of brain, 1 to several on lateral surface of P_1 base, & 1 at jaw angle; at >2.0 mm, another ventral blotch in caudal region, 2 median blotches on dorsal midline of tail, a patch embedded in otic region, scattered on snout, at lower jaw tip, gular region, posterior margin of orbit, over entire brain, on nape, opercle, & P_2 rays. *Flexion*—Posterior ventral blotch expands dorsally. *Postflexion*—By ca. 6.0 mm, patches begin to form on C rays & on D & A rays of future lobed portions of fins; by 8.0 mm, longitudinal series begin to form on trunk & tail; fully covered by ca. 14.0 mm.
Diagnostic features: Head & gut mass wider & more robust than in *B. bathymaster*; occipital ray forms earlier (during flexion stage, at ca. 4.0 mm) than in *B. bathymaster* (during postflexion stage at ca. 5.0 mm); 2 dorsal & 2 ventral tail blotches, with posterior ventral blotch enlarging.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	30–39 34	33–49 42	42–47 45	33–44 40		
BD/BL	19–26 21	27–36 30	27–33 30	16–31 22		
HL/BL	20–24 22	23–33 27	23–28 25	16–30 22		
HW/HL	38–62 48	64–80 70	66–77 71	54–77 65		
SnL/HL	10–20 13	15–32 25	25–34 28	18–29 24		
ED/HL	38–42 41	33–48 39	30–43 35	23–39 29		
P_1L/BL	0–0 0	6–12 8	7–9 8	6–8 7		
P_2L/BL	0–0 0	5–17 11	17–24 19	17–41 32		
ORL/BL	0–0 0	1–4 3	1–7 4	6–17 10		

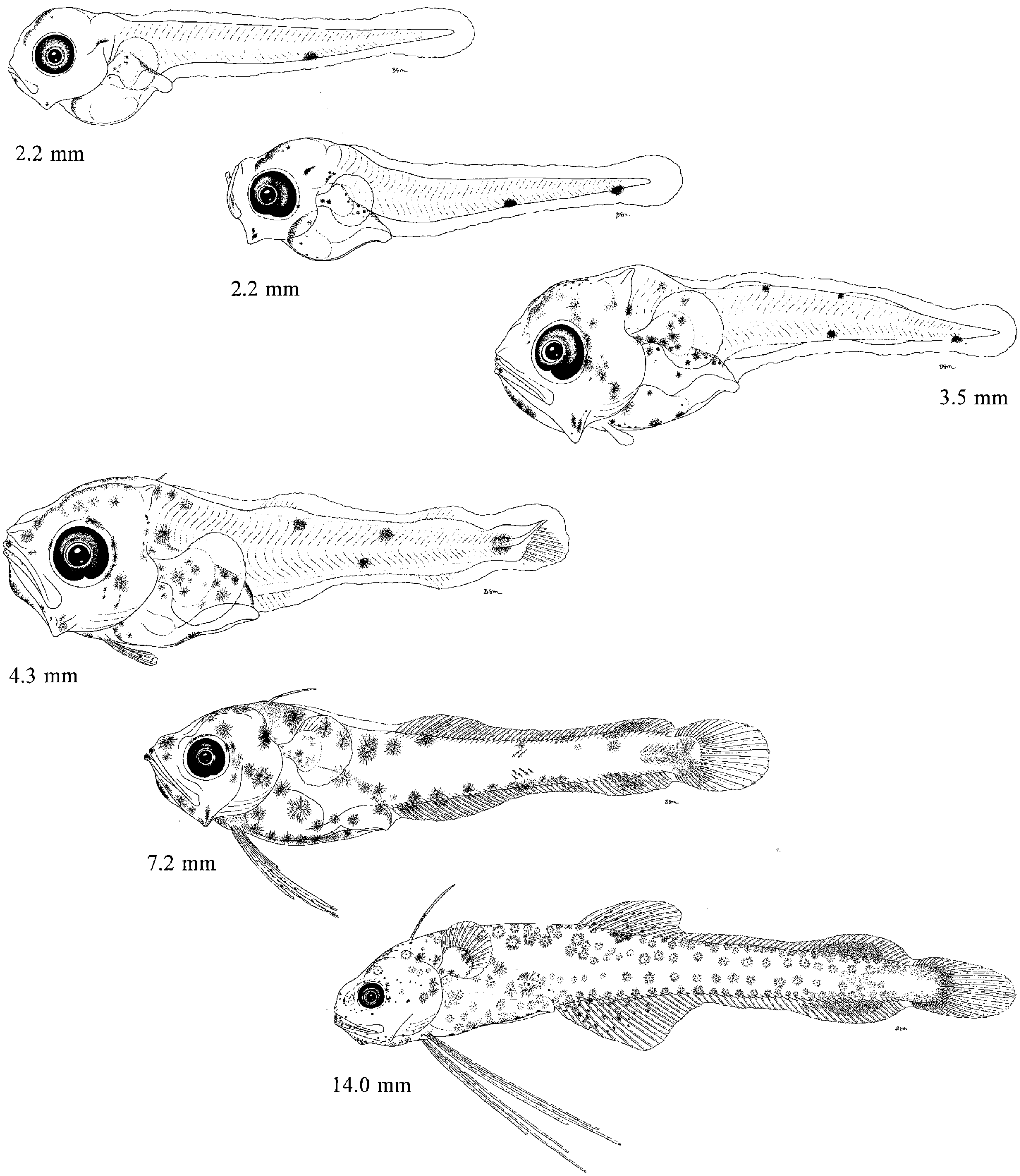


Figure Bregmacerotidae 2. Yolk-sac larva, 2.2 mm (CalCOFI 7202, station 157.55); preflexion larvae, 2.2 mm, 3.5 mm (CalCOFI 7210, station 157G.55); flexion larva, 4.3 mm (CalCOFI 7210, station 157.10); postflexion larva, 7.2 mm (CalCOFI 7210, station 157.20); transformation specimen, 14.0 mm (CalCOFI 5612, station 173G.20).

MACROURIDAE: Grenadiers

D. A. Ambrose

At least 13 macrourid species occur in the CalCOFI area (Table Macrouridae 1), but larvae of only 5 (*Albatrossia pectoralis*, *Coryphaenoides acrolepis*, *C. leptolepis*, *Mesobius berryi*, and *Nezumia* spp.) have been identified in CalCOFI ichthyoplankton samples. *Caelorinchus scaphopsis* larvae are collected in the Gulf of California. Larvae of *Coryphaenoides anguliceps*, *C. armatus*, *C. yaquinae*, and *Malacocephalus laevis* are unknown, while those of *C. filifer* are described but have not been identified in CalCOFI collections. Larvae of *Nezumia convergens*, *N. liolepis*, and *N. stelgidolepis* are identified only to genus.

Adults of these grenadiers are medium to large (ca. 30–>150 cm TL), elongate and moderately compressed fishes, with a rather large head, short trunk, and long tail tapering to a fine point with no caudal fin (Cohen et al. 1990). The high, short first dorsal fin consists of two spinous rays followed by 7–13 segmented rays. The long, low second dorsal fin is separated from the first by a gap longer than half the base of the first dorsal fin and its rays are shorter than the opposite rays of the anal fin, which is continuous to the end of the tail. Pelvic fins are thoracic in adults, but may appear jugular in larval stages. The snout is pointed, the mouth subterminal to inferior, and the scales cycloid with spinules. Branchiostegal rays number 6 or 7 and abdominal vertebrae are 12–16. A mental barbel is present on all except *Mesobius berryi*. A ventral abdominal light organ is well developed between the pelvic fin bases in *Caelorinchus scaphopsis* and *Malacocephalus laevis*. It is anterior to the rectum in *Mesobius berryi* and in all three species of *Nezumia*, but is absent in *Albatrossia* and *Coryphaenoides*. The swimbladder and retia mirabilia are well developed in most genera but are reduced in *Albatrossia* and *Mesobius*. The anus is immediately before the anal fin in *Albatrossia* and *Coryphaenoides*, slightly anterior to the anal fin in *Caelorinchus* and *Mesobius*, midway between the anal fin and the pelvic fin in *N. convergens* and *N. liolepis*, and closer to the pelvic fin in *Malacocephalus* and *N. stelgidolepis*. Adults of most macrourids are bathybenthal, ranging from the outer continental shelf to the abyssal plain. *Coryphaenoides acrolepis* and *C. filifer* are known to make vertical migrations and *Mesobius berryi* is exclusively a midwater dweller. *A. pectoralis* and *C. acrolepis* are commercially important species (Cohen et al. 1990). Macrourids are most closely allied with the Merlucciidae within the Gadiformes and dominate the benthopelagic fish fauna of the deep sea in numbers of individuals and species (Marshall and Cohen 1973).

Little is known about reproduction, but it is speculated that eggs are broadcast near the bottom and develop as they drift toward the surface (Marshall and Iwamoto 1973; Merrett 1978, 1989). For the few species described, eggs are ca. 1.0–4.0 mm in diameter (most <2 mm), with a single oil globule and a chorion with hexagonal sculpturing (Fahay and Markle 1984). Few larval macrourids are captured despite the abundance of adults in most continental slope areas; it has been suggested that larval development and descent to the bottom is rapid (Cohen et al. 1990).

Larval macrourids have a large head, short trunk, long tapering tail, early pelvic fin formation, markedly stalked pectoral fin base, and a second dorsal fin that is lower and shorter than the anal fin. Larval pigment is heavy on the abdomen and frontal head region. During transformation from larval to juvenile stage, the pectoral fin base length is greatly shortened, the mouth orientation becomes less oblique, and the snout becomes more pronounced.

Numerous characters may be used to distinguish the larvae of genera and species in the CalCOFI region, including some adult diagnostic characters such as numbers of branchiostegal rays and morphology of the retia mirabilia. Genera may be grouped into those with 7 branchiostegal rays (*Malacocephalus*, *Mesobius*, and *Nezumia*) and those with 6 branchiostegal rays (*Albatrossia*, *Caelorinchus*, and *Coryphaenoides*). *Mesobius berryi* larvae have dorsal and ventral (more numerous) pigment patches along the tail. *Nezumia* have ventral tail margin pigment and 2 rows mediolaterally along the tail. Among those with 6 branchiostegal rays, *Albatrossia* have the shortest snout-anus length (ca. 20% of BL) from the yolk-sac stage to initial anal fin formation, and the fewest gas glands (2). *Caelorinchus* have a low number of pelvic fin rays (7), a high number of pyloric caeca (15–26), 4 gas glands, anal fin formation at the smallest size (6.5 mm), elongate pelvic fin rays, and pigment absent from the posterior half of the tail. *Coryphaenoides* larvae have robust basipterygia. *C. acrolepis* have pigment on the pectoral fin base and laterally on the anterior two-thirds of the tail, 12–14 pyloric caeca, and 4 gas glands. Stein (1980b) described *C. filifer* larvae as having an oval patch of pigment extending from a position anterior to the first dorsal fin to about the 12th second dorsal fin ray. *C. filifer* also has the highest total number of first dorsal fin rays (13–16). *C. leptolepis* larvae have heavy evenly spaced pigment spots over the trunk not extending posterior to the 10th anal fin ray by the juvenile stage, 6 gas glands, and a relatively wide space between dorsal fins. The number of pelvic fin rays and gas glands may be useful in differentiating later stage larvae of three other *Coryphaenoides* species from this region: *C. anguliceps*—P_2 7–9 (usually 8), gas glands 4; *C. armatus*—P_2 10–12 (usually 11), gas glands 5–6; and *C. yaquinae*—P_2 8–11 (usually 10), gas glands 6.

The following descriptions are based on 6–19 specimens of each taxon (Table Macrouridae 2). Meristic and ecological data were obtained from the literature (Lavenberg and Fitch 1966; Novikov 1970; Miller and Lea 1972; Iwamoto and Stein 1974; Hubbs and Iwamoto 1977; Iwamoto 1978, 1979; Stein 1980a; Stein and Pearcy 1982; Matarese et al. 1989; Cohen et al. 1990). Larval series of *Albatrossia pectoralis*, *Caelorinchus scaphopsis*, and early larval stages of *Coryphaenoides leptolepis*, *Mesobius berryi*, and *Nezumia* are described for the first time. Cohen et al. (1990) were not able to differentiate between adults of *C. leptolepis* and *C. liocephalus*, and we consider *C. leptolepis* to be a single species.

Since larval macrourids do not undergo notochord flexion, anal fin formation was used to separate larval developmental stages. "Preanal fin formation" (PrAF) refers to the interval prior to initiation of anal fin formation and "anal fin formation" (AF) refers to larvae with developing or fully formed anal fins. Preanal length and head length are used as denominators for the morphometrics section because macrourid larvae captured in nets often have damaged tails. Eschmeyer's (1990) spelling of *Caelorinchus* is used, as opposed to the commonly used but incorrect *Coelorinchus*.

Table Macrouridae 1. Meristic characters for the macrourid species that occur in the California Current region.

Species	BrR	Total gill rakers (inner 1st arch)	Pyloric caeca	Gas glands	1D	P_1	P_2
Albatrossia pectoralis	6	5–14	12–16	2	9–11	16–21	6–8
Caelorinchus scaphopsis	6	9–12	15–26	4	9–11	17–20	7
Coryphaenoides acrolepis	6	5–13	12–14	4	10–13	19–22	8–9
C. anguliceps	6	7–9	9–14	4	9–12	19–24	7–9
C. armatus	6	7–14	10–13	5–6	10–12	18–22	10–12
C. filifer	6	8–14	8–12	4	13–16	18–23	9–11
C. leptolepis	6	9–16	11	6	10–12	18–22	9–10
C. yaquinae	6	11–12	10	6	8–12	16–22	8–11
Malacocephalus laevis	7	11–14	50–100+	2	11–14	16–22	8–9
Mesobius berryi	7	10–13	12–17	2	10–12	12–14	7–9
Nezumia convergens	7	7–9	21–32	2	10–12	18–22	9–11
N. liolepis	7	9–12	25–37	2	10–13	20–25	10–12
N. stelgidolepis	7	8–12	24–58	2	10–13	20–26	8–11

Table Macrouridae 2. Number of specimens (above) and total length range (in mm, below) used in preparation of the macrourid species descriptions. The symbol ">" indicates a minimum length because the end of the tail was damaged.

Species	Yolk-sac	PrAF	AF	Transformation	Juvenile
Albatrossia pectoralis	4 5.8–7.1	14 7.5–15.3	1 >22.1	0	0
Caelorinchus scaphopsis	0	1 3.7	5 6.5–>20	2 >25–>28	0
Coryphaenoides acrolepis	0	8 7.6–9.9	8 10.5–23.5	0	0
C. leptolepis	0	2 5.8–6.3	4 7.4–>42	0	0
Mesobius berryi	2 5.1–5.4	6 6.0–11.2	3 14.2–>23.4	1 73	3 148–213
Nezumia sp(p).	0	12 5.8–>13.2	3 >15.7–49.6	0	1 >94

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal	13–15	14
Fins:		
First dorsal spines	II	II
First dorsal rays	7–9	
Total first dorsal	9–11	
Pelvic	6–8	7
Pectoral	16–21	19
Pyloric caeca	12–16	
Gas glands	2	2
Gill rakers (inner first arch):		
Upper	0–2	2
Lower	5–12	10–11
Total	5–14	
Branchiostegals	6	6

LIFE HISTORY

Range: North Pacific from Japan to the Okhotsk & Bering Seas, east to the Gulf of Alaska, south to northern Baja California

Habitat: Adults near bottom 140 to 1200 m depth; young bathypelagic & settle to the bottom when about 50–60 cm long

Spawning season: Throughout the year with peaks in fall & winter

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.8 mm (M. T. Vona)
PrAF larvae, 7.5 mm, 15.3 mm (M. T. Vona)

* Body length could not be determined because of broken tails in 9 of 14 PrAF specimens & in the only AF specimen.
† P_2 rays were damaged in 8 of 14 PrAF specimens & not measured.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 5 mm
Transformation length:
Fin development sequence: P_2, 1D, A & 2D & P_1
Pigmentation: *Yolk-sac*—On snout, brain; posterior to eye; on lower jaw, nape; over cleithrum; above & scattered on lateral surface of gut; on P_1 base; blotch ventrally at midtail; scattered near end of tail. *Preanal fin formation*—Expanding on operculum & lateral surface of gut; spreading anteriorly from end of tail; midtail patch spreads until gaps at both sides filled by ca. 12.5 mm BL; by ca. 15 mm BL, along dorsal & ventral tail margins & expanding on lateral surface of tail anteriorly. *Anal fin formation*—Evenly spaced along dorsal & ventral tail margins.
Diagnostic features: Branchiostegal rays 6; total 1D 9–11; P_2 6–8; gas glands 2; Sn-A ca. 20% BL for yolk-sac through AF larvae; yolk-sac & early PrAF larvae with ventral blotch at midtail; pigment along the dorsal & ventral margins of tail in late PrAF through AF larvae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL*	20–22 21	17–23 20			
BD/Sn-An	61–73 67	48–65 58	58		
HL/Sn-An	50–68 57	51–66 61	69		
HW/HL	71–83 77	53–100 69	52		
SnL/HL	21–33 25	20–32 26	25		
ED/HL	34–42 37	38–49 42	34		
P_1L/HL	6–18 14	13–24 20	18		
P_2L/HL†	3–21 14	44–133 80	>42		
P_1BL/HL	26–36 31	38–73 58	49		

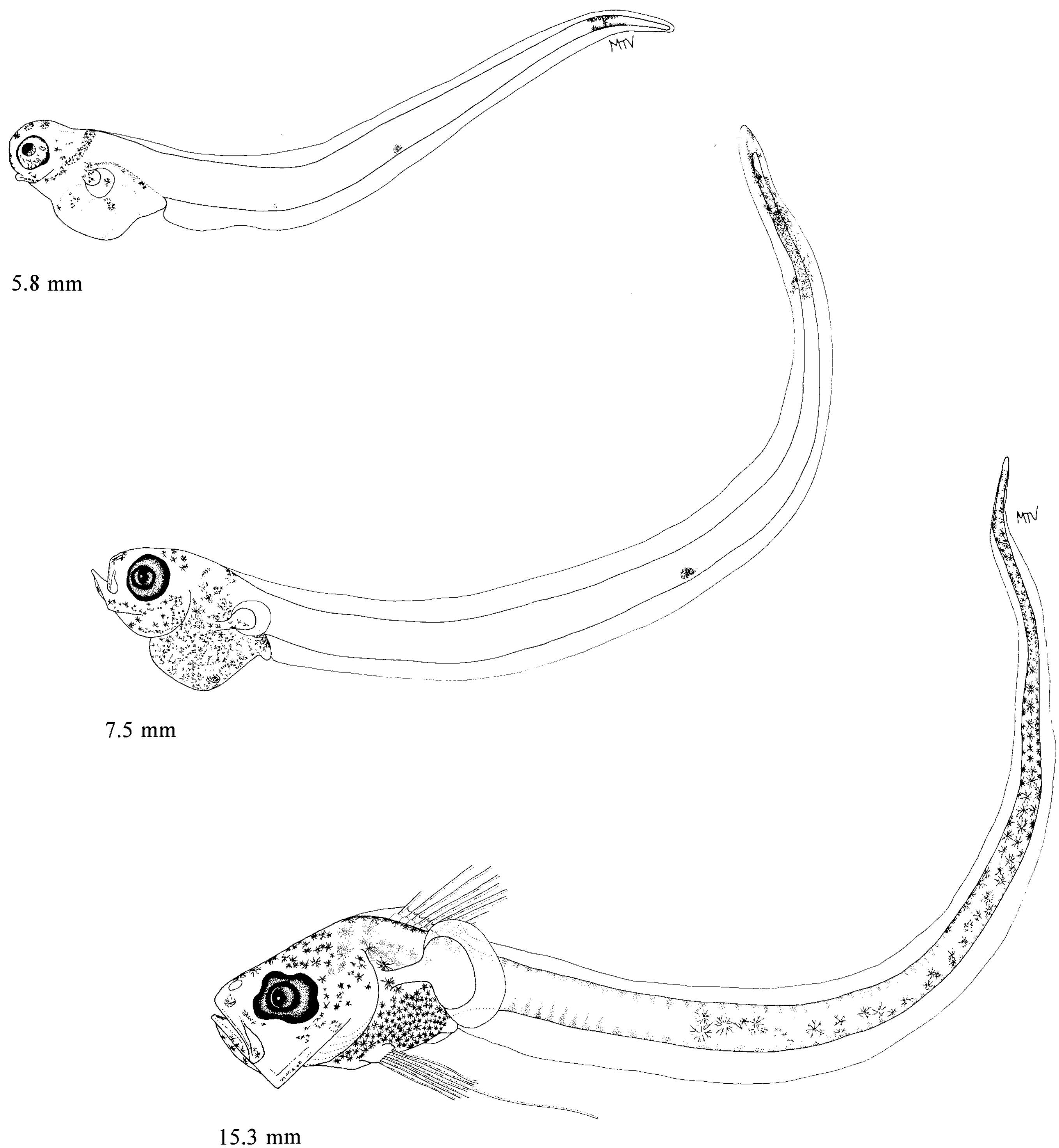


Figure Macrouridae 1. Yolk-sac larva, 5.8 mm (CalCOFI 6310, station 87.35); PrAF larvae, 7.5 mm (CalCOFI 5512, station 87.40), 15.3 mm (CalCOFI 8404, station 60.52.5).

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal		
Fins:		
First dorsal spines	II	II
First dorsal rays	7–9	8
Total first dorsal	9–11	10
Pelvic	7	7
Pectoral	17–20	
Pyloric caeca	15–26	
Gas glands	4	4
Gill rakers (inner 1st arch):		
Upper	1–2	
Lower	8–10	
Total	9–12	
Branchiostegals	6	6

LIFE HISTORY

Range: Southern California & northern Gulf of California

Habitat: Benthopelagic from 183 to 296 m depth

Spawning season: Early-stage larvae collected in February from the Gulf of California

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

PrAF larva, 3.7 mm (M. T. Vona)
AF larvae, 6.5 mm, >18.0 mm (M. T. Vona)

* Tails broken in 2 of 5 AF specimens & both transformation specimens; not included in morphometrics for damaged specimens.
† P_1 damaged on both transformation specimens & not measured.
‡ P_2 damaged on 1 of 5 AF specimens & on both transformation specimens; not measured.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Transformation length:
Fin development sequence: P_2, 1D, 2D, A, P_1
Pigmentation: *Preanal fin formation*—On top of head; posterior to eye; on preoperculum & operculum; ventral body anterior to gut; on side of gut; on ventral & lateral surface of anterior half of tail. *Anal fin formation*—Anterior on tail to about A ray 25–32; by ca. 18 mm, on base of P_1 & P_2.
Diagnostic features: Branchiostegal rays 6; total 1D rays 9–11; P_2 7; pyloric caeca 15–26; gas glands 4; BD ca. 70% of Sn-AL in PrAF & AF larvae; A forms at a small body length (by 6.5 mm); anus not adjacent to A; elongate 1D & P_2 rays; pigmentation absent from lower jaw & snout through A formation, present anteriorly on tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL*			29–37		
		36	34		
BD/Sn-An			66–71	53–64	
		69	69	58	
HL/Sn-An			57–80	70–76	
		57	76	73	
HW/HL			48–73	48–51	
		84	59	50	
SnL/HL			23–27	26–28	
		18	24	27	
ED/HL			29–37	26–30	
		45	32	28	
P_1L/HL†			15–23	>26–>36	
		29	17		
P_2L/HL‡			54–171	>50–>84	
		45	128		
P_1BL/HL			30–55	10–13	
		53	39	12	

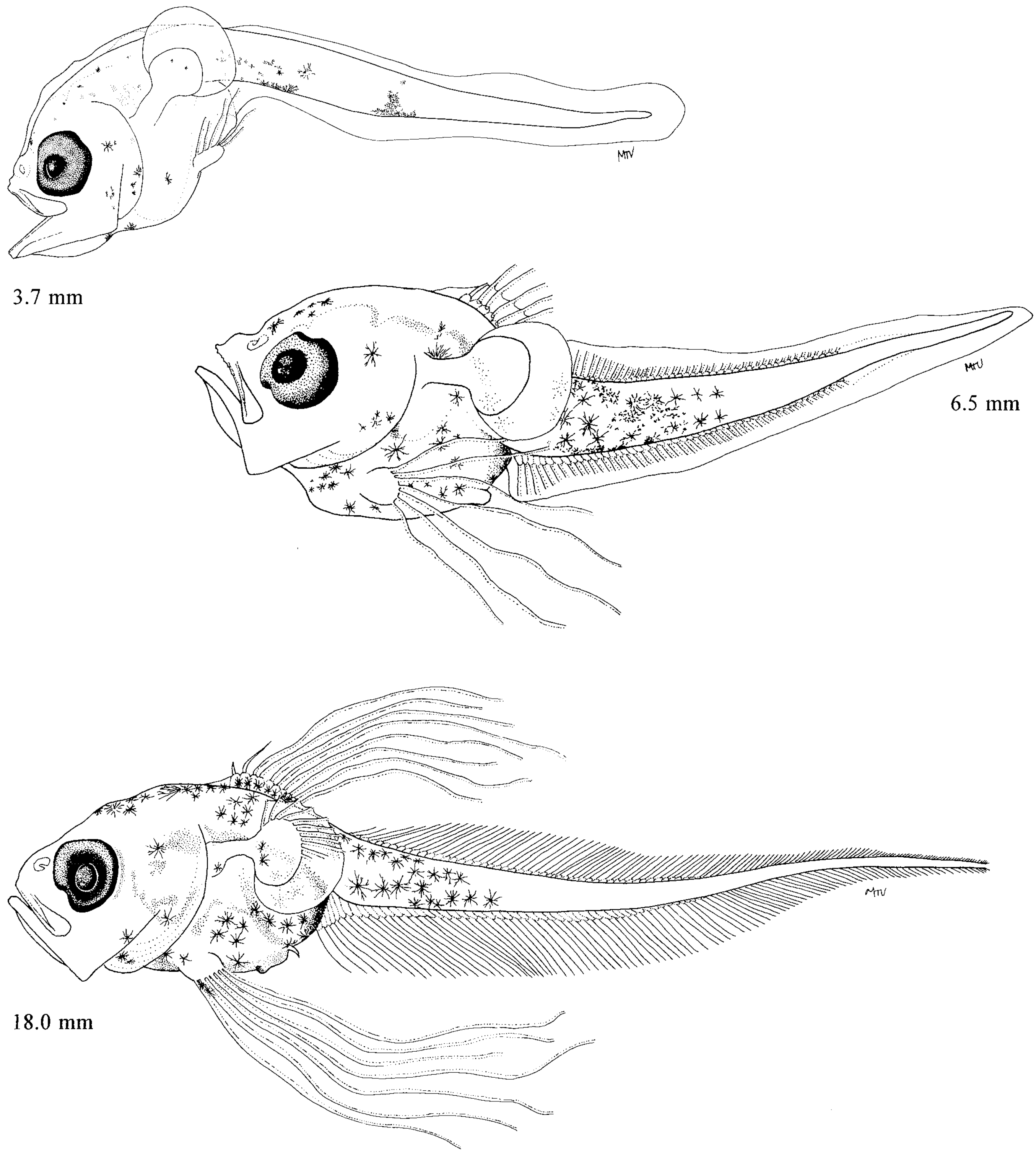


Figure Macrouridae 2. PrAF larva, 3.7 mm (CalCOFI 5702, station 121G.40); AF larvae, 6.5 mm (CalCOFI 5702, station 118.7G.32), 18.0 mm, tail broken (CalCOFI 5702, station 121G.40).

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal	12–16	
Fins:		
First dorsal spines	II	II
First dorsal rays	8–11	9 or 10
Total first dorsal	10–13	
Pelvic	8–9	8
Pectoral	19–22	
Pyloric caeca	12–14	
Gas glands	4	4
Lower		
Gill rakers (inner first arch):		
Upper	0–2	2
Lower	5–11	10 or 11
Total	5–13	
Branchiostegals	6	6

LIFE HISTORY

Range: North Pacific from northern Japan to Okhotsk & Bering Seas; south along North American coast to Isla de Guadalupe, Mexico

Habitat: Benthopelagic 600–2500 m depth, occasionally bathypelagic

Spawning season: Early-stage (PrAF) larvae occur primarily in CalCOFI ichthyoplankton collections in January & February; off Oregon, Stein & Pearcy (1982) reported ripe females captured in April, September & October, spent females in October

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Stein 1980b
Stein & Pearcy 1982
Matarese et al. 1989

* Pectoral fins damaged on 3 of 8 PrAF & 5 of 8 AF specimens; not measured.
† Pelvic fins damaged on 6 of 8 PrAF specimens & all 8 AF specimens; not measured.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Transformation length: 9.4–9.8 mm HL
Fin development sequence: P_2, 1D, A, 2D, P_1
Pigmentation: *Preanal fin formation*—Over top of head; on snout & lower jaw; internally over peritoneum; along bases of dorsal & anal finfolds; absent laterally on the posterior one-third of tail. *Anal fin formation through transformation*—Increasing laterally on body & tail; lateral posterior one-third of tail remains lightly pigmented.
Diagnostic features: Branchiostegal rays 6; total 1D 10–13; P_2 8–9; pyloric caeca 12–14; gas glands 4; Sn-A ca. 30% BL for PrAF through AF stages; basipterygia robust; lateral pigmentation light on the posterior 20% of body.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL		29–33 30	31–34 32		
BD/Sn-An		51–60 56	53–61 57		
HL/Sn-An		51–66 60	55–67 60		
HW/HL		61–82 69	48–71 59		
SnL/HL		18–24 22	19–28 24		
ED/HL		37–49 44	28–43 37		
P_1L/HL*		17–21 20	15–16 15		
P_2L/HL†		94–146 120			
P_1BL/HL		49–75 57	46–65 54		

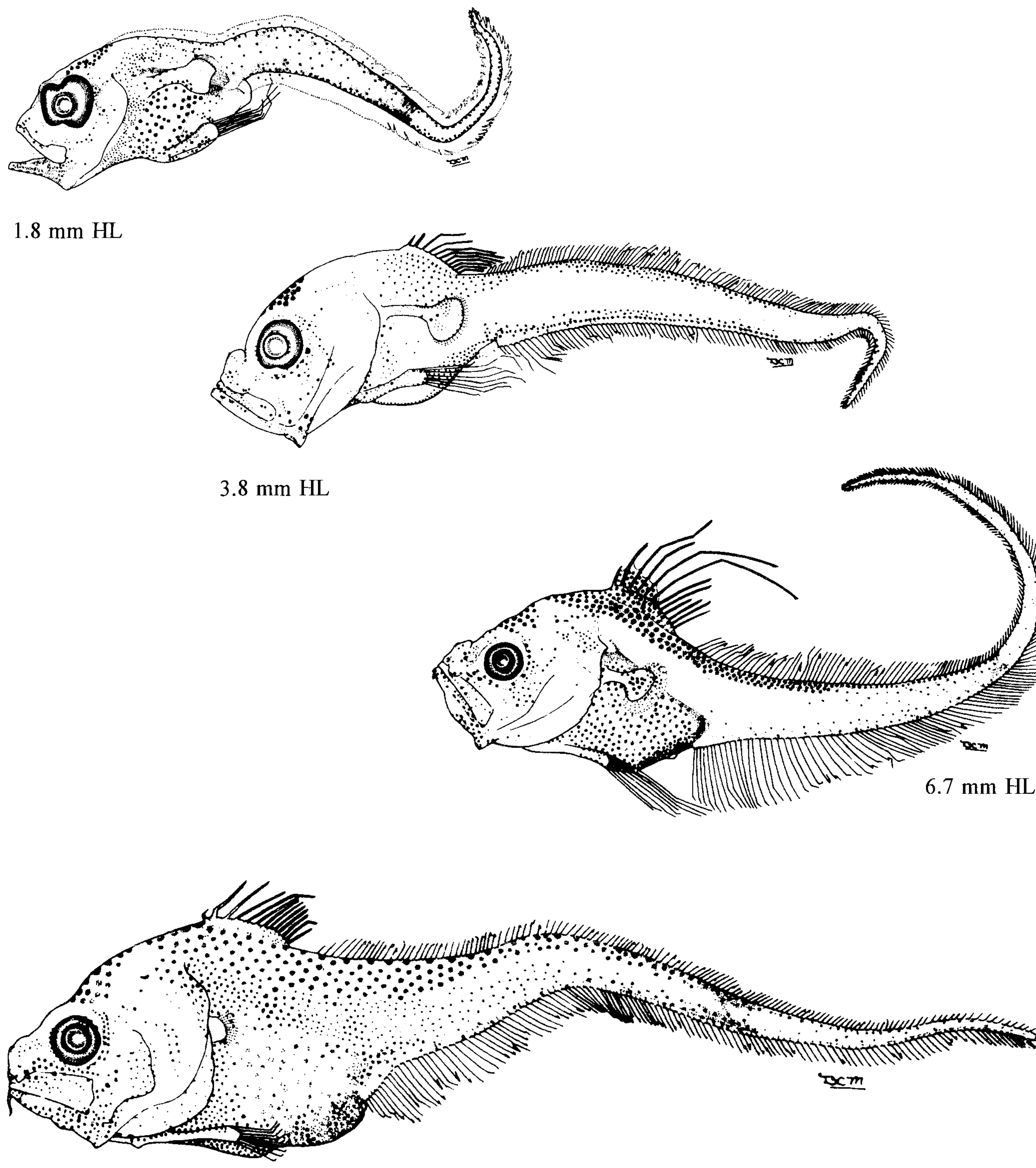


Figure Macrouridae 3. PrAF larva, 1.8 mm HL; AF larvae, 3.8 mm HL, 6.7 mm HL; transformation specimen, 9.8 mm HL (Stein 1980b).

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal		
Fins:		
First dorsal spines	II	II
First dorsal rays	11–14	12
Total first dorsal	13–16	
Pelvic	9–11	9
Pectoral	18–23	
Pyloric caeca	8–12	
Gas glands	4	4
Gill Rakers (inner first arch):		
Upper		
Lower		
Total	8–14	
Branchiostegals	6	6

LIFE HISTORY

Range: Bering Sea (66° N) to southern California (32° N)

Habitat: Bathybenthal, 2065–2904 m depth

Spawning season: Stein & Pearcy (1982) reported females with ripe eggs in January, June, July, & August off Oregon

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Stein 1980b
Stein & Pearcy 1982
Matarese et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Transformation length: 14.1–14.6 mm HL
Fin development sequence: P_2 & 1D & A & 2D, P_1
Pigmentation: *Anal fin formation*—On frontal region of head; on lower jaw & gular & suborbital regions; dorsolaterally on peritoneum; surrounding 1D & extending posteriorly to about 12th 2D ray; scattered along lateral line. *Transformation*—Similar to earlier stage, except dorsal pigmentation extending posteriorly only to ca. 7th 2D ray.
Diagnostic features: Branchiostegal rays 6; 1D 13–16; P_2 9–11; gas glands 4; prominent basipterygia; Sn-A <30% BL; oval pigment patch extending from anterior region of 1D posteriorly to about the 12th 2D ray & ventro-laterally to the lateral line.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL					
BD/Sn-An					
HL/Sn-An					
HW/HL					
SnL/HL					
ED/HL					
P_1L/BL					
P_2L/BL					
P_1BL/HL					

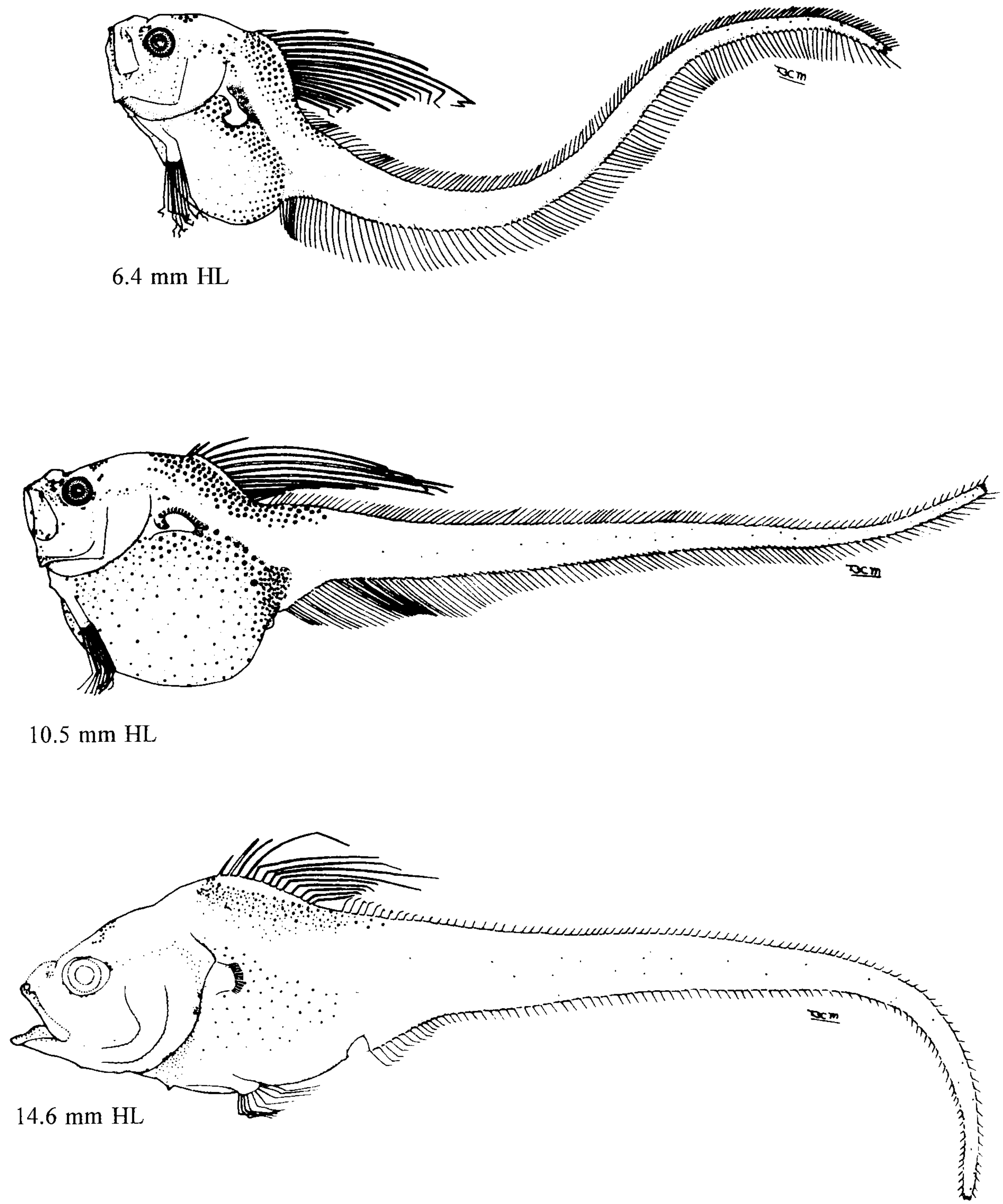


Figure Macrouridae 4. AF larvae, 6.4 mm HL, 10.5 mm HL; transformation specimen, 14.6 mm HL (Stein 1980b).

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal	12	12
Fins:		
First dorsal spines	II	II
First dorsal rays	8–10	
Total first dorsal	10–12	
Pelvic	9–10	
Pectoral	18–22	19
Pyloric caeca	11	11
Gas glands	6	6
Gill rakers (inner first arch):		
Upper	1	1
Lower	8–15	
Total	9–16	
Branchiostegals	6	6

LIFE HISTORY

Range: Southeast Alaska (55°–59° N) to south of southern California

Habitat: Bathybenthal, 2400–2800 m depth

Spawning season: PrAF larvae occur in CalCOFI ichthyoplankton tows in February & March

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Stein 1980b
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

PrAF larva, 5.8 mm (M. T. Vona)

* Tail was damaged on 3 of 4 AF specimens; not included in the morphometrics.
† Pectoral fin was damaged on 3 of 4 AF specimens; not included in the morphometrics.
‡ Pelvic fins were damaged in all specimens examined.

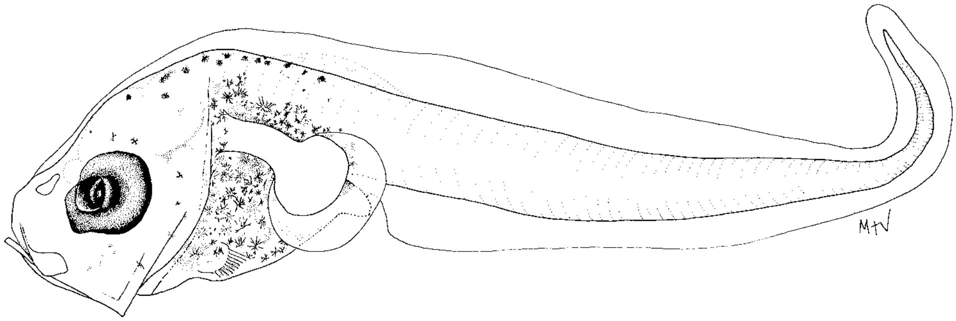
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

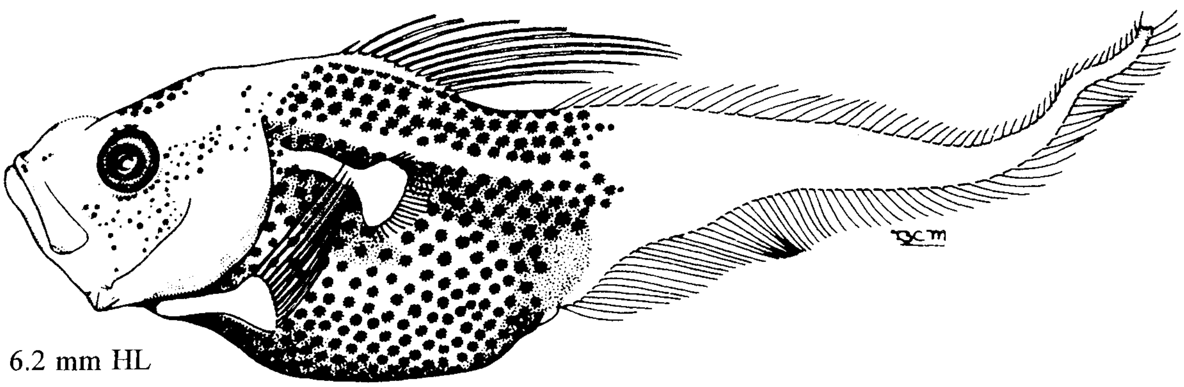
LARVAE
Hatching length:
Transformation length: >6.2 mm, <13.6 mm HL
Fin development sequence: P_2, 1D, A, 2D, P_1
Pigmentation: *Preanal fin formation*—Above, below, & posterior to eye; heavy on trunk; scattered dorsally from midbrain posteriorly to about myomere 7; absent from P_1 base. *Anal fin formation*—On frontal region of head, increasing below & posterior to eye; extending over trunk posteriorly to ca. 5th D ray. *Transformation–juvenile*—Evenly scattered spots on trunk from just anterior to 1D posterior to about the 10th A ray.
Diagnostic features: Branchiostegal rays 6; total 1D 10–12; P_2 9–10; gas glands 6; basipterygia extremely robust from AF through transformation stages; Sn-A ca. 30–40% BL from PrAF through AF stages; relatively wide space between insertion of 1D & origin of 2D; pigmentation heavy over trunk in evenly spaced spots not extending posterior to 10th A ray by juvenile.

MORPHOMETRICS (range & mean in %)

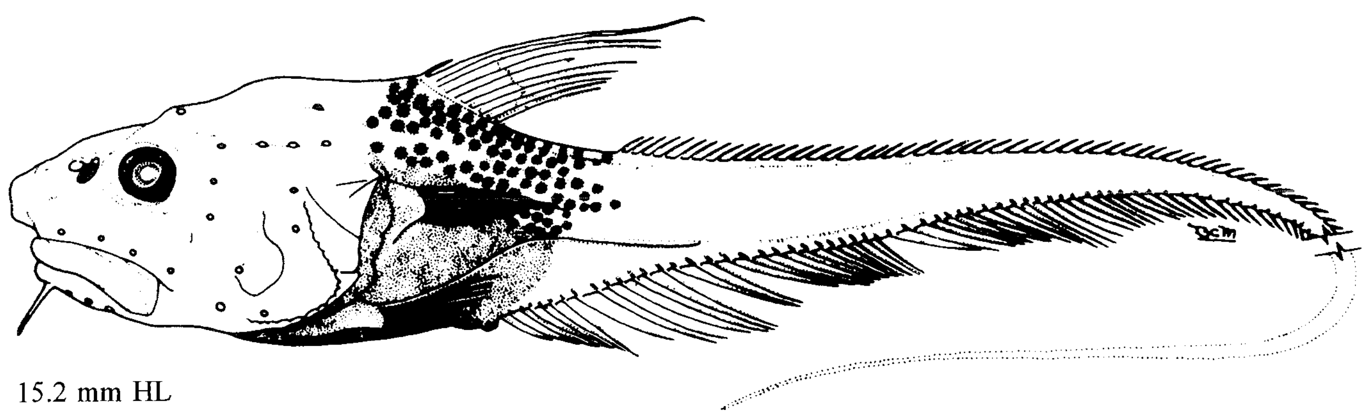
	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL*		31–37 34	 40		
BD/Sn-An		63–63 63	55–70 64		
HL/Sn-An		62–66 64	49–60 56		
HW/HL		63–75 69	42–82 54		
SnL/HL		25–28 27	25–31 28		
ED/HL		39–41 40	16–38 23		
P_1L/HL†		14–19 16	 20		
P_2L/HL‡					
P_1BL/HL		51–67 59	32–51 41		



1.2 mm HL (5.8 mm TL)



6.2 mm HL



15.2 mm HL

Figure Macrouridae 5. PrAF larva, 5.8 mm TL (1.2 mm HL) (CalCOFI 7203, station 70.65); AF larva, 6.2 mm HL; transformation specimen, 15.2 mm HL (Stein 1980b).

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal	11	11
Fins:		
First dorsal spines	II	II
First dorsal rays	8–10	9
Total dorsal	10–12	11
Pelvic	7–9	8
Pectoral	12–14	13
Pyloric caeca	12–17	
Gas glands	2	2
Gill rakers (inner first arch):		
Upper		
Lower		
Total	10–13	11
Branchiostegals	7	7

LIFE HISTORY

Range: Northeastern Pacific from southern California & Baja California to the Hawaiian Islands & Christmas Island

Habitat: Bathypelagic; captured in midwater trawls as shallow as 0–313 m to as deep as 0–2700 m; most taken in hauls to at least 650–1000 m depth

Spawning season: Yolk-sac & PrAF larvae collected in CalCOFI ichthyoplankton tows in January, April, July, & October

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Hubbs & Iwamoto 1977
Fahay & Markle 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.4 mm (M. T. Vona)
PrAF larvae, 6.7 mm, 11.2 mm (M. T. Vona)

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* Tail damaged on 2 of 3 AF specimens & on 1 of 3 juveniles; not included in morphometrics.
† P_1 damaged 3 of 6 PrAF specimens; not measured.
‡ P_2 was forming only on the larger of two yolk-sac larvae; P_2 was damaged on 1 of 5 PrAF & 1 of 3 AF specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 5 mm NL
Transformation length:
Fin development sequence: P_2, A, 2D, 1D, P_1
Pigmentation: *Yolk-sac*—Small patches on midbrain & hindbrain, & posterior to eye; 2 patches on P_1 base; about 8 dorsal patches extending posteriorly from nape along tail, more numerous row along ventral tail margin; ventro-lateral row along tail. *Preanal fin formation*—On top of gut, gradually spreading over abdomen; on branchiostegal region; on snout, lower jaw, & posterior angle of lower jaw. *Anal fin formation*—Uniformly spaced saddles dorsally & ventrally along tail; ventral saddles more numerous. *Transformation–juvenile*—Bold spotting on head & body persists.
Diagnostic features: Branchiostegal rays 7; P_1 12–14; P_2 7–9; gas glands 2; Sn-A ca. 25% BL in yolk-sac larvae, decreasing to <10% in juveniles; P_1 base length ca. 50% HL in yolk-sac larvae, increasing to ca. 70% before transformation; regularly spaced pigment patches along dorsal & ventral body, absent near end of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL*	24–26 25	18–23 21	16	7	6–9 8
BD/Sn-An	47–54 50	52–75 63	78–85 82	86	100–118 111
HL/Sn-An	52–53 53	60–72 64	77–91 84	131	115–138 129
HW/HL	62–77 70	66–73 68	57–63 60	53	42–46 44
SnL/HL	15–17 16	15–27 22	21–28 24	22	21–25 23
ED/HL	35–46 41	40–44 43	36–39 37	36	25–35 31
P_1L/HL†	3–9 6	20–27 24	10–18 15	20	25–51 38
P_2L/HL‡	0–3 2	8–35 26	38–70 54	43	25–62 45
P_1BL/HL	35–71 53	69–80 74	66–79 71	7	7–8 7

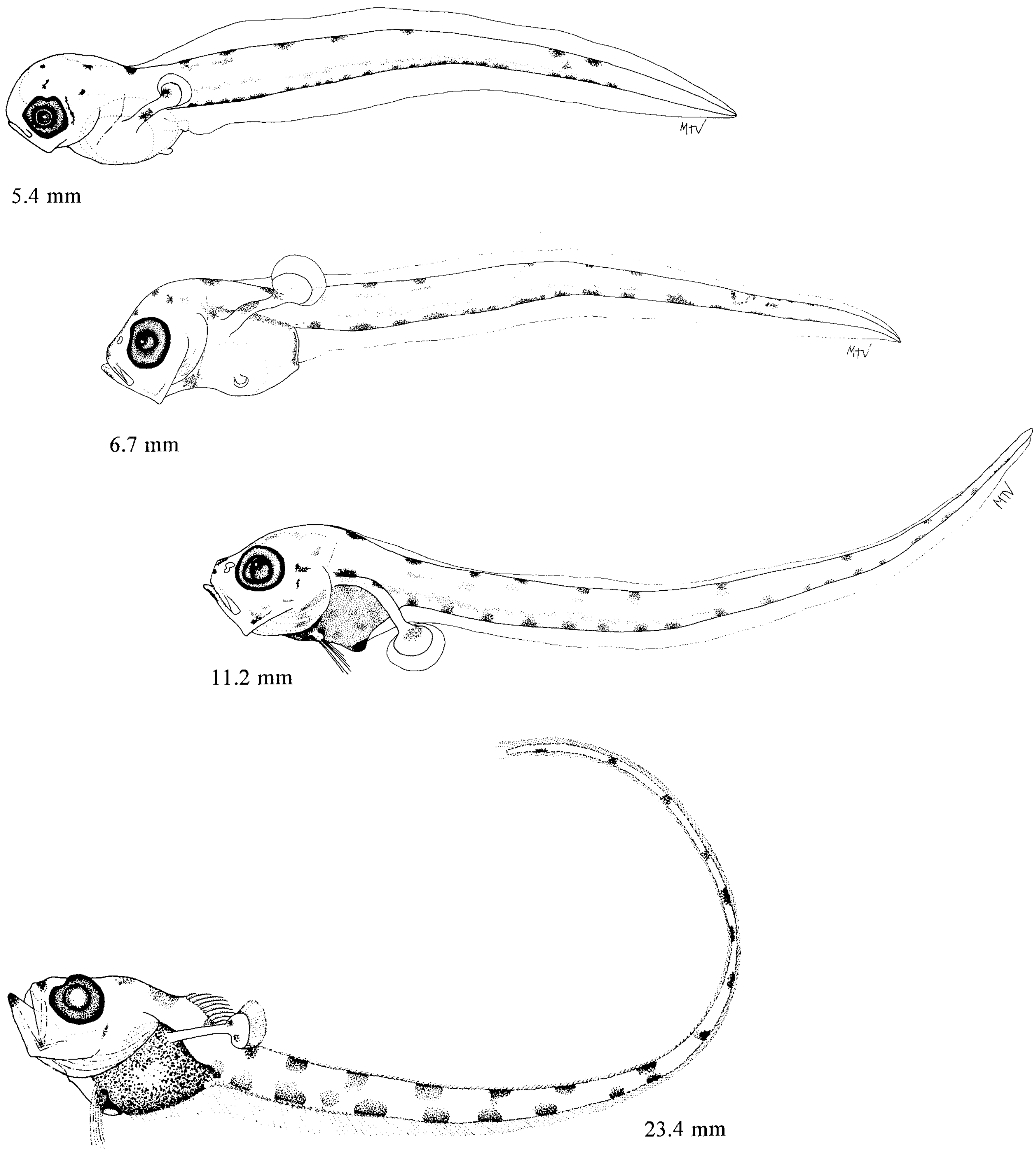

Figure Macrouridae 6. Yolk-sac larva, 5.4 mm (CalCOFI 7210, station 31.133); PrAF larvae, 6.7 mm (CalCOFI 6304, station 90.100), 11.2 mm (CalCOFI 7807, station 90.190); AF larva, 23.4 mm, tail broken (Hubbs and Iwamoto 1977).

MERISTICS

	Range	Mode
Vertebrae:		
Precaudal	13–14	
Fins:		
First dorsal spines	II	II
First dorsal rays	8–11	
Total dorsal	10–13	
Pelvic	8–12	
Pectoral	18–26	
Pyloric caeca	21–58	
Gas glands	2	2
Gill rakers (inner first arch):		
Upper		
Lower		
Total	7–12	
Branchiostegals	7	7

LIFE HISTORY

Range: *N. convergens*—Gulf of California to Chile; *N. liolepis*—Central California (ca. 37° N) to Gulf of California & southern Mexico (ca. 17° N); *N. stelgidolepis*—Vancouver Island, British Columbia to southern Peru (ca. 18° S)

Habitat: *N. convergens*—Benthopelagic in 600 to 1865 m; *N. liolepis*—Benthopelagic, 768 to 1655 m; *N. stelgidolepis*—Benthopelagic in 277–909 m depth

Spawning season: PrAF larvae occur in CalCOFI ichthyoplankton tows primarily in winter & spring

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

PrAF larvae, 8.8 mm, >13.2 mm (M. T. Vona)
AF larva, >15.7 mm (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Transformation length:
Fin development sequence: P_2, 1D, A, 2D, P_1
Pigmentation: *Preanal fin formation*—Over head, anteriorly & dorsally; on branchiostegal region; heavy on abdomen; on ventral midline & dorsal finfold of posterior one-third of tail; by ca. 13 mm, increasing anteriorly along ventral midline & a double series forming laterally along tail. *Anal fin formation*—Heavy under 1D; absent along dorsal midline & end of tail.
Diagnostic features: Branchiostegal rays 7; total 1D 10–13; P_2 8–12; gas glands 2; pyloric caeca 21–58; Sn-A <20% BL for specimens >6 mm through AF stage; pigment absent on P_1 base & along dorsal midline of tail; by ca. 13 mm, series along dorsal midline & ventral midline of tail & double series laterally on tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tr	Juv
Sn-A/BL*		15–22 17	15		
BD/Sn-An		64–85 80	81–88 85		63
HL/Sn-An		43–83 72	100–115 109		97
HW/HL		63–94 78	42–58 48		39
SnL/HL		20–32 25	18–21 20		25
ED/HL		35–56 41	22–29 25		27
P_1L/BL†		16–34 22	11–20 15		52
P_2L/BL‡		47–146 93	>34–>48		>58
P_1BL/HL		46–65 56	25–40 31		7

* Tail damaged in 2 of 12 PrAF specimens & on the only juvenile specimen & body length could not be determined.
† P_1 damaged on 1 of 12 PrAF specimens & not include in morphometrics.
‡ P_2 damaged on 6 of 12 PrAF specimens & on all AF & juvenile specimens; minimum ranges are listed for AF & juvenile specimens.

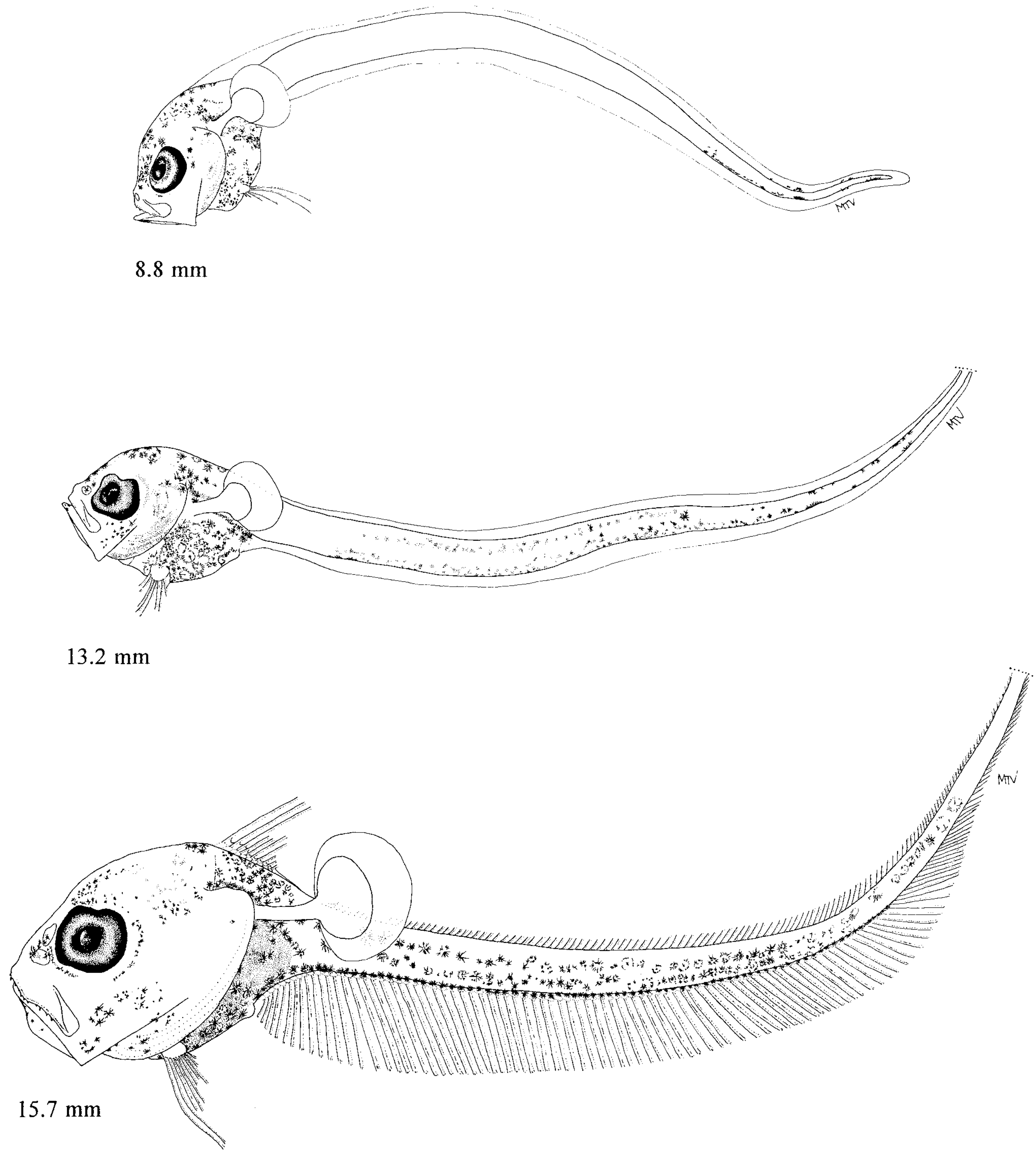

Figure Macrouridae 7. PrAF larvae, 8.8 mm (CalCOFI 6401, station 93.80), 13.2 mm, tail broken (CalCOFI 7205, station 80.52); AF larva 15.7 mm, tail broken (CalCOFI 5106, station 150.25).

MORIDAE: Codlings

D. A. Ambrose

Five morid species occur in the CalCOFI area (Table Moridae 1) but larvae of only two (*Microlepedium verecundum* and *Physiculus rastrelliger*) are collected with any regularity in CalCOFI ichthyoplankton samples. *Physiculus nematopus* larvae are collected in the Gulf of California. Larval *Antimora microlepis* and *Halargyreus johnsonii* are unknown. *H. johnsonii* adults have only recently been reported from the eastern Pacific (Logan et al. 1993).

Adult of codlings are small to medium in length (ca. 17–75 cm), elongate and moderately compressed, with the tail tapering to a slender caudal peduncle, and with a separate caudal fin (Fitch and Barker 1972; Eschmeyer et al. 1983; Cohen et al. 1990). The dorsal fin consists of a short-based anterior section and a separate long-based posterior section. A single long-based anal fin is present in all except *H. johnsonii*, which has two. All species have jugular pelvic fins. In *M. verecundum*, the number of pelvic fin rays is reduced during ontogeny from five in postflexion larvae to two in adults. All fins consist solely of soft rays. All species have cycloid scales, an otophysic connection, the first neural spine fused to the skull, and five hypural bones. *H. johnsonii* is the only morid in the California Current region without a mental barbel. *Physiculus* has a light organ on the belly in a dark scaleless area. The mouth is inferior in *A. microlepis* but subterminal in all the others. Adult *M. verecundum* are collected primarily in midwater trawls. The other morids are benthopelagic, ranging from the outer continental shelf to lower slope and some (*A. microlepis*) are important members of communities in those habitats.

Little is known of the early life and natural history of morids. For the few species described, eggs are 0.52–1.16 mm in diameter, with a single oil globule and a smooth chorion (Fahay and Markle 1984; Kitagawa et al. 1985). Fitch and Barker (1972) found advanced ovarian eggs in a 67 mm specimen of *M. verecundum*. Larval morids are noted for being stocky anteriorly with a rounded head, tapering body, elongate and early forming pelvic fins, and relatively voluminous posterior portions of the dorsal and anal fins. Pelvic fins are greatly reduced in relative size in adults, but there is little change in vertical fin base position from larvae to adults. A pronounced genital papilla develops in postflexion larvae. A mental barbel (when present) develops in the late larval or early pelagic juvenile period. The pectoral fin base is only slightly stalked and caudal fin formation is delayed. In *Physiculus*, a single dorsal fin forms, then divides late in development. Larval pigment is heavy on the gut and brain and prominent on the pelvic rays, but light on the pectoral rays. Transformation is gradual and direct with no striking changes, except for the decrease in number of pelvic fin rays in *M. verecundum*.

Numerous characters may be used to distinguish the larvae of genera and species in the CalCOFI region. *M. verecundum* has the fewest myomeres (44–46), fewest rays in the second dorsal fin (39–42), and a relatively long preanal distance (ca. 38–53% BL) compared to *Physiculus* (ca. 24–33% BL). *Physiculus* larvae have early forming, elongate pelvic fins and a heavy patch of pigment ventrally on the gut where the light organ will form. *P. rastrelliger* has a line of pigment along the ventral margin of the tail; *P. nematopus* lacks this pigment. *P. rastrelliger* has 7 pelvic rays and *P. nematopus* has 6. *P. rastrelliger* also has more caudal fin rays (27–32) than *P. nematopus* (22–26). Although larval *A. microlepis* and *H. johnsonii* are unknown, they should be readily identified by their presumed tadpole-like shape and relatively high number of precaudal myomeres (*A. microlepis*, 24–25 and *H. johnsonii*, 22–23). *A. microlepis* also has the fewest first dorsal fin rays (4–5) of any morid in the region.

The following descriptions of morid early life history stages are based on detailed examinations of between 14 and 30 specimens of each species (Table Moridae 2). Larvae of *M. verecundum* and *P. rastrelliger* are described for the first time. Meristic data were obtained from counts made during this study and from the literature (Fitch and Barker 1972; Fahay and Markle 1984; Paulin 1989). The principal source of ecological information was Fitch and Barker (1972). Cohen et. al. (1990) listed *Laemonema verecunda* as the preferred name for *Microlepedium verecundum*; however, we follow Eschmeyer (1990) and retain the latter name for this identification guide.

Table Moridae 1. Selected meristic characters for the morid species that occur in the California Current region.

	Vertebrae			Fin rays								
Species	PrCV	CV	Total	1D	2D	1A	2A	A_{TOT}	P_1	P_2	C	GR
Antimora microlepis	24–25	33	57–58	4–5	50–55	36–42	0	36–42	18–20	6–7	35–37	20
Halargyreus johnsonii	22–23	30–35	51–58	6–9	47–60	17–26	21–29	39–53	15–20	5–6	38	23–32
Microlepedium verecundum	11–13	33–35	44–46	7–9	39–42	39–42	0	39–42	19–22	2	29–32	16–19
Physiculus nematopus	11–14	38–41	51–58	9–11	57–67	62–76	0	62–76	21–25	6	22–26	14–19
P. rastrelliger	12–14	38–42	50–55	8–13	52–62	56–66	0	56–66	24–28	7	27–32	24–32

Table Moridae 2. Number of specimens (above) and size range (in mm, below) used in the preparation of the morid descriptions.

Species	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Microlepedium verecundum	10 2.7–7.5	1 9.4	1 18.5	0	2 33.2–36.1
Physiculus nematopus	10 2.4–9.8	6 8.3–10.9	9 10.7–13.5	0	5 38.0–59.8
P. rastrelliger	10 3.3–8.4	5 9.6–10.5	2 12.7–18.3	0	4 66.7–88.0

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–46	
Precaudal	11–13	
Caudal	33–35	
Fins:		
Dorsal spines	0	
Dorsal rays	7–9+39–42	
Anal spines	0	
Anal rays	39–42	
Pelvic	2	
Pectoral	19–22	
Caudal:		
Total	29–32	
Gill rakers:		
Upper	5–6	
Lower	11–13	
Branchiostegals	7	

LIFE HISTORY

Range: Oceanic area near Cabo San Lucas (ca. 28° N) south to ca. 15° N & offshore to Isla Clarion (ca. 115° W)

Habitat: Collected in midwater trawls fished down to ca. 180 m with bottom depth to ca. 3100 m

Spawning season: Preflexion larvae occur in CalCOFI icthyoplankton collections from January through September

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.3 mm, 5.9 mm (B. Sumida MacCall)
Flexion larva, 9.4 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.7 mm
Flexion length: <9.4 mm – <18.5 mm
Transformation length: <33.2 mm
Fin development sequence: P_1, P_2, 2D & A, 1D, C_1, C_2
Pigmentation: *Preflexion*—On brain, gut, nape, & P_1 & P_2 fin bases; broad bar at midtail, near end of tail in some early stage larvae; by ca. 6 mm, on snout, operculum, infraorbital, & branchiostegal region; absent from posterior half of tail. *Flexion*—On jaw tips & isthmus; gradually expanding posteriad along tail. *Postflexion–juvenile*—Occasionally on ends of first few 2D rays & ends of P_2 rays; line along dorsal & ventral margins & lateral midline of tail.
Diagnostic features: Heavy pigment bar at midtail; by flexion stage, concentrated at midtail on dorsal & ventral margins, on lateral midline, & along myosepta; 2D rays 39–42; P_2 rays 5, decreasing to 2 by adult; through postflexion stage, anus about midbody; HL ca. 33% BL & BD ca. 30% of BL; P_2 rays not as early forming or elongate as in *Physiculus*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–53 49	48	52		39–42 41
BD/BL		32–38 36	28	27		23–24 24
HL/BL		25–39 34	33	36		28–30 29
HW/HL		67–87 76	71	56		45–51 48
SnL/HL		15–26 21	19	24		17–18 17
ED/HL		37–47 41	39	26		29–29 29
P_1L/BL		5–11 8	14	20		24
P_2L/BL		0–27 13	>18	36		37

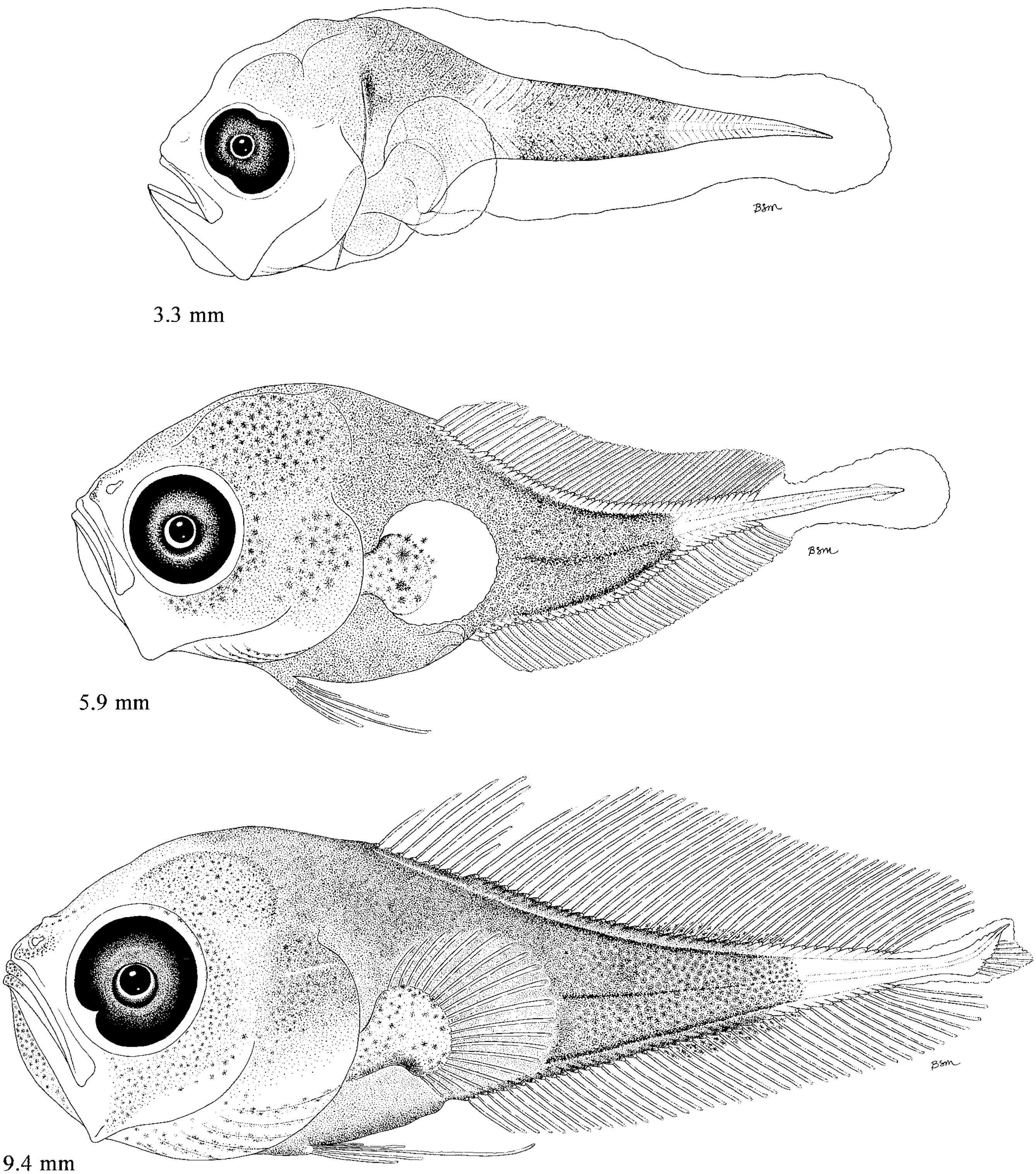

Figure Moridae 1. Preflexion larvae, 3.3 mm (CalCOFI 5706, station 157.20), 5.9 mm (CalCOFI 5706, station 148.30); flexion larva, 9.4 mm (CalCOFI 7205, station 157.10).

MERISTICS

	Range	Mode
Vertebrae:		
Total	51–58	
Precaudal	11–14	
Caudal	38–44	
Fins:		
Dorsal spines	0	
Dorsal rays	9–11+57–67	
Anal spines	0	
Anal rays	62–76	
Pelvic	6	
Pectoral	21–25	
Caudal:		
Total	22–26	
Gill rakers:		
Upper	4–6	
Lower	10–14	
Branchiostegals	7	

LIFE HISTORY

Range: Northern Gulf of California (ca. 31° N) to Gulf of Panama (ca. 7° N)

Habitat: Captured at depths ranging from 42 to 1271 m; specimens from depths greater than about 366 m probably are captured well off bottom; juveniles often taken in or near scattering layer

Spawning season: Preflexion larvae occur in CalCOFI ichthyoplankton collections from February through April

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Fahay & Markle 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.4 mm (M. T. Vona)
Postflexion larva, 14.1 mm (H. M. Orr)

* Pelvic fin lengths are minimum values because the rays usually were broken.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 8.4 through ca. 11.0 mm
Transformation length:
Fin development sequence: P_1, P_2, 2D & A, 1D & C_1, C_2
Pigmentation: *Preflexion*—On brain, gut, jaw angle, & operculum; ventral patch near midtail; finfold pigment near end of tail; by ca. 5 mm, on isthmus, at end of pelvic rays, midtail patch spreads to form bar, & a second tail patch forms anterior to the first; by ca. 7 mm, heavy patch anterior to anus & row above & below notochord along most of tail. *Flexion-postflexion*—Spreading along P_2 & on lateral tail dorsal & ventral to notochord. *Juvenile*—On fins, branchiostegal region, peritoneum, & scattered over body.
Diagnostic features: In early preflexion stage, pigment on C & patch at midtail; from late preflexion through postflexion stages, pigment absent along ventral tail margin; heavy ventral patch anterior to anus; total caudal rays 22–26; P_2 rays 6; early forming, elongate P_2 rays; anus at ca. 30% BL.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		24–31 27	24–31 28	26–32 29		29–31 30
BD/BL		19–22 21	18–23 20	19–21 20		18–21 19
HL/BL		16–26 22	22–26 24	24–26 25		27–30 29
HW/HL		71–100 79	66–80 73	66–74 70		52–64 56
SnL/HL		11–25 19	18–25 21	19–23 21		21–25 23
ED/HL		38–53 41	33–42 37	34–40 38		22–25 23
P_1L/BL		6–14 10	12–16 15	15–23 18		16–33 21
P_2L/BL*		8–30 22	20–40 26	17–43 26		29–39 34
P_1BL/BL		5–11 7	6–7 6	5–7 6		2–5 4

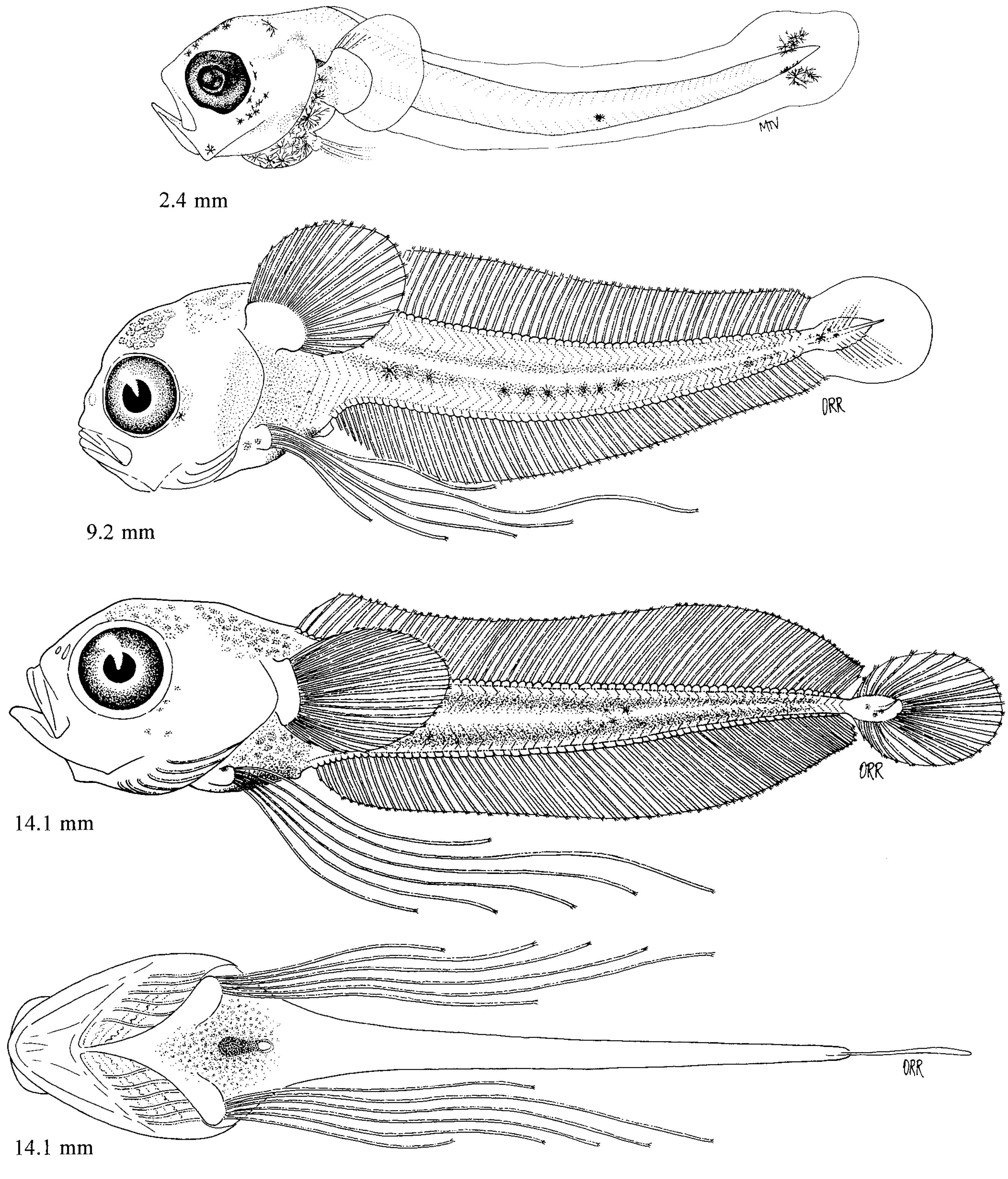

Figure Moridae 2. Preflexion larva, 2.4 mm (CFRD 7203 27/3 #9, 30°11′ N, 114°11′ W); flexion larva, 9.2 mm (Fahay and Markle 1984); postflexion larva, 14.1 mm (CalCOFI 5604, station 103G.40), ventral view (Fahay and Markle 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	50–55	
Precaudal	12–14	
Caudal	38–42	
Fins:		
Dorsal spines	0	
Dorsal rays	8–13+52–62	
Dorsal spines	0	
Anal rays	56–66	
Pelvic	7	
Pectoral	24–28	
Caudal:		
Total	27–32	
Gill rakers:		
Upper	7–10	
Lower	17–22	
Branchiostegals	7	

LIFE HISTORY

Range: Northern California (ca. 41° N) to Gulf of Panama (ca. 7° N)

Habitat: Near bottom, usually at 183–366 m; depth range 128–523 m

Spawning season: Preflexion larvae occur in CalCOFI ichthyoplankton samples primarily from December through April

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.3 mm, 8.4 mm (M. T. Vona)
Postflexion larva, 12.7 mm (M. T. Vona)

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* Fin lengths are minimum values because the rays usually were broken.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 8.5–12.5 mm
Transformation length:
Fin development sequence: P_2, P_1, 2D & A, 1D & C_1, C_2
Pigmentation: *Preflexion*—On brain, nape, gut, jaw angle, & operculum; along cleithrum; in finfold near end of tail; by 5 mm, heavy anterior to anus, on isthmus, & internal rows dorsal & ventral to notochord at midtail. *Flexion*—Line along ventral tail margin extending almost to trunk; row along dorsal tail margin, reduced near end of tail. *Postflexion*—On base of P_2 & P_1, on P_2 rays, & on dorsum in anterior tail region. *Juvenile*—On fins, peritoneum, branchiostegal region, & scattered all over body.
Diagnostic features: By late preflexion stage, pigment row present along ventral tail margin & heavy patch anterior to anus; total C rays 27–32; P_2 rays 7; morphology similar to *P. nematopus*; voluminous fins.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		26–30 27	27–31 30	28–33 30		27–30 29
BD/BL		17–21 19	21–23 22	21–24 22		15–18 17
HL/BL		18–21 19	22–24 23	24–32 28		27–30 28
HW/HL		81–100 90	79–86 82	64–84 74		56–58 57
SnL/HL		16–26 21	12–20 16	18–21 19		21–25 25
ED/HL		41–50 47	41–45 43	34–39 37		23–27 25
P_1L/BL*		7–13 8	15–25 18	19–29 24		18–20 19
P_2L/BL*		12–26 18	10–21 15	20–46 33		17–21 19
P_1BL/BL		5–8 7	6–7 7	4–6 5		3–3 3

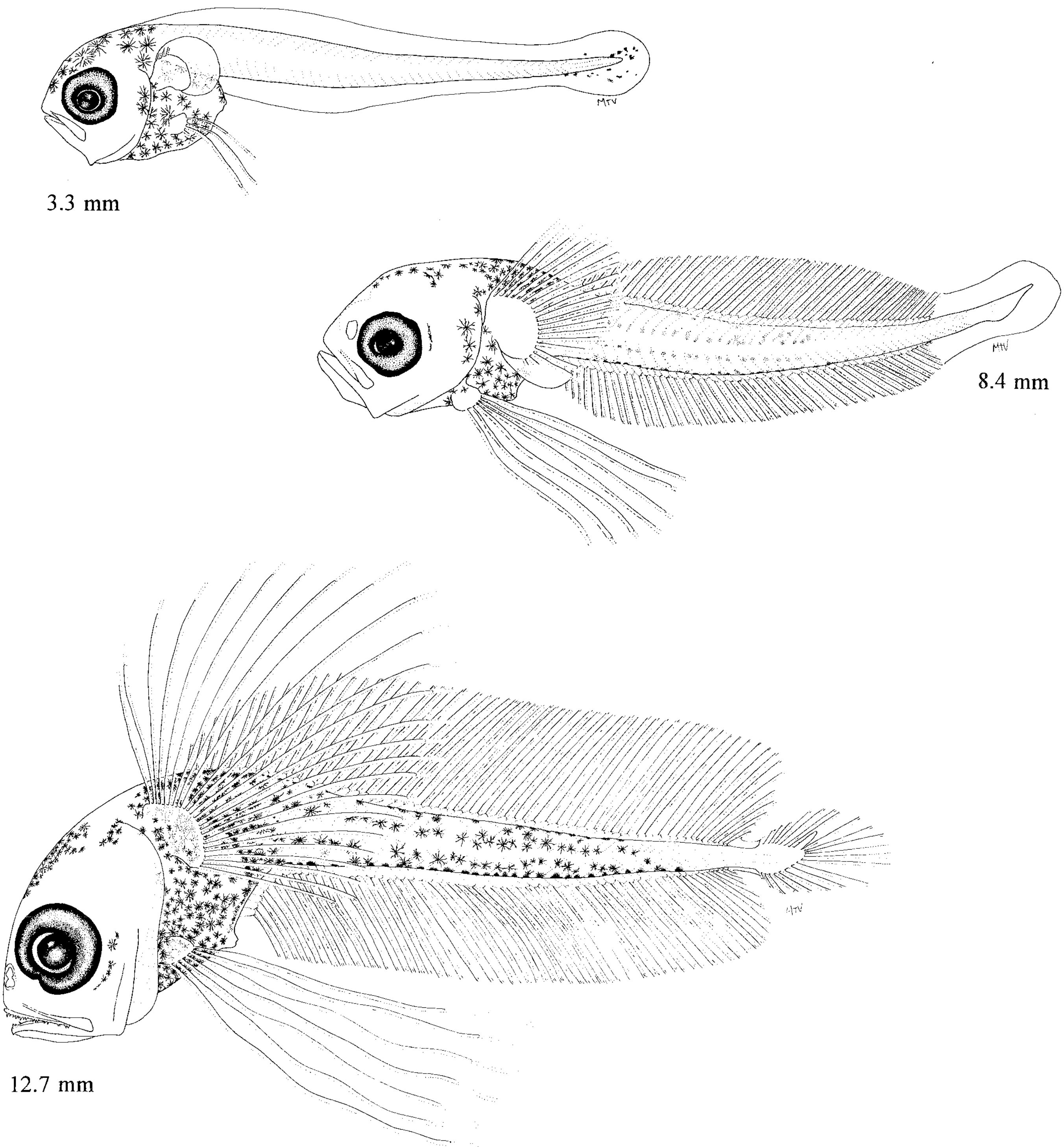


Figure Moridae 3. Preflexion larva, 3.3 mm (CalCOFI 6712, station 133.40); late preflexion larva, 8.4 mm (CalCOFI 5602, station 127.50); early postflexion larva, 12.7 mm (CalCOFI 6904; station 133.35).

MERLUCCIIDAE: Hakes

D. A. AMBROSE

Merlucciidae is variously considered a separate family or a subfamily of Gadidae. The most recent classification in Nelson (1994) includes one genus with ca. 13 species in the Merlucciidae. *Merluccius productus*, the Pacific hake or whiting, is the most common hake in the northeastern Pacific. Several possible subpopulations have been identified along the northeastern Pacific coast: (1) in the Strait of Georgia (Bailey et al. 1982), (2) in Puget Sound (Utter and Hodgins 1971), (3) a large coastal migratory population extending from Canada to Baja California, and (4) a dwarf hake found off southern Baja California (MacGregor 1971; Vrooman and Paloma 1977). Giant hake in the northern Gulf of California have been described by Mathews (1985) as *Merluccius hernandezi*; however, this species is not widely recognized (Cohen et al. 1990). *Merluccius angustimanus* ranges from Del Mar, California to Colombia, including the Gulf of California (Ginsburg 1954; Cohen et al. 1990). Only larvae attributable to the coastal migratory population of *Merluccius productus* have been identified in CalCOFI samples.

Merluccid hakes are medium to large (maximum size ca. 70–140 cm) pelagic and demersal predators on the continental shelf and upper slope of the eastern Pacific, Atlantic, and southwestern Indian oceans, and off southern New Zealand. The large head is ca. 25–33% BL with a V–shaped ridge dorsally, the mouth is large with well developed teeth, and the eye is large. The first dorsal fin is short, high, and triangular while the second, separate fin is long and deeply notched at midlength. The anal fin resembles the second dorsal fin. Pectoral fins are long, slender and placed posterior to the pelvic fins. The caudal fin becomes progressively forked with growth and the caudal skeleton includes X–Y bones (Inada 1981). Meristics for the family are V 48–58; 1D I,7–12; 2D 34–45; A 35–46; P_1 12–18; P_2 6–9 (usually 7); and Br 7. The body usually is silvery, steel-grayish on the back and lighter on the sides and belly. Almost all hakes make diel vertical migrations, when the daytime benthic schools disperse at night to feed in the water column. *Merluccius productus* apparently remains at the bottom when spawning (Bailey et al. 1982). Hake exhibit seasonal migrations generally moving to higher latitudes and inshore during the warm seasons and back to lower latitudes and deeper water during the cold season. Males grow more slowly than females, which live longer than males (Cohen et al. 1990). Hake are commercially and ecologically important fishes (Alheit and Pitcher 1995).

Hake are oviparous and spawn smooth, spherical, buoyant eggs about 0.80–1.20 mm in diameter with a single oil globule (Fahay 1983). Larvae of most species are well described (Fahay and Markle 1984). Larvae hatch with a non-functional mouth, round unpigmented eyes, and well developed pigment on the body. Larvae are identified by their general tadpole shape, the gut with a single loop, the anus located in the anterior half of the body, and one to three distinctive pigment bars on the tail which begin to disperse by the late flexion stage. Ahlstrom and Counts (1955) described in *M. productus* the multiple ossification centers of the second dorsal and anal fins which would correspond to the divided fins in other gadoids. Transformation to the juvenile is gradual. In *M. productus*, all fins except the pectorals have the full complements of rays by ca. 20 mm. Larvae of *M. angustimanus* and *M. hernandezi* are undescribed.

The following species description is based on morphometrics from Ahlstrom and Counts (1955). Meristic data were obtained from literature (Ginsburg 1954; Inada 1981; Matarese et al. 1989; Cohen et al. 1990) and ecological information was obtained from Bailey et al. (1982) and Cohen et al. (1990).

Table Merlucciidae 1. Meristic characters for the merluccid species in the California Current vicinity. All species have 7 branchiostegal rays.

	Vertebrae			Fin rays					Gill rakers	
Species	PrCV	CV	Total	1D	2D	A	P_1	P_2	U	L
Merluccius angustimanus	21–23	27–29	49–52	I,9–12	36–40	36–40	14–17	7	3–5	12–14
M. hernandezi			47–52		36–42	37–42			14–20 total	
M. productus	23–25	29–31	52–55	I,9–12	37–44	37–44	14–17	6–8	3–6	13–18

MERISTICS

	Range	Mode
Vertebrae:		
Total	52–55	53
Precaudal	23–25	24
Caudal	29–31	29
Fins:		
Dorsal spines	1	I
Dorsal rays	9–12+37–44	11+40
Anal spines	0	0
Anal rays	37–44	40
Pelvic	6–8	
Pectoral	14–17	16
Caudal:		
Principal	6+2–3	
Procurrent:		
Upper	16–18	
Lower	14–17	
Gill rakers:		
Upper	3–6	4
Lower	13–18	16
Branchiostegals	7	7

LIFE HISTORY

Range: Northern Vancouver Island, British Columbia (ca. 48° N) to ca. 23° N, including the Gulf of California

Habitat: Surface to ca. 1000 m, mainly concentrated over continental shelf & slope between 45 & 500 m depth

Spawning season: January to April or June with peak in January–February in deep water off southern California & Baja California

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Counts 1955

* Morphometrics are the ranges of average values taken from Ahlstrom & Counts (1955). The following size ranges are included in the developmental stages: preflexion, 3.0–8.4 mm; flexion & postflexion combined, 8.5–19.9 mm; transformation, 20.0–25.9; & juvenile, 40.0–46.9 mm.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.07–1.18 mm (ave. 1.12 mm)

Yolk: Homogeneous; ca. 1.0 mm diam., may appear granular

No. of OG: 1

Diam. of OG: 0.27–0.34 mm (ave. 0.30 mm)

Shell surface: Smooth, transparent

Pigment: On OG, yolk, head & dorsum of embryo

Diagnostic features: Late-stage eggs—pigment separated into 4 areas along dorsum & 1 ventrally on tail; myomeres >50.

LARVAE

Hatching length: ca. 2.4 mm

Flexion length: ca. 8.5 mm

Transformation length: ca. 30–35 mm

Fin development sequence: C, P_2, 1D, 2D & A, P_1

Pigmentation: *Yolk-sac*—Similar to late-stage embryos. *Preflexion*—Medial surface of P_1 base; 1 on occipital region; interorbital region; dorsolaterally on peritoneum; scattered ventrally on gut; ventrolaterally ca. 4 myomeres behind anus; bar at midtail; occasionally lateral rows between anus & tail bar. *Flexion–postflexion*—Increasing over head; bar behind eyes; on premaxilla & mandible; tail bar becomes indistinct; by ca. 16.5 mm, continuous along dorsum. *Transformation–juvenile*—On snout; gradually increasing on body; scattered in fin membrane by juvenile.

Diagnostic features: Vertebrae 52–55; A 37–44; preanal length <46% BL; a single pigment bar at midtail in preflexion & flexion larvae, becoming indistinct during postflexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		42–45		41–46	41–43	36–40
BD/BL		22–30		19–24	17–20	16–17
HL/BL		23–27		26–29	28–29	26–28
HW/HL						
SnL/HL						
ED/HL		36–43		28–38	27–30	25–29
P_1L/BL		0–0		0–3	4–28	33–35
P_2L/BL						

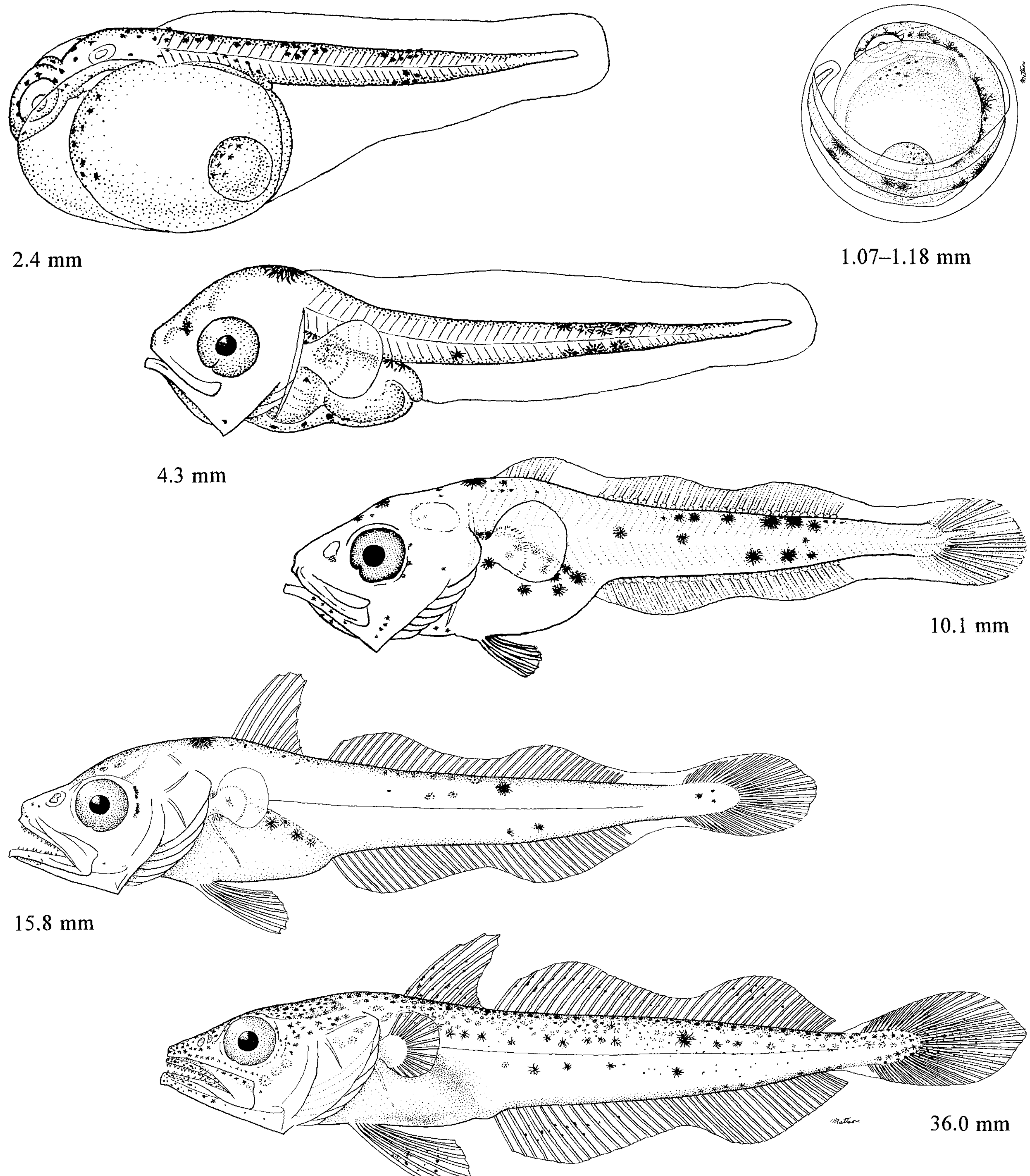


Figure Merlucciidae 1. Egg, 1.07–1.18 mm; yolk-sac larva, 2.4 mm; preflexion larva, 4.3 mm; flexion larva, 10.1 mm; postflexion larva, 15.8 mm; juvenile, 36.0 mm (Ahlstrom and Counts 1955; the fine stippling represents shape and not pigment).

OPHIDIIFORMES

D. A. Ambrose

The classification of this group is unsettled. Rosen and Patterson (1969) considered it a suborder (Ophidioidei) of the Gadiformes, while Gosline (1968, 1971) treated it as a suborder of the Perciformes. We follow Cohen and Nielsen (1978) who assigned it to a separate order. Ophidiiforms are primarily marine benthic inhabitants but occupy habitats of wide-ranging depths and salinities (intertidal to the greatest depths of the sea; also fresh water) and have a propensity for hiding or burrowing in various substrates (Svetovidov 1961).

These more or less elongate, tapering fishes have mental or jugular pelvic fins (when present), each with one or two soft rays and occasionally with a minute spine. Dorsal and anal fins are single, without spines, with long bases extending to and often joined with the caudal fin. Dorsal and anal fin pterygiophores are more numerous than the adjacent vertebrae. There are two nostrils on each side of the head (Nelson 1994).

Cohen and Nielsen (1978) used the presence or absence of viviparity to define the two ophidiiform suborders, Bythitoidei and Ophidioidei. The ophidioid families Carapidae and Ophidiidae are differentiated by the length of the anal fin (longer than the dorsal fin for carapids and equal to or shorter for ophidiids) and the presence of the supramaxillary bone (present in ophidiids and absent in carapids). The bythitoid families are separated by the swim bladder (present in Bythitidae and absent in Aphyonidae) and precaudal vertebrae (<23 in Bythitidae, >25 in Aphyonidae).

Ophidiiformes is represented by 18 genera in 4 families in the California Current vicinity. Larvae of 3 of these families have been identified in CalCOFI ichthyoplankton samples: Ophidiidae, Carapidae, and Bythitidae. The Aphyonidae are not included in this guide because their larvae have not been reported from plankton tows. Nielsen (1969) discussed the biology of this group and illustrated late-stage embryos taken from ovarian tissue (Nielsen and Eagle 1974).

Suborders and families included: Ophidioidei
- Ophidiidae
- Carapidae

Bythitoidei
- Bythitidae

OPHIDIIDAE: Cusk-eels

D. A. Ambrose

Cusk-eels formerly were included in Brotulidae and Ophidiidae. The genera have been reviewed by Cohen and Nielsen (1978). The family Ophidiidae is represented in the California Current region by at least 14 species. Larvae of seven of these (*Cherublemma emmelas*, *Chilara taylori*, *Lepophidium negropinna*, *L. stigmatistium*, *Ophidion* sp., *O. scrippsae*, and tentatively *Spectrunculus grandis*) have been identified in CalCOFI ichthyoplankton samples. Larvae of mesopelagic *Brotulataenia nielseni*, and deep-living *Dicrolene filamentosa* and *Lamprogrammus niger*, as well as the more shallow-dwelling *Lepophidium microlepis*, *Ophidion galeoides*, and *Otophidium indefatigable* are unknown. Larval *Chilara taylori* range throughout the CalCOFI sampling pattern, while *Ophidion scrippsae* are not found north of San Francisco Bay. A single preflexion larva from the Point Conception vicinity has been identified tentatively as *Spectrunculus grandis* (CFRD 8701, station 78.2.59.4). *Lepophidium nigropinna* and *L. stigmatistium* larvae occur commonly off Baja California, mainly associated with tropical refugia near bays. *Cherublemma emmelas* and *Ophidion* sp. larvae have been taken occasionally from the southernmost end of the CalCOFI pattern near Cabo San Lucas, Baja California Sur. Young *Brotula clarkae* also have been collected in midwater trawls from this area.

Adult cusk-eels are small (15 cm for some shallow water species) to medium length (about 1.5 m for some benthopelagic deep-sea forms) with the anal fin origin well behind the dorsal fin origin and the dorsal and anal fins continuous with the caudal fin. Scales are small and cycloid (in regular rows or at oblique angles to each other). The anterior nostril of each pair is higher on the snout. Males possess a unique sound-producing apparatus formed from the gas bladder, ribs, and vertebrae, which perhaps is used in courtship or mating activities (Rose 1961; Courtenay 1971). Cusk-eels are an important food source for marine mammals, birds, and fish (Fitch and Lavenberg 1968).

Gordon et al. (1984) summarized the early life history literature and presented illustrations of several larval ophidiids. Cusk-eels are oviparous and have no specialized copulatory organ, unlike the related Bythitidae. Some ophidiids produce oval pelagic eggs which float at the surface in a mucilaginous raft in their early stages at least (Sparta 1929a; Mito 1966; Fahay 1992). Late stage *Ophidion scrippsae* eggs are off-round, about 1 mm in diameter, without an oil globule, and float individually in the neuston (Ambrose et al. 1983). Larvae of the known species in the California Current vicinity hatch at ca. 2-3.5 mm with unpigmented eyes, non-functional mouth, and small pectoral fin buds. The gut loops during preflexion; larval size at gut looping, as well as the relative position of the loop, are useful taxonomic features. Larvae are elongate and relatively slender (BD 7-24% BL), with preanal length ca. 25-50% of BL. With growth, larvae become more compressed, the mouth becomes less oblique, and the pelvic fins migrate anteriorly.

Pigment appears early on the branchiostegal region for several species. All *Lepophidium* larvae have 2-10 large spots along the base of the anal finfold and 1-2 spots dorsally near the end of the tail. Larvae of *Ophidion* and *Chilara* have patterns of small stellate melanophores laterally on the body (Gordon et al. 1984). Fahay (1992) noted that in *Lepophidium* the vertebrae ossify from anterior to posterior and the pectoral fin rays form early. In *Ophidion*, vertebrae form from both ends toward the middle and the pectoral fin rays form late. *C. emmelas* and *C. taylori* have an extended nektonic prejuvenile stage.

Among the larval fishes in the CalCOFI study area, the pleuronectid, *Embassichthys bathybius*, superficially resembles those tentatively identified as *Spectrunculus grandis* (see Materese et al. 1989). *S. grandis* larvae have more myomeres (>75 vs. 65) and a less pronounced gut loop than *E. bathybius* larvae. Bythitid larval pigmentation tends to be more clumped than that of ophidiids (see Bythitidae, this volume). Several stichaeid species (see Stichaeidae, this volume) also superficially resemble some ophidiids before the gut has looped; however, the postanal pigmentation and the total myomere count will differentiate the two families.

Among the ophidiids, *C. taylori* has the most northern distribution and the highest meristic counts (Table Ophidiidae 1). *C. emmelas* has the largest head (usually greater than 22% BL) and the lowest number of myomeres (55-58). *L. negropinna* has a higher myomere count (75-77) than *L. stigmatistium* (68-71) and usually has two dorsal pigment spots near the end of the tail, compared to one for *L. stigmatistium*. *Ophidion scrippsae* and *Ophidion* sp. both have the most pigment dorsally on the tail; however, *Ophidion* sp. has a higher number of vertebrae (70-76 vs. 65-69), midlateral myoseptal pigment (not present in *O. scrippsae*), and a more southern distribution (south of Cabo San Lucas). *Brotula clarkae* may be identified by the low total vertebral count (55-56), an oval patch of stellate melanophores covering most of the cheek, and mouth barbels which are present by postflexion. The unknown larvae of *Brotulataenia nielseni*, *Dicrolene filamentosa*, *Lamprogrammus niger*, *Lepophidium microlepis*, *Ophidion galeoides*, and *Otophidium indefatigable* probably could be separated using meristic differences (Table Ophidiidae 1).

The following descriptions are based on literature and on detailed examinations of 1-34 specimens of each species (Table Ophidiidae 2). Postflexion *Brotula clarkae*, larval series of *Lepophidium stigmatistium*, *Ophidion* sp., and early larval stages of *Cherublemma emmelas*, and *Lepophidium negropinna* are described for the first time. *Ophidion* sp. is similar to *Ophidion imitator* which was described by Lea (1980, unpublished PhD dissertation). Meristic data were obtained from literature sources (Alcock 1891; Garman 1899; Robins 1961, 1962; Cohen 1974; Cohen and Nielsen 1978; Robins and Lea 1978; Lea 1980; Ambrose et al. 1983; Machida 1984; Aboussouan and Rasonarivo 1986; Matarese et al. 1989) and from counts made during this study. Ecological information was obtained primarily from Lea (1980) and Robins (1961, 1962).

Table Ophidiidae 1. Meristic characters for the ophidiid species in the CalCOFI area. A minute, hidden pelvic spine may be present but is not included in the counts. All have 2 pelvic fin rays, except they are absent in *Brotulataenia nielseni* and *Lamprogrammus niger* which may have only rudimentary buds as a juvenile. *Dicrolene filamentosa* have the lower 5–11 pectoral fin rays free and longer than the upper rays (Cohen and Nielsen 1978). Gill raker counts include rudiments.

	Vertebrae			Fin rays					
Species	PrCV	CV	Total	D	A	P_1	C	GR	BrR
Brotula clarkae	15	40–41	55–56	108–118	79–89	26–28	6+5	4–6+17–21	8
Brotulataenia nielseni	12–13		69–73	85–91	62–72	23–26	9	3–4+11–14	7
Cherublemma emmelas	13–14	42–44	55–58	99–113	81–93	24–26	4+5	4–5+12–19	7
Chilara taylori	18–19	68–72	86–91	187–229	150–181	22–26	4+5	1–4+7–9	7
Dicrolene filamentosa	13–16			100–104	84–90	22–23		5+17	8
Lamprogrammus niger	12–14			ca. 110	ca. 90	17	4+4		8
Lepophidium microlepis	14–16	51–62	66–77	117–141	97–121	21–26	4+5	9–15	7
L. negropinna	15–16	59–61	75–77	138–148	116–121	21–24	4+5	3+5–13	7
L. stigmatistium	14–16	52–56	68–71	122–130	99–109	19–22	4+5	3–4+13–15	7
Ophidion galeoides	14–17	47–49	61–64	123–143	97–114	21–23	4+5	1–3+4–5	7
O. scrippsae	14–16	50–54	65–69	124–153	99–126	20–23	4+5	2–4+4–8	7
Ophidion sp.	15–16	54–60	70–76	135–163	112–139	25–28	4+5	3–4+9–12	7
Otophidium indefatigabile	13–15	45–49	59–64	106–115	88–96	18–19	4+5	2+4	7
Spectrunculus grandis	18–23	53–56	71–79	103–148	73–113	22–23	4+4	3–4+8–9	8

Table Ophidiidae 2. Number of specimens (above) and size range (in mm, below) used in preparation of the ophidiid species descriptions. An "L" indicates literature used in the description.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Brotula clarkae	0	0	0	2 40.0–44.3	1 50.0	4 63.5–80.6
Cherublemma emmelas	0	10 2.9–10.5	4 11.8–13.3	10 14.7–42.0	5 45.0–58.1	5 60.8–75.6
Chilara taylori	L[a]	L[a]	L[a]	L[a]	5 71.7–84.4	5 94.8–104.7
Lepophidium negropinna	5 3.0–3.6	10 4.2–10.6	6 10.5–14.5	7 21.2–30.5	0	0
L. stigmatistium	1 2.4	10 3.9–10.0	6 10.1–12.8	7 13.3–17.7	0	5 45.6–61.1
Ophidion scrippsae	L[a]	L[a]	L[a]	L[a]	5 58.5–71.8	5 97.6–110.5
Ophidion sp.	1 2.7	1 7.0	1 12.7	1 36.5	0	5 54.0–88.0
Spectrunculus grandis	0	L[b], 1 7.4	0	L[b]	0	L[c]

[a] Ambrose et al. 1983
[b] Matarese et al. 1989
[c] Jordan and Thompson 1914

MERISTICS

	Range	Mode
Vertebrae:		
Total	55–56	55
Precaudal	15	15
Caudal	40–41	40
Fins:		
Dorsal spines	0	0
Dorsal rays	108–118	115
Anal spines	0	0
Anal rays	78–89	86
Pelvic*		
Pectoral	26–28	27
Caudal:		
Principal	6+5	6+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	22–26	23
Upper	4–6	5
Lower	17–21	18
Branchiostegals	8	8
Barbels†		

LIFE HISTORY

Range: Cabo San Lazaro, Baja California Sur (24°30′ N) to Peru (6° N)
Habitat: Usually collected 40–75 m deep on mud & broken shell bottom

Spawning season:

ELH pattern: Oviparous; late postflexion & transformation stage larvae in midwater

LITERATURE

Hubbs 1944

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 44.3 mm (R. C. Walker)

* One ray with two branches of unequal length.
† Three above mouth & three below on each side—12 total.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length:
Flexion length:
Transformation length: ca. 50 through <63 mm
Fin development sequence:
Pigmentation: *Postflexion*—By 40 mm, scattered over mid- & hindbrain; under eye; oval patch (stellate melanophores) on most of cheek; evenly scattered over peritoneum; several dashes along base of D & A pterygiophores; scattered medially on D; row under middle of D, spreading anteriad. *Transformation*—By 50 mm, distally on P_1 rays. *Juvenile*—By 65 mm, scattered over entire body, heaviest at edges of unpaired fins.
Diagnostic features: Vertebrae 55–56; P_1 rays 26–28 (usually 27); total C rays 6+5; branchiostegal rays 8; 12 barbels, 3 above & 3 below on each side of mouth; long P_1 & P_2 rays (>12% of BL); oval patch of stellate melanophores on cheeks; large dashed melanophores posteriolaterally on tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				46–46 46	44	43–48 44
BD/BL				16–19 17	17	17–19 18
HL/BL				22–23 23	22	24–26 25
HW/HL				31–33 32	30	30–33 32
SnL/HL				18–21 20	20	20–25 22
ED/HL				22–22 22	22	17–20 18
P_1L/BL				21–21 21	20	13–14 14
P_2L/BL				13–15 14	13	15–16 16

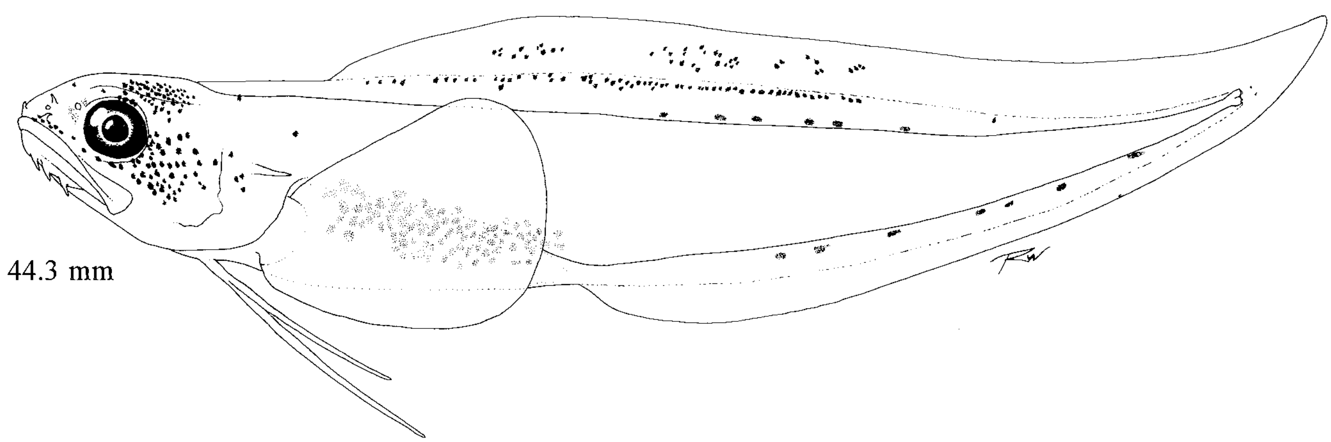


Figure Ophidiidae 1. Postflexion larva, 44.3 mm (SIO 71–343).

MERISTICS

	Range	Mode
Vertebrae:		
Total	55–58	57
Precaudal	13–14	14
Caudal	42–44	43
Fins:		
Dorsal spines	0	0
Dorsal rays	99–113	105
Anal spines	0	0
Anal rays	81–93	81 & 85
Pelvic*		
Pectoral	24–26	25
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	18–22	20
Upper	4–5	5
Lower	12–19	15
Branchiostegals	7	7

LIFE HISTORY

Range: Southern portion of Gulf of California (ca. 26° N) to Peru (ca. 9° S, EASTROPAC I, station 14.076)

Habitat: Relatively rare; on green mud bottom at ca. 102–740 m depth

Spawning season: Preflexion & flexion stage larvae taken during February in CalCOFI ichthyoplankton tows

ELH pattern: Oviparous; planktonic larvae, extended pelagic juvenile stage

LITERATURE

Trotter 1926

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.9 mm, 6.3 mm (N. Arthur)
Flexion larva, 12.2 mm (N. Arthur)

* One ray with two branches of unequal length.

EARLY LIFE HISTORY DESCRIPTION

EGGS

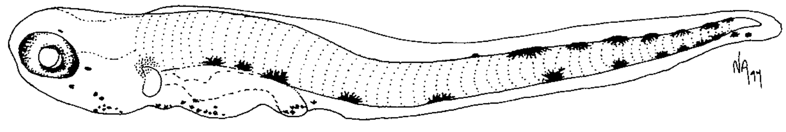
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

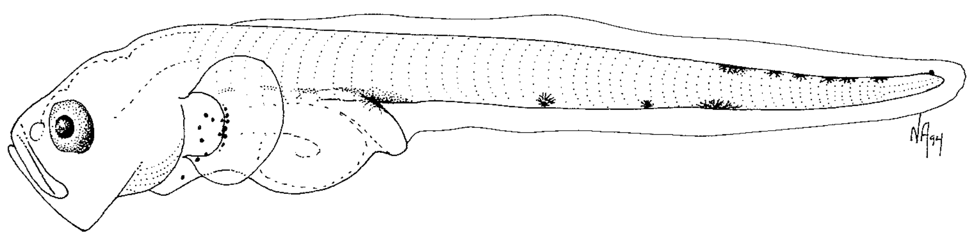
Hatching length: <3 mm
Flexion length: ca. 11 mm
Transformation length: ca. 45–60 mm
Fin development sequence: D & A & P_2, P_1, C
Pigmentation: *Preflexion*—By 2.9 mm, still forming on eye, patches above, under, & anterior to gut; near anus, patches ventrally along tail, heavy dorsally & ventrally on posterior half of tail except at tip; by ca. 4.5 mm, on P_1 base, cheek, snout, lower jaw, gas bladder, & cleithral symphysis; by ca. 7 mm, on branchiostegal region, & midlaterally along posterior third of tail; by ca. 8 mm, spreading laterally on gut. *Flexion–juvenile*—Increasing on head, body, & tail, especially on peritoneum & D & A margins.
Diagnostic features: Low total vertebral (55–58) & D ray (99–113) counts; gut loop formed by ca. 5.6 mm; head relatively large (HL >ca. 22% BL); in preflexion larvae, pigmentation on P_1 base by 4.5 mm; in flexion larvae, pigmentation on D & A & row posteriolaterally on tail; pigment increasing on peritoneum on postflexion larvae & juvenile specimens.

MORPHOMETRICS (range & mean in %)

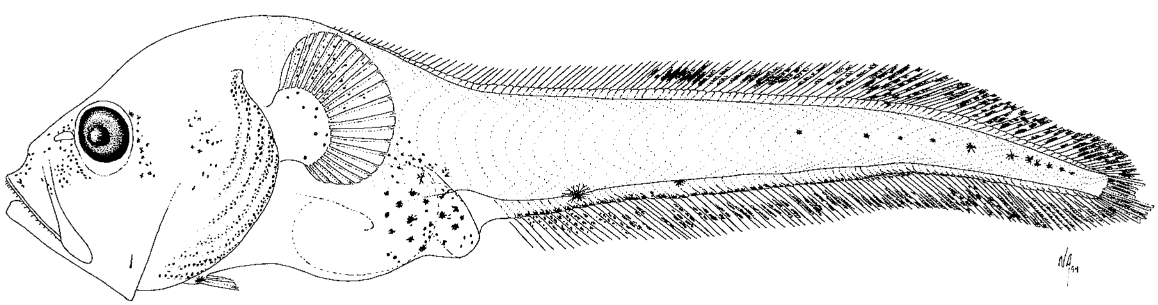
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–54 44	43–49 46	36–44 39	37–40 38	38–41 39
BD/BL		12–27 19	21–26 24	17–24 19	14–20 17	15–20 18
HL/BL		17–27 22	23–29 26	22–27 24	24–28 26	25–29 27
HW/HL		50–72 60	46–50 48	31–44 37	28–39 34	32–34 33
SnL/HL		16–30 25	30–35 33	20–34 25	21–24 23	17–21 19
ED/HL		21–44 29	20–21 21	11–20 14	14–17 15	16–18 17
P_1L/BL		2–6 4	4–7 5	7–24 13	13–14 13	12–15 13
P_2L/BL		3–3 3	4–6 5	5–13 9	7–9 8	7–8 8



2.9 mm



6.3 mm



12.2 mm

33.0 mm

Figure Ophidiidae 2. Preflexion larvae, 2.9 mm (IATTC 90002, station MAB #1), 6.3 mm (CalCOFI 7202, station 157.10); flexion larva, 12.2 mm (CalCOFI 5502, station 150.25); postflexion larva, 33.0 mm (Trotter 1926, as *Cherublemma lelepris*).

MERISTICS

	Range	Mode
Vertebrae:		
Total	86–91	88
Precaudal	18–19	18
Caudal	68–72	70
Fins:		
Dorsal spines	0	0
Dorsal rays	187–229	202
Anal spines	0	0
Anal rays	150–181	161
Pelvic*		
Pectoral	22–26	24
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	9–12	11
Upper	1–4	3
Lower	7–9	8
Branchiostegals	7	7

LIFE HISTORY

Range: Cape Elizabeth, Washington (47° N) to Bahía Santa Maria, Baja California Sur (25° N)

Habitat: Nocturnal, tail-burrowing, prefers sand, also in mud, eelgrass, & rock rubble on bottoms from <1 m to 283 m depth

Spawning season: Early-stage larvae occur in CalCOFI ichthyoplankton tows mainly from July–October with a peak in September off Baja California

ELH pattern: Oviparous; planktonic larvae, extended pelagic juvenile stage

LITERATURE

Ambrose et al. 1983
Harry 1951 (as *Ophidion novaculum*)
Matarese et al. 1989

* One ray with two branches of unequal length.
† Head width not measured in yolk-sac through postflexion specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3.5 mm
Flexion length: ca. 21–30 mm
Transformation length: ca. 70–84.5 mm
Fin development sequence: P_2, D, A, C, P_1
Pigmentation: *Yolk-sac*—Along ventrum & dorso-posterior 30% of tail. *Preflexion–postflexion*—On angle of lower jaw & gular region; double row along ventrum extending internally along base of brain & onto snout; on caudal finfold; by ca. 11 mm, on lateral tail midline, increasing anteriad; by ca. 36 mm, decreasing ventrally & generally more scattered.
Diagnostic features: High total vertebral (86–91) & D ray (187–229) counts; gut loop forms in the posterior half of the visceral cavity by ca. 14 mm SL; pigment on caudal finfold; line on snout; under brain; extending along ventral tail in a double row; row along lateral midline of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	31–44 39	33–44 39	29–32 31	25–29 27	27–30 29	29–33 31
BD/BL	6–10 9	7–11 8	7–8 7	7–8 7	8–9 9	9–10 10
HL/BL	8–15 12	10–15 13	11–13 12	11–14 12	12–14 13	15–16 16
HW/HL†					31–37 34	37–39 38
SnL/HL	14–27 20	19–40 27	26–31 29	21–27 25	19–21 20	18–22 20
ED/HL	29–41 36	23–41 30	22–26 24	21–25 23	21–24 23	22–23 23
P_1L/BL	3–3 3	2–6 3	2–3 3	2–3 3	5–6 6	7–8 7
P_2L/BL	0–0 0	0–0 0	0–1 0.6	1–3 2	5–7 6	7–8 8

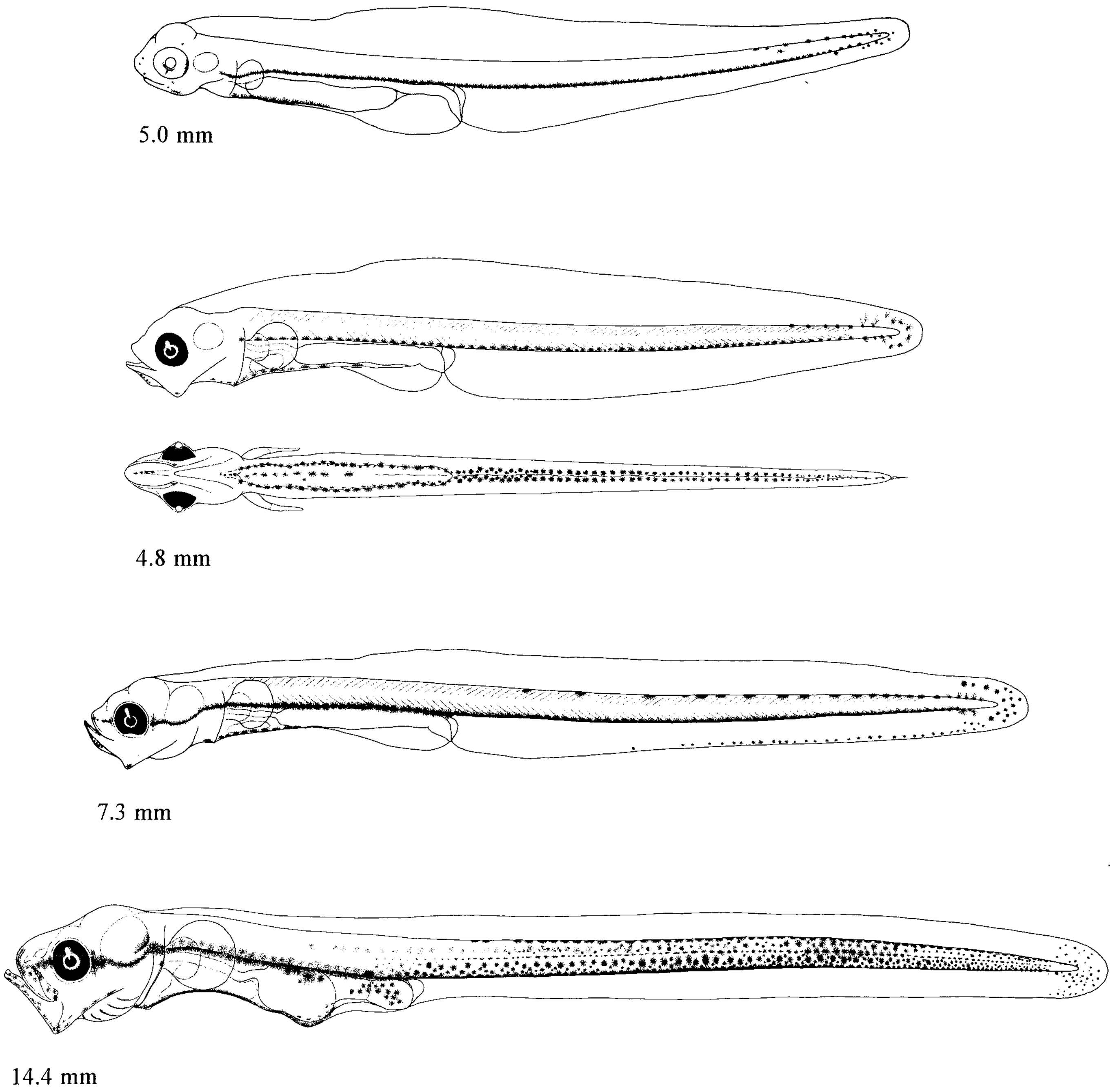


Figure Ophidiidae 3. Yolk-sac larva, 5.0 mm; preflexion larvae, 4.8 mm, lateral and ventral views, 7.3 mm, 14.4 mm (Ambrose et al. 1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	75–77	75
Precaudal	15–16	16
Caudal	59–61	59
Fins:		
Dorsal spines	0	0
Dorsal rays	138–148	143
Anal spines	0	0
Anal rays	116–121	117–119
Pelvic*		
Pectoral	21–24	23
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	9–16	
Upper	3	
Lower	5–13	
Branchiostegals	7	7

LIFE HISTORY

Range: Isla Cedros (ca. 28° N), along coast of Baja California Sur, & Gulf of California to Peru; larvae collected inshore mainly between CalCOFI lines 113 & 130

Habitat: Sandy mud, 22–139 m depth

Spawning season: Early-stage larvae occur mainly from August–October in CalCOFI ichthyoplankton tows

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Gordon et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.2 mm (N. Arthur)
Flexion larva, 13.3 mm (N. Arthur)
Postflexion larva, 30.0 mm (N. Arthur)

* One ray with two branches of unequal length.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3 mm
Flexion length: ca. 10.5–15 mm
Transformation length: > ca. 31 mm
Fin development sequence: P_2, P_1, C, D & A
Pigmentation: *Yolk-sac*—Row below eyes extending onto snout; scattered on yolk; 2 dorsally on gut; 1 anterior to anus; 4 ventrally along tail; 2 dorsally near end of tail. *Preflexion*—On angle of lower jaw; ventral body midline below P_1; at bottom of gut loop; above gas bladder; 4–6 patches ventrally along tail; 1 (small) occasionally between main ventral patches; anterior of the two dorsal tail melanophores occasionally absent. *Flexion*—Along ventral midline of gut; on branchiostegals; on base of A rays. *Postflexion*—On lower jaw & on C.
Diagnostic features: Total vertebrae 75–77; gut loop formed by ca. 6.8 mm & positioned centrally in the visceral cavity; usually 2 pigment patches dorsally near end of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	38–44 41	36–47 40	36–42 38	28–39 33		
BD/BL	6–9 7	13–16 14	13–15 14	11–15 13		
HL/BL	14–15 14	15–20 18	18–20 19	15–21 17		
HW/HL	68–82 75	49–73 62	43–52 47	42–46 45		
SnL/HL	15–19 18	20–36 31	27–36 31	25–32 28		
ED/HL	38–43 40	21–37 28	21–24 21	17–20 19		
P_1L/BL	0–2 0.8	4–5 5	4–5 4	5–7 6		
P_2L/BL	0 0	0–1 0.4	2–6 4	7–9 8		

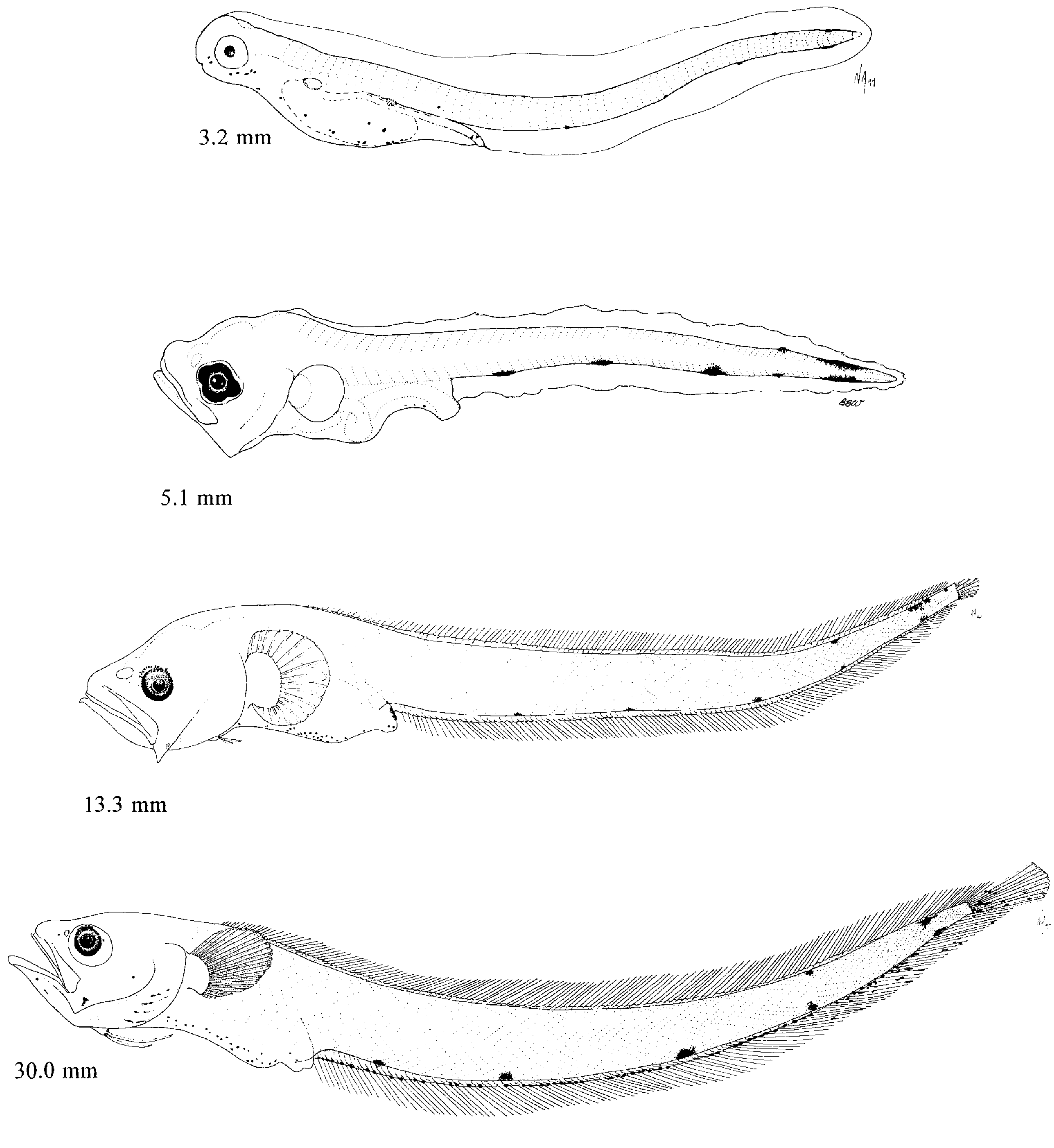


Figure Ophidiidae 4. Yolk-sac larva, 3.2 mm (CalCOFI 6607, station 117.40); preflexion larva, 5.1 mm (Gordon et al. 1984); flexion larva, 13.3 mm (CalCOFI 5709, station 120.40); postflexion larva, 30.0 mm (CalCOFI 5410, station 117.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	68–71	69
Precaudal	14–16	16
Caudal	52–56	53
Fins:		
Dorsal spines	0	0
Dorsal rays	122–130	126
Anal spines	0	0
Anal rays	99–109	103
Pelvic*		
Pectoral	19–22	19
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	17–19	18
Upper	3–4	4
Lower	13–15	14,15
Branchiostegals	7	7

LIFE HISTORY

Range: Isla Cedros (ca. 28° N), along coast of Baja California Sur & into the Gulf of California

Habitat: Demersal, 20–238 m depth

Spawning season: Early-stage larvae collected mainly in August–December

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.4 mm (N. Arthur)
Preflexion larva, 5.1 mm (N. Arthur)
Flexion larva, 11.2 mm (N. Arthur)
Postflexion larva, 15.9 mm (N. Arthur)

* One ray with two branches of unequal length.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.4 mm
Flexion length: ca. 10–13 mm
Transformation length: ca. <45 mm
Fin development sequence: P_2, D & A & C, P_1
Pigmentation: *Yolk-sac*—1 at angle of gut above anus; 5 ventrally along tail; 1 dorsally above last one in ventral tail series. *Preflexion*—On angle of lower jaw; 2 under gut; 2 or 3 internally above gut; 5–7 ventrally along tail (occasionally smaller ones between main ones). *Flexion–postflexion*—On branchiostegal region; posteriolaterally on gut; increasing ventrally on gut & along A base. *Juvenile*—Dorsally on head & dorsolaterally on body; ventrolaterally on tail; along D & A margins.
Diagnostic features: Total vertebrae 68–71; gut loop completed by ca. 6 mm & forms centrally in visceral cavity; one pigment patch dorsally near end of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		34–44	36–42	37–43		35–37
	44	39	39	38		36
BD/BL		13–16	15–17	14–17		12–12
	10	15	16	16		12
HL/BL		19–21	19–22	19–21		21–22
	19	20	20	20		21
HW/HL		51–75	45–54	42–49		33–35
	72	61	51	44		34
SnL/HL		23–37	28–36	24–39		18–22
	44	32	33	32		19
ED/HL		20–30	21–24	18–23		18–20
	39	25	22	20		19
P_1L/BL		4–5	4–5	5–5		10–11
	0	5	5	5		10
P_2L/BL		0–3	3–6	7–8		6–7
	0	1	4	8		7

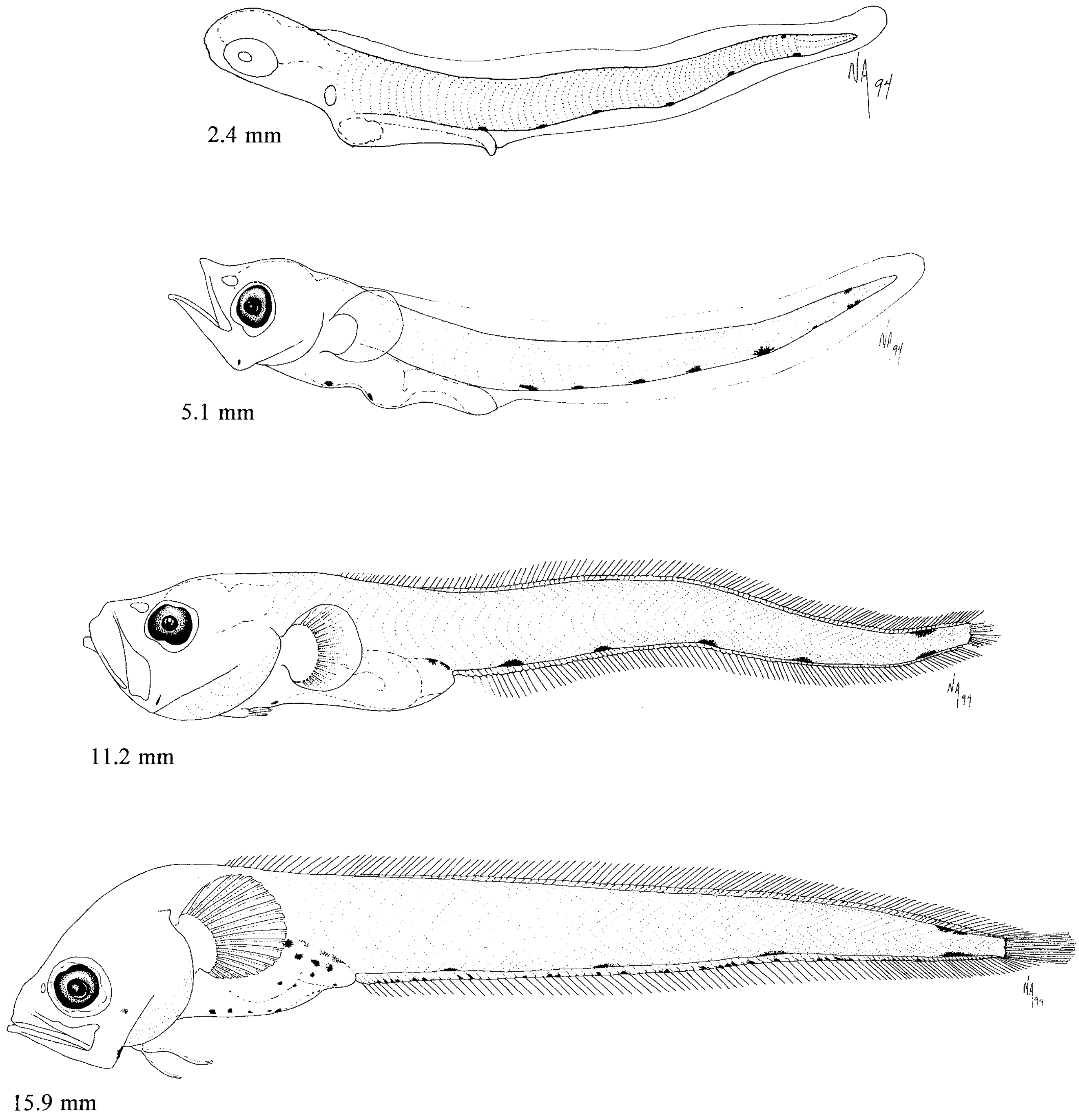


Figure Ophidiidae 5. Yolk-sac larva, 2.4 mm (CalCOFI 6909, station 133.30); preflexion larva, 5.1 mm (CalCOFI 6310, station 133.23); flexion larva, 11.2 mm (CalCOFI 6310, station 137.30); postflexion larva, 15.9 mm (CalCOFI 6509, station 133.30).

MERISTICS

	Range	Mode
Vertebrae:		
Total	65–69	67
Precaudal	14–16	15
Caudal	50–54	52
Fins:		
Dorsal spines	0	0
Dorsal rays	124–153	136
Anal spines	0	0
Anal rays	99–126	109
Pelvic*		
Pectoral	20–23	21
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	6–11	8
Upper	2–4	3
Lower	4–8	5
Branchiostegals	7	7

LIFE HISTORY

Range: Point Arguello, California (ca. 34° N) to Punta Tosca, Baja California (ca. 24° N)

Habitat: Usually on sand bottoms, also burrows in mud from ca. 3–70 m depth

Spawning season: Early-stage larvae occur in CalCOFI ichthyoplankton tows mainly July through October with a peak in August–September off Baja California

ELH pattern: Oviparous; pelagic larvae; laboratory reared larvae settled to the bottom at ca. 12 mm (early postflexion stage, 36 days after hatching) & burrowed in the sand by ca. 18 mm (day 46)

LITERATURE

Ambrose et al. 1983

* One ray with two branches of unequal length.

† Head width not measured on yolk-sac through postflexion specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.00 × 1.06 mm (0.96–1.00 × 1.00–1.06 mm)

Yolk: Homogeneous; ca. 0.72–0.84 mm diam.

No. of OG: 0

Diam. of OG:

Shell surface: Smooth, transparent

Pigment: Scattered mainly along dorsum of embryo

Diagnostic features: Off-round egg; long slender embryo with pigment scattered along dorsum posterior to head; gut length just short of midbody

LARVAE

Hatching length: ca. 25 mm

Flexion length: ca. 9.6–11.5 mm

Transformation length: ca. 30–55 mm

Fin development sequence: P_2, D, A, C, P_1

Pigmentation: *Yolk-sac*—Finely scattered over body; row near margins of dorsal & anal finfolds. *Preflexion*—Ventrally on gut & tail; near anus; dorsally on body posterior to P_1; at angle of lower jaw; frequently near tip & middle of lower jaw; internally above P_1 base. *Flexion*—On branchiostegal region; dorsally on gut extending laterally on posterior gut. *Postflexion*—Increasing laterally on tail & A; generally absent from D & C. *Transformation–juvenile*—On D & A margins.

Diagnostic features: Total vertebrae 65–69; gut loop formed at 7.5–8.5 mm in the central portion of the visceral cavity; in yolk-sac through preflexion stages, pigment row on dorsal & anal finfolds; in flexion–postflexion stages, stellate blotches laterally on body, absent from lateral midline.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	47–53 50	42–46 45	45–48 46	36–42 39	35–37 36	36–40 38
BD/BL	5–10 7	9–13 11	16–17 16	13–17 15	12–13 13	12–16 14
HL/BL	16–20 18	16–18 17	19–23 21	16–20 19	18–19 19	18–20 19
HW/HL†					37–43 38	38–42 39
SnL/HL	20–25 23	21–34 28	26–33 30	21–31 25	20–24 22	21–28 23
ED/HL	10–37 23	29–36 31	22–30 26	21–28 24	21–24 22	19–23 21
P_1L/BL	0–3 2	3–8 6	6–9 7	6–10 8	10–11 11	9–12 11
P_2L/BL	0–0 0	0–0 0	0–2 1	3–8 5	9–11 10	9–11 10

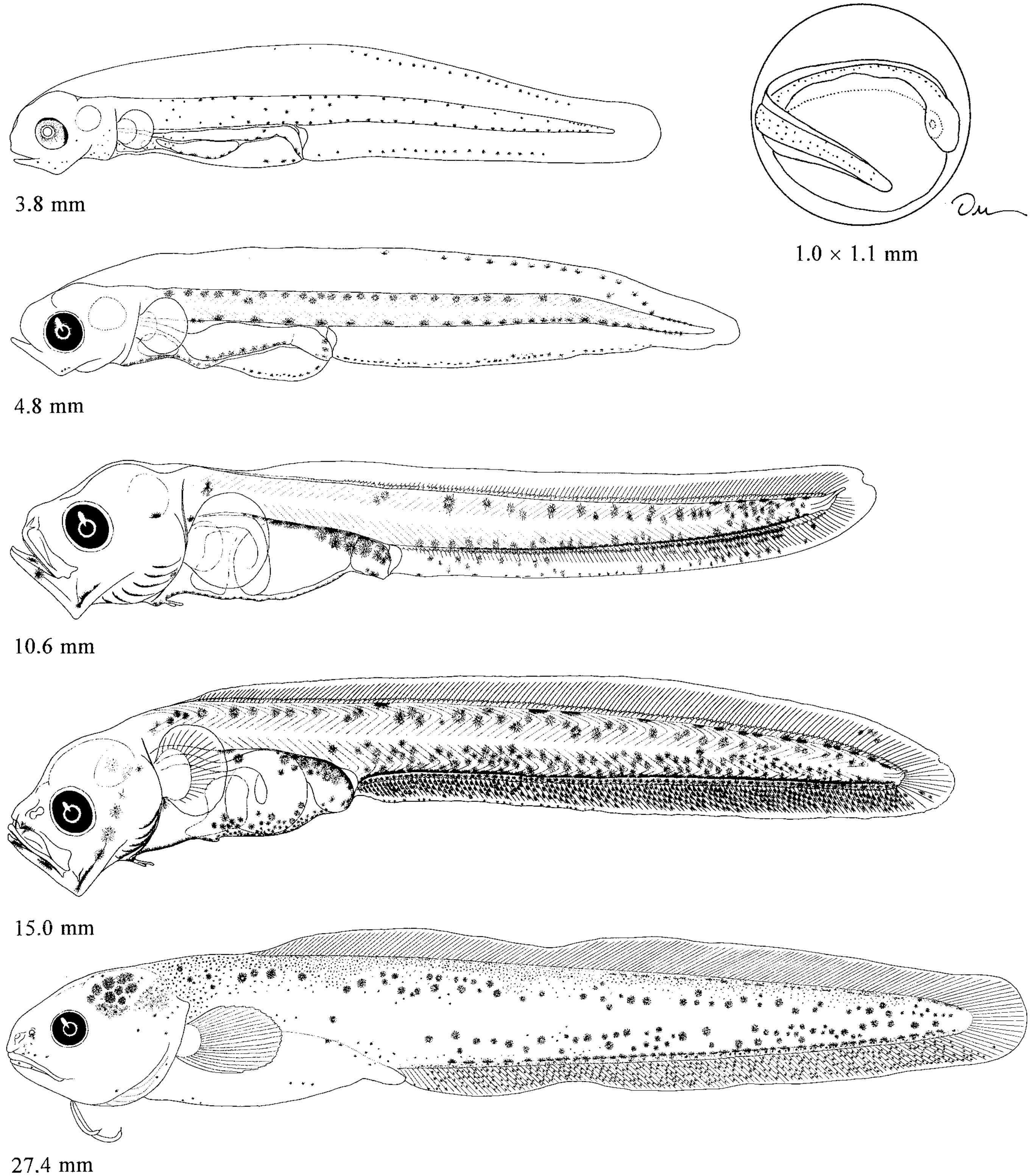


Figure Ophidiidae 7. Egg, 1.0 × 1.1 mm (Matarese and Sandknop 1984); yolk-sac larva, 3.8 mm; preflexion larva, 4.8 mm; flexion larva, 10.6 mm; postflexion larvae 15.0 mm, 27.4 mm (Ambrose et al. 1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	70–76	72
Precaudal	15–16	16
Caudal	54–60	56
Fins:		
Dorsal spines	0	0
Dorsal rays	135–163	
Anal spines	0	0
Anal rays	112–139	
Pelvic*		
Pectoral	25–28	
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	12–15	13
Upper	3–4	3
Lower	9–12	10
Branchiostegals	7	7

LIFE HISTORY

Range: Cabo San Lucas, Baja California Sur (ca. 23° N) to the Gulf of Panama; not known from the Gulf of California

Habitat: On muddy to sandy substrates at ca. 18–32 m; adults collected deeper than 40 m

Spawning season:

ELH pattern: Oviparous; planktonic larvae, extended pelagic transformation stage

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.7 mm (N. Arthur)
Preflexion larva, 7.0 mm (N. Arthur)
Flexion larva, 12.7 mm (N. Arthur)

* One ray with two branches of unequal length.
† Eye oval on yolk-sac specimen; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.7 mm
Flexion length: <12.7 mm
Transformation length: <54 mm
Fin development sequence: P_1, D & A & C & P_2
Pigmentation: *Yolk-sac*—On snout; under hindbrain; above & below gut; ca. 2 externally in P_1 area; ca. 17 ventrally along tail; ca. 17 dorsally, extending anteriorly almost to anus, eyes white. *Preflexion–flexion*—Anterior to eye; on gular & branchiostegal regions; ventral row on gut; laterally on mid- & hindbrain; internal row ventro- & dorsolaterally along body; midlateral row along tail. *Postflexion*—Fading on gut & laterally on body except near end of tail. *Juvenile*—Finely scattered over body, heaviest near end of tail, dorsal blotching by ca. 90–100 mm SL.
Diagnostic features: Total vertebrae 70–76; P_1 rays 25–28; gut loop forms at >7 mm & is well formed centrally in the visceral cavity by ca. 13 mm; numerous pigment patches along dorsum & ventrum; by flexion stage, pigment on lateral midline; internal pigment heavy laterally on body.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	39	40	39	33		37–38 38
BD/BL	10	14	12	12		11–15 13
HL/BL	18	19	19	17		20–22 21
HW/HL	72	42	38	42		30–36 32
SnL/HL	10	27	25	21		18–22 20
ED/HL†	48×28	29	25	19		18–21 19
P_1L/BL	0	22	4	5		10–11 10
P_2L/BL	0	0	2	7		13–17 15

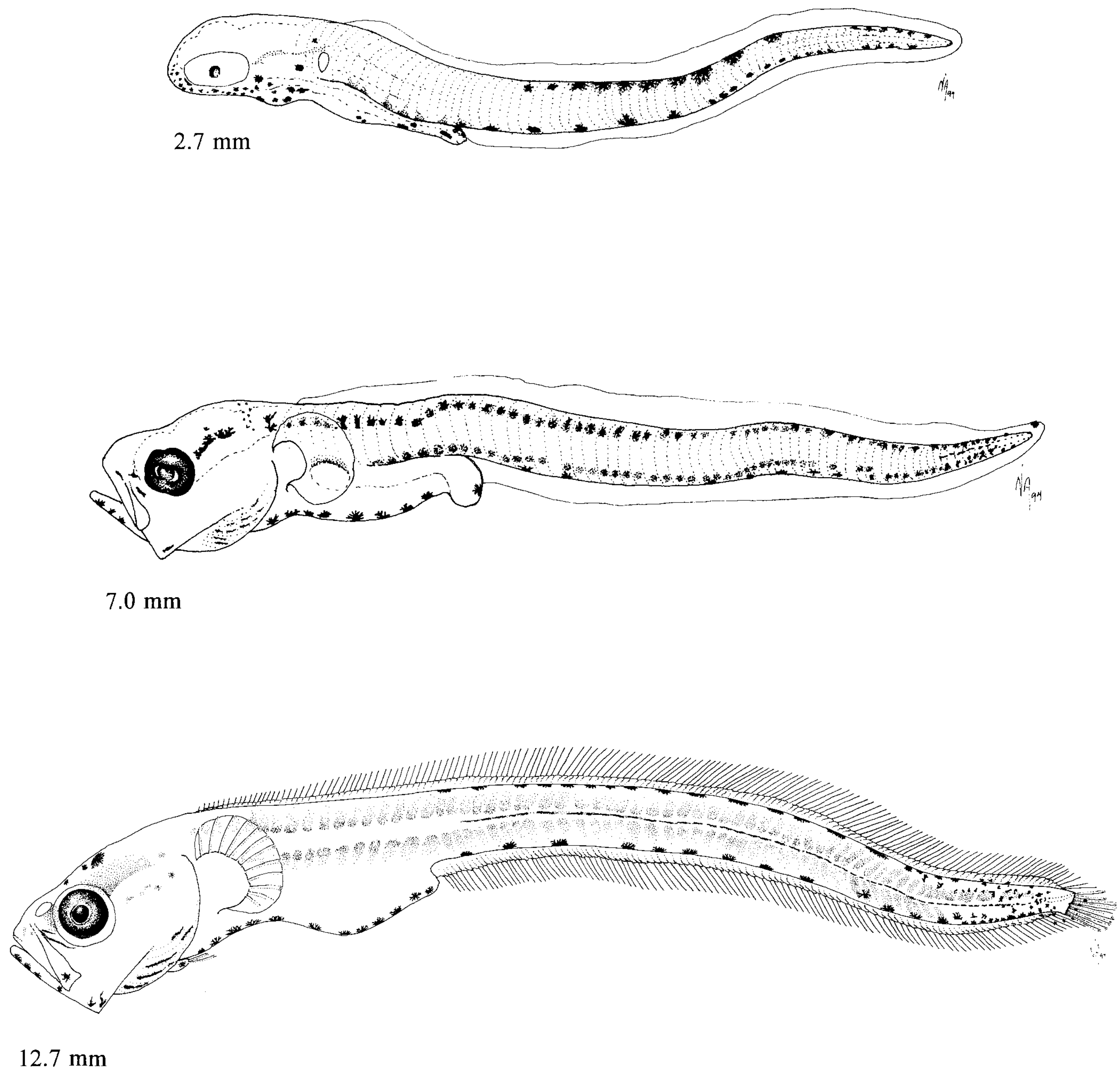


Figure Ophidiidae 6. Yolk-sac larva, 2.7 mm (IATTC 90012, station MSB #1); preflexion larva, 7.0 mm (IATTC 90006, station ASL #2); flexion larva, 12.7 mm (CalCOFI 5503, station 157.10).

MERISTICS

	Range	Mode
Vertebrae:		
Total	71–79	
Precaudal	18–23	
Caudal	53–56	
Fins:		
Dorsal spines	0	
Dorsal rays	103–148	
Anal spines	0	
Anal rays	73–113	
Pelvic*		
Pectoral	22–23	
Caudal:		
Principal	4+4	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	3–4	
Lower	8–9	
Branchiostegals	8	

LIFE HISTORY

Range: Found widely in Pacific & Atlantic

Habitat: Adults on or near the bottom at 800–4300 m depth

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Aboussouan & Rasonarivo 1986
Jordan & Thompson 1914
Matarese et al 1989
Nielsen & Hureau 1980

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* Two thick rays in each.
† Measurements taken from illustrations of 29.8 mm postflexion & 15.6 mm preflexion specimens in Matarese et al. (1989).
‡ Measurements taken from illustrations of 56 mm specimen from Jordan & Thompson (1914).
¶ Head width only measured on 7.4 mm preflexion specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS

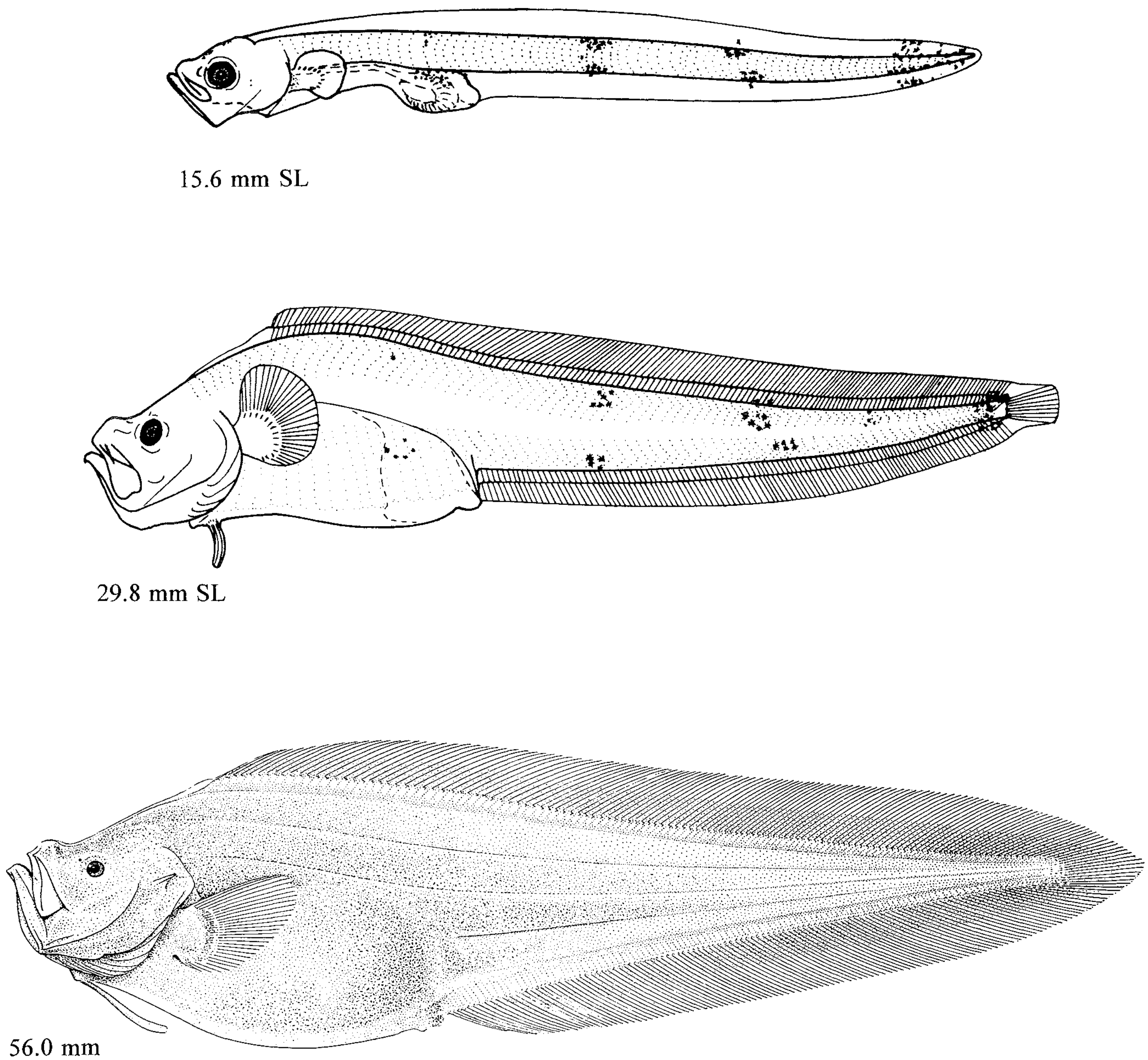
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: >15.6 mm
Transformation length: <52 mm
Fin development sequence:
Pigmentation: *Preflexion*—On fore- & midbrain; lower jaw; dorsolaterally at gut loop; 2 patches ventrally on tail; 3 patches on dorsum; heavy on end of tail. *Postflexion*—4 patches on dorsum.
Diagnostic features: Total vertebrae 71–79; branchiostegals 8; gut loop formed at <7.4 mm in the posterior portion of the visceral cavity; 3–4 pigment patches dorsolaterally & 2 ventrolaterally on body; heavy at end of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF†	Tr	Juv‡
Sn-A/BL		36–38 37		43		43
BD/BL		9–10 10		21		25
HL/BL		9–12 11		17		16
HW/HL¶		65				
SnL/HL		14–45 29		32		35
ED/HL		38–44 41		14		11
P_1L/BL		3–4 4		6		9
P_2L/BL		0 0		5		7



15.6 mm SL

29.8 mm SL

56.0 mm

Figure Ophidiidae 8. Preflexion larva, 15.6 mm; postflexion larva, 29.8 mm (Matarese et al. 1989); juvenile, 56.0 mm (Jordan and Thompson 1914).

CARAPIDAE: Pearlfishes

D. A. AMBROSE

Three carapid species are reported in the eastern Pacific (Table Carapidae 1; Markle and Olney 1990). *Echiodon exsilium* ranges from Baja California Sur and the Gulf of California to the Galápagos Islands. *Encheliophis vermicularis* is found between 30° N and 30° S in the western Pacific, in the Gulf of Aden, and in the eastern Pacific including the Gulf of California and the Galápagos Islands. *Encheliophis dubius* may be widespread, but confirmed records are from the Gulf of California to Columbia and from Hawaii. Only larvae of *Ec. exsilium* have been found in CalCOFI ichthyoplankton collections, in modest numbers at the southern end of the sampling pattern.

Adult carapids are small to medium-sized (<30 cm) highly specialized fishes which occur in temperate and tropical marine shelf and slope waters, with the highest abundance and diversity in tropical seas (Nelson 1994; Markle and Olney 1990). Although some species are free-living (e.g., *Ec. exsilium*), most are inquilines in the body cavities of living invertebrates such as bivalves (e.g., *En. dubius*), holothurians (e.g., *En. vermicularis*), and asteroids. Carapids are elongate and laterally compressed, with the anal fin rays longer than the opposing dorsal fin rays. The anal fin origin and the anus are far forward, usually beneath the pectoral fin which is rarely absent (e.g., *En. vermicularis*). The supramaxillary is absent as are scales. Vertebrae number is about 85-145. As defined by Cohen and Nielsen (1978), only the subfamily Carapinae or pearlfishes are represented within the CalCOFI study area.

Carapids are oviparous; the few known eggs are pelagic, ellipsoidal, and possess a single oil globule (Gordon et al. 1984). Early developmental stages may be contained in a mucilaginous raft. Carapid larvae are relatively well known and have proven to be of systematic value (Olney and Markle 1979; Markle and Olney 1980). Pearlfishes pass through two distinct larval stages. In the planktonic vexillifer stage, larvae possess a unique vexillum which is a long, thread-like process anterior to the dorsal fin. The second or tenuis stage is the benthic stage in which the vexillum is gone, the head is relatively small, and the body initially lengthens, then subsequently shortens (Trott 1981). A few species have exterilium larvae, named for their trailing gut appendage (Gordon et al. 1984); however none of these is found in the eastern Pacific.

Only vexillifer stage larvae have been collected in CalCOFI ichthyoplankton samples. These are elongate larvae with a moderate-sized head (<20% of BL), large eyes (ca. 30% HL), a large nasal rosette, a gut that coils early (<5 mm TL), a short preanal length (ca. 150% HL), and a tapering tail that frequently ends in a broken filament. Pigmentation typically is moderate, becoming more sparse with development.

The vexillum forms early (bud visible even in yolk-sac *Ec. exsilium*) and its placement is of systematic use. In *Echiodon*, the vexillum is just anterior to the first dorsal fin ray; while in *Encheliophis,* there is a wide gap between the vexillum and the origin of the dorsal fin. In *Ec. exsilium*, there are 8-11 vertebrae anterior to the origin of the vexillum but only 4 vertebrae for *En. dubius*. Larvae of *En. vermicularis* are unknown. The number of vertebrae anterior to dorsal fin origin for *En. dubius* (11-13) is smaller than for *En. vermicularis* (16-19). The number of dorsal fin rays anterior to the 31st vertebra probably is < 30 for *En. vermicularis* and 35 or more for *En. dubius*. Dentition of carapids is useful to separate genera (Markle and Olney 1990). *Ec. exsilium* larvae have more pectoral fin rays than have been reported in adults; 1-4 rays may be resorbed at metamorphosis (Table Carapidae 1; Olney and Markle 1979; Markle and Olney 1990).

The unique morphology of carapid larvae necessitates a change from the standard larval fish description format. Since the tail is easily damaged, head length and the 31st vertebra have been used as reference points for comparison rather than body length (Markle and Olney 1980; Markle and Olney 1990). We use anal fin formation to separate larval developmental stages. "Preanal fin formation" (PrAF) refers to the interval prior to initiation of anal fin formation and "anal fin formation" (AF) refers to larvae with developing or fully formed anal fins.

The following descriptions are based on detailed examinations of 1 yolk-sac larva (3.5 mm TL, 0.4 mm HL), 8 PrAF (4.8-13.8 mm TL, 0.6-1.3 mm HL), and 10 AF larvae (25.6-97.3 mm TL, 1.8-4.5 mm HL) of *Echiodon exsilium*; 2 PrAF larvae (3.1-5.4 mm TL, 0.5–1.0 mm HL) of *Encheliophis* sp.; and 1 AF larva (60 mm TL, 2.6 mm HL) of *Encheliophis dubius*. Yolk-sac and PrAF larvae of these taxa are described for the first time. The larval *Encheliophis* came from IATTC samples off Panama. Meristic data were obtained from the literature (Arnold 1956; Rosenblatt 1961; Trott 1970, 1981; Markle and Olney 1990) and from counts during this study. Ecological information was obtained from Arnold (1956), Trott (1970, 1981), Gordon et al. (1984), and Markle and Olney (1990).

Table Carapidae 1. Meristic characters for adults and larvae of carapid species in the CalCOFI area. Counts of dorsal fin rays are to the 31st vertebra (D_{30}), anal fin rays to the 31st vertebra (A_{30}), vertebrae to the dorsal fin origin (DFO), anal rays to the dorsal fin origin (AFO), and vertebrae to the vexillum origin (VVO).

Species	P_1	D_{30}	A_{30}	DFO	AFO	VVO
Adults						
Echiodon exsilium	19–21	38–42	47–50	10–11	8–10	0
Encheliophis dubius	16–20	35–43	47–54	11–13	17–22	0
En. vermicularis	0	19–27	36–43	16–19	17–24	0
Larvae						
Echiodon exsilium	21–25	39–42	50–51	10–11	9–11	8–11
Encheliophis dubius	20	37	48–52	12	18	4

MERISTICS

	Range	Mode
Vertebrae:		
Total	>130 tapers to uncountable filament	
Precaudal	21–25	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays to 31st vertebra (D_{30})	38–42	
Anal spines	0	
Anal rays to 31st vertebra (A_{30})	47–50	
Pelvic	0	
Pectoral	19–21	
Caudal:		
Principal		
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	3+6 rudiments	
Branchiostegals	7	

LIFE HISTORY

Range: Eastern Pacific from Baja California Sur to Panama, including the Gulf of California & the Galápagos Islands

Habitat: Free-living adults collected on outer shelf, usually deeper than 64 m over muddy sand bottoms

Spawning season: Larvae occur in CalCOFI collections thorughout the year

ELH pattern: Oviparous; specialized vexillifer planktonic stage larva, benthic tenuis stage larva

LITERATURE

Markle & Olney 1990
Olney & Markle 1979
Trott 1970

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.5 mm (M. T. Vona)
PrAF vexillifer larva, 7.3 mm (M. T. Vona)
AF vexillifer larva, 25.3 mm (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.5 mm TL
Anal fin formation length: ca. 14 mm TL
Transformation length: Vexillifer stage to ca. 130 mm TL; smallest adults ca. 85 mm TL
Fin development sequence: D & A, P_1 & C
Pigmentation: *Yolk-sac*—On lower jaw; posterior to eye; anterior to P_1 & vexillum bud; scattered on yolk; 1 ventrally near midtail; dorsally at end of tail. *Preanal fin formation* (PrAF)—On gular region; over brain & gas bladder; internally anterior & posterior to vexillum to ca. 66% of tail; primarily midlaterally in posterior ca. 33% of tail; by ca. 8 mm TL, only laterally on tail; by ca. 10.5 mm, only near end of tail; *Anal fin formation* (AF)—At ca. 14 mm, over cranium & internal ventrally on brain; by 40 mm, dorsoposteriorly on peritoneum.
Diagnostic features: 8–11 vertebrae anterior to vexillum origin; 9–11 A rays to D origin; 39–42 D rays anterior to 31st vertebra; prevexillum length > ca. 1.6×HL; vexillum just anterior to 1st D ray; PrAF larvae have pigment on tip of lower jaw, on gular region, & internally on snout; AF larvae have pigment ventrally on gut & dorsoposteriorly on peritoneum later in stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tenuis	Juv
Sn-A/HL		133–169	130–149		
	168	146	138		
BD/HL		71–82	68–90		
	55	78	77		
HL/BL		10–13	4–8		
	13	12	6		
HW/HL		45–59	34–51		
	59	53	41		
SnL/HL		20–29	20–33		
	14	25	26		
ED/HL		33–40	24–34		
	36	36	29		
P_1L/BL		16–29	16–25		
	18	23	21		
PrVL/HL		169–194	167–197		
	190	179	183		

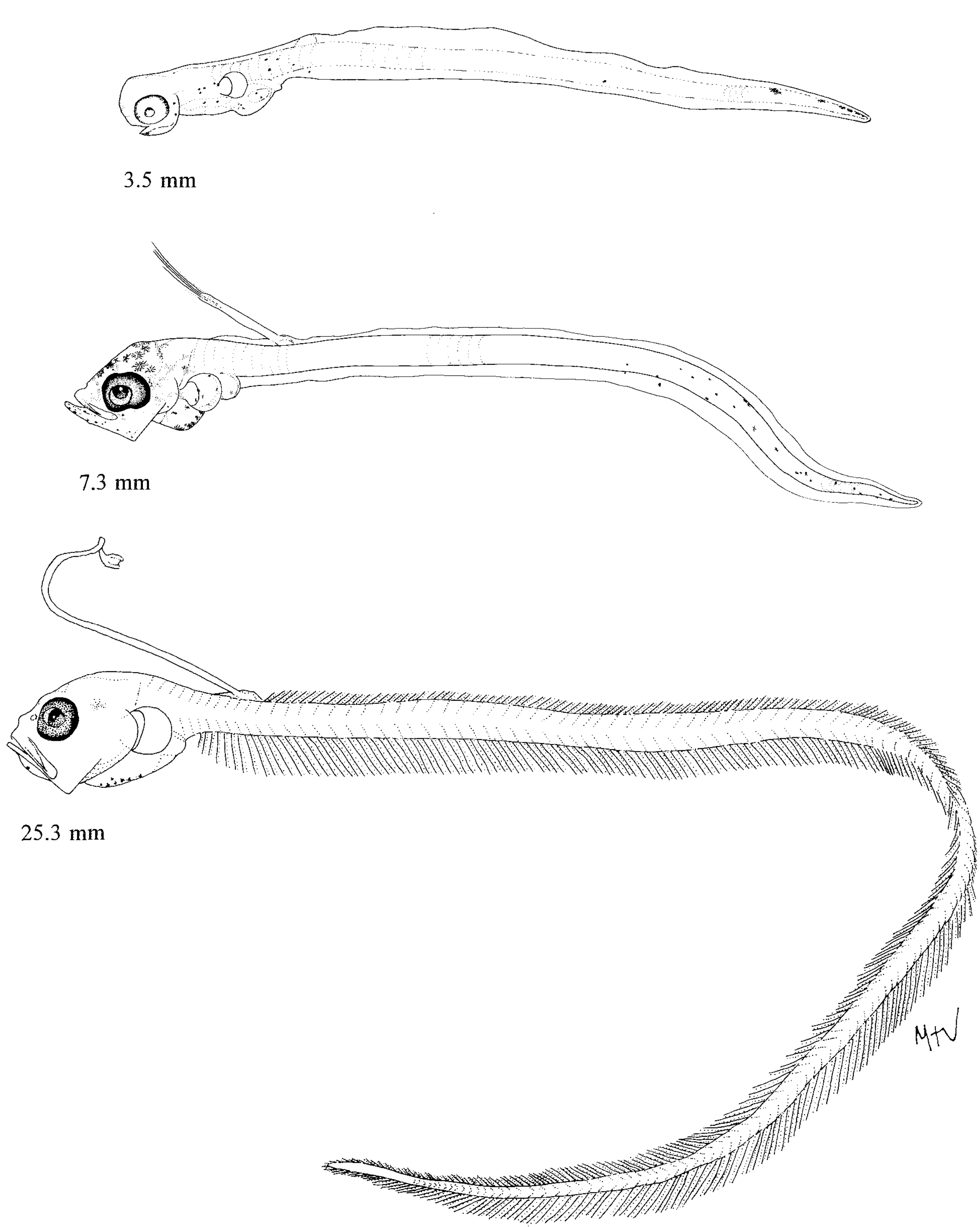


Figure Carapidae 1. Yolk-sac larva, 3.5 mm (CalCOFI 7202, station 137.35); PrAF vexillifer larva, 7.3 mm (IATTC 90014, station MSB #1); AF vexillifer larva, 25.3 mm (CalCOFI 5503, station 157.10).

MERISTICS

	Range	Mode
Vertebrae:		
Total		
Precaudal	19–21	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	35–43	
to 31st vertebra (D_{30})		
Anal spines	0	
Anal rays	47–54	
to 31st vertebra (A_{30})		
Pelvic	0	
Pectoral	16–20	
Caudal:		
Principal		
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	6–7	

LIFE HISTORY

Range: May be widespread, but confirmed in eastern Pacific from Gulf of California to Colombia & from Hawaii

Habitat: Molluscan-inhabiting from tenuis stage onward

Spawning season: Early stage larvae collected in February & July from Panama

ELH pattern: Oviparous; pelagic vexillifer stage, benthic tenuis stage

LITERATURE

Markle & Olney 1990
Trott 1970, 1981 (as *Encheliophis jordani*)

ORIGINAL ILLUSTRATIONS (Illustrator)

PrAF larvae, 3.1 mm, 5.4 mm (R. C. Walker)
AF larva, 60.0 mm (R. C. Walker)

* PrAF larvae are attributable to *Encheliophis* sp., since larvae of the sympatric congener *En. vermicularis* are unknown.
† Eye moderately elongate (horizontally) in PrAF larvae; horizontal axis given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3 mm
Anal fin formation: < ca. 60 mm
Transformation length: adults as small as 57 mm TL
Fin development sequence: D & A, P_1, C
Pigmentation: *Preanal fin formation*—By ca. 3 mm TL, over brain between eyes, under brain posterior to eyes, anteriodorsally on gut, & 2 ventrally near end of tail; by ca. 5.5 mm, on isthmus, vexillum, & ventrally on tail. *Anal fin formation*—1 (minute) anterior to base of A rays, on vexillum, a few specks dorsally near end of tail, one speck dorsally on fore & midbrain.
Diagnostic features: 4 vertebrae to vexillum origin; ca. 18 A rays to D origin; ca. 37 D rays to 31st vertebra; prevexillum length < ca. 1.4× HL; vexillum well anteriad of first D ray; maxilla free & movable; pigmentation absent from lower jaw & gular region; fine row along base of A.

MORPHOMETRICS (range & mean in %)

	Y-S	PrAF	AF	Tenuis	Juv
Sn-A/HL		133–154 144		144	
BD/HL		78–92 85		102	
HL/BL		16–19 17		4	
HW/HL		39–67 53		40	
SnL/HL		17–28 22		29	
ED/HL†		32–50× 24–35 41×30		27	
P_1L/HL		16–21 18		8	
P_2L/HL		0 0		0	
PrVL/HL		122–125 123		135	

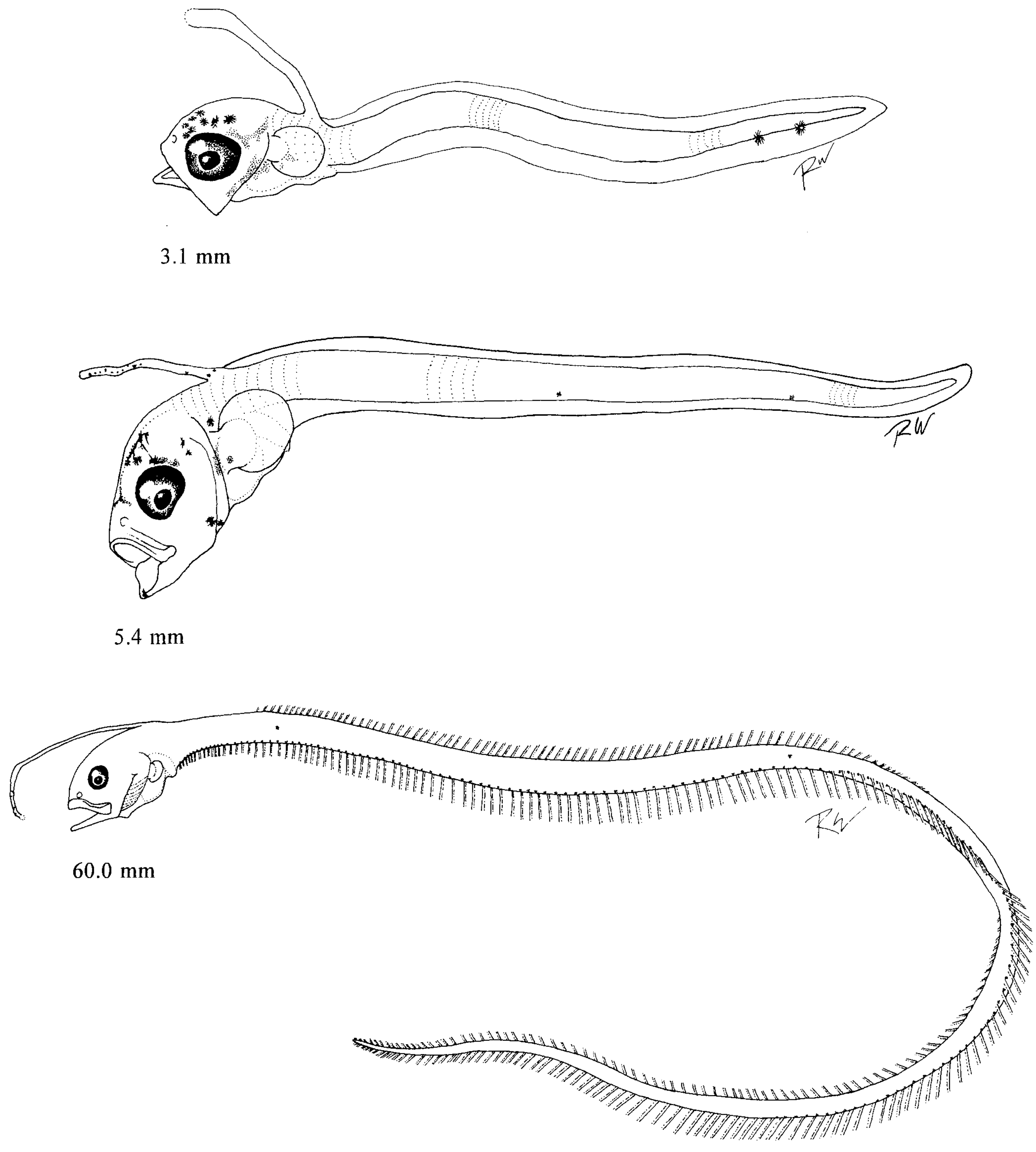


Figure Carapidae 2. *Encheliophis* sp. PrAF larvae, 3.1 mm (IATTC 91006, station T8 0-5), 5.4 mm (IATTC 90022, station AAB1 #2); *Encheliophis dubius* AF larva, 60.0 mm (IATTC 90021, station ASBT10).

BYTHITIDAE: Brotulas

D. A. AMBROSE

Cohen (1986) recognized at least 23 bythitid genera with at least 200 species, half of which are undescribed. These fishes were formerly included in the Brotulidae. At least three bythitid species occur in the CalCOFI study area (Table Bythitidae 1). *Brosmophycis marginata* and *Cataetyx rubrirostris* are north-temperate species whose larvae occur commonly in the CalCOFI study area south to central Baja California, Mexico. *Oligopus diagrammus* prefers warmer water southward from San Clemente Island, California; its larvae have not been identified in CalCOFI ichthyoplankton collections.

Adult bythitids are similar in body shape to the cusk-eels but are live-bearers, most have the anterior nostril lower on the snout, and males have an intromittent organ (Cohen and Nielsen 1978). Sizes range from less than 5 cm for some cryptic intertidal and freshwater forms to longer than 70 cm for some deep-sea benthopelagic species. *Cataetyx* and *Oligopus* have a single thoracic pelvic fin ray, as well as dorsal and anal fins contiguous with the caudal fin. *Brosmophycis* has two thoracic pelvic fin rays which are nearly joined at the tip and a caudal fin that is separate from the dorsal and anal fins.

Gordon et al. (1984) summarized the small amount of information available on larval bythitids. All the known larvae in our study area have preanal lengths about 40-50% of body length and are born with a straight gut. *O. diagrammus* young are known only from late stage intraovarian embryos (ca. 3.5 mm BL) which have trophotaenia similar to those described by Wourmes and Cohen (1975) for *Oligopus longhursti*. The smallest *C. rubrirostris* available (7.3 mm BL) already has the gut looped posteriorly in the visceral cavity. The smallest *B. marginata* (ca. 8 mm BL) is still a yolk-sac larva with pigmented eyes, well-formed mouth, and straight gut. Its centrally positioned gut loop does not form until 9-10 mm BL. *B. marginata* and *C. rubrirostris* have a prolonged notochord flexion stage that persists until transformation. In the transition stage, *B. marginata* has a more rounded head and snout, and *C. rubrirostris* has a deeper body and relatively smaller eyes than those of the juveniles or adults. Pigmentation is more or less continuous along the dorsum and ventrum of *O. diagrammus* embryos, mostly posteriorly on the gut and tail of *C. rubrirostris*, and in alternating patches along the body margins of *B. marginata*.

The following descriptions are based on detailed examination of 10-28 specimens of each species (Table Bythitidae 2). A larval series of *C. rubrirostris* and early larval stages of *B. marginata* and *O. diagrammus* are described for the first time. Meristic data were obtained from literature (Best 1957; Cohen 1964a; Grinols and Greenfield 1966; Follett 1970; Miller and Lea 1972; Cohen and Nielsen 1978; Matarese et al. 1989) and from counts made during this study. Ecological information came primarily from Eschmeyer et al. (1983) and Gibbs (1991).

Table Bythitidae 1. Meristic characters for the bythitid fishes in the CalCOFI area. A minute, hidden pelvic spine is not included in the counts. The rudimentary gill rakers were excluded from the counts of *Cataetyx rubrirostris* and *Oligopus diagrammus*.

	Vertebrae			Fin rays						
Species	PrCV	CV	Total	D	A	P_1	P_2	C	Gill rakers	BrR
Brosmophycis marginata	16–17	47–49	63–65	98–110	72–81	20–26	2	8–9+8	4–5+15–16	7
Cataetyx rubrirostris	14–15	46–49	60–63	100–114	76–86	25–26	1	4–5+4	0+3	8
Oligopus diagrammus	12	37–41	49–53	95–115	75–91	24–29	1	3–5+4–5	0–2+3	8

Table Bythitidae 2. Number of specimens (above) and size range (in mm, below) used in preparation of the bythitid species descriptions. *Oligopus diagrammus* yolk-sac larvae were removed from a pregnant female (SIO 53–169, 184 mm).

Species	Yolk-sac	Preflexion	Flexion	Transformation	Juvenile
Brosmophycis marginata	5 7.9–8.7	10 8.5–16.7	8 16.5–35.6	2 37.5–41.0	3 81.2–125.0
Cataetyx rubrirostris	0	10 7.3–10.3	6 12.5–30.6	7 24.5–57.8	5 72.4–103.8
Oligopus diagrammus	5 3.4–3.6	0	0	0	5 31.2–60.0

MERISTICS

	Range	Mode
Vertebrae:		
Total	63–65	64
Precaudal	16–17	16
Caudal	47–49	48
Fins:		
Dorsal spines		
Dorsal rays	98–110	101
Anal spines	72–81	75
Anal rays		
Pelvic	2	2
Pectoral	20–26	
Caudal:		
Principal	8–9+8	8+8
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Total	9–21	
Upper	4–5	
Lower	15–16	
Branchiostegals	7	7

LIFE HISTORY

Range: Temperate northeastern Pacific, from Petersburg, Alaska to at least Ensenada, Mexico; larvae collected as far south as Punta Eugenia, Baja California Sur (ca. 27° N)

Habitat: Rocky bottom; 3–256 m, usually deeper than 15 m

Spawning season: March–September with a peak in May

ELH pattern: Live-bearers; planktonic larvae

LITERATURE

Gordon et al. 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 9.8 mm (H. M. Orr)
Flexion larva, 17.2 mm (M. T. Vona)
Transformation specimen, 37.5 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Length at birth: < ca. 8 mm
Flexion length: ca. 17–36 mm
Transformation length: ca. 37 to < 81 mm
Fin development sequence: D & A, C, P_1, P_2
Pigmentation: *Yolk-sac*—Similar to 9.8 mm preflexion larva; on lip; gas bladder; above cleithrum; 3 patches laterally on gut; 4 more or less alternating patches dorsally & ventrally; heavy along tail margins & onto finfold anterior to notochord tip. *Flexion*—On opercle & snout; row along base of D & A pterygiophores; scattered on base of C & in D & A. *Transformation–juvenile*—Scattered over body.
Diagnostic features: Total vertebrae 63–65; total P_1 rays 16–17; branchiostegals 7; gut looped at ca. 9–10 mm BL & is positioned about mid-cavity; pigmentation in alternating patches along dorsum & ventrum through midflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF*	Tr	Juv
Sn-A/BL	41–48 45	43–50 46	43–47 45		44–50 47	48–51 50
BD/BL	9–10 10	10–11 10	11–19 14		16–18 17	17–20 18
HL/BL	17–19 18	17–20 19	16–23 19		23–24 24	24–26 25
HW/HL	47–58 52	44–51 46	39–54 45		49–53 51	32–38 35
SnL/HL	17–23 21	26–39 31	23–37 31		29–30 29	16–18 16
ED/HL	25–29 28	17–23 21	11–16 12		11–12 12	13–17 16
P_1L/BL	3–4 4	4–5 4	5–14 8		13–14 14	14–16 16
P_2L/BL	0–0 0	0–2 0.3	2–16 7		16–17 17	17–27 21

* No postflexion stage, since a prolonged flexion stage persists until transformation.

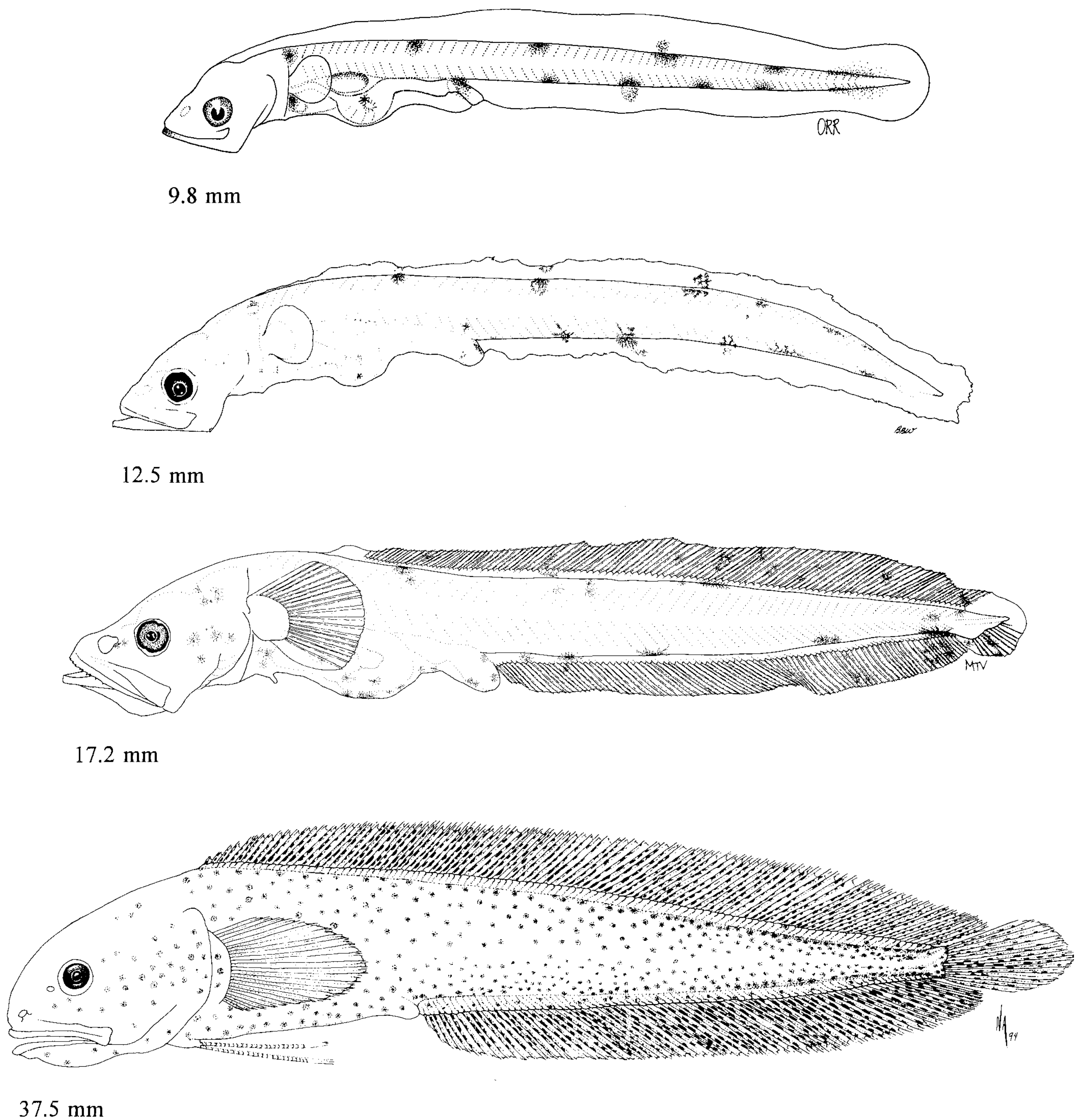


Figure Bythitidae 1. Preflexion larvae, 9.8 mm (CalCOFI 5906, station 87.40), 12.5 mm (Gordon et al. 1984); flexion larva, 17.2 mm (CalCOFI 6806, station 87.65); transformation specimen, 37.5 mm (CalCOFI 7808, station 93.5.29).

MERISTICS

	Range	Mode
Vertebrae:		
Total	60–63	62
Precaudal	14–15	14
Caudal	46–49	47
Fins:		
Dorsal spines	0	0
Dorsal rays	100–114	103,105
Anal spines	0	0
Anal rays	76–86	81
Pelvic	1	1
Pectoral	25–26	25
Caudal:		
Principal	4–5+4	5+4
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	3	3
Branchiostegals	8	8

LIFE HISTORY

Range: Northern Oregon (ca. 46° N) to at least Islas Coronados, Mexico (ca. 32° N); also from Gulf of California (ca. 29° 40′ N)

Habitat: Mesopelagic, usually deeper than 300 m

Spawning season: March–July

ELH pattern: Live-bearers; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 7.3 mm (B. Sumida MacCall)
Flexion larvae, 12.5 mm, 23.8 mm (B. Sumida MacCall)
Transformation specimen, 29.0 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Length at birth: <7 mm
Flexion length: ca. 12 through 25–31 mm
Transformation length: ca. 25–31 to <72 mm
Fin development sequence: D & A, C, P_1, P_2
Pigmentation: *Preflexion–flexion*—Scattered dorsolaterally at gut loop; heavy dorsally & ventrally along body margin before end of tail, also extending onto anal finfold or fin. *Transformation*—Heavy on peritoneum; fine specks dorsolaterally on body spreading posteriad. *Juvenile*—On P_1, D & A; over entire body.
Diagnostic features: Total vertebrae 60–63; single unbranched P_2 ray; gut loop formed at < ca. 7.3 mm posteriorly in the abdominal cavity; pigment patch posteriorly on gut & near end of tail, extending onto the A.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF*	Tr	Juv
Sn-A/BL		42–50 46	44–50 47		42–45 43	43–47 45
BD/BL		9–13 12	13–18 16		11–17 15	15–17 16
HL/BL		21–24 22	21–24 23		24–28 26	25–26 25
HW/HL		53–62 58	46–59 53		34–42 38	32–38 35
SnL/HL		24–36 30	29–36 33		18–28 22	17–20 19
ED/HL		19–26 23	8–19 12		10–17 14	14–16 15
P_1L/BL		3–5 4	3–4 4		7–15 13	13–16 14
P_2L/BL		0–0 0	0–2 1		6–15 10	12–14 13

* No postflexion stage, since a prolonged flexion stage persists until transformation.

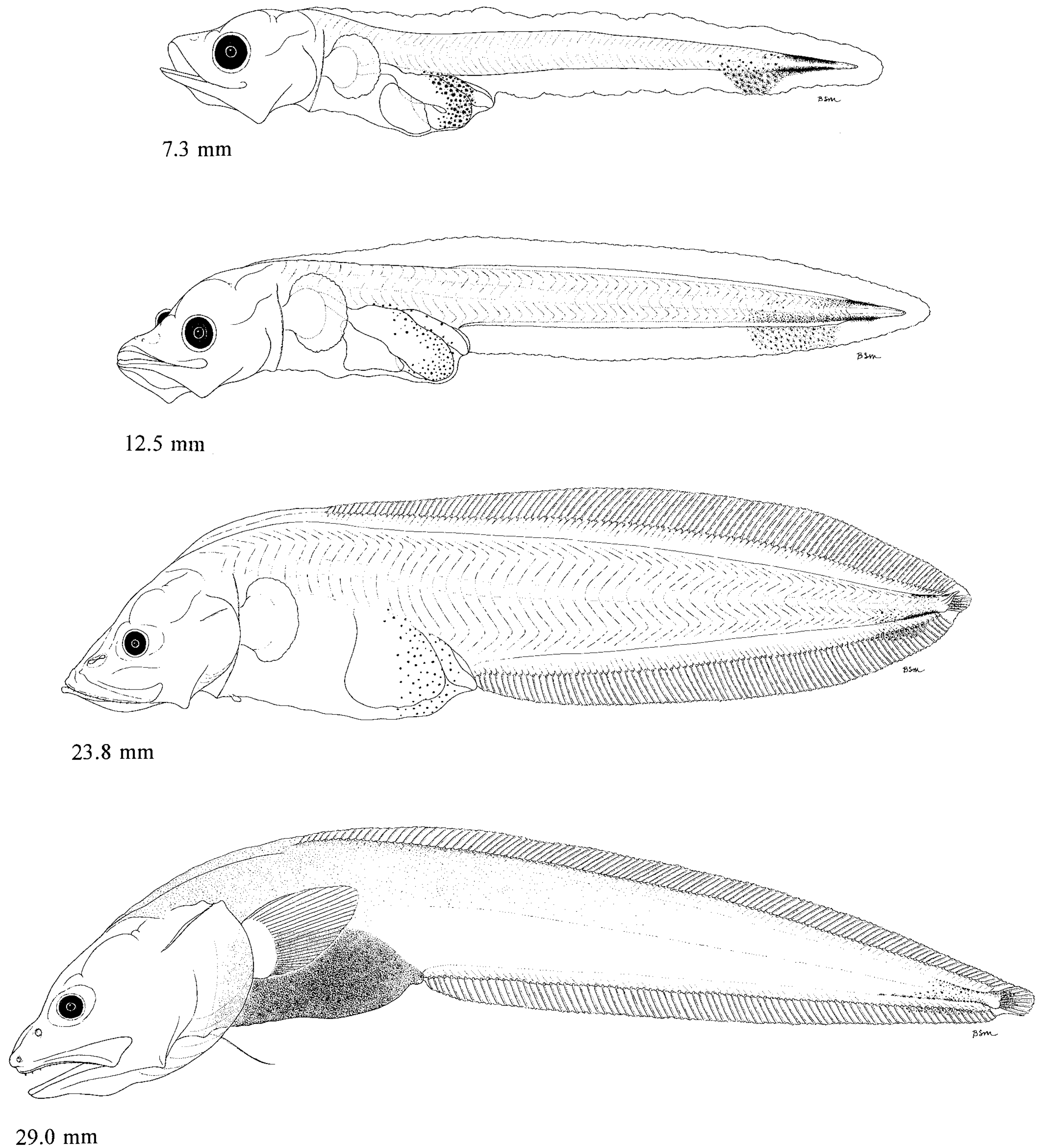


Figure Bythitidae 2. Preflexion larva, 7.3 mm (CalCOFI 8107, station 76.7.55); flexion larvae, 12.5 mm (CalCOFI 7808, station 70.65), 23.8 mm (CalCOFI 7507, station 77.80); transformation specimen, 29.0 mm (CFRD Ref. Coll., T. Matsui, M7, station 3; 32°35′ N, 118°11′ W).

MERISTICS

	Range	Mode
Vertebrae:		
Total	49–53	52
Precaudal	12	12
Caudal	37–41	40
Fins:		
Dorsal spines	0	0
Dorsal rays	95–115	99
Anal spines		
Anal rays	75–91	77
Pelvic	1	1
Pectoral	24–29	27
Caudal:		
Principal	3–5+4–5	5+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	2–3	3
Branchiostegals	8	8

LIFE HISTORY

Range: San Clemente Island, California; the Gulf of California; Isla de Guadalupe, Mexico; south to Panama & the Galápagos Islands

Habitat: Rocky areas at 5.5–18 m depth; hides during the day

Spawning season: Spring

ELH pattern: Live-bearers; larval habitat unknown, not collected in CalCOFI samples

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Intraovarian embryo, 3.5 mm (R. C. Walker)
Juvenile, 31.2 mm (R. C. Walker)

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* Intraovarian larvae stripped from 184 mm specimen (SIO53–169)

† Eye of yolk-sac larvae slightly oval; horizontal axis given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Length at birth: ca. 3.5 mm
Flexion length:
Transformation length: < ca. 30 mm
Fin development sequence: Probably D & A, C, P_1, P_2
Pigmentation: *Yolk-sac (intraovarian)*—1 anterior to P_1 bud; scattered along dorsum posteriorly from nape & ventrally along tail margin to ca. 80% BL; gap followed by blotch dorsally & ventrally & fine specks almost to end of tail. *Juvenile*—Heavy on D, A, & C; scattered over anterior 66% of body, increasing posteriad; body completely covered by 34 mm.
Diagnostic features: Total vertebrae 49–53; juveniles have deeper body & larger head than the other brotulids in study area; pigment heavier than other brotulids from region.

MORPHOMETRICS (range & mean in %)

	Y-S*	PrF	F	PoF	Tr	Juv
Sn-A/BL	42–44 43					45–48 47
BD/BL	7–8 8					21–23 22
HL/BL	15–16 15					26–29 27
HW/HL	74–85 79					37–47 42
SnL/HL	15–19 18					18–20 19
ED/HL†	40–46× 33–37 42×35					14–16 15
P_1L/BL	0.6–0.8 0.6					15–19 16
P_2L/BL	0–0 0					13–15 14

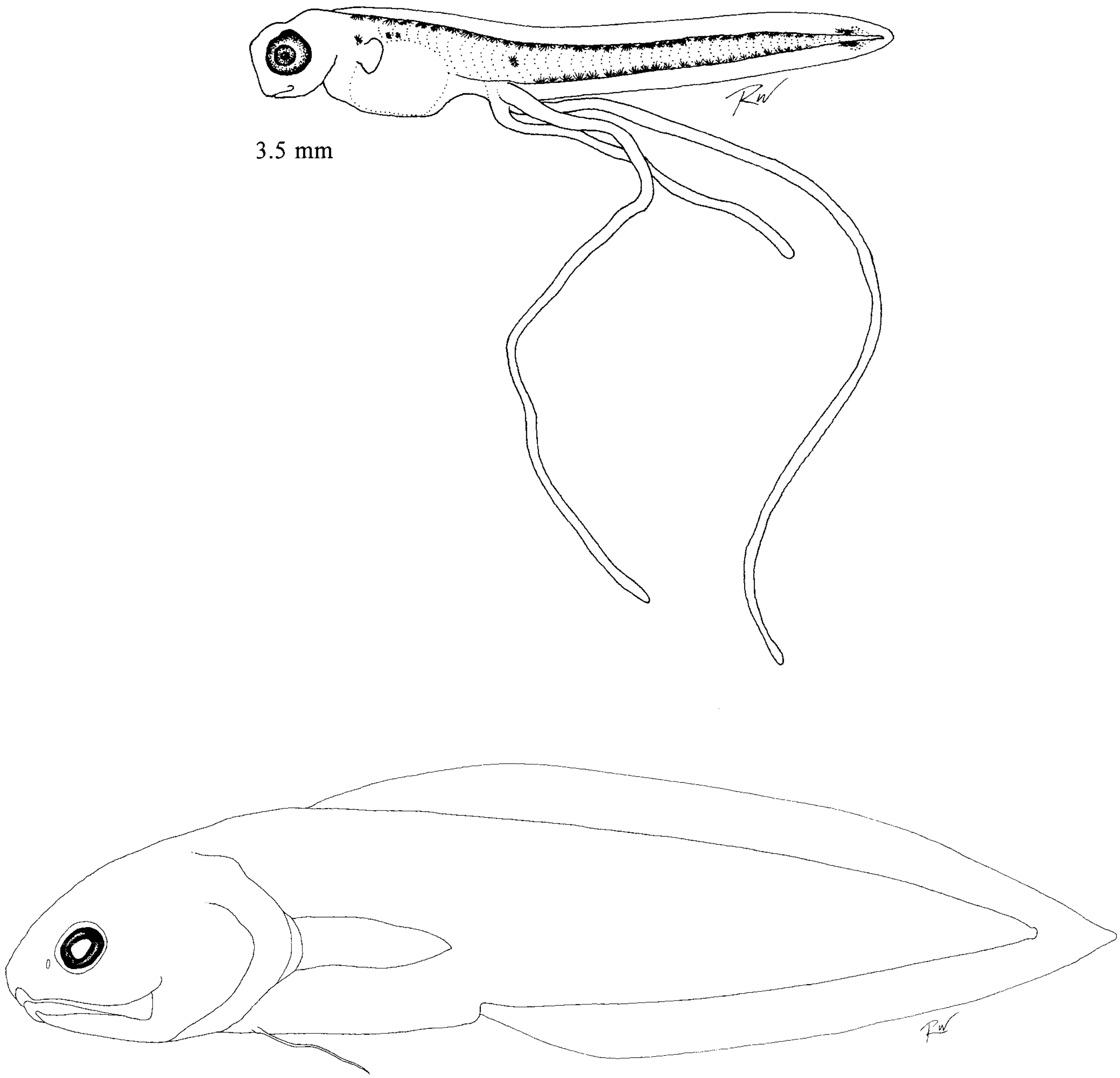


Figure Bythitidae 3. Intraovarian embryo, 3.5 mm (SIO 53–169); juvenile, 31.2 mm (SIO 63–184). Pigment not shown on juvenile.

BATRACHOIDIDAE: Toadfishes, midshipman

W. WATSON

The order Batrachoidiformes contains a single family: Batrachoididae. The batrachoidids are represented in the California Current region by five *Porichthys* species (Table Batrachoididae 1). Larval *Porichthys* are benthic and attached in nests, and thus do not occur in CalCOFI collections. However, newly released juveniles, primarily *P. notatus*, occasionally are taken in CalCOFI samples.

Adult *Porichthys* are elongate and somewhat depressed anteriorly, with large heads, long-based anal and second dorsal fins, and thoracic pelvic fins. Their most striking feature is the presence of photophores, which are arranged in characteristic lateral and ventral rows (e.g., Walker and Rosenblatt 1988). All *Porichthys* species are demersal, living primarily on soft bottom of the continental shelf. Reproductive adults of some species occupy the intertidal zone.

Little published information is available concerning *Porichthys* early life history. All presumably spawn large eggs attached in a nest guarded by a parent. For example, a *P. notatus* nest typically contains ca. 200–500 eggs attached in a single layer under a rock or shell, and is guarded by the male. *P. notatus* hatch about two to three weeks after being spawned, and remain attached in the nest until detaching as juveniles ca. one month later (Aurora 1948; Hart 1973). The characteristic photophore series form prior to detachment. The young free-swimming juveniles of all species are elongate and tadpole-like. In addition to the prominent photophore series, all have series of more or less distinct dorsolateral pigment saddles arrayed from the head to the caudal peduncle. The number of saddles, together with the branchiostegal photophore patterns, fin ray counts, and geographic location, provide the means for identifying the *Porichthys* species (Table Batrachoididae 1).

Porichtys notatus is described based on the literature (Arora 1948) and on detailed examination of nine recently released juveniles (15.8–21.1 mm, all with yolk sac or remnant of yolk sac). The other species are not described separately here, but morphometric data based on measurements of 4 *P. analis* (17.8–18.9 mm, all with remnant of yolk sac), 6 *P. ephippiatus* (20.6–25.0 mm, none with remnant of yolk sac), 5 *P. margaritatus* (13.4–16.6 mm, specimens 13.4–14.7 mm with remnant of yolk sac), and 4 *P. myriaster* (17.3–21.1 mm, a 17.5 mm specimen with remnant of yolk sac) are given in Table Batrachoididae 2. Refer to Walker and Rosenblatt (1988) for figures and additional information.

Table Batrachoididae 1. Characters useful for identifying juvenile *Porichthys* in the California Current vicinity.

Species	Most common fin-ray counts 2D	A	P_1	Saddles under 2D	Shape of apex, BrR photophore series	Geographic range
P. analis	37–38	35–36	18–20	6–7	Very small ~U-shaped projection	Gulf of California to Michoacan & Pacific coast of Baja California Sur south from Bahía Magdalena
P. ephippiatus	31–32	28–29	17–18	5	V, no projection	Southern tip of Baja California & Sinaloa through Oaxaca
P. margaritatus	34–35	30–32	17–18	6–7	V, no projection	Southern tip of Baja California & Oaxaca to Peru
P. myriaster	38–39	36–37	18–19	9–10	Pronounced U-shaped projection	Pacific coast, southern California to Bahía Almejas, Baja California Sur
P. notatus	35–37	32–34	18–19	6–7	V, no projection	British Columbia to Bahía Magdalena, Baja California Sur

Table Batrachoididae 2. Morphometric data for recently released and small juvenile *Porichthys* species.

	P. analis	*P. ephippiatus*	*P. margaritatus*	*P. myriaster*
Sn-A/BL	40–43 41	40–43 41	40–42 41	38–44 41
BD/BL	18–19 19	23–28 25	18–22 20	16–23 19
HL/BL	31–34 32	31–33 32	33–35 34	27–34 31
HW/HL	66–78 72	69–85 76	69–72 71	57–78 66
SnL/HL	13–17 16	13–15 14	12–15 13	15–20 18
ED/HL	23–25 24	18–21 19	19–22 20	19–24 21
P_1L/BL	26–27 26	26–32 30	26–28 27	25–29 27
P_2L/BL	16–17 16	13–16 15	15–18 16	13–15 14

MERISTICS

	Range	Mode
Vertebrae:		
Total	42–46	42–44
Precaudal	10–12	11
Caudal	30–36	31–33
Fins:		
Dorsal spines	II	II
Dorsal rays	33–38	35–37
Anal spines	0	0
Anal rays	30–35	32–34
Pelvic	I,2	I,2
Pectoral	15–20	18
Caudal:		
Principal	6+6	6+6
Procurrent:		
Upper	2	2
Lower	1	1
Gill rakers:		
Upper	1	1
Lower	9–12	10–11
Branchiostegals	6	6

LIFE HISTORY

Range: British Columbia to Bahía Magdalena, Baja California Sur

Habitat: Intertidal to 303 m depth, uncommon in shallow water south of central California; on soft bottom, near rocky areas during spawning season.

Spawning season: Late spring–summer

ELH pattern: Oviparous with eggs & larvae attached to nest wall; nest guarded by male.

LITERATURE

Arora 1948
Hart 1973
Hubbs 1920
MacGinitie 1935
Walker and Rosenblatt 1988
Wang 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Demersal embryo, 8.9 mm (B. Sumida MacCall)
Juvenile, 20.0 mm, lateral & ventral views (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 4–6 mm × 4–8 mm (6 mm) **Yolk:**
No. of OG: 0 **Diam. of OG:**
Shell surface: Unornamented
Pigment: Yolk yellowish to orange in life, pale beige to pink in formalin
Diagnostic features:

LARVAE

Hatching length: 7–8 mm
Flexion length: Before hatching
Transformation length: Juveniles detach at ca. 16–19 mm
Fin development sequence:
Pigmentation: Initially dorsally on head & gut, expands caudad & ventrad; 4–8 dorsolateral saddles present by time of detachment.
Diagnostic features: Branchiostegal photophore series with anteriorly directed V-shaped apex; 4–8 (usually 6–7) dorsolateral pigment saddles under 2D, anterior saddles (including saddle at nape) typically more prominent than posterior 1–3 saddles; usually no prominent saddle on head.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL						37–42 40
BD/BL						20–25 23
HL/BL						29–33 32
HW/HL						68–83 77
SnL/HL						14–17 15
ED/HL						25–28 26
P_1L/BL						25–33 28
P_2L/BL						14–18 16

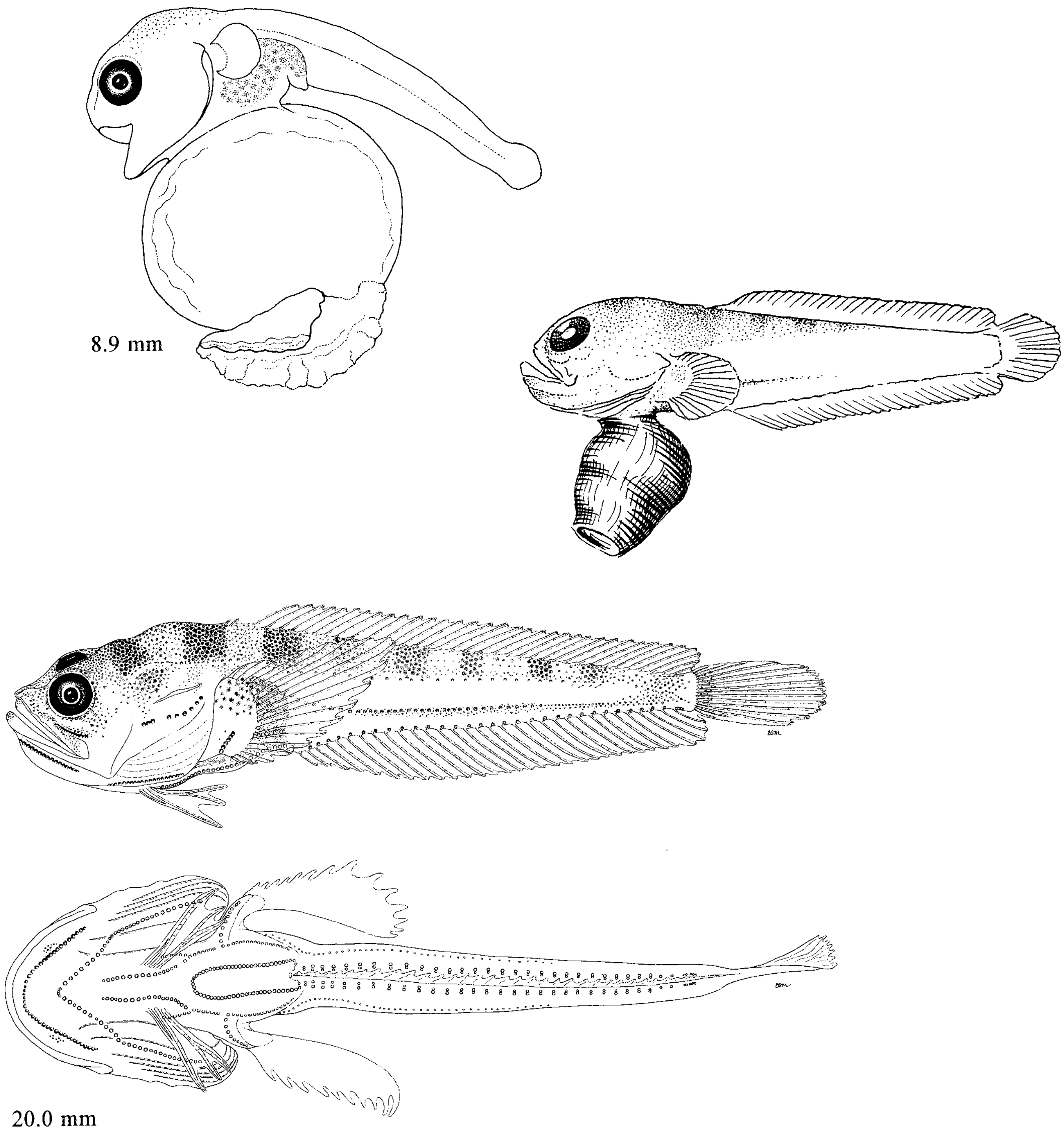


Figure Batrachoididae 1. Demersal embryo, 8.9 mm with 5.5 mm diameter yolk mass (SIO 88–143; note attachment disc at bottom of yolk); demersal larva, 17 days after hatching (Arora 1948; no size given); free-swimming juvenile, 20.0 mm, lateral view and ventral view showing characteristic photophore pattern (MEC I93, station D–E).

LOPHIIFORMES

W. WATSON

The lophiiform fishes typically are small (most species <30 cm, although a few may exceed 1 m) odd-looking fishes that exhibit a variety of body forms ranging from globular to strongly compressed or strongly flattened. Nearly all have the first ray of the spinous dorsal fin displaced far forward on the head and modified into a luring apparatus: the illicium (in the suborder Ceratioidei only females have the illicium; absent in Neoceratiidae). All have a low number of vertebrae and most have low numbers of rays in the unpaired fins (e.g., Table Lophiiformes 1). Gill rakers in the usual sense are lacking; instead, many have variously developed tooth plates on the branchial arches while others have none. Representatives of the order can be found in all major oceans between about 65° N and 65° S, and in habitats ranging from the intertidal to the bathypelagic zone. Spawning is known for only a few of the Lophiiformes, but that information together with the similarity of ovarian anatomy among the lophiiform taxa suggests that most spawn floating gelatinous egg rafts (see Bertelsen 1984; Pietsch 1984; Pietsch and Grobecker 1987). The planktonic larvae typically are globular, with an inflated epidermis. Larval pigmentation ranges from absent to heavy; it commonly is light to moderate and largely restricted to the gut and upper half of the body.

Approximately 30 lophiiform species, representing twelve families, occur in the vicinity of the California Current (Table Lophiiformes 1). Although only a few species have been identified as larvae in CalCOFI collections, they represent ten of the families. Among these, only larvae of the ceratioid families Oneirodidae and Gigantactinidae occur somewhat commonly in CalCOFI collections. Species descriptions are included here for representatives of nine of the lophiiform families (listed below). Three families (Chaunacidae, Centrophrynidae, Thaumatichthyidae) are not included owing to insufficient material. Representatives of these three families are shown in Figure Lophiiformes 1; refer to Bertelsen (1951, 1984), Bertelsen and Struhsaker (1977), and Pietsch (1972b, 1976, 1984) for additional information.

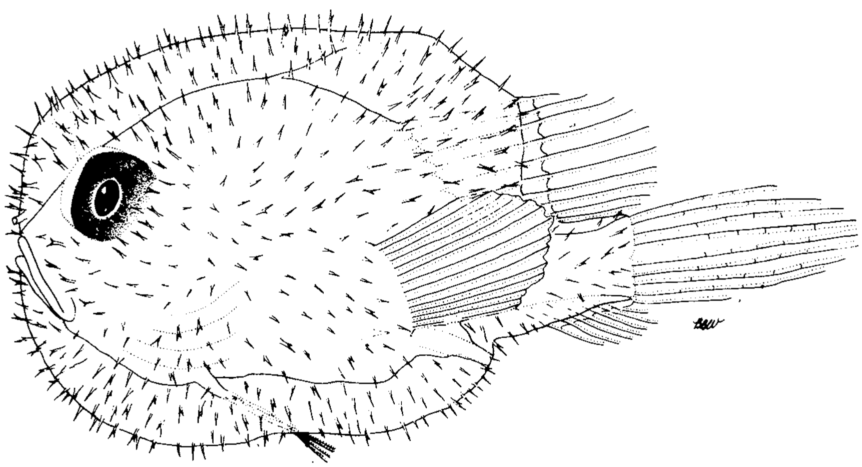
Suborders and families included:

- Lophioidei
  - Lophiidae
- Antennarioidei
  - Antennariidae
- Ogcocephaloidei
  - Ogcocephalidae
- Ceratioidei
  - Caulophrynidae
  - Melanocetidae
  - Oneirodidae
  - Ceratiidae
  - Gigantactinidae
  - Linophrynidae

Table Lophiiformes 1. Fin ray and vertebral counts for the lophiiform species likely to be encountered in the CalCOFI sampling area. The illicium, modified from the first cephalic fin ray, is not shown here for ogcocephalids or ceratioids. Taxa are listed in alphabetic order.

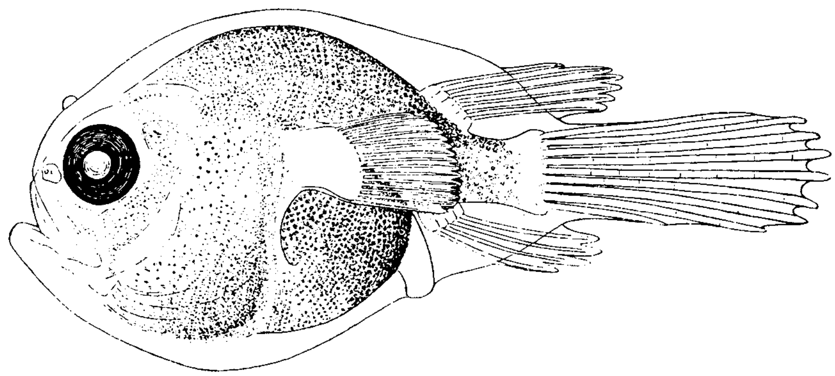
Taxon	D	A	P_1	P_1	C	Vertebrae
Antennariidae						
Antennarius avalonis	III+12–14	8–9	12–13	I,5	9	9–10+9–10=19
Caulophrynidae						
Caulophryne jordani	16–19	14–18	16–18	0–4[a]	8	9–10+10–11=20
C. pelagica	14–17	12–16	15–18	0–4[a]	8	
C. polynema	19–22	17–19	15–18	0–4[a]	8	
Centrophrynidae						
Centrophryne spinulosa	6–7	5–6	15–16	0	9	7+14
Ceratiidae						
Ceratias holboelli	3–4	4	15–19	0	9	20
Cryptopsaras couesii	4–5	4	14–18	0	8	20
Chaunacidae						
Bathychaunax coloratus	III+11	5–6	11–12	I,4	8	19
Gigantactinidae						
Gigantactis gargantua	5–7	6	19–22	0	9	
G. macronema	5–6	5–6	17–20	0	9	7+15
G. microdontis	4–6	4–6	17–19	0	9	7+16
G. savagei	4–6	4–6	18–20	0	9	21
G. vanhoeffeni	5–7	5–7	17–19	0	9	7+15
Linophrynidae						
Borophryne apogon	3	3	15–18	0	9	4–5+15
Lophiidae						
Lophiodes caulinaris	III+III–IV+8	6–7	16–21	I,5	8	19
L. spilurus	III+III+7–8	6–7	15–18	I,5	8	19
Melanocetidae						
Melanocetus eustalus	15	4	16	0	9	20
M. johnsoni	13–17	3–5	17–23	0	9	5–7+13–15=20
Ogcocephalidae						
Zalieutes elater	4–6	4	12–14	I,5	9	18–19
Oneirodidae						
Bertella idiomorpha	5–6	4–5	17–21	0	8–9	5+15
Chaenophyryne longiceps	6–7	5–6	17–22	0	9	4–5+15
C. melanorhabdus	6–8	5–6	16–18	0	9	20
Dolopichthys longicornis	5–7	4–6	17–21	0	9	4+15
D. pullatus	5–7	4–6	17–22	0	9	5+16
Microlophichthys microlophus	5–7	4–6	18–23	0	9	20–21
Oneirodes acanthias	5–7	4	15–18	0	9	4+16
O. basili	5–6	4	15–16	0	9	4+16
O. eschrichtii	5–7	4	15–19	0	9	4+16
Phyllorhinichthys micractis	5	5	21	0	9	20
Thaumatichthyidae						
Thaumatichthys axeli	6–7	4	14–16	0	9	21–22

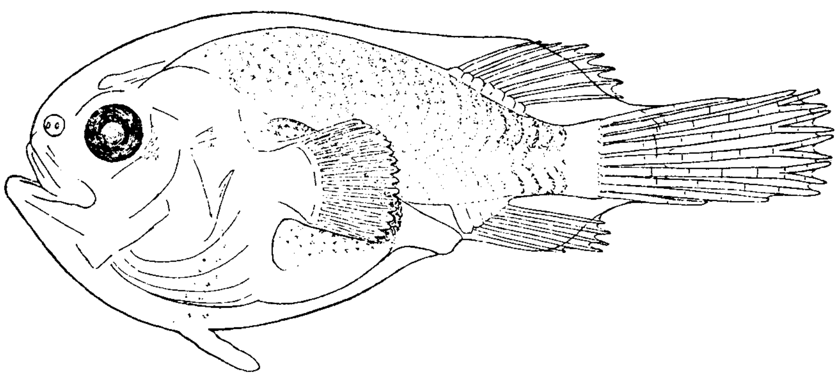
[a] Pelvic fin rays are present only during larval and transformation stages in the Caulophrynidae.



Chaunax sp.
9.8 mm

Thaumatichthys sp.
10.0 mm TL





Centrophryne spinulosa
10.5 mm TL

Figure Lophiiformes 1. Representative larvae of three lophiiform families: Chaunacidae—*Chaunax* sp., 9.8 mm (Pietsch 1984); Thaumatichthyidae—*Thaumatichthys* sp., 10.0 mm TL (Bertelsen 1951); Centrophrynidae—*Centrophryne spinulosa*, 10.5 mm TL (Bertelsen 1951).

LOPHIIDAE: Goosefishes

W. WATSON

Lophiidae contains 25 species in four genera (Caruso 1985); two species, *Lophiodes caulinaris* and *L. spilurus*, occur in the eastern Pacific Ocean (Caruso 1981). Both are primarily tropical, but have been reported to range northward to central California (Lea et al. 1984). Larvae of both are uncommon in CalCOFI samples: only *L. caulinaris* has been collected from the Pacific coast, in samples south of Punta Abreojos, Baja California Sur. Both species have been taken in CalCOFI samples from the Gulf of California and in other plankton samples collected south of Baja California.

Adults of the two goosefish species are small (<30 cm), demersal predators on soft bottom at depths of ca. 15–475 m (usually ≥100 m) (Fitch and Lavenberg 1968; Caruso 1981). Both species have a flattened head and a large mouth. The first two dorsal spines are displaced far forward (onto the snout), and the first is modified into a lure used to attract prey.

Spawning has not been described for *Lophiodes*, but another genus, *Lophius*, is oviparous, spawning large ribbon-like gelatinous egg rafts containing numerous oval eggs, each in a separate chamber within the raft (e.g., Martin and Drewry 1978). Planktonic larvae are known for *Lophius* and *Lophiomus* (e.g., Pietsch 1984; Matsuura and Yoneda 1986; Minami 1988), but larval development has not been described for *Lophiodes* or *Sladenia*. Larvae of *Lophius americanus* hatch with a large yolk sac, pigmented eyes, and lacking a functional mouth (Martin and Drewry 1978). Presumably, other lophiids hatch at a similar stage of development. Lophiid larvae are moderately deep-bodied, with a short to moderate preanal length. Pelvic fins and dorsal fin spines begin to develop during the yolk-sac stage (e.g., *Lophius americanus*) or early preflexion stage (e.g., *Lophiodes spilurus*). These rays typically become quite elongate; the second and third dorsal spines are especially long in larval *Lophiodes*. At some time between the preflexion and early postflexion stage the skin begins to inflate, giving the larvae a balloon-like appearance. Both *L. caulinaris* and *L. spilurus* have a special pelagic juvenile stage characterized by the presence of the illicium with esca and the body tendrils typical of the adult, by being somewhat laterally compressed rather than depressed as in the adult, and by retaining the elongate fin rays and inflated epidermis of the larvae. Larval pigment ranges from light to moderate, and on the body it is largely subdermal. Fin pigmentation ranges from absent to quite heavy; pelvic fins typically are pigmented.

Larval lophiids are distinctive and easily recognized once the pelvic fin rays and dorsal fin spines begin to form (by early preflexion); prior to that they may be difficult to distinguish from some lophiiform and tetraodontiform species which share a similar general appearance and low (usually ≤20) myomere count. The two goosefish species that may be encountered in CalCOFI samples (only *L. caulinaris* is likely to be collected) cannot always be distinguished during the preflexion stage but usually are distinguishable on the basis of pigment (primarily on the pectoral fin and tail), pectoral fin ray counts, and size of the frontal spines from about mid-flexion onward.

The following descriptions are based on detailed examinations of 23 specimens of *L. caulinaris* and 26 *L. spilurus* (Table Lophiidae 1). Meristic data were obtained from Caruso (1981) and from counts made during the present study.

Table Lophiidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the goosefish species descriptions.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Pelagic juvenile	Benthic juvenile
Lophiodes caulinaris	0	2	7	5	6	3
		3.1–4.6	5.0–6.1	5.9–9.4	9.8–19.8	22.6–41.5
L. spilurus	1	13	2	1	7	2
	2.1	2.0–4.0	4.6–5.6	8.1	11.0–46.3	45.2–47.9

MERISTICS

	Range	Mode
Vertebrae:		
Total	19	19
Precaudal		
Caudal		
Fins:		
Dorsal spines	III+III–IV	III+III
Dorsal rays	8	8
Anal spines	0	0
Anal rays	6–7	6
Pelvic	I,5	I,5
Pectoral	16–21	18–20
Caudal:		
Principal	4+4	4+4
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Eastern Pacific Ocean, vicinity of Morro Bay, California to Peru

Habitat: Demersal, at depths of ca. 15–311 m

Spawning season: Larvae collected in most months

ELH pattern: Oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 5.1 mm (W. Watson)
Flexion larva, 5.9 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3 mm
Flexion length: ca. 5–6 mm
Transformation length: ca. 10–20 mm
Fin development sequence: 1D, P_2, 2D & A & C, P_1
Pigmentation: *Preflexion–pelagic juvenile*—Over & under brain; on nape, extending to myomere 5 by ca. 5 mm & to myomere 10 by ca. 6 mm; heavy on dorsal, dorsolateral, & anterior surfaces of gut; distal on P_2 & D spines; may be a few on inner surface of P_1 base by ca. 8–9 mm; bar begins to form on caudal peduncle at ca. 9–10 mm; occasionally some on outer surface of P_1 base or under notochord tip (rarely both in same specimen).
Diagnostic features: P_1 usually unpigmented, except on inner surface of base after 8–9 mm; tail largely unpigmented before postflexion stage; bar on caudal peduncle by 9–10 mm; frontal spines small; P_1 usually 18–20; 8–9 preanal myomeres (through flexion stage), 19–20 total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		50–53 52	46–64 54	55–71 61	65–73 70	68–81 73
BD/BL		35–48 41	34–52 43	46–65 56	44–63 52	30–41 34
HL/BL		31–44 37	31–44 36	39–49 44	48–59 51	49–53 51
HW/HL		63–91 77	63–89 77	65–122 83	59–94 79	61–98 81
SnL/HL		16–23 19	18–21 20	16–26 21	28–38 31	33–35 34
ED/HL		37–42 40	36–44 40	26–40 35	16–28 21	16–17 16
P_1L/BL		8–9 9	10–16 12	14–27 21	18–27 24	19–21 20
P_2L/BL		36–38 37	41–107 72	42–107 71	30–50 38	16–22 18

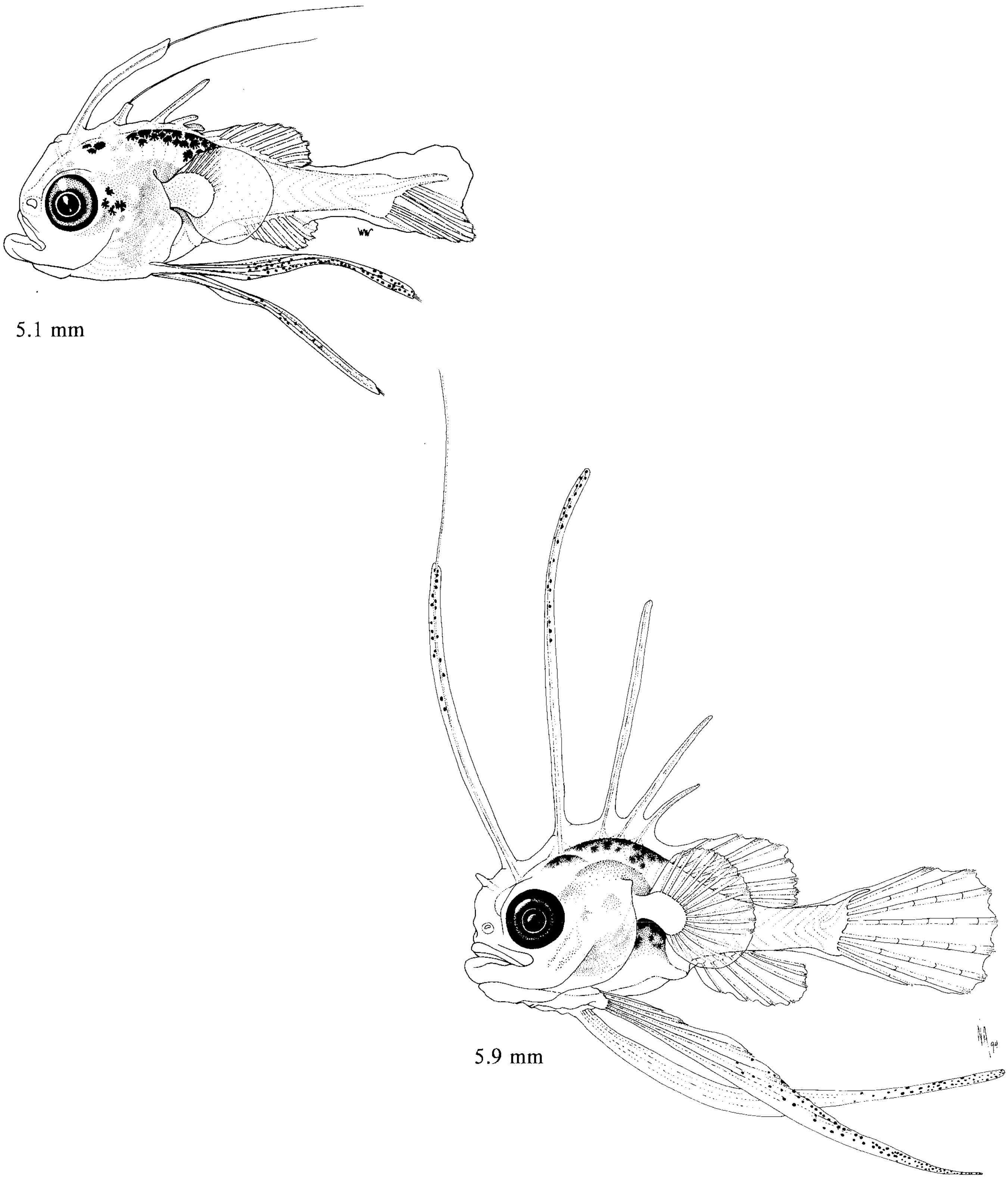


Figure Lophiidae 1. Early flexion larva, 5.1 mm (IATTC 90008, station PSH #1 Red); late flexion larva, 5.9 mm (IATTC 90001, station ASB #1 Red).

MERISTIC

	Range	Mode
Vertebrae:		
Total	19	19
Precaudal		
Caudal		
Fins:		
Dorsal spines	III+III	III+III
Dorsal rays	7–8	8
Anal spines	0	0
Anal rays	6–7	6
Pelvic	I,5	I,5
Pectoral	15–18	17
Caudal:		
Principal	4+4	4+4
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Eastern Pacific Ocean, vicinity of Santa Cruz, California to Chile

Habitat: Demersal on soft bottom, ca. 120–475 m depth

Spawning season: Larvae collected in most months; preflexion stage larvae taken most commonly January–August.

ELH pattern: Oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.4 mm (M. T. Vona)
Preflexion larva, 3.5 mm (W. Watson)
Flexion larva, 4.6 mm (W. Watson)
Postflexion larva, 8.1 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2 mm
Flexion length: ca. 4.5–6.0 mm
Transformation length: ca. 10 mm to ≥38 mm
Fin development sequence: 1D, P_2, C, 2D & A & P_1
Pigmentation: *Yolk-sac through postflexion*—Under hindbrain; forming on nape at ca. 2.3 mm; spreading over brain & caudad after 3.5–4 mm; heavy on dorsal, dorsolateral, & anterior surfaces of gut; few along ventral margin of posterior half of tail, mostly internal after ca. 4 mm; usually few on inner & outer surfaces of P_1 bases; forming along P_1 rays after ca. 4 mm; distally on P_2 & on D spines. *Pelagic juvenile*—Body nearly completely pigmented except little on jaws & snout before ca. 26 mm, none on end of caudal peduncle.
Diagnostic features: P_1 & ventral margin of tail usually pigmented (both never unpigmented in same specimen); caudal pigment usually present through flexion stage; body mostly pigmented in pelagic juvenile stage; frontal spines prominent by ca. 8 mm; P_1 usually 17; 5–7 preanal myomeres (preflexion stage), 19–20 total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		33–50	51–55		60–81	72–77
	34	43	53	69	73	74
BD/BL		30–42	35–43		44–55	23–34
	30	36	39	59	50	29
HL/BL		24–33	35–37		46–56	47–50
	24	30	36	49	51	48
HW/HL		62–108	78–83		76–121	88–110
	98	78	80	113	92	99
SnL/HL		9–26	17–23		28–33	30–33
	26	21	20	29	30	32
ED/HL		39–55	35–40		19–28	20–21
	46	44	38	28	22	20
P_1L/BL		5–12	11–11		21–28	27–28
	6	8	11	20	24	27
P_2L/BL		0–54	47–57		25–43	24–25
	0	25	52	100	30	25

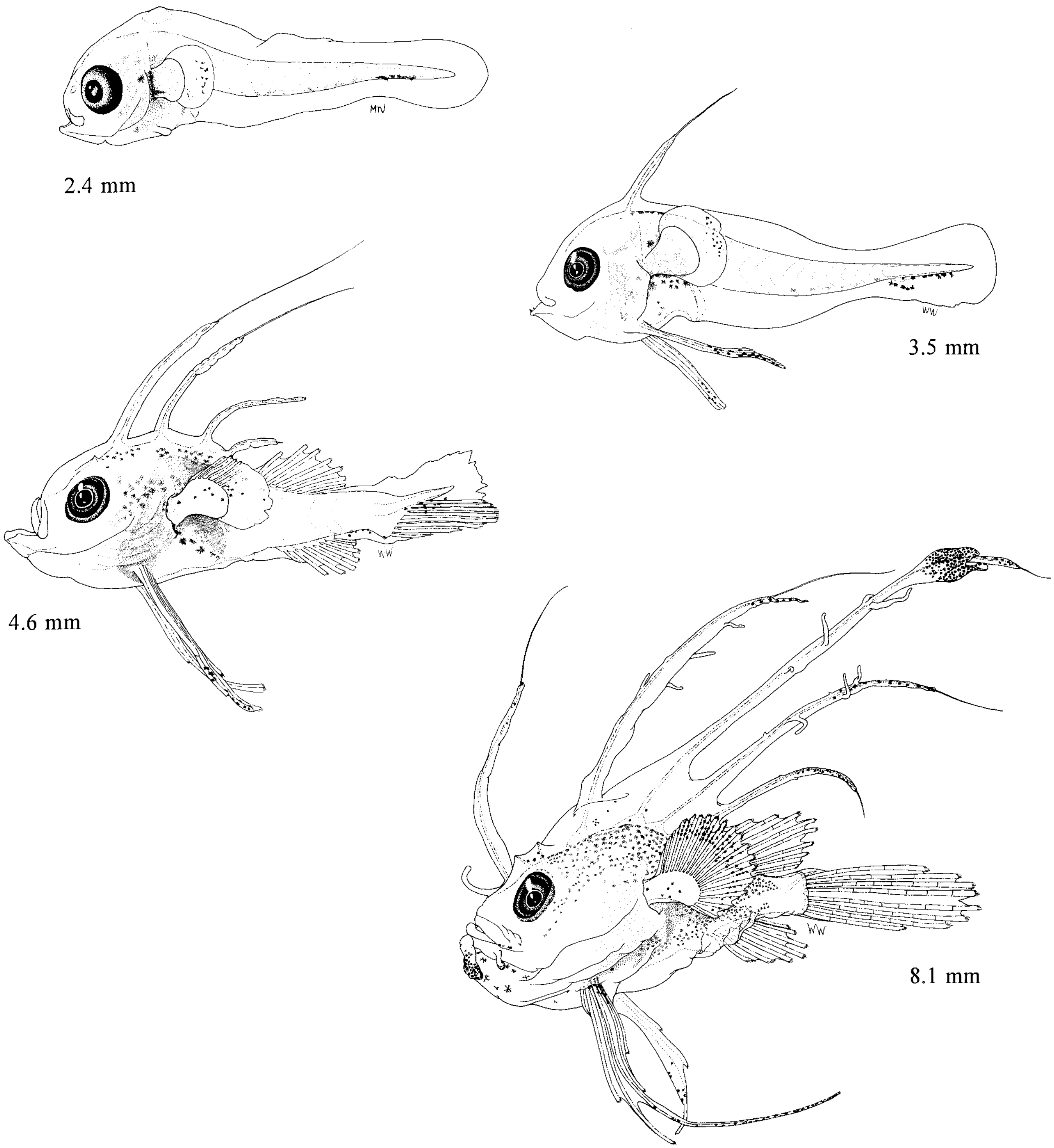


Figure Lophiidae 2. Preflexion larvae, 2.4 mm (IATTC 89023, station MSL #1 Red), 3.5 mm (TO 59–1, station 24); early flexion larva, 4.6 mm (EASTROPAC II, station OP.048); postflexion larva, 8.1 mm (TO 58–1, station 48).

ANTENNARIIDAE: Frogfishes

W. Watson

Antennariidae contains 41 species in 12 genera (Pietsch and Grobecker 1987). (Nelson [1994] treated these as an antennariid subfamily, Antennariinae, and included the monotypic families Tetrabrachiidae and Lophichthyidae as additional antennariid subfamilies.) A single frogfish species, *Antennarius avalonis*, occurs in the CalCOFI area. Two other species, *A. sanguineus* and *Antennatus strigatus*, co-occur with *Antennarius avalonis* in the Gulf of California and south along the Pacific coast to northern South America. Although *A. avalonis* ranges as far north as Santa Catalina Island, California, its larvae are rare north of Baja California Sur.

Adult frogfishes are small (usually <30 cm), demersal, largely sedentary predators that use a first dorsal spine modified into a lure to attract prey. They typically are associated with reef habitats.

Antennariids are oviparous. Both planktonic egg rafts and attached eggs are known (e.g., Mosher 1954; Pietsch and Grobecker 1980, 1987; Pietsch 1984); spawning of gelatinous, ribbon-like rafts containing large numbers of eggs probably is most common. Planktonic larvae are known for a few species (e.g., Pietsch 1984; Pietsch and Grobecker 1987). Larval *Histrio histrio* and *Antennarius striatus* hatch at ca. 1 mm, with unpigmented eyes, with a large yolk sac, and without a functional mouth (Mosher 1954; Rasquin 1958). Larvae initially are moderately deep-bodied with a moderate preanal length, and with development they become more or less globose. Throughout development they are enclosed in the inflated and somewhat balloon-like skin characteristic of the Lophiiformes. Pigmentation typically is moderate, subdermal, and largely restricted to the anterior half of the body, particularly the gut region. A special juvenile stage, the "scutatus," characterized especially by the development of bony plates extending posteriorly from the cranium, has been described in *Antennarius radiosus* (Pietsch 1984; Pietsch and Grobecker 1987). *Antennarius avalonis* and *A. sanguineus* also go through the scutatus stage.

Larval antennariids are distinctive and by mid-flexion are unlikely to be confused with any other family. Small preflexion stage larvae may resemble those of the Gigantactinidae or Scorpaeninae. *Antennarius avalonis* has fewer myomeres than the scorpaenines (19 vs. 24–25), and is somewhat more heavily pigmented than *Gigantactis*. In addition, *Gigantactis* has larger pectoral fins and begins development of a specialized illicium early in the preflexion stage, in contrast to development during flexion of the cephalic dorsal rays of *Antennarius*. Larvae of the three antennariid species can be distinguished from one another by small differences in pigmentation, and from mid-flexion onward, by the number of pectoral fin rays. Only *A. avalonis* is likely to be encountered along the Pacific coast of California and Baja California.

The following description of *A. avalonis* is based on detailed examinations of 13 larval (7 preflexion, 2.2–2.8 mm; 2 flexion, 3.3 mm; 4 postflexion, 3.3–5.2 mm) and 5 juvenile (13.7–23.9 mm) specimens.

MERISTICS

	Range	Mode
Vertebrae:		
Total	19	19
Precaudal	9–10	9
Caudal	9–10	10
Fins:		
Dorsal spines	III	III
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	8–9	8
Pelvic	I, 5	I, 5
Pectoral	12–13	13
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Santa Catalina Island, California, to Peru, including Gulf of California

Habitat: Reefs; juveniles in shallower areas, adults may be deeper

Spawning season: Larvae collected primarily August–October

ELH pattern: Oviparous; presumably, eggs contained within an elongate, floating, gelatinous mass; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.3 mm (B. Sumida MacCall)
Flexion larva, 3.3 mm (B. Sumida MacCall)
Postflexion larva, 3.6 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 3 mm
Transformation length: >3.6 mm, <13.7 mm
Fin development sequence: C, D & A & P_1 & P_2
Pigmentation: *Pre- to postflexion*—On nape, becoming internal during flexion stage, extending posteriorly over notochord; under mid- & hindbrain; dorsally & dorsolaterally on gut; ventrally on gut beginning posteriorly, spreading anteriorly during flexion; inside gill cover at level of eye beginning in flexion stage. *Juvenile*—Completely pigmented, with scattered darker spots; bands on D, A, C, P_1.
Diagnostic features: Small, deep-bodied, with large head; skin inflated & somewhat balloon-like; 5–6 preanal myomeres (through flexion stage), 18–20 total myomeres; "scutatus" stage develops between 3.4–3.6 mm; diagnostic fin ray counts present by 3.3 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–54 45	57–62 60	69–70 69		68–75 73
BD/BL		36–47 41	56–58 57	62–72 67		52–69 58
HL/BL		29–37 33	38–44 41	45–56 50		36–45 43
HW/HL		74–103 90	88–92 90	77–107 94		77–103 94
SnL/HL		14–24 19	12–13 13	12–17 15		15–21 18
ED/HL		29–42 37	30–37 33	31–36 33		23–28 25
P_1L/BL		9–12 10	13–14 14	24–29 26		20–36 29
P_2L/BL		0	4–6 5	8–19 12		13–21 18

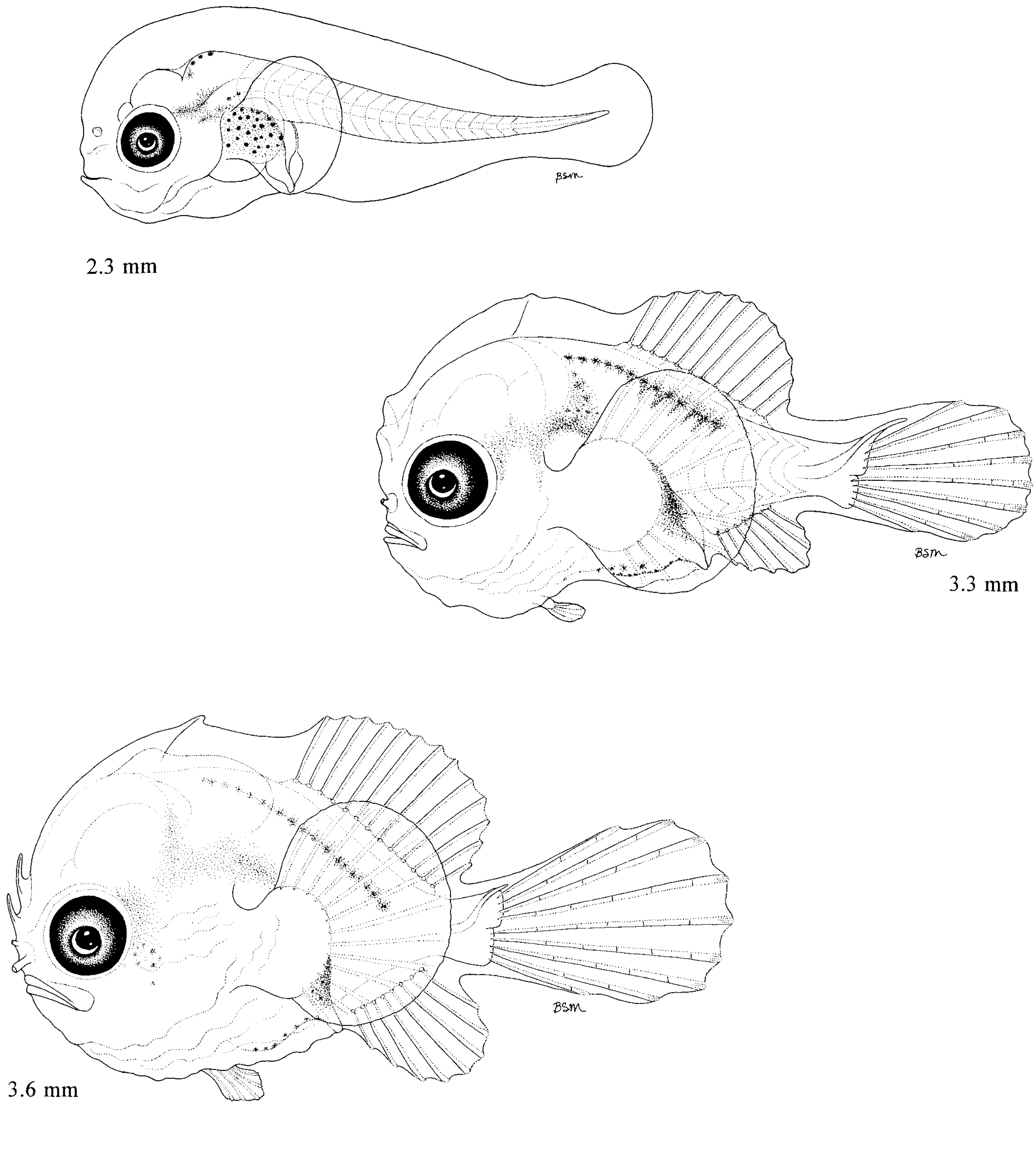


Figure Antennariidae 1. Preflexion larva, 2.3 mm (CalCOFI 5708, station 103G.55); flexion larva, 3.3 mm (CalCOFI 5708, station 133G.40); postflexion "scutatus" stage larva, 3.6 mm (CalCOFI 5708, station 141G.29).

OGCOCEPHALIDAE: Batfishes

W. WATSON

Ogcocephalidae contains 62 species in nine genera (Nelson 1994). A single species, *Zalieutes elater*, occurs in the CalCOFI area (Miller and Lea 1972; Eschmeyer et al. 1983). Some species of *Dibranchus* range northward to near the CalCOFI area (Garman 1899; Bradbury 1967); however, all the larval ogcocephalids identified to date from CalCOFI collections and other surveys in nearby waters appear to be a single species referable to *Z. elater*. Although *Z. elater* is reported to occur as far north as Point Conception, California (Eschmeyer et al. 1983), its larvae have been collected only from the Gulf of California and southward from the southern tip of Baja California Sur.

Batfishes are small (*Z. elater* reaches ca. 15 cm), benthic inhabitants of sandy or muddy bottom at depths ranging from a few meters to a few hundred meters. Most are tropical or subtropical; only a few range into temperate waters. Batfishes typically are strongly flattened; all are armored with scales modified into stiff tubercles of various forms and all are equipped with an illicium (a modified first dorsal fin spine) used to lure prey. Batfishes move about primarily by walking on the bottom using their pelvic and pectoral fins.

Neither spawning nor eggs have been documented for the batfishes; however, since their ovaries are scrolled as in other Lophiiformes, they may produce floating egg rafts such as are known for some of the other lophiiform fishes (e.g., Pietsch 1984; Pietsch and Grobecker 1987). The size and developmental stage of larvae at hatching are unknown. The least developed specimen recognized to date (ca. 1.8 mm) has a moderate yolk sac with segmented yolk and large oil globule, incompletely developed mouth, and pigmented eyes. Larval batfishes are characterized throughout development by their large head, large pectoral fins, and strongly inflated epidermis. Tubercle-like scales also typify at least the larger larval batfishes; in *Z. elater* the tubercles initially form during the preflexion stage as widely spaced bumps on the epidermis which soon become capped with ca. 10–20 spinules each. Subsequently, the spaces between these first tubercles are filled with numerous smaller tubercles, each bearing 1–4 spinules. The number, shape, and spination of the epidermal tubercles may differ between the ogcocephalid genera (for example, c.f. Pietsch 1984, Figure 164C, and *Z. elater* here). The illicium forms during notochord flexion. Larval pigment in batfishes occurs principally on the dorsum, gut, and pectoral fins.

Preflexion stage *Z. elater* resemble *Caulophryne*, but are readily distinguished by having pectoral and tail pigment (both lacking in *Caulophryne*), fewer pectoral fin rays (Table Lophiiformes 1) and smaller pelvic fins. After the tubercles begin to form larval *Z. elater* cannot be confused with the larvae of any other family. It is unknown how larval *Zalieutes* might be distinguished from larval *Dibranchus*.

The following species account is based on detailed examination of 29 larval (1 yolk-sac, 1.8 mm; 10 preflexion, 1.7–3.0 mm; 7 flexion, 2.6–4.0 mm; 11 postflexion, 4.0–11.0 mm) and 5 juvenile (17.2–20.4 mm) *Zalieutes elater*.

MERISTICS

	Range	Mode
Vertebrae:		
Total	18–19	19
Precaudal		
Caudal		
Fins:		
Dorsal spines	IL*	IL
Dorsal rays	4–6	5
Anal spines	0	0
Anal rays	4	4
Pelvic	I,5	I,5
Pectoral	12–14	13
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Point Conception, California, to Peru, including Gulf of California

Habitat: On sandy bottom, ca. 18–113 m depth

Spawning season: Larvae collected May–December

ELH pattern: Oviparous; presumably, eggs contained in floating rafts; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.8 mm (M. T. Vona)
Preflexion larva, 1.7 mm (M. T. Vona)
Flexion larva, 3.4 mm (W. Watson)
Postflexion larvae, 4.7 mm, 10.1 mm (W. Watson)

* IL = illicium, the first D spine modified to form a lure

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ≤1.8 mm
Flexion length: ca. 3–4 mm
Transformation length: >11 mm, <17 mm
Fin development sequence: P_1, C, P_2 & IL, D, A
Pigmentation: *Yolk-sac*—Under hindbrain; dorsally on anterior part of gut & on yolk sac; band around tail at ca. myomeres 15–17. *Preflexion–postflexion*—Dorsal & dorsolateral, initially at nape, spreading caudad to level of anus by early postflexion stage; usually band around tail in vicinity of postanal myomeres 8–13; dorsally, dorsolaterally, & anteriorly on gut; under mid- & hindbrain; under opercle; usually on P_1 base, increases in postflexion stage; usually some distally on P_1 blade or rays after 2 mm, usually forming short bands near middle & distal parts of upper P_1 in postflexion stage. *Juvenile*—Completely pigmented except belly & P_2.
Diagnostic features: Large, early forming P_1; moderately large P_2; strongly inflated dermal sac, with tubercles bearing up to 20 small spinules each beginning at 2.5–3 mm; pigment dorsally & dorsolaterally on trunk & distally on P_1 beginning at ca. 2 mm; band usually present around tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		32–40	38–51	53–71		63–65
	42	36	44	65		65
BD/BL		28–39	39–55	53–78		23–27
	29	32	44	64		26
HL/BL		23–33	27–37	40–52		42–46
	23	27	32	46		44
HW/HL		90–125	96–140	82–155		66–91
	83	101	113	107		76
SnL/HL		15–28	14–25	12–24		16–19
	29	20	18	18		18
ED/HL		34–50	38–46	19–40		21–23
	34	44	41	28		22
P_1L/BL		8–32	30–43	37–59		23–32
	4	19	36	52		28
P_2L/BL		0–3	3–20	18–35		19–22
	0	0.4	9	30		21
DW/BL		21–36	36–50	48–73		51–67
	19	28	42	61		56

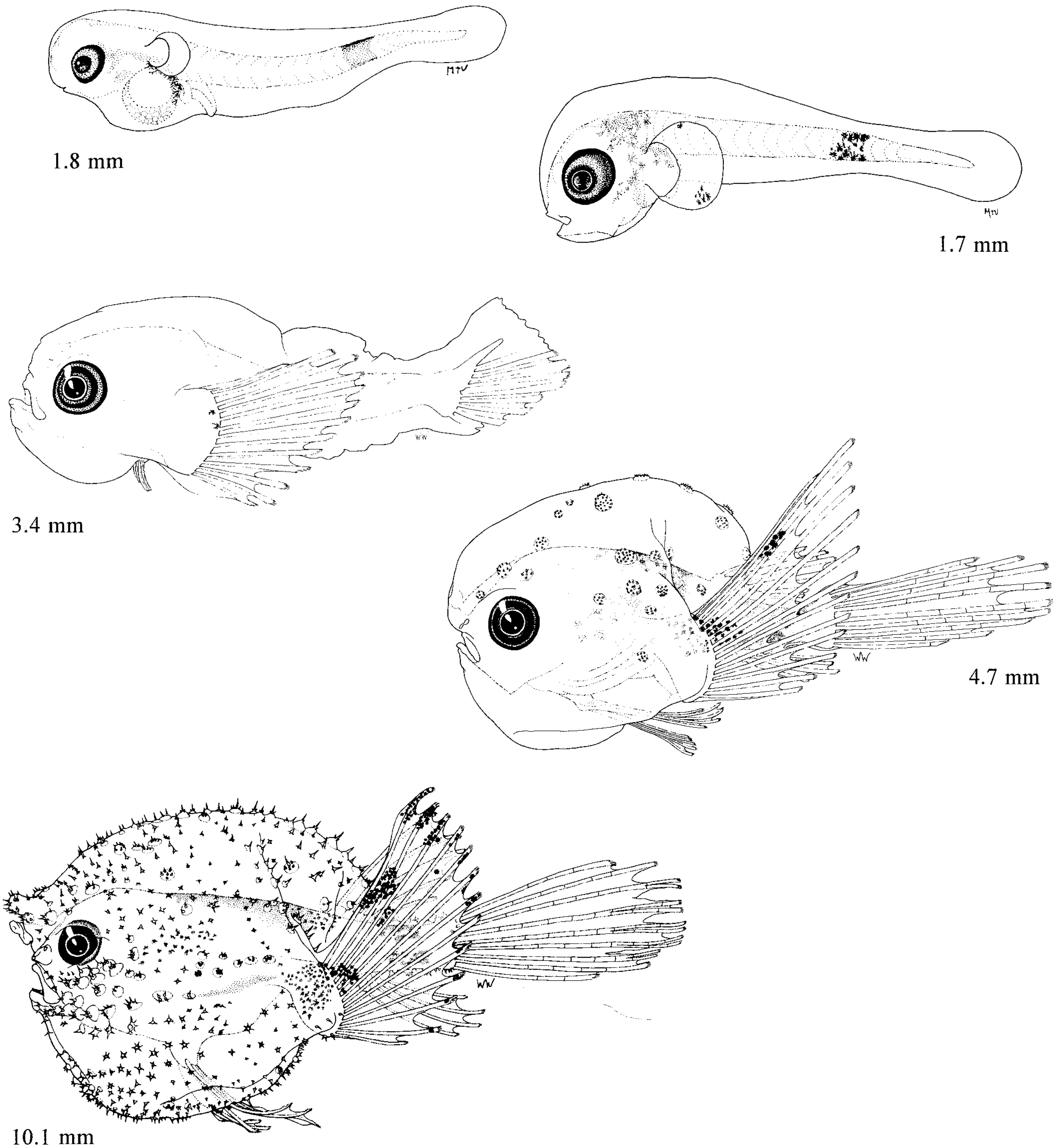


Figure Ogcocephalidae 1. Yolk-sac larva, 1.8 mm (IATTC 89023, station MAB #2 Grn); preflexion larva, 1.7 mm (IATTC 90031, station MAB #2 Grn); flexion larva, 3.4 mm (CalCOFI 5708, station 153G.35); early postflexion larva, 4.7 mm (CalCOFI 5209, station 153G.32); late postflexion larva, 10.1 mm (CalCOFI 5612, station 160G.20).

CAULOPHRYNIDAE: Fanfins

W. WATSON

Caulophrynidae contains about four species in two genera; three species (*Caulophryne jordani*, *C. pelagica*, and *C. polynema*) are known to occur in the California current vicinity (Pietsch 1979). Larval *Caulophryne*, however, are quite rare: none was identified from regular CalCOFI samples, and only a single specimen was found at an offshore station on an extended CalCOFI survey. Larvae are slightly less rare farther from shore and farther south.

Caulophrynids are epi- and mesopelagic inhabitants of the Atlantic, Indian, and Pacific Oceans between about 50° N and 40° S. Most specimens have been collected between about 40° N and 4° S at depths of ca. 1000–1500 m (Pietsch 1979). Adult female *Caulophryne* are small (<15 cm), deep-bodied and broad, with a relatively long preanal length, large head, large mouth, and long-based dorsal and anal fins (D 14–22, A 12–19) bearing very long fin rays. In contrast to other ceratioids, caulophrynids have an esca composed only of filaments: there is no escal bulb. The skin is dark brown to black and lacks spinules. Males are poorly known. Bertelsen (1951) described a free-living transforming male 7.5 mm long which was relatively slender, with well developed olfactory organs, a toothless mouth with lower denticle, and unpigmented skin. Parasitic males 12 and 16 mm long were entirely pigmented (Bertelsen 1951; Pietsch 1979). Pietsch (1976) described caulophrynid males as facultative sexual parasites that may become permanently attached to females or not, depending on the length of the time between attachment and spawning.

Spawning is unknown in the caulophrynids; it is assumed that they spawn floating gelatinous egg rafts (e.g., Bertelsen 1984). Larval size and stage of development at hatching are unknown. The least developed larva known, 3.0 mm, lacks yolk or oil droplet and has pigmented eyes, open mouth, straight notochord, and pectoral, pelvic, and caudal fin rays already forming. The pelvic, and especially the pectoral, fins are very large in larval *Caulophryne*, but the pelvics are lost during transformation and the pectorals become relatively smaller. Larval *Caulophryne* are deep-bodied and robust, with a moderate preanal length and large eyes. The epidermis is strongly inflated. Larval pigment is light, subdermal, and largely restricted to the head and gut. Males and females differ little, if at all, from one another prior to transformation.

Larval *Caulophryne* are distinguished from the larvae of all other ceratioids by having pelvic fins, as well as by having a strongly inflated epidermis, enormous pectoral fins, and high dorsal and anal fin-ray counts. High dorsal, anal, and pectoral fin-ray counts also allow discrimination of larval *Caulophryne* from the similar ogcocephalid larvae (Table Lophiiformes 1), as do their lack of pigment on the pectoral fins and tail, and lack of epidermal tubercles and spinules (present in postflexion ogcocephalids). Larvae of the three *Caulophryne* species cannot be reliably distinguished, although high dorsal and anal fin-ray counts may allow separation of larger postflexion stage *C. polynema* (Table Lophiiformes 1).

The following description is based on literature (Bertelsen 1951, 1984; Pietsch 1976) and on detailed examination of seven larval (1 preflexion, 3.0 mm; 1 flexion, 2.8 mm; 5 postflexion, 4.4–6.1 mm) and one juvenile female (19.9 mm) *Caulophryne* sp(p)., and two juvenile female *C. jordani* (19.2 and 28.6 mm). Meristic and zoogeographic data are from Bertelsen (1951) and Pietsch (1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	20	
Precaudal	9–10	
Caudal	10–11	
Fins:		
Dorsal spines	IL*	
Dorsal rays	14–22	
Anal spines	0	
Anal rays	12–19	
Pelvic	0–4†	
Pectoral	15–18	
Caudal:		
Principal	4+4	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	6	

LIFE HISTORY

Range: Atlantic, Indian, & Pacific Oceans, primarily ca. 40° N to 4° S

Habitat: Epi-, meso-, & bathypelagic, primarily ca. 1000–1500 m depth

Spawning season:

ELH pattern: Males are facultative sexual parasites; females oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

Bertelsen 1951, 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.8 mm (W. Watson)

* IL = illicium, a modified first D ray (Bertelsen 1951).
† P_2 present only in larvae.
‡ Females only.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 3–4 mm
Transformation length: ca. 12–16 mm
Fin development sequence: P_1 & P_2 & C, IL, D & A
Pigmentation: *Larvae*—Pigment subdermal; dorsally on peritoneum, spreading ventrad to cover upper 50–67% of gut; little on hindbrain. *Juvenile*—Epidermis completely pigmented.
Diagnostic features: Extremely large P_1; P_2 present; high D & A counts; large eyes; strongly inflated epidermis lacking spinules or tubercles; light pigmentation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv‡
Sn-A/BL				66–71		72–76
		56	56	69		73
BD/BL				76–90		38–50
		40	65	86		44
HL/BL				36–42		47–51
		36	36	40		50
HW/HL				77–93		35–61
		78	110	86		48
SnL/HL				16–26		35–42
		19	16	22		39
ED/HL				31–35		8–8
		39	39	33		8
P_1L/BL				32–49		
		23	26	40		21
P_2L/BL				31–53		0–0
		19	24	39		0

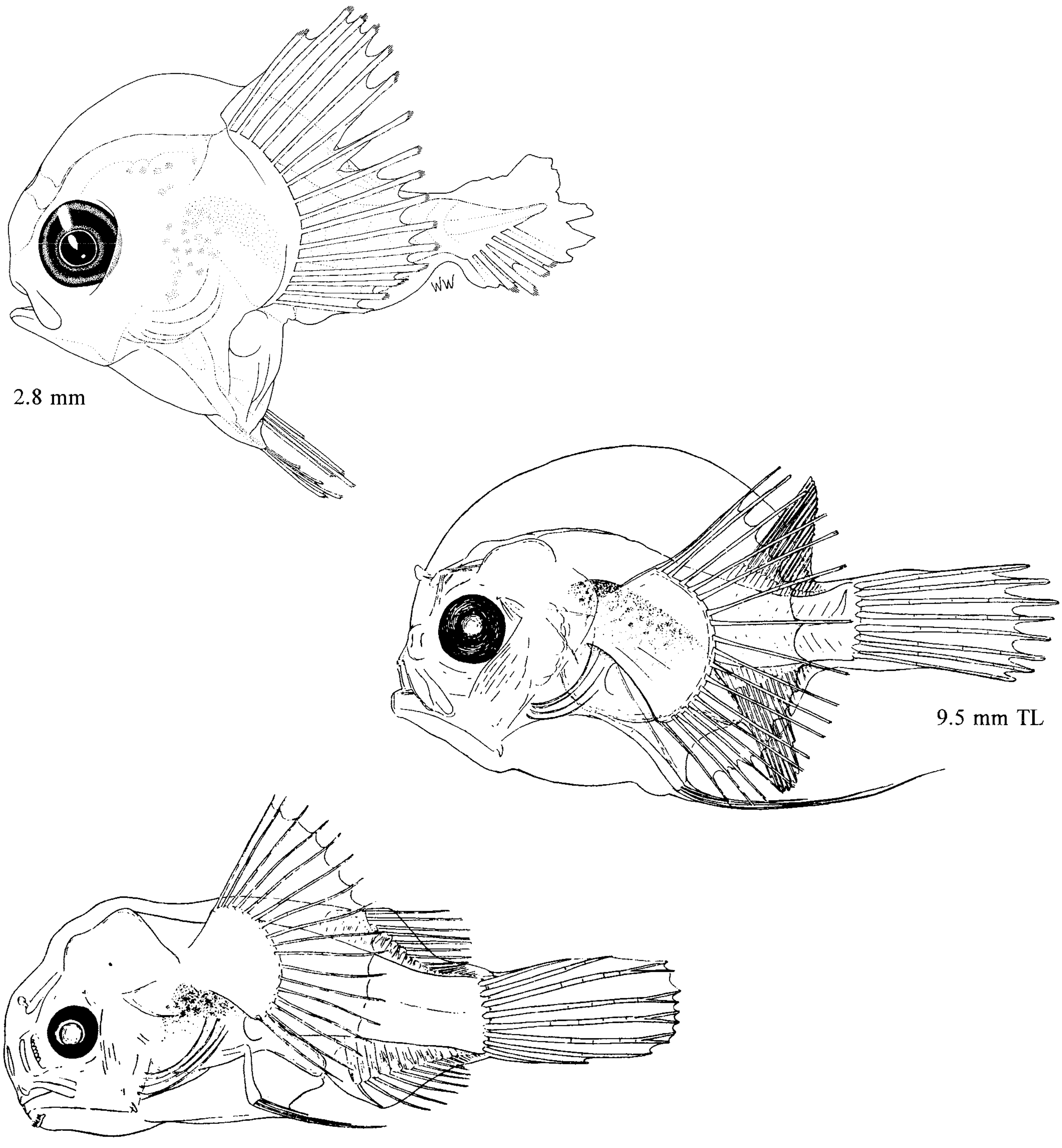


Figure Caulophrynidae 1. Preflexion larva, 2.8 mm (TC 8406, station 199); postflexion larva, 9.5 mm TL; transformation male, 10.0 mm TL (Bertelsen 1951).

MELANOCETIDAE: Blackdevils

W. WATSON

Melanocetidae contains five species in the genus *Melanocetus*; two of these, *M. johnsoni* and *M. eustalus*, occur in the vicinity of the California Current (Pietsch and VanDuzer 1980; Balushkin and Fedorov 1981). Larvae occur occasionally in CalCOFI samples off southern California and Baja California but are distributed primarily farther from shore and farther south.

Melanocetids occur in all the major oceans; *M. johnsoni* is cosmopolitan (Pietsch and VanDuzer 1980). Melanocetids are meso- and bathypelagic predators (Bertelsen 1951), occurring primarily in the 500–2,500 m depth range (Pietsch and VanDuzer 1980). Larvae do not range so far poleward, and occur primarily in the upper 200 m (Bertelsen 1951).

Melanocetids have high dorsal fin-ray counts (12–17) and low anal fin-ray counts (3–5). Adult females are small (generally ≤12 cm), deep-bodied and broad, with a moderately long preanal length and a large oblique mouth equipped with long fang-like teeth. The illicium is short to moderate in length with an unornamented or slightly ornamented esca. The skin is brown to black and partly ornamented with small dermal spinules. Free-living males are small (generally ≤4 cm), elongate, with oval eyes, rather pointed snouts, jaws lacking teeth but with well developed denticles, and skin that is lightly to darkly pigmented and spinulose or naked (Bertelsen 1951). Sexual parasitism apparently does not occur (Bertelsen 1951; Pietsch 1976).

It is assumed that melanocetids spawn floating gelatinous egg rafts (Bertelsen 1984). Larval size and development at hatching are unknown; the smallest known larvae (2.5 mm) are preflexion stage with pigmented eyes, functional mouth, and lacking fin rays. Larvae initially are deep-bodied with a short, coiled gut and slightly inflated epidermis. Body depth and preanal length increase substantially by the postflexion stage, and the epidermis becomes moderately inflated. The illicium is visible in females beginning late in the preflexion stage, the dorsal, anal, and caudal fin rays are present by the end of the flexion stage, and the pectoral fins are completed early in the postflexion stage. Melanocetids have 19–20 myomeres. Pigment is subdermal and initially occurs only on the branchial area and peritoneum. Melanophores subsequently are added on the occipital area, dorsally and dorsolaterally on the trunk, and on the pectoral fin base and/or caudal peduncle, depending on species. The epidermis becomes pigmented during transformation.

Larval melanocetids can be recognized by a combination of characters (P_1 not enlarged, notochord not strongly S-shaped, epidermis not strongly inflated, melanophores in distinct areas, D 12–17, A 3–5). Small preflexion specimens may resemble oneirodids or the ceratiid *Cryptopsaras couesii*. These usually can be separated by pigment differences and notochord shape. Prior to formation of the caudal peduncle pigment (ca. 3.5–3.8 mm), larval *M. johnsoni* cannot be reliably distinguished from other *Melanocetus* species (Bertelsen 1951). Larvae lacking caudal peduncle pigment were identified as *M. johnsoni* here based on a collection off southern California, where only *M. johnsoni* is reported to occur. The identification of free-living males was based primarily on similarities of their subdermal pigment patterns to the larval pattern of *M. johnsoni*.

The following description is based on literature (Bertelsen 1951, 1984; Miller et al. 1979), and on detailed examinations of 15 larvae (5 preflexion, 2.5–3.6 mm; 3 flexion, 3.6–3.9 mm; 7 postflexion, 3.7–11.7 mm), 1 transforming female (11.3 mm), 2 free-living males (19.3–20.0 mm), and 5 juvenile females (13.0–17.2 mm) of *M. johnsoni*.

MERISTICS

	Range	Mode
Vertebrae:		
Total	20	20
Precaudal	5–7	5
Caudal	13–15	15
Fins:		
Dorsal spines	IL*	IL
Dorsal rays	13–17	14–15
Anal spines	0	0
Anal rays	3–5	4
Pelvic	0	0
Pectoral	17–23	18–20
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Atlantic, Indian, & Pacific Oceans in tropical & subtropical water

Habitat: Meso- & bathypelagic, primarily 500–1500 m depth; larvae primarily in upper 100 m

Spawning season: Summer–fall (Bertelsen 1951)

ELH pattern: Oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

Bertelsen 1951, 1984
Miller et al. 1979

* IL = illicium, a modified D ray (Bertelsen 1951).
† Female.
‡ Males & females diverge markedly in morphology during transformation. The given ranges encompass both sexes; means are given separately for each sex: males first & females second. The eye becomes strongly oval in transformed males: only the horizontal (long) axis is given.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.3 mm
Flexion length: ca. 3.5–4 mm
Transformation length: ca. 11–15 mm
Fin development sequence: IL & C, A & P_1, D
Pigmentation: *Larvae*—Initially little dorsally, over hindbrain only; dorsal & dorsolateral trunk pigment present by 3.2 mm, spreads caudad to middle of D base by ca. 3.5 mm, to caudal peduncle by 7.8 mm; saddle on caudal peduncle by 3.5–3.8 mm, spreads ventrad to form bar by ca. 5.1 mm; gill cover moderately pigmented; dorsally & dorsolaterally on gut, spreading ventrad. *Juveniles*—Uniformly pigmented except on fin rays & illicium.
Diagnostic features: Deep-bodied, somewhat globular shape; epidermis slightly to moderately inflated; D usually 14–15; A usually 4; P_2 absent; pigment saddle or bar on caudal peduncle after ca. 3.5 mm becomes confluent with dorsal trunk pigment by ca. 8 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr†	Juv‡
Sn-A/BL		44–56	63–75	72–84		66–76
		51	68	77	74	73/70
BD/BL		34–53	51–61	55–80		34–100
		45	57	67	81	35/86
HL/BL		27–37	34–42	43–49		41–49
		33	38	45	41	49/44
HW/HL		84–100	94–109	71–105		54–155
		90	101	95	147	54/139
SnL/HL		19–29	18–19	20–34		24–39
		23	18	27	34	36/32
ED/HL		40–49	43–48	18–45		13–18
		44	45	30	17	14/15
P_1L/BL		9–11	11–13	14–15		11–27
		10	12	15	22	13/23

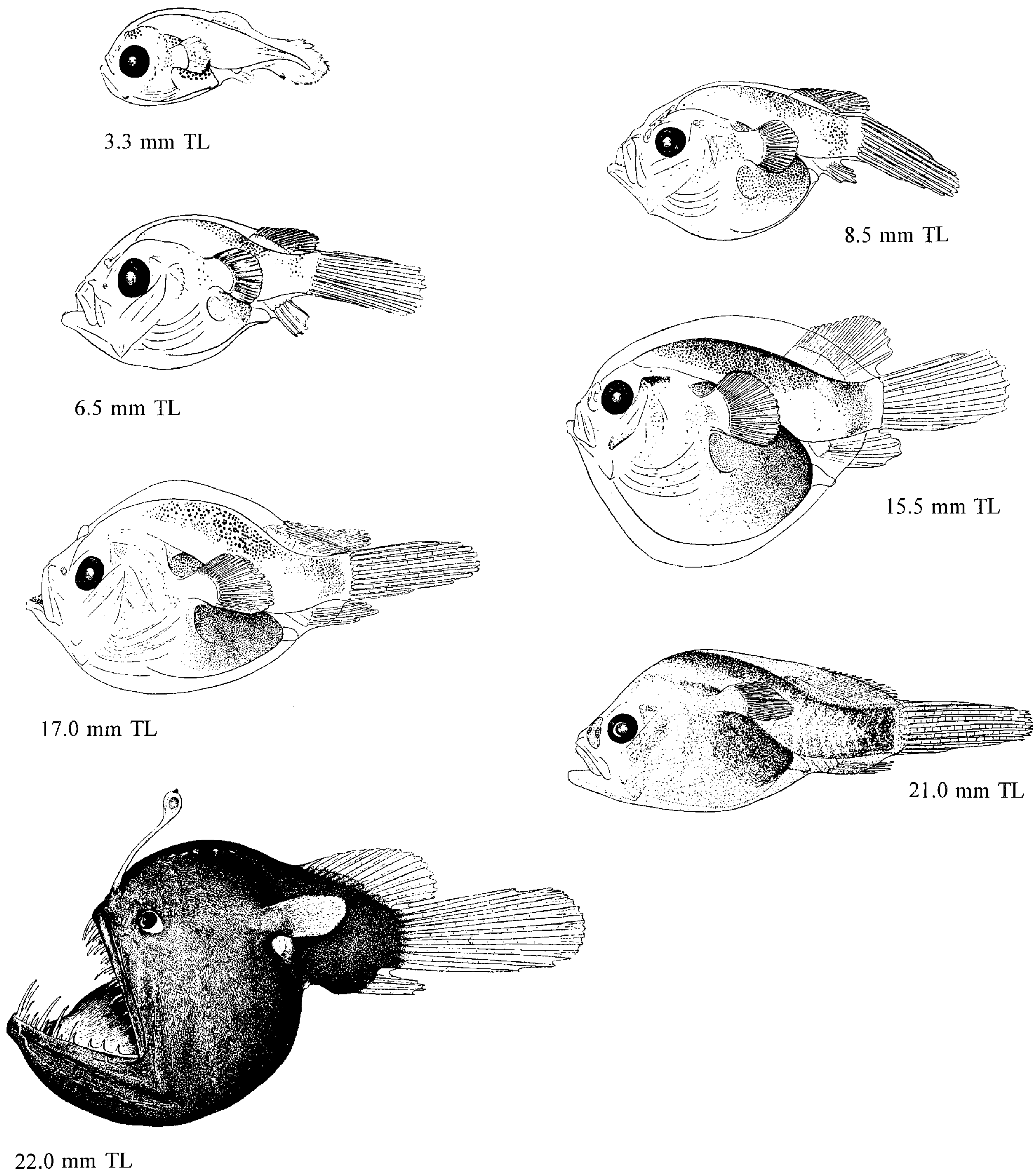


Figure Melanocetidae 1. Females are shown on the left, males on the right (Bertelsen 1951).

ONEIRODIDAE: Dreamers

W. Watson

Oneirodidae contains about 60 species in 16 genera (Nelson 1994); nine species of five genera are known to occur in the California Current region (Table Lophiiformes 1). Oneirodids are the most commonly occurring ceratioid larvae in CalCOFI samples: most are *Oneirodes* spp. Larval *Dolopichthys* spp. are taken occasionally, and rarely, *Chaenophryne longiceps* and *C. melanorhabdus*. *Microlophichthys microlophus* has not been identified from regular CalCOFI samples, but a few larvae were taken at offshore stations on extended CalCOFI surveys. Although both *Dolopichthys* and *Oneirodes* larvae have been collected as far north as Point Arguello, California, and larval *Chaenophryne* as far north as Point Reyes, California, all occur most frequently off Baja California and farther south.

Oneirodids occur in all major oceans, most commonly in tropical and subtropical water. Individual species may have rather restricted ranges (e.g., Pietsch 1974). Females are meso- and bathypelagic predators (e.g., Bertelsen 1951; Fitch and Lavenberg 1968); feeding has not been shown in males although postmetamorphic growth in the non-parasitic species implies that they do feed (Pietsch 1976).

Adult female oneirodids are small (most species <20 cm), globular to somewhat elongate, with a large head typically bearing prominent sphenotic spines and a preanal length about two-thirds of body length. The illicium with variously ornamented esca provides the primary means by which species are recognized (Pietsch 1974; Orr 1991). The skin is dark brown to black and is naked or ornamented with minute spinules, depending on genus. Males are quite small (<2 cm), moderately slender and elongate, with large olfactory organs and short denticles. The skin is dark brown to black. Male *Leptacanthichthys* are thought to be facultative sexual parasites that attach temporarily or permanently, depending on the length of time between attachment and spawning (Pietsch 1976). Male *Chaenophryne*, *Microlophichthys*, probably *Dolopichthys*, and at least some *Oneirodes* species apparently are not parasitic (Bertelsen 1951; Pietsch 1976).

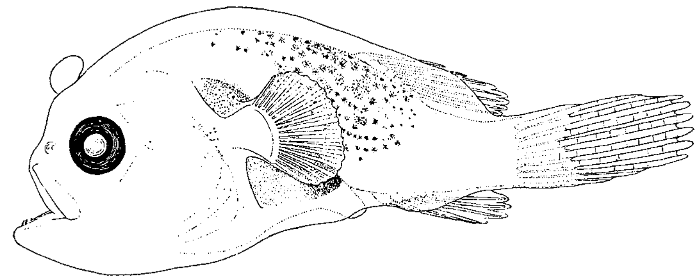
Spawning is unknown in oneirodids, but females with well developed ovaries, containing maturing eggs ranging from 0.2–0.7 mm in diameter, are known for several species (e.g., Pietsch 1972a, 1973, 1974, 1976; Bertelsen and Pietsch 1977). It is assumed that oneirodids spawn floating gelatinous egg rafts (Bertelsen 1984). Larval size and stage of development at hatching are unknown. Two apparently recently hatched preflexion stage *Oneirodes* spp. (2.0 mm) have pigmented eyes, functional mouths, small yolk reserve (one specimen) with a few small oil globules (both specimens), and have not yet begun development of the dorsal, anal, and caudal fins. Larvae initially are moderately deep-bodied with a moderately short, coiled gut, but quickly become deep-bodied (BD usually >50% BL) with moderate to long preanal length (ca. 60–75% BL). The epidermis is slightly to moderately inflated. By midway through notochord flexion the full complements of dorsal, anal, and caudal fin rays are visible; the pectoral fin is completed in the postflexion stage. Oneirodids have 19–23 myomeres (usually 20–21), but it seldom is possible to make accurate counts of the preanal myomeres owing to the inflated epidermis. Larval pigment is largely subdermal and may occur in any of several areas: on the gill cover and peritoneum, dorsally and dorsolaterally on the trunk, on the caudal peduncle, and on the caudal fin. The epidermis becomes pigmented during transformation. Larval males and females differ little from one another, except that the illicium is visible in females beginning early in the preflexion stage, and the enlarged olfactory organs are visible in the larger postflexion stage males.

Larval oneirodids can be recognized by a combination of morphology (P_1 not enlarged, vertebral column more or less straight, epidermis not strongly inflated), pigment (melanophores usually in distinct areas), and meristics (D<9, A usually >3, P_2 absent, 6 branchiostegal rays) (Bertelsen 1951). Pigment and meristic characters allow identification of some oneirodid species and species groups (Bertelsen 1951). Presently, larval *Oneirodes* and *Dolopichthys* can be identified only to genus, while *Chaenophryne* in CalCOFI samples can be identified to species, largely because only two species have been reported from the California Current vicinity (Pietsch 1975). Larvae identified as *C. longiceps* and *C. melanorhabdus* closely resemble larvae of the *C. longiceps* group and *C. draco* group, respectively, that were described by Bertelsen (1951). Both are shown in Figure Oneirodidae 1, but species accounts are not given since very few specimens were available. Likewise, *Microlophichthys microlophus*, whose larvae were described by Bertelsen (1951), is shown in Figure Oneirodidae 1 but not described separately here. Larval *Phyllorhinichthys micractis* and *Bertella idiomorpha* were not identified in CalCOFI samples; Bertelsen and Pietsch (1977) described a larva of *P. micractis* (reproduced in Figure Oneirodidae 1), while larvae of *B. idiomorpha* are unknown (Pietsch 1973).

The following descriptions are based on literature (Bertelsen 1951) and on detailed examinations of 18 larval *Dolopichthys* spp., 2 juvenile females of *D. longicornis* and 4 of *D. pullatus*, 28 larval and 3 juvenile male *Oneirodes* spp., a transforming female *O. acanthias* and 2 juvenile females each of *O. acanthias* and *O. eschrichtii*. (Table Oneirodidae 1).

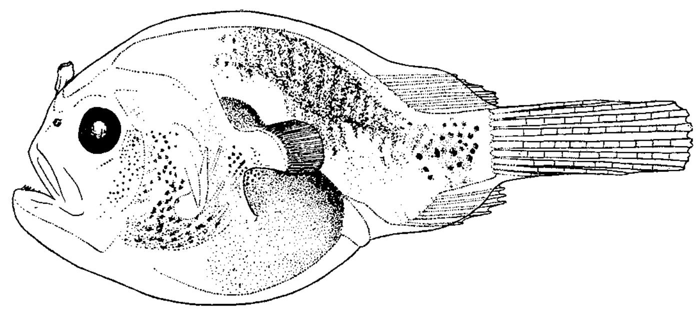
Table Oneirodidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the oneirodid species descriptions.

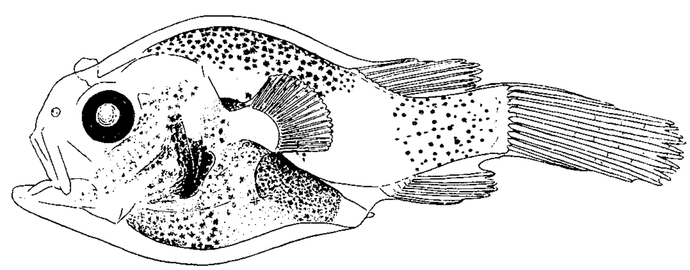
Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Dolopichthys spp.	0	8	5	5	0	6
		1.9–3.5	3.0–5.0	3.8–7.9		13.9–19.3
Oneirodes spp.	2	10	6	10	1	7
	2.0	2.2–3.4	3.0–4.1	3.6–6.5	11.5	12.6–18.3



Chaenophryne draco species group
13.0 mm TL

Chaenophryne longiceps species group
19.0 mm TL





Microlophichthys microlophus
12.1 mm TL

Phyllorhinichthys micractis
10.8 mm

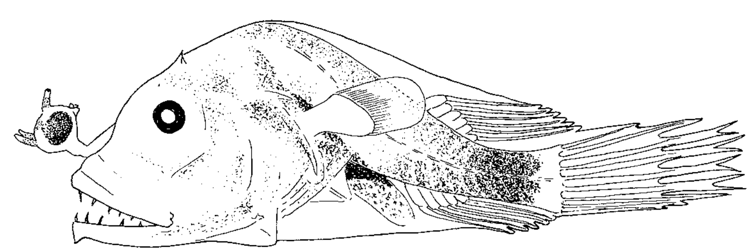


Figure Oneirodidae 1. Larval female oneirodids that occur in the California Current but are not described in this chapter. All illustrations except *Phyllorhinichthys* are from Bertelsen (1951); *P. micractis* is from Bertelsen and Pietsch (1977).

MERISTICS

	Range	Mode
Vertebrae:		
Total	19–21	
Precaudal	4–5	
Caudal	15–16	
Fins:		
Dorsal spines	IL†	
Dorsal rays	5–7	
Anal spines	0	
Anal rays	4–6	
Pelvic	0	
Pectoral	17–22	
Caudal:		
Principal	4+5	
Procurrent:		
Upper	0	
Lower	0	
Gill rakers:		
Upper	0	
Lower	0	
Branchiostegals	6	

LIFE HISTORY

Range: Atlantic, Pacific, & Indian Oceans; in eastern Pacific, *D. longicornis* ca. 41° to 7° N, *D. pullatus* ca. 34° N to 34° S, including the Gulf of California

Habitat: Meso- & bathypelagic

Spawning season: Summer (Bertelsen 1951)

ELH pattern: Oviparous; presumably, eggs contained in floating gelatinous raft; larvae are planktonic

LITERATURE

Bertelsen 1951, 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 4.5 mm (M. T. Vona)

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* *D. longicornis* & *D. pullatus* occur in the California Current region; most of the larvae examined here were from the eastern tropical Pacific, where *D. allector* also occurs (ca. 5° N to 35° S).

† IL=illicium, a modified D ray (Bertelsen 1951).

‡ Females only: *D. longicornis* (2) & *D. pullatus* (4).

EARLY LIFE HISTORY DESCRIPTION

EGGS

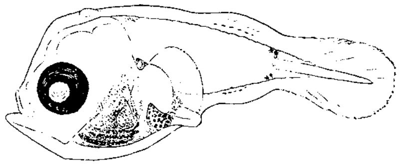
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

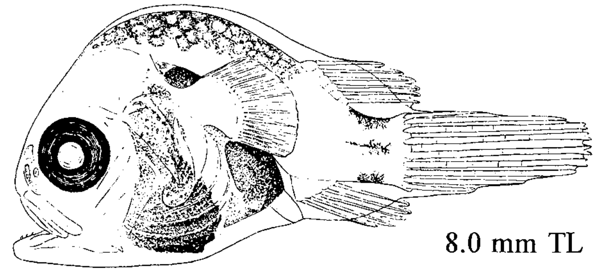
Hatching length: <2.3 mm
Flexion length: ca. 3–4 mm
Transformation length: Males ca. 11–15 mm, females ca. 12–14 m
Fin development sequence: IL, D & A & P_1 & C
Pigmentation: *Larvae*—Initially little or none dorsally on nape & trunk, increases rapidly & spreads caudad to level of D origin by ca. 5 mm; densely covering upper 75% of gut initially, spreads ventrad to completely surround gut by ca. 3 mm; heavy on branchiostegal membrane, may be denser along margin before ca. 3 mm; internal & external bar on caudal peduncle usually consisting of distinct dorsal, midlateral, & ventral groups. *Juvenile*—Entirely pigmented.
Diagnostic features: Heavily pigmented gill cover; gut completely surrounded with pigment by ca. 3 mm; trunk & peritoneal pigment not contiguous; trunk pigment extending caudad only slightly past D origin; caudal peduncle pigment bar usually of more or less distinct dorsal, midlateral, & ventral groups.

MORPHOMETRICS (range & mean in %)

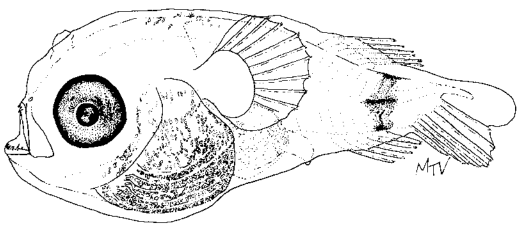
	Y-S	PrF	F	PoF	Tr	Juv‡
Sn-A/BL		44–55 48	58–64 60	68–76 71		65–77 71
BD/BL		31–43 37	42–54 48	54–60 57		42–51 47
HL/BL		28–36 30	32–38 35	38–43 40		43–53 47
HW/HL		81–109 98	78–106 90	90–107 96		54–80 69
SnL/HL		19–27 24	17–23 20	20–23 22		41–58 49
ED/HL		39–50 43	38–44 42	36–41 39		8–15 10
P_1L/BL		6–16 10	10–12 11	11–14 13		10–16 13



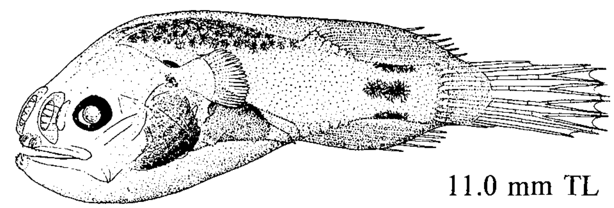
2.6 mm TL



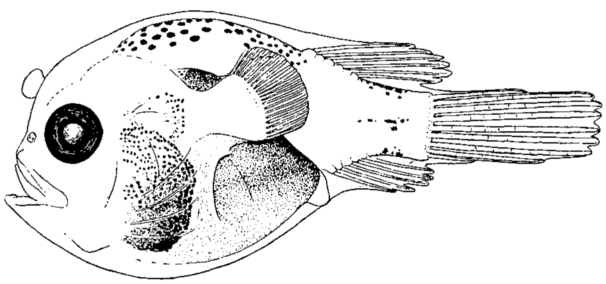
8.0 mm TL



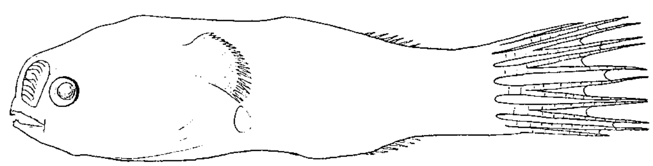
4.5 mm



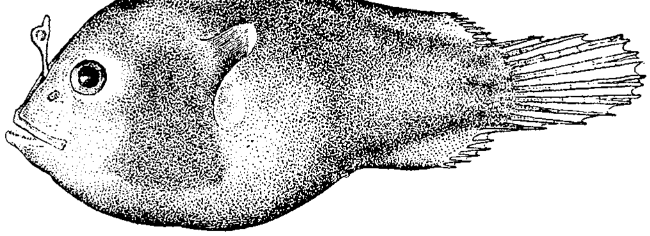
11.0 mm TL



10.4 mm TL



17.3 mm TL



14.3 mm TL

Figure Oneirodidae 2. Females are shown on the left, males on the right. Preflexion female, 2.6 mm TL; flexion female, 4.5 mm (EASTROPAC II, station 46.86); postflexion male, 8.0 mm TL; postflexion female, 10.4 mm TL; transformation male, 11.0 mm TL; transformation female, 14.3 mm TL; mature free-living male, 17.3 mm TL. The caudal peduncle pigment is clearly separated into dorsal, lateral, and ventral melanophore patches in the Atlantic Ocean specimens; in eastern Pacific specimens, the melanophore groups are less clearly separated. All figures except the 4.5 mm female are from Bertelsen (1951).

MERISTICS

	Range	Mode
Vertebrae:		
Total	19–21	20
Precaudal	4–5	4
Caudal	14–16	16
Fins:		
Dorsal spines	IL*	IL
Dorsal rays	5–7	6
Anal spines	0	0
Anal rays	3–5	4
Pelvic	0	0
Pectoral	15–19	15–17
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Genus is worldwide between ca. 60° N & 65° S; species are more restricted; *O. acanthias*, *O. basili*, *O. eschrichtii* in CalCOFI area

Habitat: Meso- & bathypelagic to ca. 3,000 m, primarily ca. 500–1500 m depth; larvae primarily in upper 200 m

Spawning season:

ELH pattern: Oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic; males are not parasitic.

LITERATURE

Bertelsen 1951, 1984
Minami 1988

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.1 mm (W. Watson)
Preflexion larva, 2.4 mm (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2 mm
Flexion length: ca. 3–4 mm
Transformation length: Males ca. 6–10 mm, females ca. 12 m
Fin development sequence: IL & C, D & A, P_1
Pigmentation: *Larvae*—On posterior margin of gill cover, spreading over entire gill cover by ca. 2.2 mm; dorsally on gut, spreading down sides to cover upper 60–70% of gut by ca. 3 mm; on nape & hindbrain, spreading down to meet peritoneal pigment by ca. 2.2 mm & caudad to D origin by ca. 3 mm & to D insertion by ca. 5–6 mm. *Juvenile*—Body brown to black.
Diagnostic features: Heavy opercular pigment; trunk & gut pigment usually continuous; caudal peduncle unpigmented; epidermis slightly to moderately inflated; D usually 6; A usually 4; 6 branchiostegal rays.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr†	Juv‡
Sn-A/BL	42–46 44	36–48 41	45–59 55	67–80 74	 72	61–79 63/75
BD/BL	26–28 27	26–41 33	39–53 46	48–67 60	 49	31–63 33/56
HL/BL	23–25 24	21–30 26	30–35 33	38–50 43	 44	30–58 38/55
HW/HL	96–100 98	78–94 87	76–117 96	83–101 94	 73	59–100 73/74
SnL/HL	21–24 22	19–29 24	17–25 20	17–23 20	 38	26–43 29/36
ED/HL	44–48 46	37–50 44	33–48 41	33–44 36	 13	5–19 18/7
P_1L/BL	6–7 6	7–9 8	9–12 10	11–17 14	 14	11–22 12/19

* IL = illicium, a modified D ray (Bertelsen 1951).
† *Oneirodes acanthias* female.
‡ Males & females diverge morphometrically during transformation. The given ranges encompass both sexes; means are given separately for each sex: males first & females second. Females are *O. acanthias* (2) & *O. eschrichtii* (2).

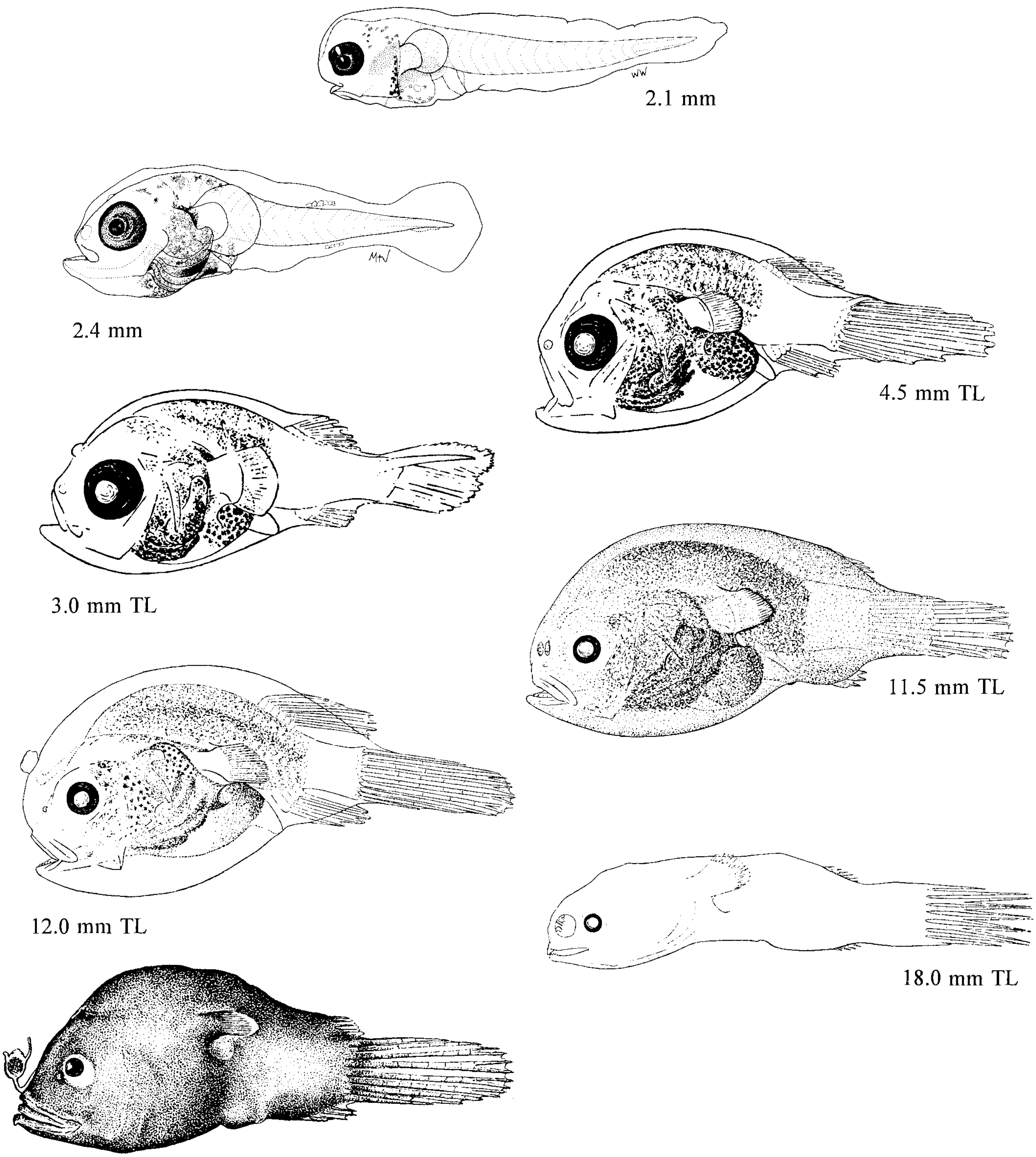


Figure Oneirodidae 3. Females are shown on the left, males on the right. Yolk-sac larva, 2.1 mm (CalCOFI 6909, station 100.60); preflexion female, 2.4 mm (CalCOFI 7510, station 103.90); flexion female, 3.0 mm TL and male 4.5 mm TL; postflexion female, 12.0 mm TL; transformation male, 11.5 mm TL; juvenile female, 12.5 mm TL and male 18.0 mm TL (Bertelsen 1951).

CERATIIDAE: Seadevils

W. WATSON

Although two of the four ceratiid species, *Ceratias holboelli* and *Cryptopsaras couesii*, are known to occur in the CalCOFI area (Pietsch 1986), only a single larva of *C. couesii* has been identified from regular CalCOFI collections. A few larval *C. couesii* have been taken at offshore stations on extended CalCOFI surveys and larvae of both species have been taken on cruises to the south and farther from shore.

Adult female ceratiids are moderately large (*Cryptopsaras* to at least 44 cm, *Ceratias holboelli* to at least 77 cm), deep-bodied and compressed. They have a nearly vertical mouth opening, an illicium with esca, 2 (*Ceratias*) or 3 (*Cryptopsaras*) caruncles on the back just before the dorsal fin, heavily spinulose and pigmented skin, and very small eyes. Free-living transformed males, in contrast, are small (<ca. 14 mm), rather slender, with large eyes and a more-or-less horizontal mouth bearing well developed denticles. They lack the illicium, caruncles, and spinules, and are lightly pigmented. Males larger than ca. 10 mm typically are parasitically attached to females: sexual parasitism apparently is obligatory in the ceratiids (Pietsch 1976).

Ceratiids are thought to be oviparous and are assumed to spawn floating gelatinous egg rafts, as has been documented for some of the other lophiiform fishes (Bertelsen 1984). Bertelsen (1951) described recently hatched 3-mm TL *Ceratias holboelli* as having pigmented eyes, undifferentiated fins, elongated notochord, and some remaining yolk.

Larval ceratiids are moderately deep-bodied, with a large head, nearly vertical mouth opening, preanal length about half to two-thirds of body length, somewhat inflated epidermis, and strongly arched notochord/vertebral column which results in a "humpbacked" appearance (Bertelsen 1951). The caruncles are visible, forming in the dorsal finfold, in the smallest larval females examined. Larval pigmentation ranges from absent (some *C. holboelli*) to moderate (*Cryptopsaras*); when present, it is primarily dorsal and dorsolateral on the trunk and gut. During transformation, males and females diverge markedly in both morphology and pigmentation (males become heavily pigmented after attachment).

Larval ceratiids usually can be distinguished from similar-appearing larvae (principally Lophiiformes and some Tetraodontiformes) by their strongly "humpbacked" shape, nearly vertical mouth opening, and at least as early as notochord flexion by having 4 rays each in the dorsal and anal fins (rarely 3 or 5 dorsal rays), 8 or 9 caudal fin rays, 6 branchiostegal rays, and no pelvic fins (Table Lophiiformes 1). The caruncles provide certain identity (to Ceratiidae) of larval females. The two ceratiid species that might be encountered in the California Current vicinity are easily distinguished by counts of caudal fin rays and by larval pigmentation, especially the distinctive ring of melanophores encircling the "neck" of larval *Cryptopsaras couesii*. When the caruncles are adequately developed (during the postflexion stage), their number allows discrimination of female *Ceratias* from *Cryptopsaras*.

The following descriptions are based on detailed examinations of 14 specimens of *Ceratias holboelli* and 29 *Cryptopsaras couesii* (Table Ceratiidae 1), together with literature sources (Bertelsen 1951, 1984; Mead et al. 1964; Pietsch 1976, 1986; Minami 1988). Meristic data were obtained from Bertelsen (1951), Pietsch (1986), and from counts made during this study.

Table Ceratiidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the ceratiid species descriptions.

				Transformation		Juvenile	
Species	Preflexion	Flexion	Postflexion	Male	Female	Male	Female
Ceratias holboelli	0	6 2.4–3.6	2 4.1–5.1	0	1 11.9	0	5 9.1–26.5
Cryptopsaras couesii	1 2.7	5 2.5–3.3	9 2.8–8.7	4 6.4–8.6	1 8.0	4 8.9–10.2	5 10.5–14.8

MERISTICS

	Range	Mode
Vertebrae:		
Total	20	20
Precaudal		
Caudal		
Fins:		
Dorsal spines	IL, 2Ca*	IL, 2Ca
Dorsal rays	3–4	4
Anal spines	0	0
Anal rays	4	4
Pelvic	0	0
Pectoral	15–19	17–18
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Worldwide, primarily north of ca. 10° S; throughout CalCOFI area, well offshore

Habitat: Epi-, meso-, & bathypelagic, primarily ca. 400–2000 m depth; larvae shallower than adults

Spawning season: Summer (Bertelsen 1951)

ELH pattern: Parasitic males; females oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

Bertelsen 1951, 1984
Minami 1988

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larvae, 2.9 mm, 3.4 mm (W. Watson)
Transformation female, 11.9 mm (W. Watson)

* IL = illicium; Ca = caruncle. Both are modified from D rays (Bertelsen 1951).
† Females only.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: Near 3 mm
Flexion length: ca. 3.5–4 mm
Transformation length: ca. 9–12 mm
Fin development sequence: IL & Ca, D & C, A, P_1
Pigmentation: *Flexion–postflexion*—Little or no pigment; when present, sparse on dorsal & dorsolateral surfaces of gut &, internally, on caudal peduncle near base of hypural plate. *Transformation*—Females completely pigmented except on inner surface of P_1 base; males remain lightly pigmented.
Diagnostic features: Vertebral column strongly arched; D & A rays 4; C rays 9; P_2 absent; branchiostegal rays 6; little or no larval pigment; 2 caruncles visible on females by 2.4–3.4 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr†	Juv†
Sn-A/BL			48–61 54	65–70 68	66	62–77 68
BD/BL			43–67 53	53–60 57	45	38–55 43
HL/BL			34–45 38	43–47 45	45	38–53 45
HW/HL			76–118 98	96–116 106	61	49–82 66
SnL/HL			26–48 33	38–40 39	45	37–52 42
ED/HL			27–41 33	22–25 24	9	6–16 9
P_1L/BL			9–17 12	13–15 14	13	7–15 11

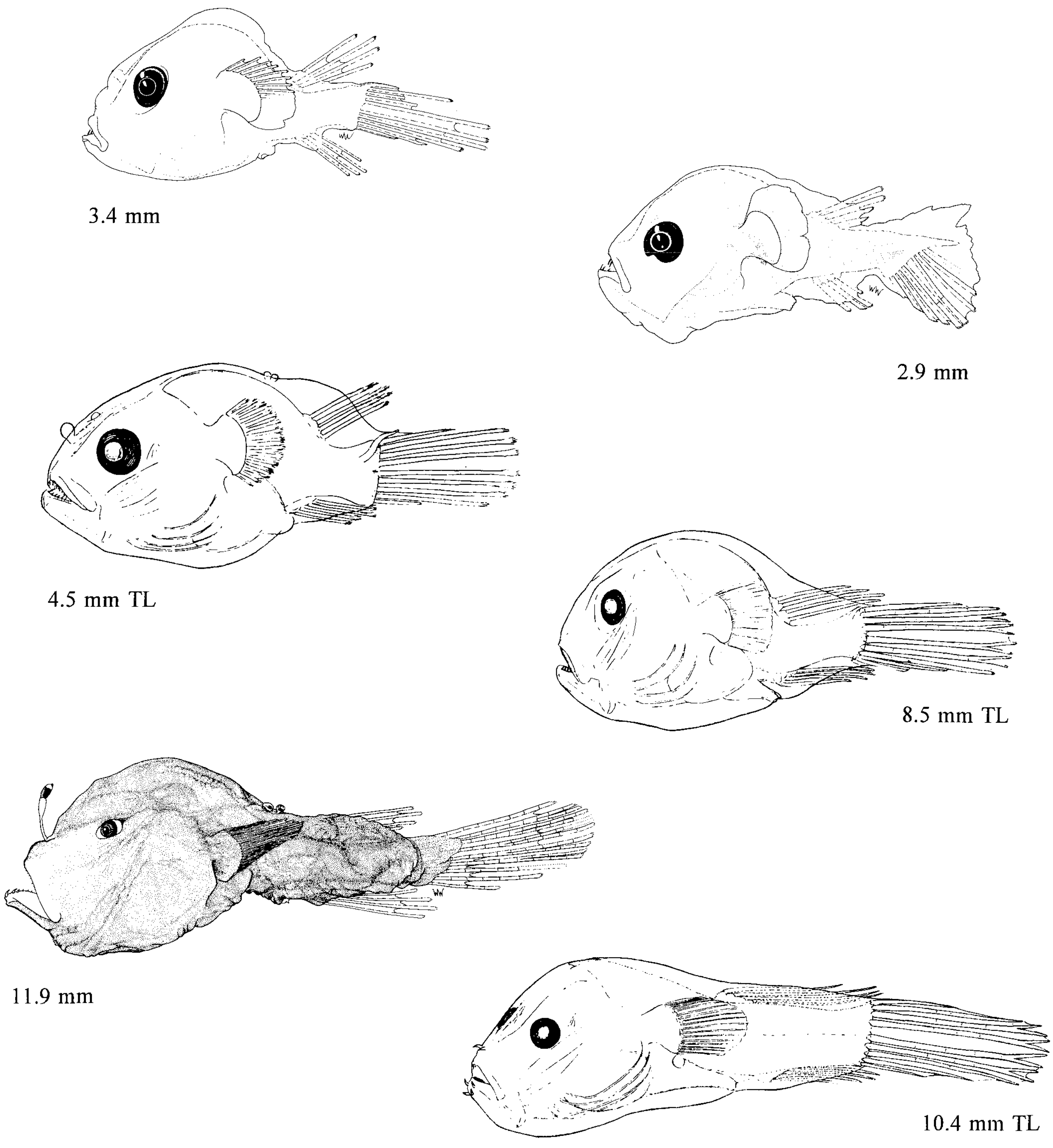


Figure Ceratiidae 1. Females are shown on the left, males on the right. Flexion female, 3.4 mm (Aries IX, station A2) and male, ca. 2.9 mm (EASTROPAC II, station 46.161); postflexion female, 4.5 mm TL and male, 8.5 mm TL (Bertelsen 1951); transformation female, 11.9 mm (SIO 71–308) and male, 10.4 mm TL (Bertelsen 1951).

MERISTICS

	Range	Mode
Vertebrae:		
Total	20	20
Precaudal		
Caudal		
Fins:		
Dorsal spines	IL, 3Ca*	IL, 3Ca
Dorsal rays	4–5	4
Anal spines	0	0
Anal rays	4	4
Pelvic	0	0
Pectoral	14–18	15–17
Caudal:		
Principal	4+4	4+4
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Worldwide; throughout CalCOFI area south of Monterey Bay, California

Habitat: Epi-, meso-, & bathypelagic, typically ca. 500–1250 m depth; larvae shallower than adults

Spawning season: Probably summer (Bertelsen 1951)

ELH pattern: Parasitic males; females oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

Bertelsen 1951, 1984
Minami 1988

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 3.3 mm (W. Watson)

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* IL = illicium; Ca = caruncle. Both are modified from D rays (Bertelsen 1951).

† Males & females diverge markedly during transformation. The given ranges encompass both sexes; means are given separately for each sex: males first & females second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 3 mm
Transformation length: Males ca. 6.5–8.5 mm, females ca. 8–10 mm
Fin development sequence: IL & Ca & C, D, A & P_1
Pigmentation: *Flexion–postflexion*—Narrow band encircling body at level of nape; dorsally & dorsolaterally on body above gut, spreading ventrad & caudad; laterally on caudal peduncle; internally on dorsal & dorsolateral surfaces of gut. *Transformation*—females completely pigmented except on D, A, & C rays; males lightly pigmented, retain larval pattern.
Diagnostic features: Vertebral column strongly arched; D & A rays 4; C rays 8; P_2 absent; branchiostegal rays 6; ring of melanophores around "neck"; 3 caruncles visible on females by 3.3 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr†	Juv‡
Sn-A/BL			40–62	64–74	67–71	68–77
		50	55	71	69/71	70/73
BD/BL			44–62	53–69	31–72	28–65
		50	52	61	39/72	31/57
HL/BL			31–53	40–49	43–53	41–53
		36	39	46	47/53	45/50
HW/HL			74–110	70–129	51–117	43–72
		110	91	97	60/117	48/67
SnL/HL			15–35	29–40	31–49	40–55
		30	30	34	37/37	44/47
ED/HL			29–44	17–45	19–26	11–22
		37	36	26	21/26	20/11
P_1L/BL			8–14	12–16	10–13	9–16
		12	11	14	12/13	11/15

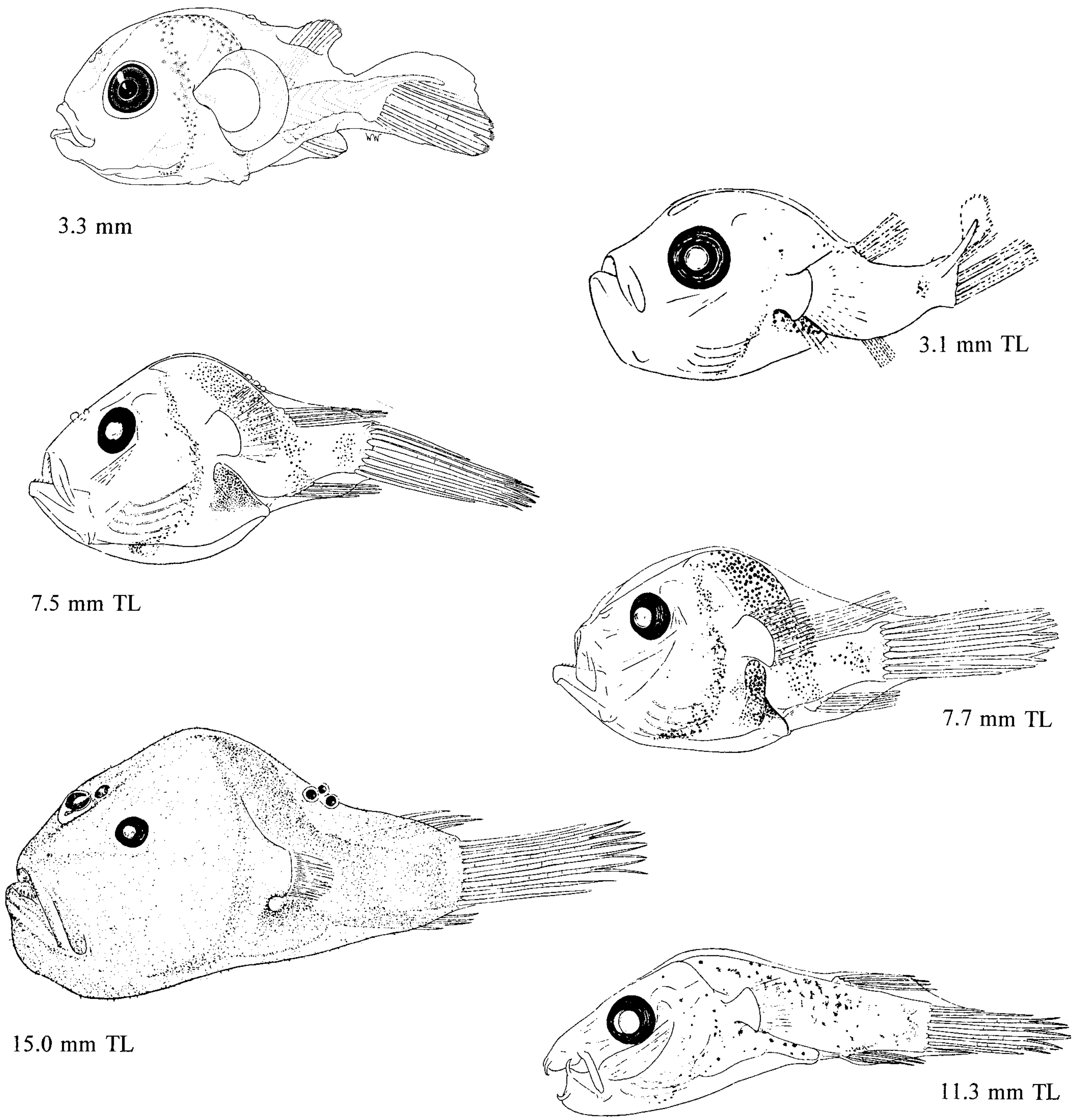


Figure Ceratiidae 2. Females are shown on the left, males on the right. Flexion female, 3.3 mm (EASTROPAC II, station OP.072) and male, 3.1 mm TL (Bertelsen 1951); postflexion female, 7.5 mm TL and male, 7.7 mm TL (Bertelsen 1951); transformation female, 15.0 mm TL; juvenile male, 11.3 mm TL (Bertelsen 1951).

GIGANTACTINIDAE: Whipnoses

W. WATSON

Gigantactinidae contains 21 species in two genera; five *Gigantactis* species (Table Lophiiformes 1) occur in the California Current vicinity (Bertelsen et al. 1981; Kharin 1984). One or two larval types occur in small numbers in CalCOFI collections off southern California and Baja California, primarily at the offshore stations.

Gigantactinid females are active meso- and bathypelagic predators (Fitch and Lavenberg 1968) widely distributed (ca. 63° N to 63° S) through the Atlantic, Indian, and Pacific Oceans. Larvae and males have been reported only between about 48° N and 34° S (Bertelsen 1951; Bertelsen et al. 1981). Adult females are small to medium-size (up to ca. 60 cm, but most species within ca. 10–40 cm range), moderately slender fishes with heavily pigmented, spinulose skin, well developed dentition, very small eyes, and a long illicium with ornamented esca. Males are small (<30 mm), moderately slender, lack an illicium, and have skin that is unpigmented to heavily pigmented and naked or spinulose, depending on species. All males have large olfactory organs and well developed denticles. There is no evidence that males attach parasitically to females (Pietsch 1976).

Gigantactinids are thought to be oviparous, with eggs contained in floating gelatinous rafts (Bertelsen 1984). A recently hatched 1.9 mm *Gigantactis* has fully pigmented eyes, a well developed mouth, and a small amount of yolk. Larvae are deep-bodied, with large head, preanal length ca. 50–67% of body length, greatly inflated epidermis, and very large pectoral fins. Pigmentation of the California Current larval types ranges from nearly absent to moderate. The least pigmented larvae, corresponding to Bertelsen's (1951) Type B, have a few dorsal melanophores on the gut through the early part of the postflexion stage, then add light pigmentation on the dorsum from the nape to dorsal fin. The most heavily pigmented larvae, perhaps corresponding to Bertelsen's (1951) Type A, are more heavily pigmented in these same areas beginning in the preflexion stage. Males and females differ little before transformation, except that the illicium is visible in postflexion stage females.

Larval gigantactinids can be distinguished from similar-appearing larvae (some Lophiiformes and some newly hatched Scorpaeninae) by a combination of characters: light pigmentation, strongly inflated epidermis, very large pectoral fins lacking pigment, no pelvic fins, and 21–22 myomeres (accurate counts often cannot be made through the inflated epidermis). The *Gigantactis* larval types in CalCOFI samples cannot always be distinguished from one another because pigmentation is variable and there is slight overlap in some meristic characters (Type B: 5–6 rays in D and A, 18–20 P_1; Type A(?): 4–5 D rays, 4 A rays, 16–17 P_1). Bertelsen et al. (1981) identified Type A as larvae of the *G. vanhoeffeni* species group; among these, only *G. vanhoeffeni* occurs in the CalCOFI area, but it has higher counts of dorsal, anal, and pectoral fin rays (Bertelsen et al. 1981). Type B larvae may include at least three species from the CalCOFI area: *G. gargantua*, *G. microdontis*, and *G. savagei* (Bertelsen et al. 1981).

The following descriptions are based on literature (Bertelsen 1951, 1984; Bertelsen et al. 1981) and on detailed examinations of 10 Type A larvae (2 yolk-sac, 1.8–1.9 mm; 6 preflexion, 2.6–3.3 mm; 2 flexion, 3.3–4.2 mm), 18 type B larvae (4 preflexion, 2.7–4.0 mm; 4 flexion, 3.7–4.9 mm; 10 postflexion, 4.0–8.4 mm), 2 unidentified juvenile males (12.0, 15.1 mm), and 4 juvenile females (*G. savagei* 34.4 mm; 3 *G. vanhoeffeni* 28.4–38.5 mm). Meristic data were obtained from Bertelsen (1951), Bertelsen et al (1981), and from counts made during the present study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	21–23	22
Precaudal	7	7
Caudal	15–16	15
Fius:		
Dorsal spines	IL*	IL
Dorsal rays	4–7	5–6
Anal spines	0	0
Anal rays	4–7	5–6
Pelvic	0	0
Pectoral	17–22	18–19
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Worldwide except Mediterranean, Gulf of California, Gulf of Mexico, & polar seas; larvae tropical & subtropical

Habitat: Meso- & bathypelagic, typically ca. 1000–2500 m depth

Spawning season: Summer (Bertelsen 1951)

ELH pattern: Oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic

LITERATURE

Bertelsen 1951, 1984
Bertelsen et al. 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 1.9 mm (W. Watson)

* IL = illicium, a modified D ray (Bertelsen 1951).
† Males & females diverge morphometrically during transformation. The given ranges encompass both sexes; means are given separately for each sex: males first & females second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 1.8–1.9 mm
Flexion length: ca. 3.3–4.9 mm
Transformation length: Males ca. 11–16 mm, females ca. 9–25 mm
Fin development sequence: IL & P_1, C, D & A
Pigmentation: *Preflexion–postflexion*—Pigment light to absent; when present, located on upper part of gut & on nape; spreads laterally & posteriorly to D base, & down sides & front of gut. *Juvenile*—Females completely pigmented, dark red-brown to black; males diffusely pigmented, pale to dark brown.
Diagnostic features: Strongly inflated epidermis lacking ornamentation; very large P_1; P_2 absent; pigment usually light & restricted to dorsal surface of gut & dorsum above gut, or absent.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv†
Sn-A/BL	40–45 43	38–49 44	51–63 58	59–79 70		44–72 69/52
BD/BL	27–35 31	32–52 40	59–69 61	60–82 72		19–44 39/22
HL/BL	27–30 28	25–34 29	31–40 35	37–47 42		12–46 43/25
HW/HL	96–98 97	67–107 90	85–114 97	88–129 103		41–60 57/49
SnL/HL	29–35 32	23–31 27	24–29 26	23–32 28		31–39 38/33
ED/HL	45–50 47	40–50 44	40–44 42	25–37 32		8–10 9/8
P_1L/BL	11–12 11	12–26 18	23–28 26	24–32 27		9–15 14/11

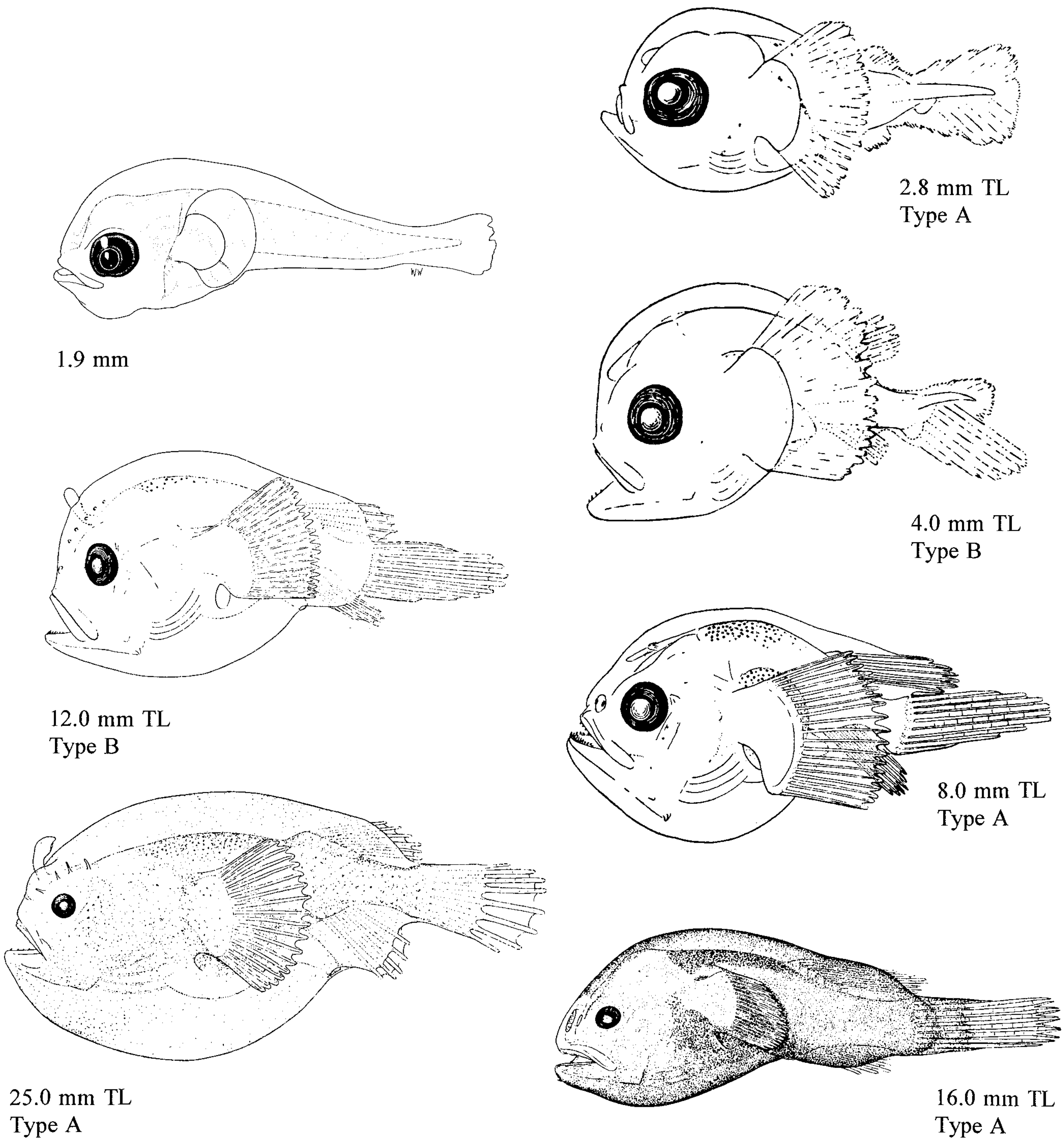


Figure Gigantactinidae 1. Females are shown on the left, males on the right. Preflexion female with small amount of yolk remaining, 1.9 mm (CalCOFI 6909, station 130.60); preflexion Type A male, 2.8 mm TL; flexion Type B male, 4.0 mm TL; postflexion Type B female, 12.0 mm TL, and Type A male, 8.0 mm TL; transformation Type A female, 25.0 mm TL, and male, 16.0 mm TL. All figures except the 1.9 mm female are from Bertelsen (1951).

LINOPHRYNIDAE: Netdevils

W. WATSON

Linophrynidae contains about 25 species in five genera (Bertelsen 1984); only *Borophryne apogon* is known to occur within our study area. Larval *B. apogon* have been taken only rarely in CalCOFI samples off Baja California Sur; they are more common farther south. A few "Hyaloceratias" larvae have been taken at offshore southern stations on extended CalCOFI surveys.

Linophrynids are largely tropical and subtropical residents of the Atlantic, Indian and Pacific Oceans. Adult females are meso- and bathypelagic predators (Bertelsen 1951). Free-living males are not known to feed, and attached males are thought to obtain nutrition parasitically from the female (Bertelsen 1951, Pietsch 1976). Adult females are deep-bodied and broad, with a moderately long preanal length. All have moderate to long sphenotic spines, a short to moderately long illicium with variously ornamented esca, and a naked black skin (except *Haplophryne* with unpigmented skin). Some species have a hyoid barbel. Maximum size is less than ca. 10 cm; adults typically are 25–50 mm SL. Males are obligatory sexual parasites (Pietsch 1976). Free-living transformed males are lightly to heavily pigmented, relatively slender, with large olfactory organs, relatively large, somewhat forward-directed eyes, and with short denticles in the upper and lower jaws.

Spawning is unknown; however, based on the collection of a female *Linophryne arborifera* with a partly extruded cluster of eggs embedded in a gelatinous matrix, Bertelsen (1984) concluded that the Ceratioidei spawn floating gelatinous egg rafts. Larval size and development at hatching are unknown, although Bertelsen (1951) suggested that 2.9 mm (TL) "Hyaloceratias" with straight notochord, developing dorsal and anal fins, pigmented eyes and open mouth were newly hatched. Larval linophrynids range from moderately slender and elongate to deep-bodied and robust, with preanal length ranging from short to moderately long depending on species. All have a greatly inflated, usually unpigmented, epidermis, three dorsal and anal fin rays (rarely 2 or 4), five branchiostegal rays (rarely 4), and 20 myomeres (usually not countable through the inflated epidermis). *Borophryne apogon* and some *Linophryne* species have large sphenotic spines. Larval pigment may be present (lateral only) or absent, depending on species. For more complete descriptions and illustrations of larval linophrynids refer to Bertelsen (1951).

Larval *B. apogon* are robust and unpigmented, with strong sphenotic spines. They are unlikely to be confused with any other fish larvae, except other linophrynids of the *L. macrorhinus* group, which also includes unpigmented larvae with strong sphenotic spines. However, the *L. macrorhinus* group species have not been reported from the CalCOFI area.

The following description of *B. apogon* is based on literature (Bertelsen 1951) and on detailed examination of 16 larvae (1 flexion, 3.4 mm; 15 postflexion, 3.4–13.4 mm), 2 free-living juvenile males (11.0, 12.8 mm), and 4 post-transformation females (25.4–30.5 mm). Larval "Hyaloceratias" are not described separately, but are shown in Figure Linophrynidae 1. Refer to Bertelsen (1951) for description.

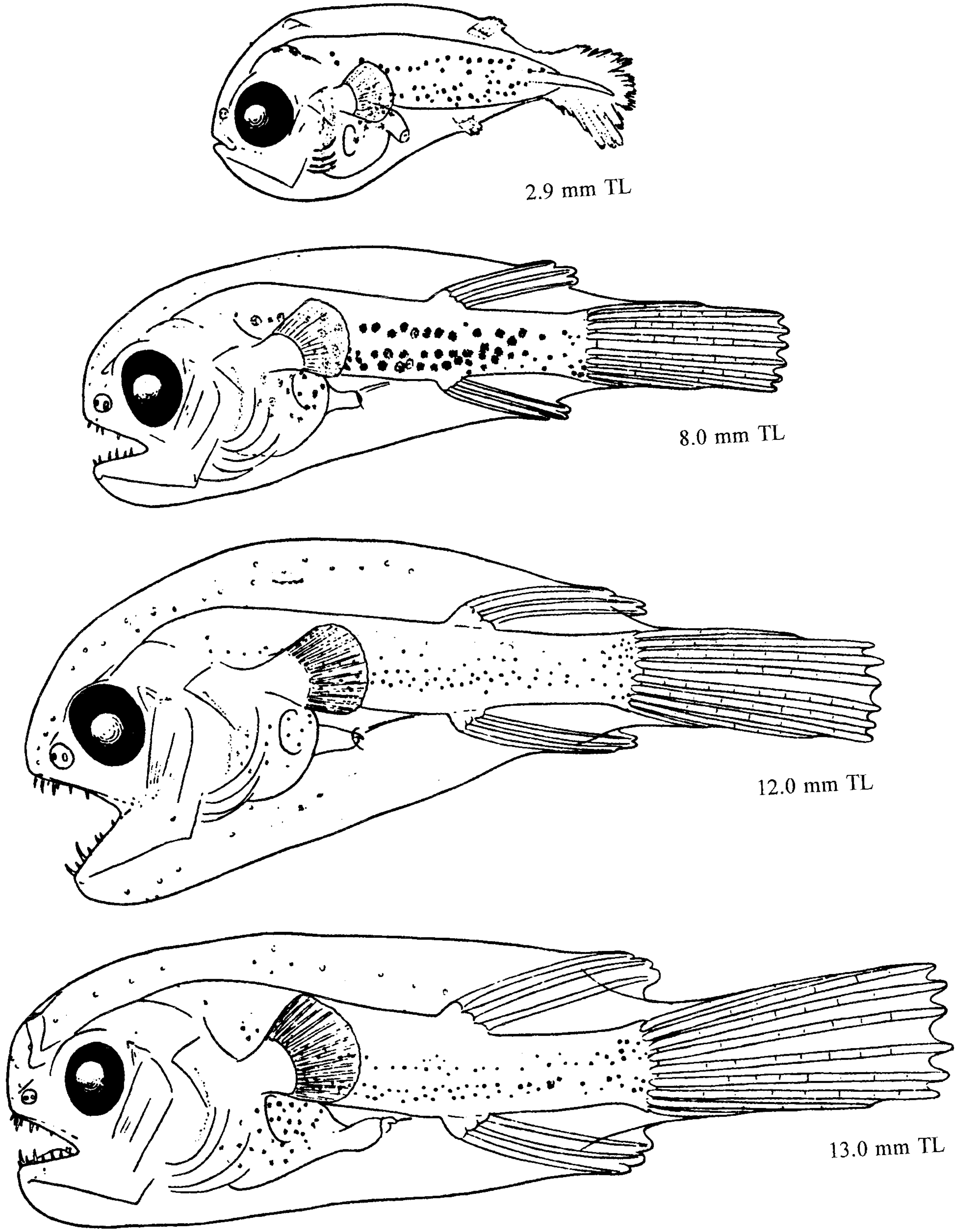


Figure Linophrynidae 1. Larval "Hyaloceratias": the 2.9 mm TL and 13.0 mm TL specimens are females; the 8.0 mm TL and 12.0 mm TL specimens are males (Bertelsen 1951).

MERISTICS

	Range	Mode
Vertebrae:		
Total	19–20	19–20
Precaudal	4–5	4–5
Caudal	15	15
Fins:		
Dorsal spines	IL*	IL
Dorsal rays	3	3
Anal spines	0	0
Anal rays	3	3
Pelvic	0	0
Pectoral	15–18	16–17
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	5	5

LIFE HISTORY

Range: Lower Gulf of California to Gulf of Panama

Habitat: Meso- & bathypelagic; larvae primarily mesopelagic

Spawning season:

ELH pattern: Parasitic males; females oviparous; presumably, eggs contained in floating gelatinous rafts; larvae are planktonic.

LITERATURE

Bertelsen 1951, 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larvae, 4.0 mm, 12.8 mm (W. Watson)

* IL = illicium, a modified D ray (Bertelsen 1951).

† Males & females diverge morphometrically during transformation. The given ranges encompass both sexes; means are given separately for each sex: males first & females second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**

No. of OG: **Diam. of OG:**

Shell surface:

Pigment:

Diagnostic features:

LARVAE

Hatching length:

Flexion length: ca. 3.5–4 mm

Transformation length: males ca. 11 mm, females ca. 25 mm

Fin development sequence: IL & D & A & C, P_1

Pigmentation: *Larvae*—Unpigmented except eyes. *Juvenile*—Free-living males unpigmented to lightly pigmented; females heavily pigmented but lighter on dorsum, ventrum, P_1 & C before ca. 30 mm.

Diagnostic features: Strongly inflated epidermis; strong sphenotic spines; D & A rays 3; P_2 absent; branchiostegal rays 5; body depth (subdermal) ca. 40–60% BL; unpigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv†
Sn-A/BL				64–80		66–84
			60	75		66/79
BD/BL				58–88		40–65
			70	68		47/61
HL/BL				39–53		45–53
			45	48		49/50
HW/HL				66–145		67–112
			104	93		78/94
SnL/HL				23–29		29–40
			20	26		31/36
ED/HL				17–41		6–17
			32	23		15/7
P_1L/BL				12–15		9–15
			13	14		14/12
BDi/BL				42–49		40–65
			44	45		47/61

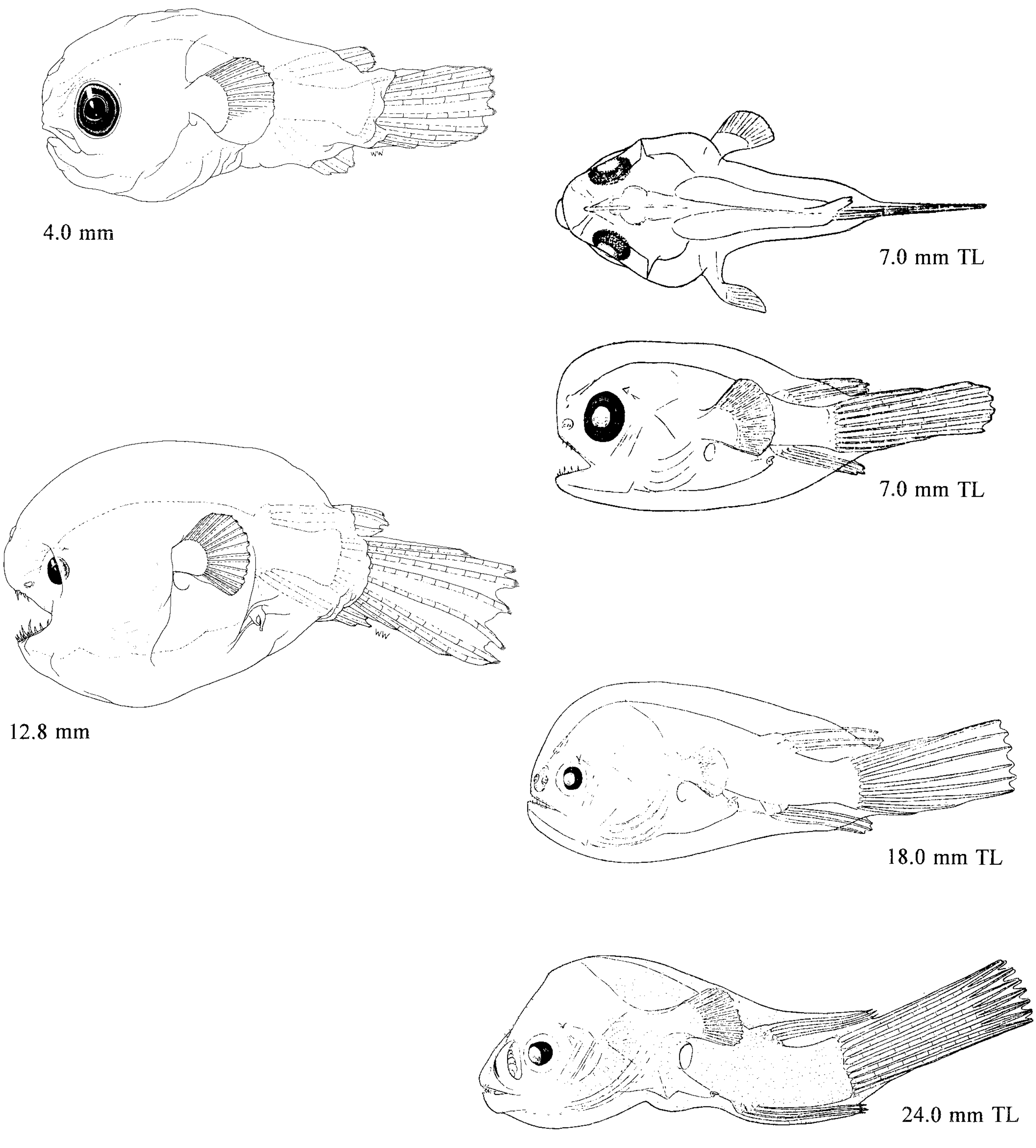


Figure Linophrynidae 2. Females are shown on the left, males on the right. Early postflexion female, 4.0 mm (CalCOFI 5708, station 145G.70); postflexion male, 7.0 mm TL, dorsal and lateral views (Bertelsen 1951); postflexion female, 12.8 mm (EASTROPAC II, station OP.44); transformation male, 18.0 mm TL; juvenile male, 24.0 mm TL (Bertelsen 1951).

GOBIESOCIFORMES

W. WATSON

The phylogenetic position of the gobiesocid fishes is not yet resolved. The gobiesocids have been placed in the paracanthopterygian order Gobiesociformes by some authors (e.g., Greenwood et al. 1966; Nelson 1984). However, Gosline (1970) suggested that gobiesocid affinities are with the callionymids, a perciform group, and Patterson and Rosen (1989) concluded that there is no reason to include gobiesocids in the Paracanthopterygii. Nelson (1994) accepted these views, placing the gobiesocids in the perciform suborder Gobiesocoidei, but noted that some authors consider the case far from settled (e.g., Allen 1984) and stated that definitive studies have yet to be done. Here, we follow Eschmeyer (1990) in considering the gobiesocids a separate order, consisting of a single family, Gobiesocidae. The family contains about 36 genera and 120 species (Nelson 1994). The gobiesocids are widely distributed demersal inhabitants of shallow nearshore tropical and warm temperate marine waters; a few tropical species inhabit coastal streams (Briggs 1955). Eight marine species in two genera occur in the CalCOFI study area.

Families included: Gobiesocidae

GOBIESOCIDAE: Clingfishes

W. WATSON

Eight clingfish species occur along the Pacific coast of California and Baja California (Table Gobiesocidae 1). Their larvae generally are restricted to shallow nearshore waters; most are rare in CalCOFI ichthyoplankton samples. Larval *Gobiesox eugrammus* have been taken with some regularity at inshore stations along the northern coast of Baja California and larval *G. rhessodon* commonly occur near shore along the southern California coast (e.g., Barnett et al. 1984).

Most adult clingfishes are small (≤7 cm) demersal inhabitants of the intertidal and shallow subtidal zones, where they shelter under rocks and shells, among sea urchin spines, on kelp or eelgrass, etc. Clingfishes typically are flattened anteriorly and have pelvic fins modified to form a suction disc that allows attachment to the substrate.

Clingfishes are oviparous, with demersal eggs attached in a single layer in a nest tended by a parent (e.g., Allen 1984). The eggs typically are ellipsoidal to hemispherical, with a major axis of ca. 1–2 mm (e.g., Marliave 1975; Allen and Ilg 1983; Allen 1984). The yolk is pigmented, usually yellow to orange (e.g., Marliave 1975; Allen 1984), and contains one or more oil globules. Larvae are ca. 4–6 mm long and well developed at hatching, with pigmented eyes, functional mouth, and small yolk sac (e.g., Marliave 1975; Allen 1979; Allen and Ilg 1983). Larval clingfishes initially are cylindrical to slightly compressed, becoming somewhat depressed during the postflexion or transformation stage. They initially are somewhat elongate, becoming very slender to robust, depending on species. The head is small to moderate and rounded initially, but the snout elongates and the ventral surface flattens during development. The eye is oval to round. The gut is moderately long (preanal length ca. 50–75% BL). The gas bladder is anterior. The characteristic pelvic disc typically becomes visible in the preflexion or flexion stage, although Marliave (1975) noted that in *Rimicola muscarum* the disc forms before hatching. He speculated that in contrast to the other clingfishes, *R. muscarum* may lack a planktonic larval stage (pers. comm. cited in Matarese et al. 1989). Melanistic pigmentation of larval clingfishes ranges from absent to nearly complete; most larvae are moderately to heavily pigmented. Melanophores typically are located dorsally on the gas bladder and gut, laterally on the trunk and/or tail, and to a lesser extent dorsally on the head and on the dorsal and/or ventral margins of the body. Pigmentation typically changes little during larval development. Development is a gradual process, with no clearly identifiable transformation stage.

Larval clingfishes are distinctive and unlikely to be confused with the larvae of any other family, except perhaps during the early preflexion stage, when they resemble larval gobies. The gobies are more compressed than the clingfishes, and have the gas bladder over the middle of the gut rather than anteriorly. None of the local goby species has a larval pigment pattern that resembles any of the local clingfish patterns. Once the clingfish suction disc becomes apparent (no later than the flexion stage), the larvae cannot be confused with any other family (snailfishes also have a suction disc, but do not resemble clingfishes otherwise).

The larvae of *Gobiesox papillifer* and *Rimicola sila* are unknown. Among the other species in the study area, larval *Rimicola dimorpha* and *R. muscarum* are distinguishable from at least the flexion stage onward by their lack of melanophores. Male *R. dimorpha* >10 mm are identifiable by the large genital papilla (Briggs 1955), but it is unknown how females or smaller specimens might be consistently distinguished from *R. muscarum*. Larval *G. maeandricus* are recognizable by their lack of lateral melanophores on the trunk and tail and their high vertebral count combined with high dorsal and anal fin ray counts (Table Gobiesocidae 1, Figure Gobiesocidae 1). Among the three species with lateral pigment, *R. eigenmanni* larvae lack melanophores dorsally on the head and along the dorsal and ventral margins, have few, if any, dorsolateral melanophores, and have a high vertebral count combined with low dorsal and anal fin ray counts (Table Gobiesocidae 1). Larval *G. eugrammus* have heavy dorsal head pigment and a short row of melanophores along the dorsal margin of the trunk, while *G. rhessodon* typically are lightly pigmented or unpigmented on the head and lack the dorsal margin pigment. Pectoral fin-ray counts distinguish these last two species, as well (Table Gobiesocidae 1).

The following descriptions are based on the literature (Marliave 1975; Allen 1979; Allen and Ilg 1983) and on detailed examinations of 5–31 specimens of each taxon (Table Gobiesocidae 2). *G. maeandricus* is not described separately since only a few preflexion stage specimens were available; instead, larvae are shown in Figure Gobiesocidae 1 and the reader is referred to Allen and Ilg (1983) and Matarese et al. (1989) for descriptions. Meristic data were obtained from Briggs (1955), Greenfield and Wiley (1968), and counts made during this study. Primary sources for ecological information were Briggs (1955) and Eschmeyer et al. (1983).

Table Gobiesocidae 1. Meristic characters for the gobiesocid species that may occur along the Pacific coast of California and Baja California. All species listed have I,4 pelvic fin rays and 6 branchiostegal rays.

	Vertebrae			Fin rays					
Species	PrCV	CV	Total	D	A	P_1	C_1	C_2	GR
Gobiesox eugrammus	13–14	15–16	26–29	11–13	8–10	21–26	5–6+5–6	5–6+5–6	
G. maeandricus	12–15	19–20	32–35	13–16	13–15	21–23	5–6+5–6	6–7+5–7	8
G. papillifer	13	11–12	24–25	12–13	9–11	23–25	5+5	5+4–5	6
G. rhessodon	13	15–16	28–29	10–12	9–10	18–21	5+5	4–7+4–6	7
Rimicola dimorpha	16–17	19	35–36	5–7	6–8	14–16	4+4	3–4+3–4	5–6
R. eigenmanni	15–16	17–18	33–35	5–8	5–8	17–19	4+4	4–5+4	5
R. muscarum	16–17	17–20	34–36	5–8	6–8	14–17	4+4	3–5+3–4	5
R. sila	16	18–19	34–35	6–7	7–8	16–17	4+4	4+3	5

Table Gobiesocidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the gobiesocid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Gobiesox eugrammus	0	0	11 3.8–6.6	5 6.2–7.5	4 7.0–8.8	1 7.4	3 12.5–21.3
G. rhessodon	L[a]	L[b]	L[b], 11 3.0–4.5	L[b], 5 4.8–5.6	L[b], 10 5.5–6.5	0	5 15.6–19.3
Rimicola dimorpha	0	0	0	0	0	0	6 10.4–15.0
R. eigenmanni	0	1 2.8	10 2.8–4.2	5 4.0–4.5	10 4.5–5.4	0	5 10.6–12.1
R. muscarum	L[c]	0	0	0	0	0	5 17.6–20.6
Rimicola spp.	0	0	0	4 5.0–5.7	11 6.5–9.9	0	0

[a] Allen 1984
[b] Allen 1979
[c] Marliave 1975

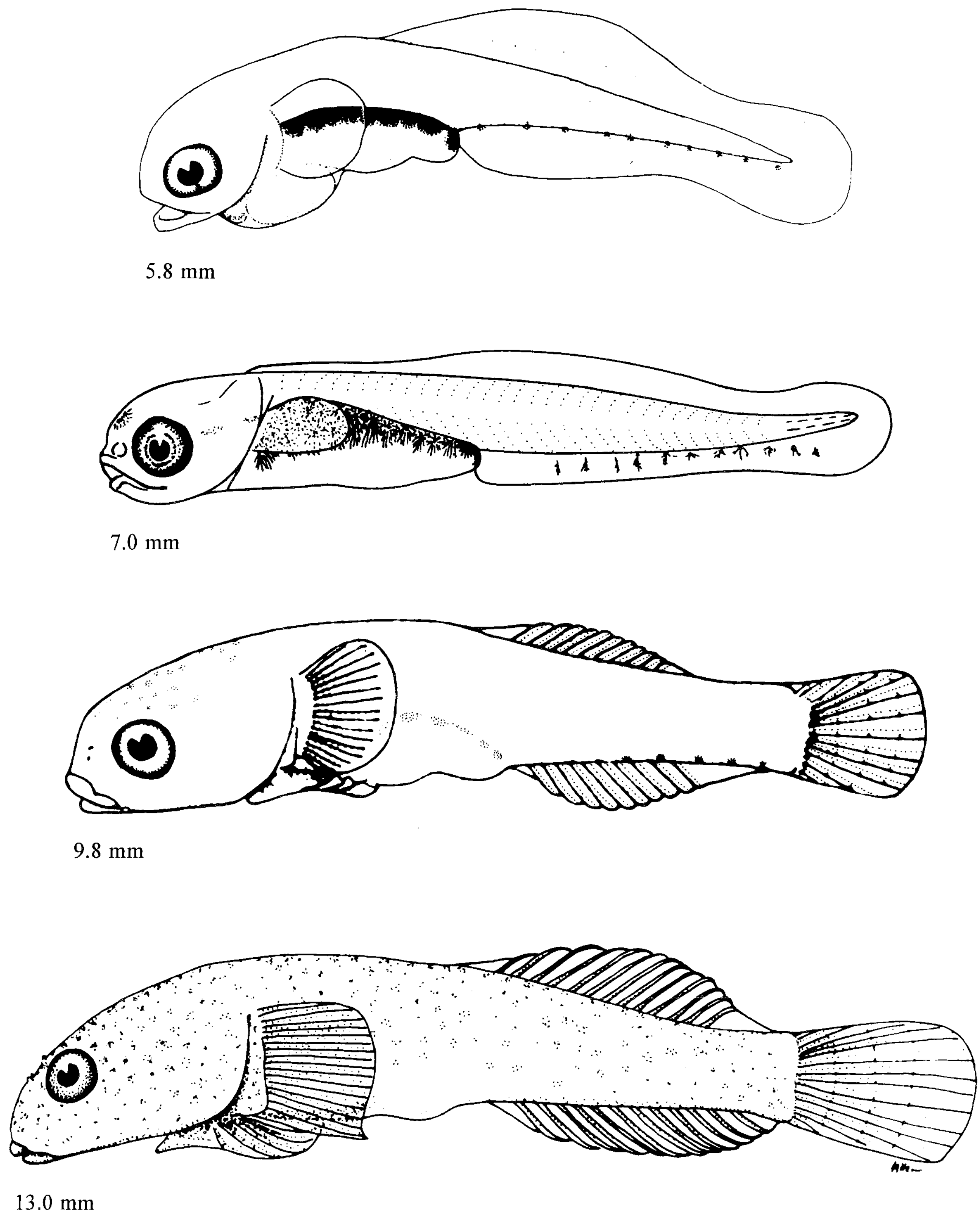


Figure Gobiesocidae 1. Development of northern clingfish, *Gobiesox maeandricus*. Recently hatched larva, 5.8 mm (Allen and Ilg 1983); postflexion larva, 7.0 mm (Matarese et al. 1989); postflexion larva, 9.8 mm; juvenile, 13.0 mm (Allen and Ilg 1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–29	27–28
Precaudal	13–14	13
Caudal	15–16	15
Fins:		
Dorsal spines	0	0
Dorsal rays	11–13	12
Anal spines	0	0
Anal rays	8–10	10
Pelvic	I,4	I,4
Pectoral	21–26	22–23
Caudal:		
Principal	5–6+5–6	5+5
Procurrent:		
Upper	5–6	6
Lower	5–6	6
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: San Diego, California, to Isla de Guadalupe & central coast of Baja California

Habitat: Demersal at depths of ca. 9–80 m, usually associated with the red sea urchin *Strongylocentrotus franciscanus*

Spawniug season: Larvae collected in September & October

ELH pattern: Oviparous; attached, demersal eggs; larvae are planktonic.

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.2 mm (M. T. Vona)
Flexion larva, 7.5 mm (M. T. Vona)
Postflexion larva, 7.8 mm (M. T. Vona)
Transformation specimen, 7.4 mm (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diaguostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: ca. 6.1–6.6 mm through ca. 7.0–7.5 mm
Transformation length: ≥7.4 mm, ≤12.5 mm
Fin development sequence: C_1, P_1, D & A, P_2 & C_2
Pigmentation: *Preflexion–postflexion*—ca. 5–8 (large) over fore-, mid-, & hindbrain; internally under brain & on floor of otic capsule by flexion stage; 0–4 (usually 4, rarely 0) on dorsal margin between myomeres 2 & 14 (usually 3–9); few to ca. 20–30, ventrolaterally from level of P_1 base to postanal myomere 4–6 (usually 4 or 5), often in 1–3 irregular rows; internally over gut & gas bladder; 1–2 externally, near P_1 insertion, by ca. 6 mm; 0–ca. 10 (usually ca. 2–5) irregularly spaced along ventral margin of tail; 0 to few on C beginning in flexion stage. *Juvenile*—Completely pigmented except on ventrum; D, A & C dark.
Diagnostic features: 12–14 (usually 13–14) preanal myomeres, 27–29 (usually 28) total myomeres; P_1 21–26 (usually 22–23: full complement present in postflexion stage); usually moderate to heavy dorsal pigment on head; 2–4 melanophores on dorsal margin between ca. myomeres 3 & 9; ventrolateral pigment from level of P_1 base to ca. 4th postanal myomere; usually a few melanophores on ventral margin of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–62 57	58–61 59	59–65 63	64	61–66 63
BD/BL		15–18 17	16–18 18	19–22 20	24	22–26 24
HL/BL		20–25 23	24–28 25	25–29 28	34	34–37 35
HW/HL		65–74 69	58–68 64	61–80 70	71	98–100 99
SnL/HL		18–26 22	24–28 26	23–26 25	27	22–27 24
ED/HL		29–42 35	28–31 30	28–32 30	24	25–28 27
P_1L/BL		7–8 7	7–9 7	10–13 11	16	16–19 17
P_2L/BL		0–1 0.3	1–2 1	3–8 5	14	16–20 18

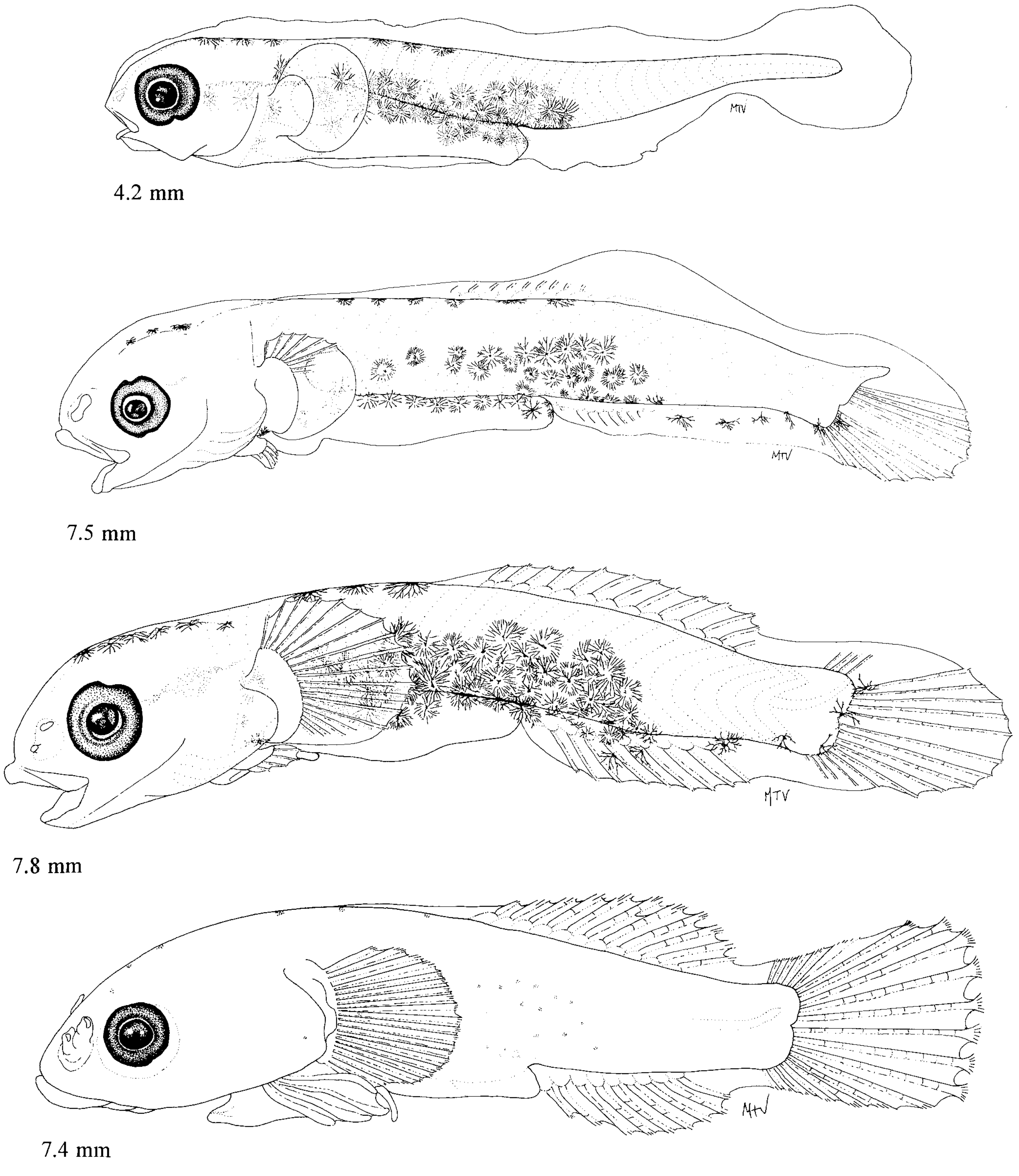


Figure Gobiesocidae 2. Preflexion larva, 4.2 mm (CalCOFI 7510, station 103.29); flexion larva, 7.5 mm (CalCOFI 7510, station 103.30); postflexion larva, 7.8 mm (CalCOFI 6110, station 103.30); tranformation specimen, 7.4 mm (CFRD Ref. Coll., Bahía Ballenas, Baja California Sur).

MERISTICS

	Range	Mode
Vertebrae:		
Total	28–29	29
Precaudal	13	13
Caudal	15–16	16
Fins:		
Dorsal spines	0	0
Dorsal rays	10–12	11–12
Anal spines	0	0
Anal rays	9–10	10
Pelvic	I,4	I,4
Pectoral	18–21	20–21
Caudal:		
Principal	5+5	5+5
Procurrent:		
Upper	4–7	4–6
Lower	4–6	4–6
Gill rakers:		
Total	7	7
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Pismo Beach, California, to Bahía San Bartolomé, Baja California Sur

Habitat: Demersal on intertidal & shallow subtidal (to ca. 10 m depth) rocky bottom

Spawning season: Principally spring & summer, possibly year-round

ELH pattern: Oviparous; eggs attached under rocks & cobble & guarded by adult; planktonic larvae

LITERATURE

Allen 1979, 1984

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment: Orange
Diagnostic features:

LARVAE

Hatching length: 3–4 mm
Flexion length: 5–5.5 mm through 5.5–6.9 mm
Transformation length: ca. 8–12 mm
Fin development sequence: C_1, D & A, P_1 & P_2 & C_2
Pigmentation: *Preflexion–postflexion*—0–4 dorsally on head (usually 0–1); present or absent internally under hindbrain (usually present); on P_1 base near insertion (sometimes absent); dorsally along length of gut & over gas bladder; ca. 8–17 externally laterally on body, from level of P_1 to ca. first to third postanal myomere; 1 to ca. 7 or 8 along ventral margin of tail, often restricted to posterior half of tail. *Juvenile*—Body completely pigmented, usually with mottled or weakly banded pattern.
Diagnostic features: Lateral melanophores on trunk & first 1–3 postanal myomeres; melanophores on ventral margin of tail; myomeres 13–15 + 14–17 = 28–30 (usually 13–14 + 15–16 = 29).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		54–62 58	59–63 61	60–66 62		58–65 62
BD/BL		17–21 19	18–21 19	18–22 20		21–22 21
HL/BL		20–24 22	23–28 26	27–31 29		30–35 33
HW/HL		70–88 81	67–75 72	66–74 71		90–99 94
SnL/HL		11–23 18	21–25 23	20–30 26		22–34 27
ED/HL		36–47 42	29–37 32	26–30 28		19–23 20
P_1L/BL		5–9 7	8–10 9	11–15 14		15–18 16
P_2L/BL		0–1 0.2	1–5 3	7–12 10		15–16 16

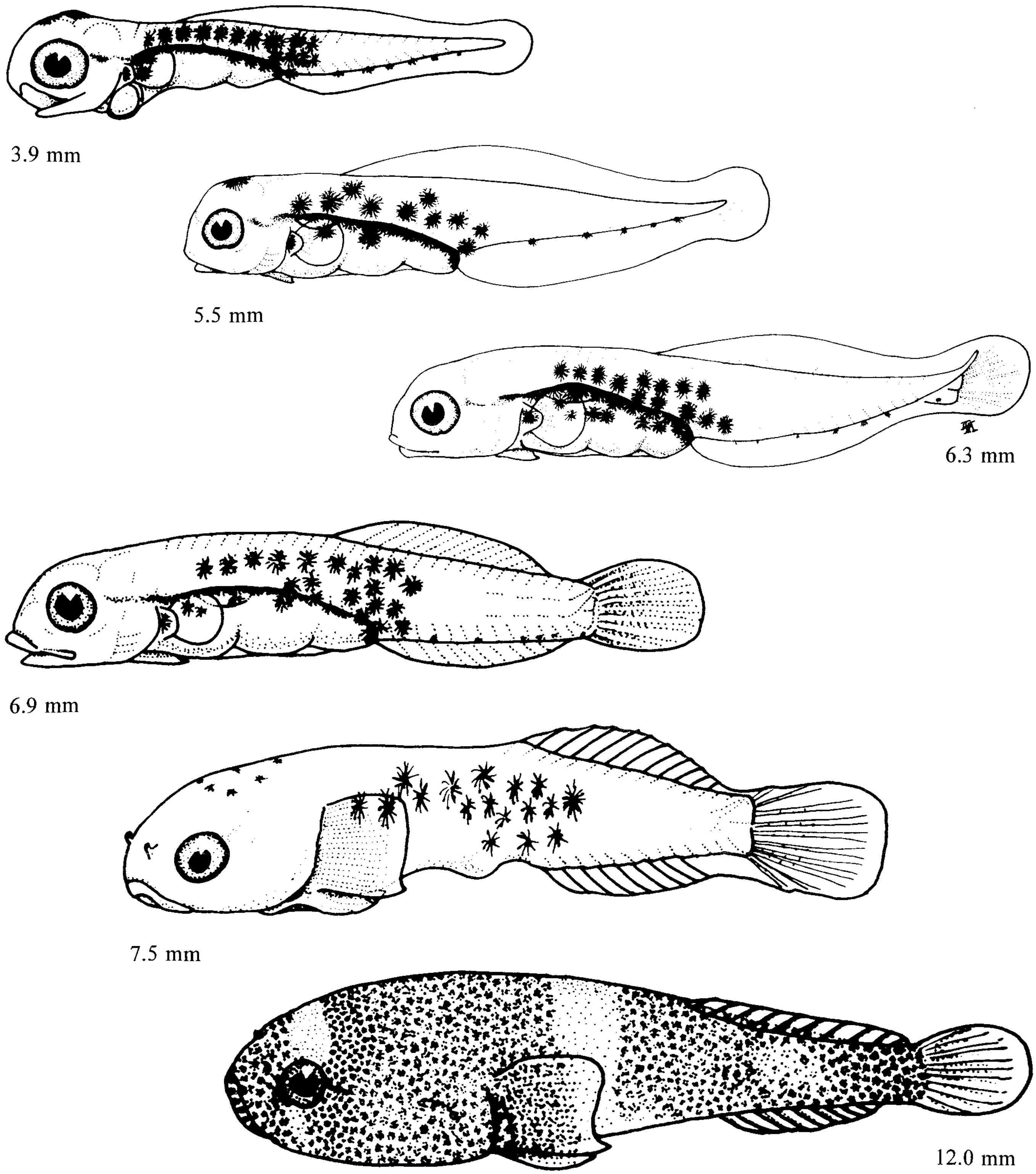


Figure Gobiesocidae 3. Recently hatched larva, 3.9 mm; preflexion larva, 5.5 mm; flexion larva, 6.3 mm; early postflexion larva, 6.9 mm; late postflexion larva, 7.5 mm; benthic juvenile, 12.0 mm (Allen 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	33
Precaudal	15–16	16
Caudal	17–18	17
Fins:		
Dorsal spines	0	0
Dorsal rays	5–8	6–7
Anal spines	0	0
Anal rays	5–8	7
Pelvic	I,4	I,4
Pectoral	17–19	18
Caudal:		
Principal	4+4	4+4
Procurrent:		
Upper	4–5	4–5
Lower	4	4
Gill rakers:		
Total	5	5
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Palos Verdes peninsula, Los Angeles County, California, to Bahía San Juanico, Baja California Sur

Habitat: Demersal in intertidal & shallow subtidal (to ca. 15 m depth) zones

Spawning season:

ELH pattern: Oviparous; attached demersal eggs; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Recently hatched larva, 2.8 mm (N. Arthur)
Preflexion larva, 4.2 mm (N. Arthur)
Flexion larva, 4.4 mm (N. Arthur)
Postflexion larva, 5.1 mm (N. Arthur)
Juvenile, 10.6 mm (N. Arthur)

* Eye initially is oval but becomes round by flexion stage, then again becomes oval in the juvenile stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.8 mm
Flexion length: ca. 4–4.5 mm
Trausformation length: >5.4 mm, <10.6 mm
Fin development sequence: C_1, P_1, D & A, P_2 & C_2
Pigmentation: *Yolk-sac through postflexion*—7–22 laterally in 1–3 longitudinal rows between myomeres 3–5 & 19–20, usually ca. 11–16 to flexion stage, decreasing to 8–10, mainly along lateral midline, by postflexion stage; series (widely spaced) internally under hindbrain & over gas bladder & gut to end of hindgut, becoming more or less continuous pigment by ca. 3.5 mm; 1 (large) laterally under P_1 base in preflexion stage, disappears during flexion stage; dorsal & ventral margins unpigmented. *Juvenile*—No melanistic pigment.
Diagnostic features: Myomeres 16–18 (usually 16–17) + 15–18 (usually 16–17) = 32–35 (usually 33–34); D & A rays 5–8; P_1 rays 17–19 (usually 18: full complement present in postflexion stage); eyes more or less round in larval stage; larvae with lateral pigment, usually in single row along lateral midline from ca. myomere 3–5 through 10–12, usually expanding to 2 or 3 rows to ca. postanal myomere 3–5; no pigment on dorsal or ventral margins.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		60–64	63–69	67–73		57–59
	62	62	66	70		58
BD/BL		17–20	17–19	18–20		12–13
	21	18	18	19		13
HL/BL		21–25	24–28	28–33		27–29
	24	23	26	29		28
HW/HL		75–87	65–77	54–77		60–70
	85	82	72	70		64
SnL/HL		14–21	17–23	21–25		24–27
	17	18	20	23		26
ED/HL*		35–45× 31–39	29–35× 27–35	28–31× 26–31		21–23× 16–19
	48×42	40×36	32×32	29×28		22×18
P_1L/BL		6–10	8–10	11–14		13–15
	6	8	9	13		14
P_2L/BL		0–1	3–4	5–9		7–8
	0	0.4	4	7		8

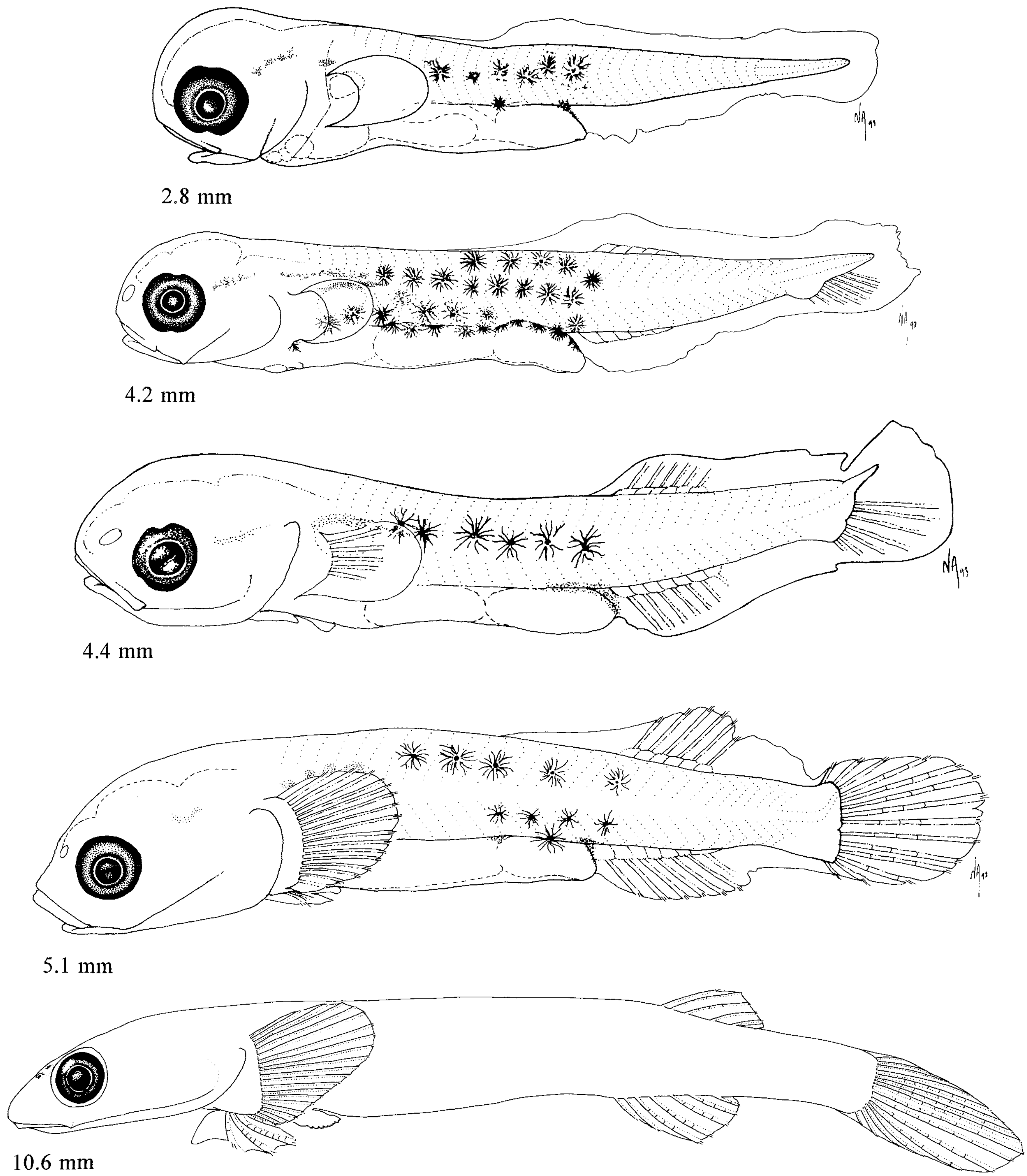


Figure Gobiesocidae 4. Recently hatched larva, 2.8 mm (MEC I–0T, station T–E, replicate 2); late preflexion larva, 4.2 mm (MEC I–04, station T–500, replicate 3); flexion larva, 4.4 mm (MEC I–0T, station T–E, replicate 2); postflexion larva, 5.1 mm (MEC I–0T, station T–E, replicate 2); juvenile, 10.6 mm (SIO H48–86).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	35–36
Precaudal	16–17	16–17
Caudal	17–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	5–8	5–6
Anal spines	0	0
Anal rays	6–8	5–7
Pelvic	I,4	I,4
Pectoral	14–17	15–16
Caudal:		
Principal	4+4	4+4
Procurrent:		
Upper	3–5	4
Lower	3–4	3–4
Gill rakers:		
Total	5–6	
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: *R. muscarum*—Queen Charlotte Island, British Columbia, to Punta Baja, Baja California; *R. dimorpha*—Northern channel islands, off southern California, to Islas San Benito, Baja California

Habitat: Kelp; occasionally in tidepools

Spawning season:

ELH pattern: *R. muscarum* is oviparous with demersal eggs attached to kelp & guarded by parent, larvae may remain on kelp; *R. dimorpha* is assumed to have a similar ELH pattern

LITERATURE

Marliave 1975
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 5.7 mm (N. Arthur)
Postflexion larva, 7.5 mm (N. Arthur)
Juvenile, *R. muscarum*, 17.6 mm (N. Arthur)
Juvenile, *R. dimorpha*, 13.0 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.3 mm (*R. muscarum*) **Yolk:**
No. of OG: 1 (*R. muscarum*) **Diam. of OG:**
Shell surface:
Pigment: *R. muscarum* eggs are yellow
Diagnostic features:

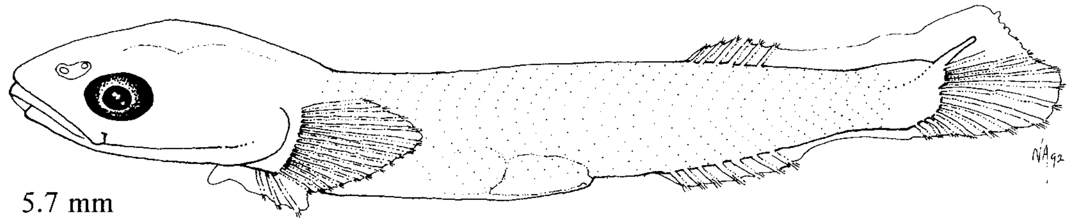
LARVAE

Hatching length: ca. 4 mm (*R. muscarum*)
Flexion length: ca. 5–6 mm
Transformation length:
Fin development sequence:
Pigmentation: *Preflexion*—Melanophores over gut. *Flexion–juvenile*—No melanophores.
Diagnostic features: Larvae (from at least flexion stage) & juveniles lack melanophores; very slender, depressed, ventrally flattened; oval eyes from at least flexion stage onward; D & A rays 6–8; P_1 rays 14–17 (usually 15–16: full complement present by late flexion stage); myomeres 14–16 + 18–20 = 34–35.

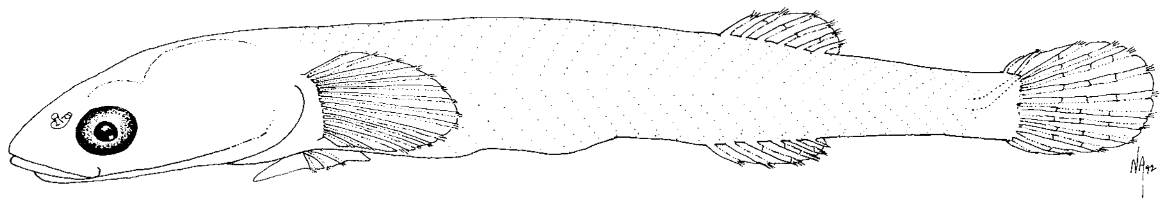
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv†
Sn-A/BL			57–64 60	56–64 61		60–69 65/62
BD/BL			14–17 15	12–16 13		10–13 11/11
HL/BL			29–30 30	24–32 29		27–30 29/28
HW/HL			55–63 59	53–61 56		46–57 50/52
SnL/HL			23–30 26	23–31 27		29–36 31/31
ED/HL‡			23–27× 18–19 25×18	21–26× 16–21 24×18		16–22× 13–19 17×14/ 21×16
P_1L/BL			13–14 13	13–16 14		12–14 13/13
P_2L/BL			5–7 6	6–9 8		7–8 8/8

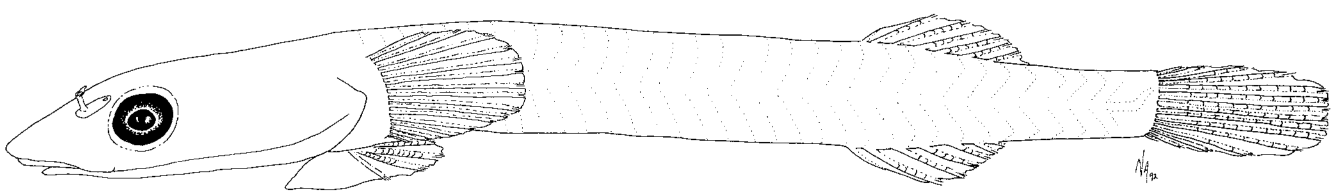
* *Rimicola dimorpha* & *R. muscarum*. Six specimens >10 mm, all classified as juveniles, are *R. dimorpha*; the remainder probably all are *R. muscarum*.
† Ranges encompass both *R. dimorpha* & *R. muscarum*; means are given separately: *R. muscarum* first & *R. dimorpha* second.
‡ Eye is horizontally elongate; horizontal axis is given first, vertical axis second.



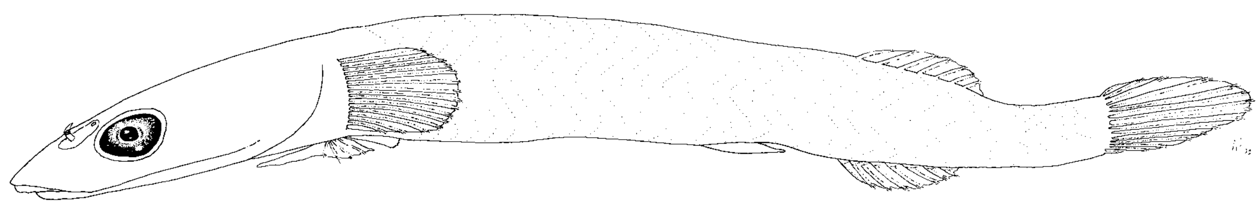
5.7 mm



7.5 mm



17.6 mm



13.0 mm

Figure Gobiesocidae 5. Flexion larva, 5.7 mm (MEC I–PS1, kelp station replicate 3); postflexion larva, 7.5 mm (CFRD Ref. Coll., Isla San Benito, Baja California); juvenile *R. muscarum*, 17.6 mm (MEC I–PS1, kelp station replicate 2); juvenile *R. dimorpha*, 13.0 mm (MEC I–PS1, kelp station replicate 3).

ATHERINIFORMES

W. WATSON

The order Atheriniformes as used here (Eschmeyer 1990) contains about 235 species in two families of coastal marine, estuarine, and freshwater fishes. The taxonomic status of this order is not resolved and other classifications have been proposed (e.g., Parenti 1993; Nelson 1994). White et al. (1984) reviewed atheriniform early life history studies. This order is represented in the CalCOFI study area by five species of the family Atherinidae.

Family included: Atherinidae

ATHERINIDAE: Silversides

W. WATSON

Six atherinid species occur in the CalCOFI study area (Table Atherinidae 1), including an introduced species, *Menidia beryllina*, which occurs in the vicinity of the Sacramento-San Joaquin Estuary. Larvae of all except *M. beryllina* have been taken in CalCOFI samples, principally in neuston collections, but only *Atherinopsis californiensis* and *Leuresthes tenuis* occur relatively commonly.

Marine atherinids are small to moderate-size (ca. 5–45 cm) schooling fishes that reside in estuaries, bays, and along the shallow open coast. They are elongate, with a small terminal mouth, two separate dorsal fins, a relatively long anal fin, abdominal pelvic fins, and a broad, silvery lateral stripe. Some species, including the three California marine species, are utilized in commercial and sport fisheries.

Spawning is well known in the Atherinidae (e.g., Breder and Rosen 1966; White et al. 1984). All are oviparous; most species produce a medium-size (typically ca. 1–2 mm; range 0.6–3.5 mm) spherical egg that contains one to more than 100 oil globules and is attached to a spawning substrate via one or more adhesive filaments that are affixed to the chorion singly or in tufts (Breder and Rosen 1966; White et al. 1984). The eggs of *Leuresthes tenuis*, which lack filaments, are deposited in the sand on beaches just below the high tide line on spring tides (e.g., Thompson and Thompson 1919; Clark 1925; Walker 1952). Incubation periods for atherinid eggs typically are on the order of 1–2 weeks. Larvae are large (ca. 4–9 mm) and well developed at hatching, with pigmented eyes and an open mouth, and usually with a moderately large yolk sac. Larvae are elongate and slender, with a short, coiled gut (preanal length ca. 30–40% BL, increasing to ca. 50% during transformation), relatively large oval to round eyes, and a short, rounded snout that elongates somewhat and becomes more acute with development. Larval pigmentation apparently always includes melanophores on the dorsal surfaces of the head and gut, and typically includes a melanophore series along the dorsal margin of the trunk and tail, laterally along the trunk and tail, and on the ventral margin of the tail. Among these last three melanophore groups, the dorsal series is present most commonly.

Larval atherinids are distinctive and unlikely to be confused with those of any other family. Among the atherinid species whose larvae may have been collected during CalCOFI surveys, the two *Atherinella* species, neither of which occurs north of Baja California Sur, can be distinguished from the others by their lack of the dorsal and ventral melanophore series and by their lower myomere counts (usually 38–40 versus ≥44 for the others). It is unknown how the *Atherinella* species might be distinguished from one another prior to completion of notochord flexion but during the postflexion stage the presence of melanophores externally above the hindbrain and on the dorsal and ventral margins of the caudal peduncle, together with the more posterior position of its second dorsal fin, distinguishes *A. nepenthe* from *A. eriarcha*. Among the other three genera, larval *Atherinopsis californiensis* typically are larger at the same developmental stage, have more myomeres (usually >50 versus usually <50), and are more lightly pigmented than the others. Larval *Atherinops affinis* typically have several ventral melanophores on the gut, often arrayed in a series along the longitudinal midline; the others have little or no ventral pigment on the gut before transformation. In larger postflexion stage larvae, the anal fin origin is below about the middle of the first dorsal fin in *A. affinis*, below or behind the first dorsal fin insertion in *Atherinopsis californiensis*, and below or ahead of the first dorsal fin origin in *Leuresthes tenuis*.

The following descriptions are based on literature and on detailed examinations of 0–58 eggs and 18–41 larval and juvenile specimens of each species (Table Atherinidae 2). Larval *Menidia beryllina* are not described here; refer to Martin and Drewry (1978) and Wang (1981) for descriptions. Meristic data were obtained from the literature (Hubbs 1918; Miller and Lea 1972; Myers and Wade 1942; White et al. 1984), Clothier and Baxter (unpublished manuscript), and from counts made during this study. Principal sources of ecological information were Clark (1925, 1929), Eschmeyer et al. (1983), and Myers and Wade (1942).

Table Atherinidae 1. Meristic characters for the atherinid species in the CalCOFI area. All have 9+8 principal caudal fin rays, I,5 pelvic fin rays, and 6 branchiostegal rays (occasionally 5).

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers
Atherinella eriarcha	12–14	24–28	37–41	III–V+I,9–13	0–I,23–31	13–15	11–13+11–14	3–6+14–17
A. nepenthe	14–16	25–26	39–41	II–V+I,9–11	I,24–30	13–14	10–11+10–12	3–4+16–19
Atherinops affinis	11–15	32–37	44–52	V–IX+I,8–14	I,19–25	13–15	8–10+9–12	4–8+21–34
Atherinopsis californiensis	9–14	37–41	50–54	V–IX+I,11–14	I,21–26	15–17	9–12+10–13	18–44 total
Leuresthes tenuis	10–13	35–39	47–50	III–VII+I,8–10	I,20–24	12–15	10–12+10–13	5–7+23–29

Table Atherinidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the atherinid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Atherinella eriarcha	L[a]	0	0	1 6.1	12 7.7–14.5	4 23.2–25.7	5 27.2–36.6
A. nepenthe	0	0	0	0	12 10.8–13.1	1 12.8	5 34.7–41.5
Atherinops affinis	L[b], 58 1.4–1.8	5 5.0–5.4	5 7.1–8.9	4 8.3–10.4	10 9.8–13.3	5 14.5–21.1	5 30.1–39.3
Atherinopsis californiensis	L[c], 17 1.9–2.1	5 6.2–8.8	10 7.8–11.3	5 11.5–12.7	10 11.7–19.7	5 19.8–25.4	5 25.8–37.0
Leuresthes tenuis	L[d,e], 10 1.6–1.7	5 6.0–7.5	10 7.1–8.6	5 8.0–9.3	10 10.1–14.8	6 15.4–20.3	5 31.0–38.8

[a] White et al. 1984
[b] Curless 1979
[c] Wang 1981
[d] David 1939
[e] Moffatt and Thomson 1978

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–41	38
Precaudal	12–14	13
Caudal	24–28	25
Fins:		
Dorsal spines	III–V+I	IV+I
Dorsal rays	9–13	10–11
Anal spines	0–I	I
Anal rays	23–31	25–29
Pelvic	I,5	I,5
Pectoral	13–15	13
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	11–13	11
Lower	11–14	12–13
Gill rakers:		
Upper	3–6	
Lower	14–17	
Branchiostegals:	6	6

LIFE HISTORY

Range: Bahía San Hippolito, Baja California Sur, & lower Gulf of California to Puerto Utria, Choco, Colombia

Habitat: Surf zone & upper water column near shore along the open coast & in bays

Spawning season:

ELH pattern: Oviparous; presumably, eggs attached to spawning substrate via adhesive filaments; planktonic larvae

LITERATURE

White et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 6.1 mm (N. Arthur)
Postflexion larva, 7.7 mm (N. Arthur)
Postflexion larva, 11.6 mm, lateral & dorsal views (N. Arthur)
Transformation specimen, 23.2 mm (N. Arthur)
Juvenile, 36.6 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: 1.7 mm (ovarian egg) **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface: Numerous anchor-shaped pedicels distributed over chorion; 1 long filament attached to one pedicel, possibly few smaller filaments attached to some of the others
Pigment: Brownish bands on chorion
Diagnostic features: Pedicels

LARVAE
Hatching length:
Flexion length: ca. 6–7 mm
Transformation length: ca. 20–26 mm
Fin development sequence: C_1, 2D & A & P_1, C_2, 1D & P_2
Pigmentation: *Flexion–transformation*—1 (large) posteriorly over midbrain; 2 anteriorly over midbrain, number increases; over forebrain, near nostrils, & on upper lip after 12 mm; ventrally on brain, spreading around brain by ca. 25 mm; under gill cover; anteriorly & dorsally on gut, surrounding it by ca. 25 mm; midlateral series on tail, spreading from myomeres 16–34 in flexion stage to 4–5 through 35 by ca. 25 mm; internally on hypurals & urostyle; few over last few vertebrae & under most caudal vertebrae by ca. 11 mm; on hypural margin in postflexion stage; on bases of some anterior D & A rays after ca. 12 mm. *Juvenile*—Broad lateral stripe, constricted at ca. myomeres 34–36, then expanded into diamond shape; heavy on distal half of C.
Diagnostic features: No external pigment over hindbrain before transformation stage; usually none on trunk or tail before ca. 14 mm except lateral stripe which ends at myomere 34–35 in larvae & is constricted in same area in juveniles; internal pigment in tail is sparse; 2D insertion above 3rd or 4th from last A ray; myomeres usually 7–8+30–31=38–39 through postflexion stage, 13+25 in transformation & juvenile stages.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				33–43	44–46	42–43
			31	36	45	43
BD/BL				17–25	21–23	20–21
			20	20	22	21
HL/BL				14–23	22–24	20–23
			22	21	23	21
HW/HL				53–71	53–59	54–68
			67	61	56	63
SnL/HL				23–32	27–30	24–29
			21	27	29	27
ED/HL				32–39	32–36	34–40
			39	36	34	37
P_1L/BL				8–15	15–17	16–17
			9	11	16	16
P_2L/BL				0–6	8–9	8–9
			0	3	8	9

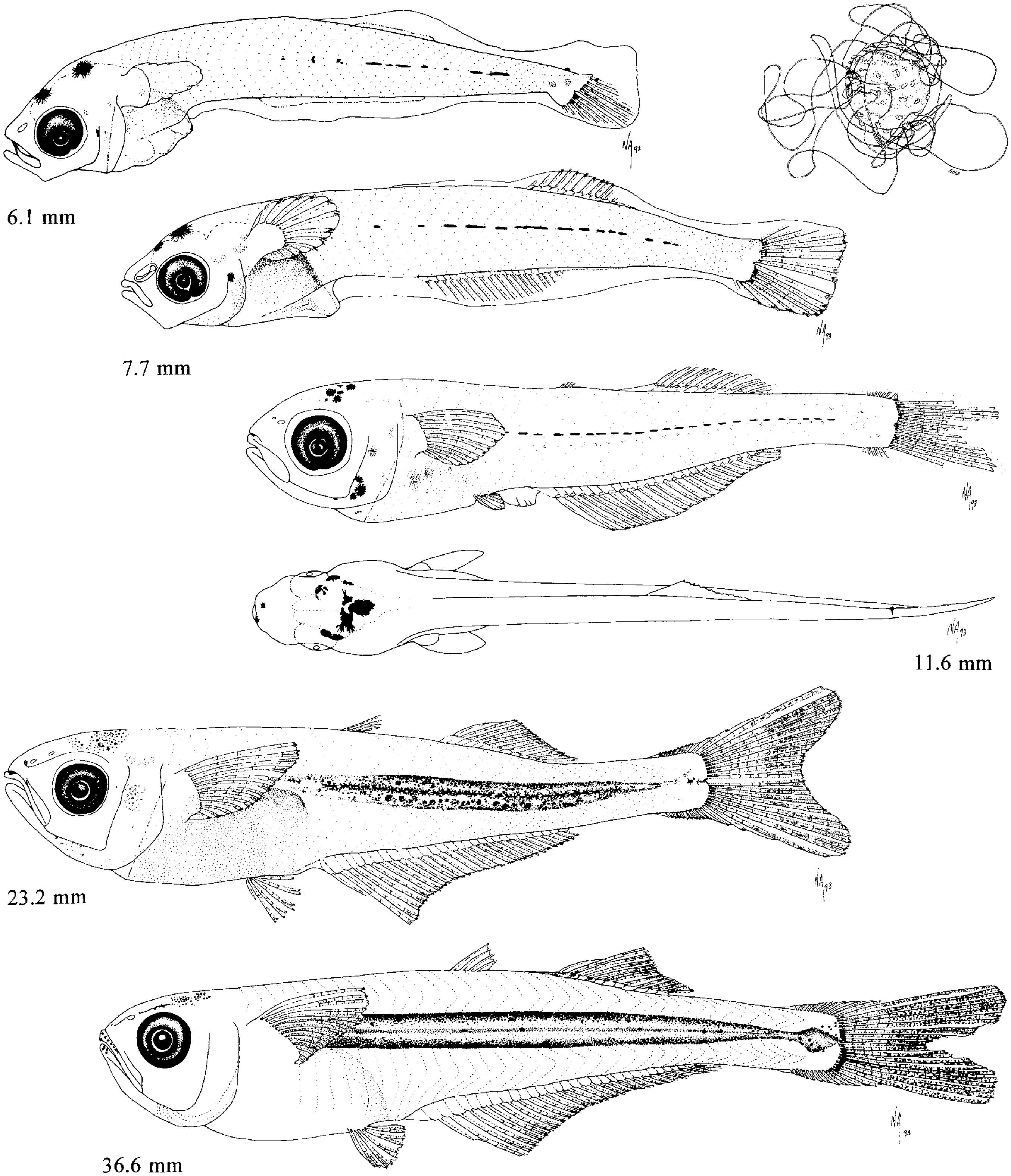


Figure Atherinidae 1. Ovarian egg (White et al. 1984; size not given); flexion larva, 6.1 mm (SIO 61–225); postflexion larvae, 7.7 mm (SIO 61–225), 11.6 mm, lateral and dorsal views (SIO 59–225); transformation specimen, 23.2 mm; juvenile, 36.6 mm (SIO 70–392). Scales are not shown on the transformation and juvenile specimens.

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	40
Precaudal	14–16	14
Caudal	25–26	26
Fins:		
Dorsal spines	II–V+I	IV+I
Dorsal rays	9–11	10–11
Anal spines	I	I
Anal rays	24–30	25–27
Pelvic	I,5	I,5
Pectoral	13–14	13
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–11	10
Lower	10–12	11–12
Gill rakers:		
Upper	3–4	
Lower	16–19	
Branchiostegals:	6	6

LIFE HISTORY

Range: Punta Abreojos, Baja California Sur, to Mazatlán, Sinaloa

Habitat: Surf zone & upper water column near shore along the open coast & in bays

Spawning season:

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 11.7 mm, lateral & dorsal views (N. Arthur)
Juvenile, 37.5 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <10.8 mm
Transformation length: ca. 12–13 mm to <34 mm
Fin development sequence: C_1, 2D & A & P_1, C_2, P_2, 1D
Pigmentation: *Postflexion–transformation*—3 (large) in triangular pattern over midbrain; 1 to several anteriorly over hindbrain; over forebrain, near nostrils, & on upper lip & dentary by 10.8 mm; under gill cover, spreading onto branchiostegal membrane by ca. 11.7 m; laterally & ventrally on brain, surrounding it after 12.8 mm; heavy dorsally on gut, scattered & increasing laterally & ventrally; midlateral series on tail at myomeres 8 to 35–38, broadening & extending to P_1 base after 12.8 mm; internal series above & below vertebral column; 1–2 each on dorsal & ventral margins near C. *Juvenile*—Heavy around brain, on snout, under gill cover, & around gut; broad stripe from P_1 base to hypural margin; on anterior D & A ray bases; on C, primarily outer third of fin.
Diagnostic features: External pigment over hindbrain in larvae; dorsal & ventral tail pigment only on caudal peduncle; midlateral stripe extends to 2nd–4th from last myomere in larvae, to hypural margin with no posterior constriction in juveniles; 2D fin insertion above last or next to last A ray; myomeres 9–10+30–31=39–40 in postflexion stage, 14–15+25–26=40 in juveniles.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				36–40 38	40	44–47 46
BD/BL				17–19 18	18	19–20 19
HL/BL				20–21 21	24	20–22 21
HW/HL				56–61 58	51	53–57 55
SnL/HL				23–28 26	29	26–29 27
ED/HL				37–39 38	30	35–37 36
P_1L/BL				11–14 13	14	15–17 16
P_2L/BL				5–7 6	8	9–9 9

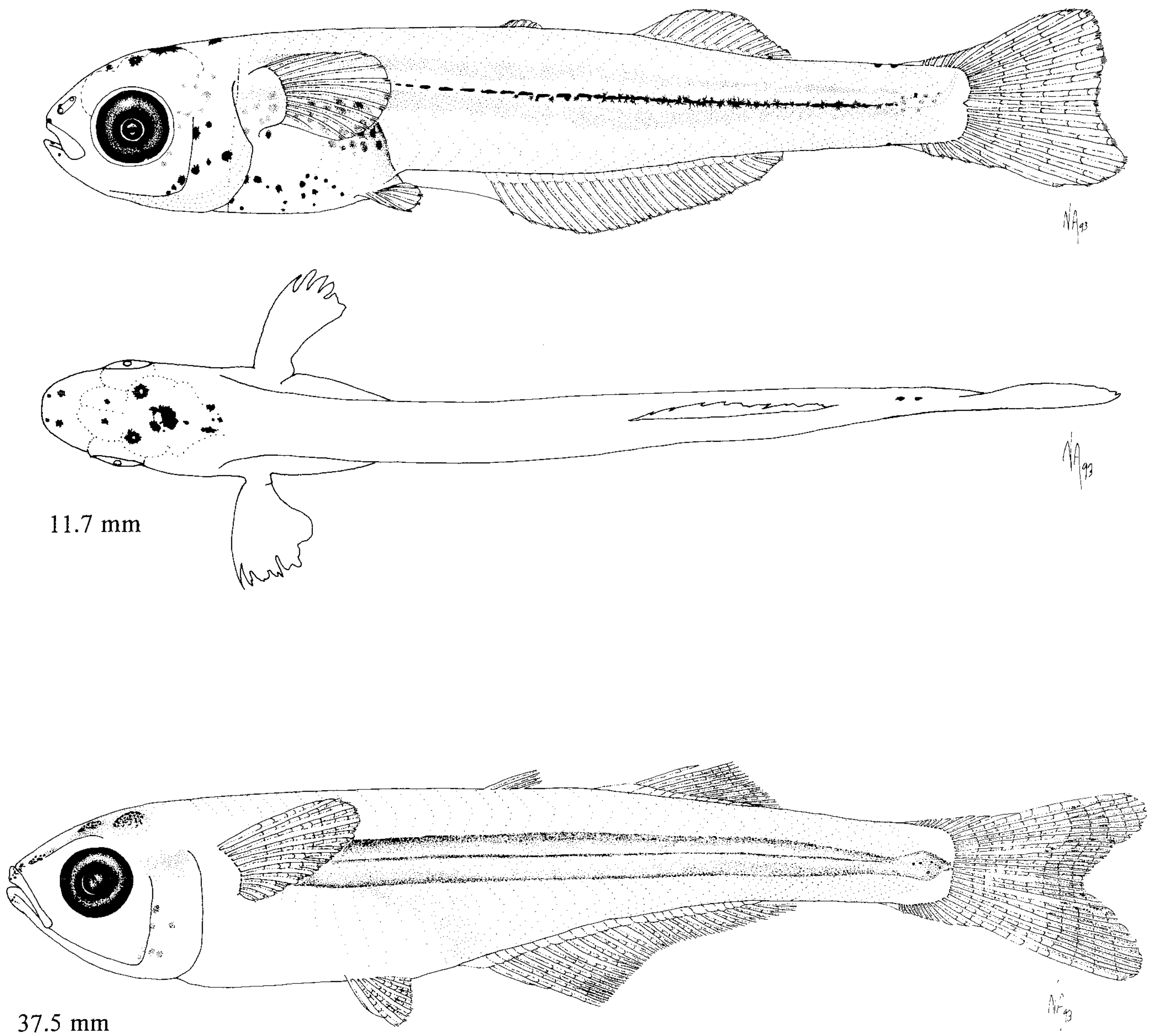


Figure Atherinidae 2. Postflexion larva, 11.7 mm, lateral and dorsal views (CFRD Ref. Coll., Survey P48–15, Bahía Ballenas, Baja California Sur); juvenile, 37.5 mm (SIO 59–206). Scales are not shown on the juvenile specimen.

MERISTICS

	Range	Mode
Vertebrae:		
Total	44–52	46–48
Precaudal	11–15	13–14
Caudal	32–37	33–35
Fins:		
Dorsal spines	V–IX+I	V–VI+I
Dorsal rays	8–14	10
Anal spines	I	I
Anal rays	19–25	21–22
Pelvic	I,5	I,5
Pectoral	13–15	14
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	10
Lower	9–12	11
Gill rakers:		
Upper	4–8	
Lower	21–34	
Branchiostegals:	5–6	6

LIFE HISTORY

Range: Vancouver Island, British Columbia, to the Gulf of California

Habitat: Schools near shore, especially in bays & estuaries & near kelp beds

Spawning season: March through September with peak from April through July

ELH pattern: Oviparous; eggs attached to spawning substrate & to one another via adhesive filaments; larvae are planktonic, primarily neustonic

LITERATURE

Curless 1979
Matarese et al. 1989
Middaugh et al. 1990
Wang 1981
White et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Dorsal view of 7.9 mm flexion larva (W. Watson)

* Eye is slightly to moderately oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

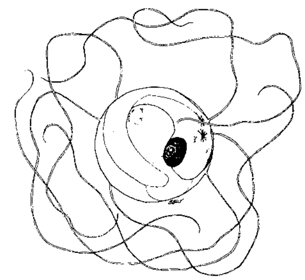
Shell diam.: 1.4–1.7 × 1.5–1.8 mm
Yolk: Homogeneous; 1.4–1.6 mm diam.
No. of OG: 5 to many, usually coalescing to 1
Diam. of OG: 0.02–0.54 mm
Shell surface: 5–13 long filaments, each attached at one end, or 40–78 filaments attached at both ends, scattered over surface
Pigment: Yolk yellowish to amber; melanophores develop on dorsal surface & gut of embryo beginning ca. 4 days after fertilization
Diagnostic features: Diameter; 5–13 (usually 6–8) long filaments or 40–78 looped filaments on chorion

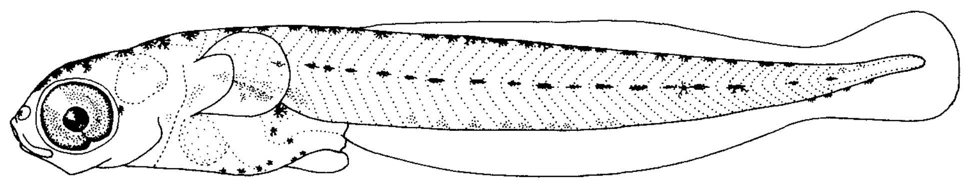
LARVAE

Hatching length: 4.3–5.4 mm
Flexion length: 7.7–8.9 mm through 9.6–10.5 mm
Transformation length: ca. 14–21 mm
Fin development sequence: C_1, 2D & A, P_1, C_2, P_2, 1D
Pigmentation: *Yolk-sac*—3 (large) over midbrain, 1 over hindbrain; 16–19 on dorsal margin to last myomere; 4–17 on lateral midline of tail; dorsally on gut; scattered ventrally on yolk sac. *Preflexion–postflexion*—2 over forebrain & 1 at each nostril by 7.6 mm; under hindbrain by ca. 8 mm; on jaws, gill cover, & increasing on head after 8.2 mm; increasing on dorsum, forming on 2D bases & spreading onto some rays by 13 mm; increasing on lateral midline, extending from myomere 4–5 to end of tail by 8.3 mm; series along ventral margin of tail by ca. 6–7 mm; internal series above & below vertebral column by ca. 10 mm; on hypural margin by ca. 8 mm; on C rays by ca. 10 mm; spreading ventrally on gut. *Transformation*—Increasing on head, gut, dorsolaterally on trunk & tail, & on 2D, A, & C; lateral stripe broadens on tail.
Diagnostic features: Myomeres 44–50, usually 10–11+37 to flexion stage, 11–13+34–35 thereafter; A origin usually below ca. middle of 1D base; external ventral melanophores on gut, usually along longitudinal midline.

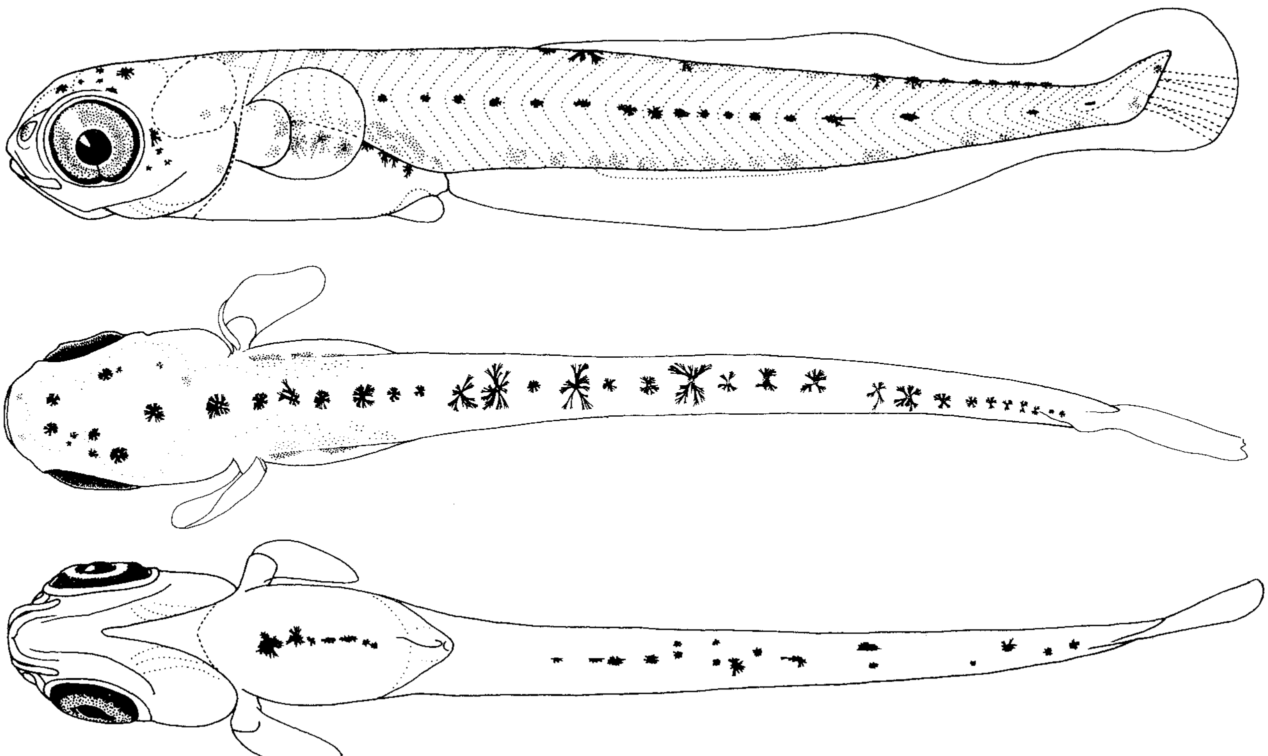
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	37–41 40	33–40 36	42–44 43	44–51 46	54–60 57	57–58 58
BD/BL	17–23 20	11–14 13	15–16 15	14–17 15	16–18 17	16–18 17
HL/BL	18–20 19	17–22 19	21–24 22	22–25 24	25–29 27	25–27 26
HW/HL	60–78 72	62–67 64	58–61 60	51–61 56	40–55 48	47–51 50
SnL/HL	7–17 12	15–23 19	18–23 21	21–27 24	24–29 26	26–30 28
ED/HL*	42–43× 38–39	35–45× 32–36	34–36× 29–33	31–36× 28–33	31–34× 28–31	30–33× 27–31
	42×38	40×34	35×31	33×30	33×29	31×29
P_1L/BL	6–6 6	6–7 7	7–8 7	7–11 9	12–16 14	16–17 16
P_2L/BL	0–0 0	0–0 0	0–0 0	0.3–5 2	5–7 6	7–8 8

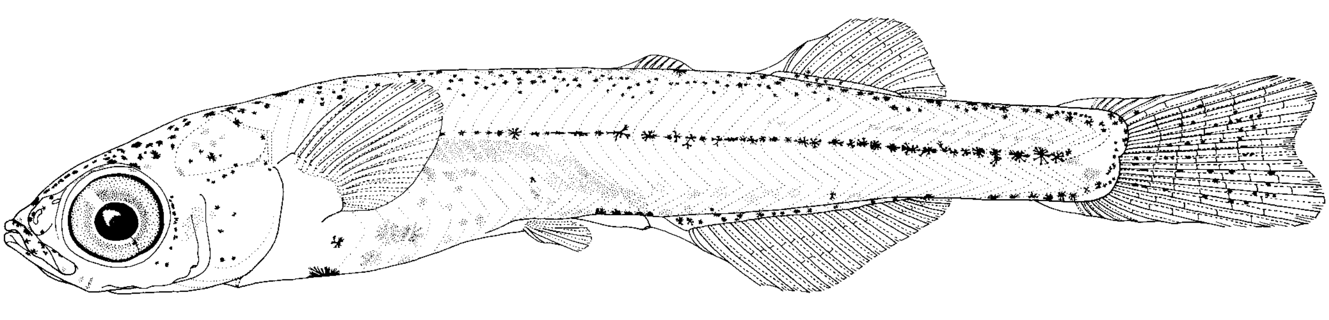




6.2 mm



7.9 mm



14.0 mm

Figure Atherinidae 3. Egg (White et al. 1984; size not given); late yolk-sac larva, 6.2 mm; early flexion larva, 7.9 mm, lateral, dorsal, and ventral views; late postflexion larva, 14.0 mm (Matarese et al. 1989; dorsal view of 7.9 mm larva not in Matarese et al. 1989). Larvae reared at MEC Research Facility.

MERISTICS

	Range	Mode
Vertebrae:		
Total	50–54	51
Precaudal	9–14	11–12
Caudal	37–41	39–40
Fins:		
Dorsal spines	V–IX+I	VI–VIII+I
Dorsal rays	11–14	12–13
Anal spines	I	I
Anal rays	21–26	23–24
Pelvic	I,5	I,5
Pectoral	15–17	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–12	11–12
Lower	10–13	12
Gill rakers:		
Total	18–44	
Upper		
Lower		
Branchiostegals:	5–6	6

LIFE HISTORY

Range: Yaquina Bay, Oregon, to Bahía Santa Maria, Baja California Sur

Habitat: Schools near shore along open coast & in bays

Spawning season: October to April, primarily November through March

ELH pattern: Oviparous; eggs attached to one another & to spawning substrate via adhesive filaments; larvae are planktonic, primarily neustonic

LITERATURE

Matarese et al. 1989
Middaugh et al. 1990
Wang 1981
White et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Dorsal & ventral views of 9.9 mm flexion larva (W. Watson)
Transformation specimen, 21.6 mm (N. Arthur)

* Eye is slightly to moderately oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

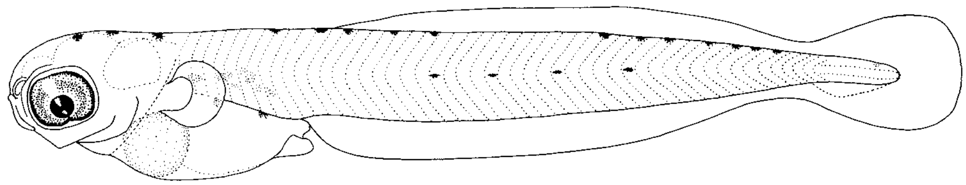
Shell diam.: 1.9–2.5 mm **Yolk:** Homogeneous; 1.7–2.3 mm diam.
No. of OG: 23–44, coalesce to 1 **Diam. of OG:** 0.03–0.63 mm
Shell surface: 12–20 long filaments scattered over surface
Pigment: Yolk yellow to yellow-orange; melanophores form on dorsal surface & gut of embryo beginning ca. 6 days after fertilization
Diagnostic features: Diameter; 12–20 (usually ca. 15–16) long filaments on chorion

LARVAE

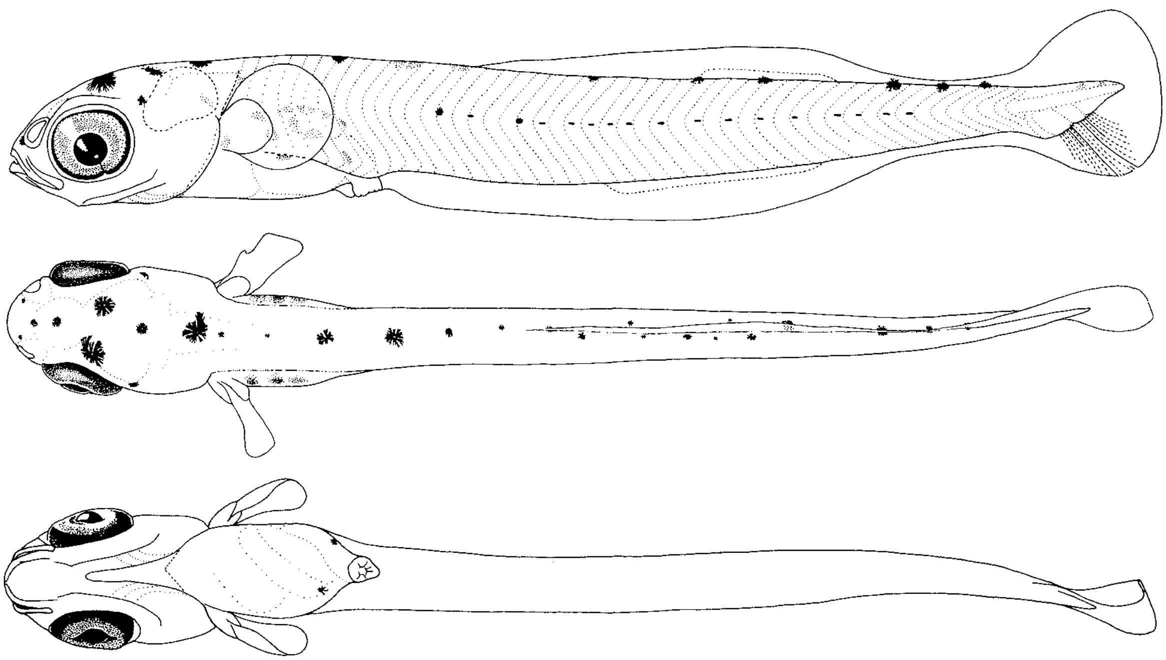
Hatching length: 6–9 mm, usually ca. 7.5–8.5 mm
Flexion length: 9.8–11.3 mm through 11.6–12.8 mm
Transformation length: 18.1–19.8 mm through ca. 25.4 mm
Fin development sequence: C_1, 2D & A & P_1, C_2, P_2, 1D
Pigmentation: *Yolk-sac*—3 (large) over midbrain; 1 over hindbrain; 17–21 on dorsal margin to 2nd–6th from last myomere; 0–7 on lateral midline of tail; dorsally on gut. *Preflexion–postflexion*—1 over forebrain by 9.5 mm; 1 at each nostril by ca. 11 mm; on gill cover by ca. 12.5 mm; increasing on head in postflexion stage; increases along lateral midline, reaching trunk by end of flexion stage; on ventral margin, beginning posteriorly at ca. 11.5–12.5 mm; internally under vertebral column & over last few vertebrae in postflexion stage; on hypural margin; spreading ventrad on gut. *Transformation*—Increases dorsally; lateral stripe broadens on tail; ventral margin series reaches P_2 base; few on C rays.
Diagnostic features: Myomeres 50–54, usually 10–11+41–42 through flexion stage, 13–14+37–38 in postflexion stage; 1D insertion above or just ahead of A origin; ventral pigment on tail usually does not extend cephalad beyond A origin in larvae.

MORPHOMETRICS (range & mean in %)

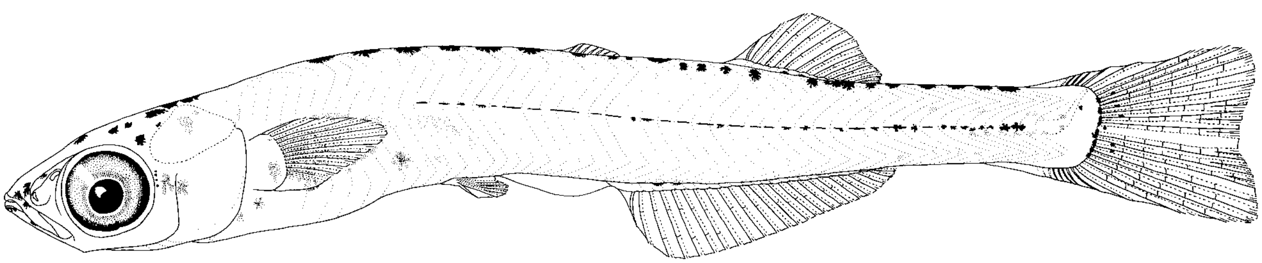
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	30–36 32	31–33 32	33–38 35	37–44 40	43–48 46	54–58 56
BD/BL	15–30 18	11–14 12	12–14 13	13–14 13	14–15 14	15–16 15
HL/BL	16–17 16	16–20 18	18–21 19	20–22 21	22–23 23	24–26 25
HW/HL	65–72 69	60–64 62	54–61 58	53–60 55	49–55 52	44–48 46
SnL/HL	9–18 14	17–24 20	18–25 22	22–28 24	25–29 27	27–29 28
ED/HL*	42–48× 35–43 45×39	35–42× 29–35 38×32	34–38× 31–33 36×32	30–38× 28–34 33×31	30–31× 28–30 31×29	28–30× 24–27 29×26
P_1L/BL	4–7 6	5–7 7	5–8 7	7–11 9	11–12 11	14–15 15
P_2L/BL	0–0 0	0–0 0	0–0.2 0.1	0–5 2	5–6 6	7–9 8



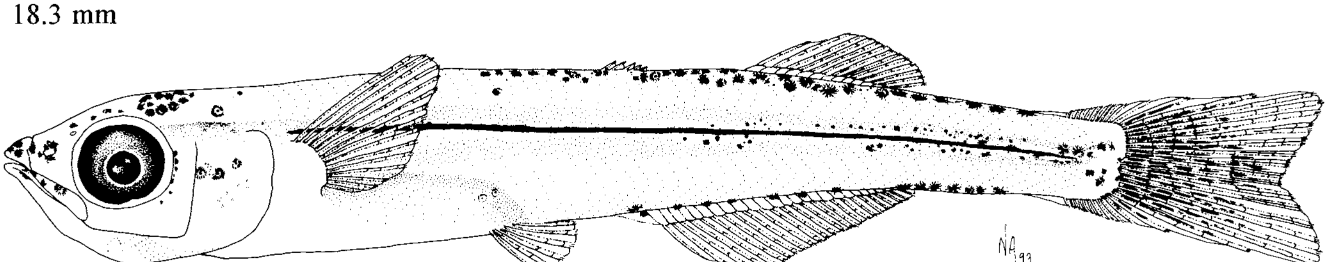
7.7 mm



9.9 mm



18.3 mm



21.6 mm

Figure Atherinidae 4. Egg (White et al. 1984; size not given); newly hatched larva, 7.7 mm; early flexion larva, 9.9 mm, lateral, dorsal, and ventral views; late postflexion larva, 18.3 mm (Matarese et al. 1989; dorsal and ventral views of 9.9 mm larva not in Matarese et al. 1989); transformation specimen, 21.6 mm, developing scales not shown (SIO H45–62). Larvae reared at MEC Research Facility.

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–50	49
Precaudal	10–13	12
Caudal	35–39	37
Fins:		
Dorsal spines	III–VII+I	V+I
Dorsal rays	8–10	9–10
Anal spines	I	I
Anal rays	20–24	21
Pelvic	I,5	I,5
Pectoral	12–15	14–15
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–12	10
Lower	10–13	11
Gill rakers:		
Upper	5–7	
Lower	23–29	
Branchiostegals:	6	6

LIFE HISTORY

Range: San Francisco, California, to Bahía Magdalena, Baja California Sur

Habitat: Schools near shore, usually at or near surface along open coast & in bays

Spawning season: March–August, peak in April–May

ELH pattern: Oviparous; eggs are deposited in the sand at night just below the high spring tide line; larvae are planktonic, primarily neustonic

LITERATURE

Clark 1925
David 1939
Moffatt & Thomson 1978
Wang 1981
White et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 6.9 mm (W. Watson)
Flexion larva, 9.6 mm, lateral, dorsal, & ventral views (W. Watson)
Transformation specimen, 15.3 mm (W. Watson)

* Eye is slightly to moderately oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.5–2.2 mm
Yolk: Homogeneous; 1.1–2.0 mm diam.
No. of OG: 25 to >115, coalescing to 1
Diam. of OG: 0.02–0.18 mm
Shell surface: Unsculptured, without filaments
Pigment: Yolk yellow-green to orange & oil globules orange, fading to yellow; melanophores on dorsum & intestine of embryo by day 3–4.
Diagnostic features: Diameter, embryo, eggs buried in high intertidal beach sand

LARVAE

Hatching length: 6.5–7.0 mm
Flexion length: ca. 8–9.5 mm
Transformation length: ca. 15–20 mm
Fin development sequence: C_1, 2D & A, P_1 & C_2, P_2, 1D
Pigmentation: *Yolk-sac*—3 (large) over midbrain; 1 over hindbrain; under mid- & hindbrain; 14–20 (large) on dorsal margin to 2nd or 3rd from last myomere; 3–13 on lateral midline of tail; dorsally on gut. *Preflexion–postflexion*—1 added over forebrain, at each nostril, under preopercle, in otic capsule by ca. 7.5 mm; increasing on head in postflexion stage; 18–27 on dorsal margin; 10–20 on lateral midline, extending to P_1 base by ca. 10.5 mm; on ventral margin beginning posteriorly during flexion stage, extending forward as double row, reaching P_2 bases by ca. 10.5 mm; internally under vertebral column at ca. 9 mm, over it at ca. 10.5 mm; spreading ventrad to surround gut by ca. 15 mm. *Transformation*—Broad lateral stripe; heavy on dorsum; double row on ventrum; on C & middle 2D rays.
Diagnostic features: Myomeres 47–49, usually 9–10+38–39 through flexion stage, 12–15+33–36 in postflexion stage; 1D origin above to behind A origin; double row of melanophores along ventral margin beginning in flexion stage, reaching P_2 bases by 10.5 mm (usually more uniform series than similar pigment in *A. affinis*).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	32–37 34	30–35 33	34–35 35	40–48 43	49–57 54	56–59 58
BD/BL	14–17 15	11–13 12	11–14 13	13–16 14	14–16 15	15–16 15
HL/BL	16–18 17	17–19 18	19–21 20	21–24 23	23–27 25	26–27 26
HW/HL	66–74 69	61–66 64	56–65 61	51–62 55	50–55 53	40–45 43
SnL/HL	7–17 11	15–22 20	20–27 25	21–29 26	26–33 30	28–34 31
ED/HL*	43–48× 35–44 45×39	36–39× 30–34 37×32	33–39× 29–32 36×30	28–37× 27–34 33×30	29–33× 27–31 32×29	28–31× 26–28 29×28
P_1L/BL	5–8 6	7–9 8	7–9 8	9–14 11	11–15 13	16–18 17
P_2L/BL	0–0 0	0–0 0	0–0.2 0.1	1–8 4	7–9 8	9–10 9

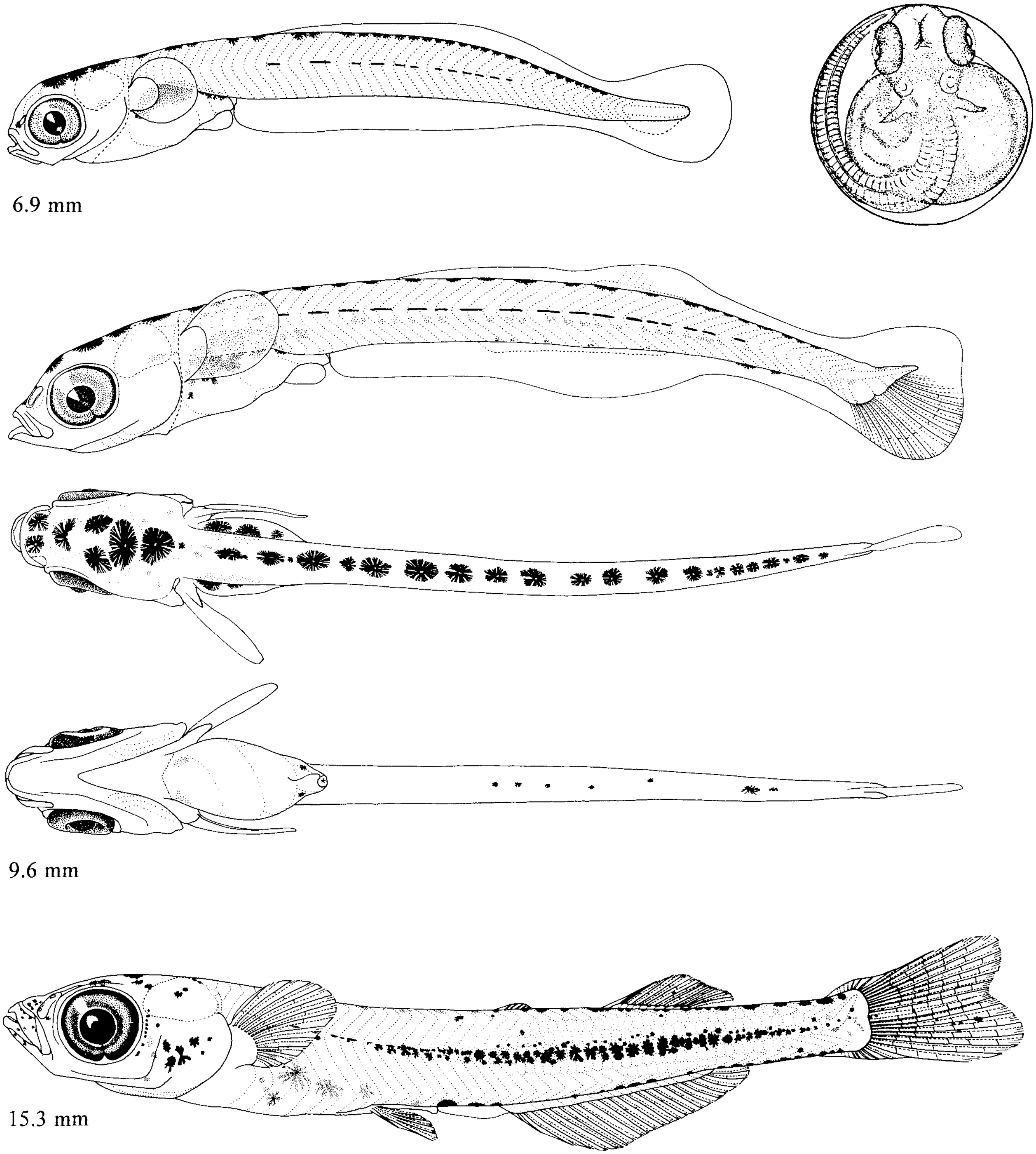


Figure Atherinidae 5. Egg, 5.5 days after fertilization (David 1939; size not given); newly hatched larva, 6.9 mm; 11-day-old early flexion larva, 9.6 mm, lateral, dorsal, and ventral views; transformation specimen, 15.3 mm. Larvae and transformation specimen reared by G. E. McGowen.

CYPRINODONTIFORMES

W. WATSON

The order Cyprinodontiformes is a very large (ca. 800 species) and diverse group of mostly small fishes living in shallow freshwater, estuarine, and marine habitats worldwide in tropical and temperate latitudes (Nelson 1994). Monophyly of the order as established in the revisionary study of Parenti (1981) is generally accepted. Able (1984) reviewed cyprinodontiform early life history studies. This order is represented in the CalCOFI study area by two species which, following Eschmeyer (1990), we place in the cyprinodontid subfamily Fundulinae. Parenti (1981) considered the fundulines to be a separate family, Fundulidae.

Family included: Cyprinodontidae

CYPRINODONTIDAE: Killifishes

W. WATSON

Two cyprinodontid species, the California killifish, *Fundulus parvipinnis*, and the rainwater killifish, *Lucania parva*, occur in marine and/or estuarine waters in the CalCOFI study area. *F. parvipinnis* is a common inhabitant of coastal lagoons, salt marshes, and the shallow margins of bays from central California to southern Baja California Sur, while *L. parva*, an introduced species, occurs only in the vicinity of the Sacramento-San Joaquin estuary (e.g., Hubbs and Miller 1965). Neither species has been taken in CalCOFI ichthyoplankton collections.

Cyprinodontids are small (<20 cm) residents of shallow fresh, brackish, and nearshore marine waters. They range in form from moderately elongate to deep-bodied. All have dorsal and anal fins composed only of soft rays and located approximately opposite one another at midbody or farther posteriorly. The caudal fin is truncate or rounded. The lateral line system is restricted to the head. Killifishes are well known in the aquarium trade and as research animals.

Killifishes are oviparous, spawning round to slightly oval demersal eggs ca. 1–3 mm in diameter that contain a colorless to yellowish yolk with one to 300 or more oil globules ca. 0.02–0.40 mm in diameter. The chorion is covered with adhesive filaments that may be clustered or single, and that are so fine, short, or closely applied to the chorion in some species that they are difficult to see. The filaments attach the eggs to the spawning substrate. Embryonic development ranges from a few days to a month or more; hatching can be delayed during unfavorable environmental conditions in many species (e.g., Able 1984).

Larvae typically are ca. 3–6 mm long and well developed at hatching with pigmented eyes, a functional mouth, fully flexed notochord and developing caudal fin rays, often with developing pectoral fin rays, and with a moderately large yolk sac. Dorsal and anal fin anlagen develop just before to soon after hatching and pelvic fins form near the end of the larval stage. Larvae typically are moderately elongate and slender initially, becoming deeper-bodied and more robust. The mouth is small and terminal, the snout rounded, and the eyes moderately large and round to somewhat oval. Preanal length is ca. one-third to half of body length. The gas bladder may be prominent in young larvae but is obscured by the increasing lateral pigmentation in older larvae. Larvae are heavily pigmented on the dorsal surface of the head and typically have longitudinal dorsal, midlateral, and ventral melanophore series, although some species have melanophores arranged in saddles and lateral blotches instead. Pigmentation typically is heaviest on the upper half of the head and body.

Among larval fishes in marine and estuarine ichthyoplankton collections in the CalCOFI area, only atherinids and perhaps some cottids (e.g., *Leptocottus*) might be confused with the larval cyprinodontids. However, these should be distinguishable by myomere and fin ray counts, presence of preopercular spines (cottids), presence of a spiny dorsal fin (older atherinids and cottids), and shorter preanal length (atherinids). The pigment patterns of the atherinids and cottids do not closely resemble the cyprinodontid patterns. The eggs of *L. parva* are much smaller than those of *F. parvipinnis* (1.0–1.3 mm versus 2.3–2.8 mm, respectively) and have more prominent filaments, and the larvae have fewer myomeres (26–27 versus 34–36), fewer pectoral fin rays (10–15 versus 16–21, all present after ca. 9 mm), and less prominent longitudinal melanophore series.

The following description of *F. parvipinnis* is based primarily on detailed examination of 32 eggs, 32 larvae and transformation specimens (5 yolk-sac, 5.6–6.9 mm; 18 postflexion, 6.7–10.1 mm; 7 transformation, 11.2–13.6 mm), and 5 juveniles (13.4–19.1 mm) of two developmental series reared from artificially spawned and fertilized eggs obtained from adults collected in San Elijo Lagoon and in Mission Bay, California. Eggs and larvae of *L. parva* were unavailable and are not described here; descriptions and illustrations are given by Hardy (1978a) and Wang (1981).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–37	36
Precaudal	14–16	15
Caudal	19–22	21–22
Fins:		
Dorsal spines	0	0
Dorsal rays	10–15	14
Anal spines	0	0
Anal rays	11–13	12–13
Pelvic	6	6
Pectoral	16–21	18
Caudal:		
Principal	5–6+6–7	6+6–7
Procurrent:		
Upper	14–17	16
Lower	14–16	14
Gill rakers:		
Upper	0–1	
Lower	7–10	
Branchiostegals	5–6	5

LIFE HISTORY

Range: Morro Bay, California, to Bahía Almejas, Baja California Sur

Habitat: Bays, lagoons, and salt marshes; may enter fresh water

Spawning season: April through September; principally April through June

ELH pattern: Oviparous; single demersal eggs attach via small weakly adhesive filaments to spawning substrate; larvae micronecktonic

LITERATURE

Able 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 2.3 mm (W. Watson)
Yolk-sac larva, 6.3 mm (N. Arthur)
Postflexion larvae, 7.8 mm, 8.5 mm (N. Arthur)
Transformation specimen, 11.3 mm (N. Arthur)

* Eye is oval, becoming round or nearly round by the juvenile stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.3–2.8 × 2.4–2.8 mm **Yolk:** Homogeneous; some weak segmentation occasionally visible
No. of OG: ca. 175 to >200 **Diam. of OG:** 0.02–0.20 mm
Shell surface: Small adhesive filaments scattered on chorion
Pigment: Yolk unpigmented; melanophores form on dorsal and dorsolateral surfaces of embryo, internally along notochord, on yolk adjacent to embryo, and on vitelline blood vessels
Diagnostic features: Diameter, oil globules, adhesive filaments on chorion

LARVAE

Hatching length: 5.6–6.8 mm
Flexion length: Before hatching
Transformation length: ca. 11 mm through 13–14 mm
Fin development sequence: C, P_1, A, D, P_2
Pigmentation: *Larvae*—Heavy over mid- and hindbrain; light over forebrain and on snout; light on gill cover and dentary; upper half of head becoming heavily pigmented by ca. 8 mm; 2 rows along dorsal margin and ventral margin of tail; 1 row along lateral midline; dorsolaterally on trunk, spreading caudad and ventrad to cover upper half by 9 mm; ventrolaterally on tail after 9 mm; on and under brain; over and under vertebral column; on C, D, and A by ca. 8.5 mm, on P_1 by 10 mm; 0–few ventrally on gut. *Juvenile*—Heavily pigmented dorsally and dorsolaterally, lighter ventrolaterally; irregular barred pattern, mainly on tail.
Diagnostic features: Robust body; short D and A approximately opposite one another at midbody; C rounded, symmetrical; myomeres 8–11+24–26=34–36; prominent dorsal, ventral, and midlateral melanophore series, becoming somewhat obscured by heavy dorsolateral pigment after ca. 9–10 mm; irregularly barred pattern on juveniles.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	46–50 47			45–54 50	55–59 56	57–60 59
BD/BL	16–48 29			16–20 18	19–22 20	20–22 22
HL/BL	24–28 26			25–30 27	27–29 28	28–30 29
HW/HL	73–84 79			67–79 73	67–73 71	65–73 70
SnL/HL	13–16 15			14–20 16	18–20 18	16–20 19
ED/HL*	36–47× 29–40			32–39× 30–35	31–32× 29–31	28–31× 27–31
	39×33			36×33	31×30	30×30
P_1L/BL	8–9 8			8–13 11	13–15 14	15–17 16
P_2L/BL	0–0 0			0–1 0.1	1–5 3	6–9 7

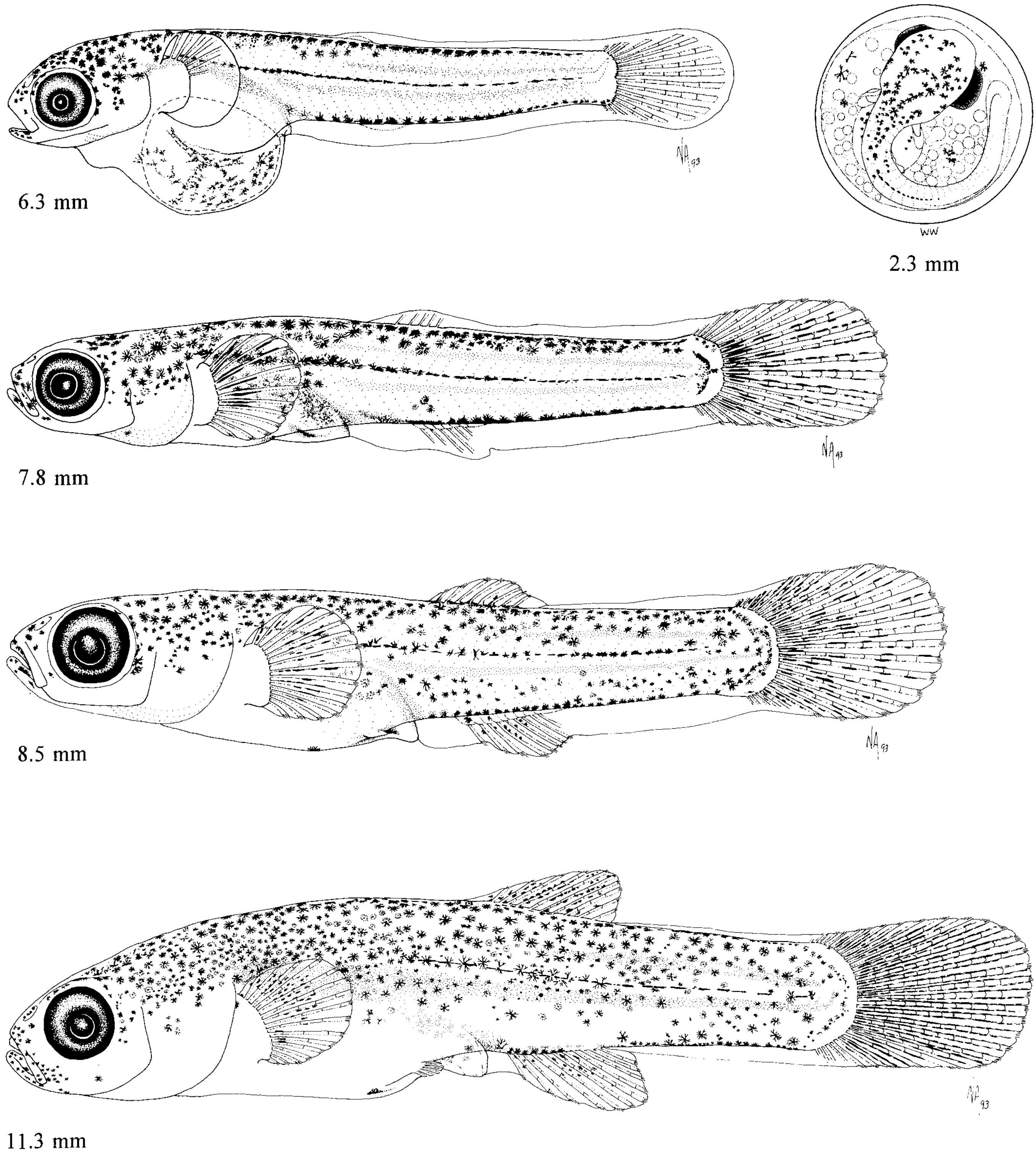


Figure Cyprinodontidae 1. Egg 14 days after fertilization, 2.3 mm; newly hatched larva, 6.3 mm; larva, 7.8 mm, 6 days after hatching; larva, 8.5 mm, 10 days after hatching; transformation specimen, 11.3 mm, 17 days after hatching, scales not shown. All specimens reared at MEC Research Facility from artificially spawned and fertilized eggs, from San Elijo Lagoon, California, April 14, 1979.

BELONIFORMES

W. WATSON

The order Beloniformes contains five families and about 190 species of marine (most species), estuarine, and freshwater fishes (Collette et al. 1984a; Nelson 1994). The beloniform fishes range from moderately to very elongate and from nearly cylindrical to strongly compressed. Most have a relatively long preanal length (ca. 67–75% BL, except shorter in the Adrianichthyidae), dorsal and anal fins placed far posteriorly, 6 pelvic fin rays, 7+8 principal caudal fin rays, and 38–99 vertebrae (except fewer in the Adrianichthyidae). Elongate pelvic fins typify most flyingfishes and some halfbeaks, and an elongate lower jaw is characteristic of the halfbeaks, some flying fishes, and the "halfbeak" developmental stage of the needlefishes. Mature needlefishes typically have both jaws elongated. The beloniform fishes are strongly surface-oriented residents primarily of tropical and subtropical waters; some range well into temperate waters.

Most beloniform fishes are oviparous, spawning spherical to oval eggs ca. 1.0–4.5 mm in diameter that contain a colorless to lightly pigmented homogeneous yolk having none to many small oil globules that may coalesce to a few or one, and commonly having the chorion ornamented with filaments ranging from short and bristle-like to long and slender. The long filaments, which may be evenly spaced over the chorion or arranged in groups, typically serve to attach the eggs to one another, to floating objects, or to a spawning substrate. After an incubation period on the order of 1–2 weeks, larvae typically hatch with a fully flexed notochord, developing rays in at least the caudal fin, pigmented eyes, and a functional mouth. Larvae commonly are elongate and slender (some are rather robust) with a long preanal length. Characteristic elongate fin rays and/or jaws are not developed at hatching but soon become apparent. Pigmentation ranges from light to heavy; larvae nearly always are heavily pigmented on the dorsum, reflecting their upper water column (principally neustonic) habitat.

About 16 marine species representing four of the five beloniform families occur in the California Current vicinity (Table Beloniformes 1). However, the larvae of about half of these are rare or absent in CalCOFI collections. Only larvae of the Pacific saury, California needlefish, and two or three flyingfish species occur with some regularity in plankton collections off California and northern Baja California.

Families included: Scomberesocidae
Belonidae
Hemiramphidae
Exocoetidae

Table Beloniformes 1. Meristic characters for the beloniform species that may be encountered in the CalCOFI area. All have 7+8 principal caudal fin rays and 6 pelvic fin rays (*Euleptorhamphus viridis* can have up to 9 pelvic fin rays, and *Strongylura exilis* can have as few as 5).

	Vertebrae			Fin rays					
Taxon	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers	BrR
Scomberesocidae									
Cololabis saira	37–40	26–29	62–69	9–12+4–6 finlets	12–15+ 4–7 finlets	12–14	5–6+5–6	32–43	12–15
Belonidae									
Ablennes hians	51–64	30–37	82–99	22–27	24–29	11–15		0	
Platybelone argalus pterura	39–40	24–25	62–65	11–14	15–18	10–12	6+6	4–5+ 6–7	11–12
Strongylura exilis	41–46	24–29	67–74	13–17	16–19	11–13	5–6+5–6	0	11–12
Tylosurus acus pacificus	50	26	74–80	20–24	18–22	12–13	6+7	0	14
Hemiramphidae									
Euleptorhamphus viridis	44–47	26–29	70–75	21–25	21–24	7–9	4–5+4	6–8+ 18–23	12–14
Hemiramphus saltator	36–41	16–18	54–58	12–15	11–13	10–12	4–6+5–6	9–14+ 23–32	13–15
Hyporhamphus gilli	32–34	18–19	50–52	14–16	15–16	11–12	4–5+4–5	37–50	11–12
H. rosae	30–33	17–18	47–50	13–15	14–16	9–11	4–5+3–5	28–36	10–12
H. unifasciatus	31–35	17–19	51–54	14–16	15–18	11–12	4–5+4–5	8–12+ 22–26	11–13
Oxyporhamphus micropterus micropterus	30–32	17–19	47–50	13–15	13–16	11–13	3–4+3–5	7–9+ 21–26	11–14
Exocoetidae									
Cheilopogon heterurus hubbsi	31–32	15–17	47–49	12–14	8–11	14–16	6–7+7	5–7+ 15–17	10–12
C. papilio	28–29	14–15	42–44	9–10	9–11	12–13	4–5+6	6–7+ 18–21	9
C. pinnatibarbatus californicus	31–35	16–17	48–51	9–13	9–12	14–15	5–6+6–8	4–8+ 13–16	10–12
C. xenopterus	28–29	14	42–43	12–13	9–10	12–13		7+15	
Cypselurus callopterus	27–29	13–15	41–43	11–12	8–10	14–15	5+6–7	2–3+ 12–13	9
Exocoetus monocirrhus	25–26	16–17	42–45	13–14	12–14	14–15		4–6+ 20–21	
E. volitans	24–26	19–20	43–46	12–15	12–14	14–16	5+5–7	20–37	9–11
Fodiator acutus rostratus	24–26	14–16	39–41	9–11	9–12	12–14	4–6+5–7	7–8+ 21–26	9–11
Hirundichthys marginatus	28–29	14–18	43–46	9–11	10–12	16–19	5–7+7–8		9–10
H. rondeletii	29–31	14–17	43–47	10–12	10–13	15–18	5–7+6–8	25–29	10–11
H. speculiger	27–28	17–19	44–47	10–12	11–13	17–19	5–7+5–8	23–28	10–11
Prognichthys tringa	27–30	11–14	39–43	9–11	7–9	15–17	5–6+5–7	17–22	8–11

SCOMBERESOCIDAE: Sauries

W. WATSON

The family Scomberesocidae contains four species in to or four genera (Hubbs and Wisner 1980; Collette et al. 1984a) and is represented in the California Current by a single species: *Cololabis saira*, the Pacific saury. Eggs and larvae of the Pacific saury are common in CalCOFI collections, particularly those from the neuston at offshore stations. A dwarf saury, either a species of *Cololabis* (Parin 1968; Collette et al. 1984a) or another genus (*Elassichthys adocetus*: Hubbs and Wisner 1980), occurs in the eastern part of the North Equatorial Current and southward into the northern Peru Current region. Larvae and juveniles of this small saury have been collected in extended CalCOFI surveys at far seaward southern stations.

Sauries are small to medium-size (*C. saira* to ca. 35 cm, *E. adocetus* to ca. 7 cm), elongate, slender, compressed fishes with a pointed snout, long preanal length, and dorsal and anal fins located far posteriorly. Series of finlets follow both the dorsal and anal fins. In life, sauries are blue to green dorsally and bright silver to silvery white laterally. All are epipelagic near-surface residents.

Sauries are oviparous, spawning large oval eggs that contain an unpigmented and unsegmented yolk, lack an oil globule, and have a chorion lacking filaments, or covered with short bristle-like filaments, or with long clustered filaments (e.g., Collette et al. 1984a). *C. saira* eggs have a polar cluster of long thin filaments and a single thicker filament attached on the side. These filaments intertwine to attach the eggs to one another and to floating objects. The incubation period is about two weeks (Yusa 1960). Larvae hatch at about 6–7 mm SL with pigmented eyes, an open mouth, fully flexed notochord and developing caudal fin rays, and with a small to moderate yolk sac. Larvae are elongate and slender, with preanal length about two-thirds of body length. Proportions change relatively little during development, except that the snout grows from short and rounded to long and pointed, and the body becomes increasingly compressed. Pigmentation is heavy at hatching, except laterally and ventrally on the head, ventrally on the gut, and on the fins. It increases only a little, primarily ventrally, during larval development. In life the larvae are green to blue dorsally and greenish-white to silvery laterally (Yusa 1960). Larvae are neustonic.

Saury larvae superficially resemble larval needlefish, but hatch at a smaller size, lack the greatly elongate lower and upper jaws, have dorsal and anal finlets which the needlefish lack, and are more compressed than the needlefish. Larval *C. saira* and *E. adocetus* differ mainly in meristic characters: *E. adocetus* has fewer pectoral and procurrent caudal fin rays, vertebrae, and gill rakers (Hubbs and Wisner 1980). During transformation, the pectoral fins of *C. saira* become relatively longer than those of *E. adocetus*, but *E. adocetus* develops relatively longer pelvic fin rays.

The following description of *Cololabis saira* is based on detailed examinations of 31 specimens (5 yolk-sac, 6.1–6.5 mm; 16 postflexion, 6.9–21.8 mm; 5 transformation, 21.6–28.8 mm; 5 juvenile, 31.1–46.5 mm) in addition to published literature (Mito 1958; Mukacheva 1960; Yusa 1960; Collette et al. 1984a; Matarese et al. 1989). Meristic data were obtained from Hubbs and Wisner (1980) and from counts made during the present study. Ecological information was obtained from Smith and Ahlstrom (1970), Hubbs and Wisner (1980), and Eschmeyer et al. (1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	62–69	65
Precaudal	37–40	38
Caudal	26–29	27
Fins:		
Dorsal spines	0	0
Dorsal rays	9–12+4–6 finlets	11+5 finlets
Anal spines	0	0
Anal rays	12–15+4–7 finlets	14+6 finlets
Pelvic	6	6
Pectoral	12–14	13
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	5–6	5–6
Lower	5–6	6
Gill rakers:		
Total	32–43	36–40
Upper		
Lower		
Branchiostegals	12–15	12

LIFE HISTORY

Range: North Pacific Ocean; in the eastern Pacific from the Gulf of Alaska to Islas de Revillagigedo, Mexico

Habitat: Primarily epipelagic, at or near surface

Spawning season: Year-round; spring peak in the CalCOFI area

ELH pattern: Oviparous; eggs attached via filaments to one another & to floating objects; larvae are neustonic

LITERATURE

Chen 1988
Collette et al. 1984a
Matarese et al. 1989
Mito 1958
Mukacheva 1960
Yusa 1960

ORIGINAL ILLUSTRATIONS (Illustrator)

Larvae, 6.3 mm, 9.9 mm, 16.5 mm (G. Mattson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.5–1.8 mm × 1.6–1.9 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Cluster of 12–20 filaments at pole, 1 thicker lateral filament
Pigment: Yolk colorless; late stages with melanophores almost completely covering embryo & scattered on yolk
Diagnostic features: Shape, arrangement of filaments

LARVAE

Hatching length: ca. 5–7 mm
Flexion length: Before hatching
Transformation length: ca. 21–30 mm
Fin development sequence: C, D & A, P_1, P_2
Pigmentation: *Larvae*—Head, body & gut heavily pigmented except none ventrally on head, none ventrally on gut before ca. 14 mm, & light pigment on otic capsule & opercular area; fins unpigmented except light pigment on P_1 base. *Juvenile*—Head lightly pigmented ventrally & ventrolaterally; light pigment along C rays.
Diagnostic features: Elongate & slender; strongly compressed by ca. 12 mm; dorsal & anal finlets discernable by 9.5–10 mm; beak never forms; heavily pigmented except light on lower part of head & none on fins before transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL	65–68 66	64–70 68	65–65 65	63–66 65
BD/BL	16–17 17	9–12 10	11–13 12	12–14 13
HL/BL	18–18 18	18–21 19	19–21 20	19–22 21
HW/HL	73–75 74	36–65 50	32–35 33	29–33 31
SnL/HL	9–12 10	12–20 16	21–24 23	23–31 27
ED/HL	37–41 40	28–38 35	26–30 28	24–28 26
P_1L/BL	9–10 9	7–11 9	9–11 10	9–10 9
P_2L/BL	0–0 0	0–3 0.2	2–4 3	4–5 5

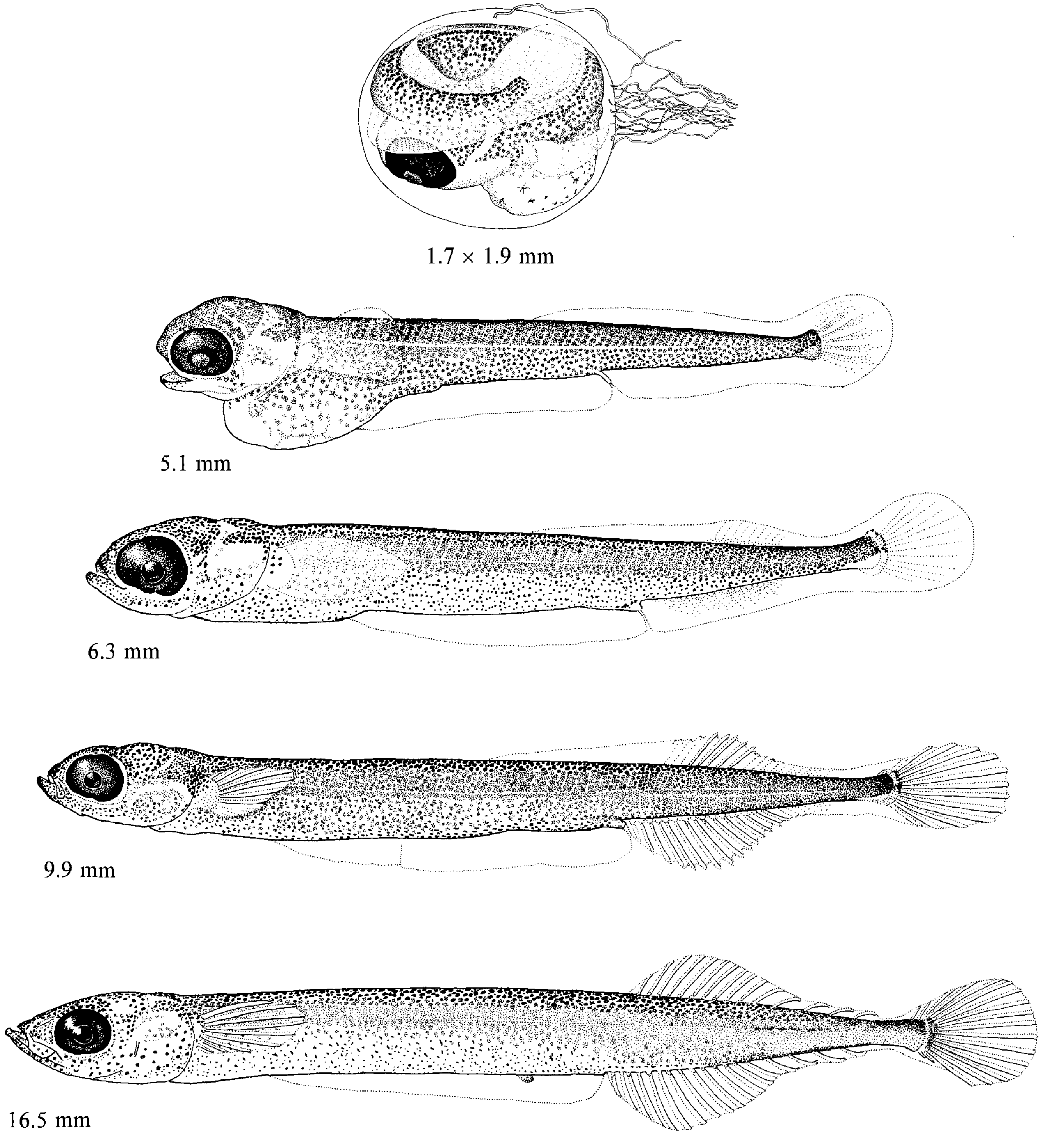


Figure Scomberesocidae 1. Egg, 1.7 × 1.9 mm (Matarese and Sandknop 1984); yolk-sac larva, 5.1 mm (Collette et al. 1984a); larvae, 6.3 mm (CalCOFI 4907, station 111.48), 9.9 mm (CalCOFI 5002, station 83.70A), 16.5 mm (CalCOFI 5007, station 113.25).

BELONIDAE: Needlefishes

W. WATSON

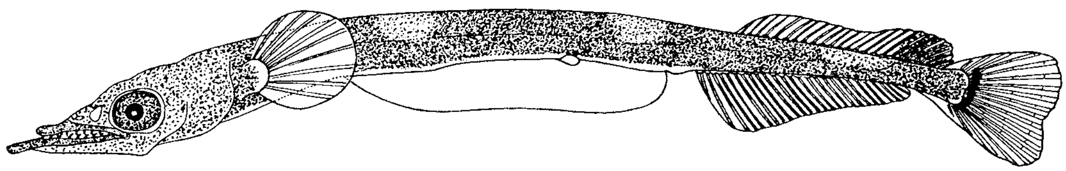
Belonidae contains about 32 species in 10 genera (Nelson 1994); four or five species in three genera enter the CalCOFI study area. *Strongylura exilis* occurs along the Pacific coast of California and Baja California. The widely distributed tropical species *Ablennes hians* ranges northward to the central Pacific coast of Baja California and the Gulf of California. *Platybelone argalus pterura* ranges northward along the Pacific coast of Baja California Sur and the lower Gulf of California, while *Tylosurus acus pacificus* reaches the southern coast of Baja California Sur and *T. crocodilus fodiator* ranges southward from the Gulf of California (Collette 1995a). All of these last four species are distributed primarily outside the CalCOFI study area. Larvae of none of these species has been identified in CalCOFI ichthyoplankton samples; however, larval *S. exilis* are relatively common during the summer in the neuston near shore off southern California.

Adult needlefishes are medium length (most species ≤1 m), elongate and slender, usually with both jaws elongated and bearing many needle-like teeth, with a long preanal length, and with dorsal and anal fins opposite one another far posteriorly. Most species are marine piscivores that school just below the surface near shore; some species are epipelagic, while others inhabit the surface zone in fresh water.

Needlefishes are oviparous, spawning large spherical eggs (usually ca. 2–4 mm in diameter) containing an unsegmented yolk and lacking oil globules (e.g., Collette et al. 1984a). Long filaments or filament tufts uniformly spaced over the chorion attach the eggs to floating or stationary objects and to one another. The typical incubation period is about one to two weeks (e.g., Hardy 1978a; Ambrose and Moser 1988). Larvae are large (ca. 4–15 mm: Collette et al. 1984a; Leis and Trnski 1989) and well-developed at hatching, with a functional mouth, pigmented eyes, flexed notochord, and fin ray development ranging from some of the principal caudal rays formed to most rays formed in all but the pelvic fins. Larvae are elongate and slender, with preanal length ca. 67–75% BL. The jaws are short initially, but the lower jaw soon lengthens, followed much later by the upper jaw. Thus, needlefishes pass through a "halfbeak" stage (Collette et al. 1984a; Boughton et al. 1991). Heavy pigmentation forms on the body during embryonic development and persists through the larval stage.

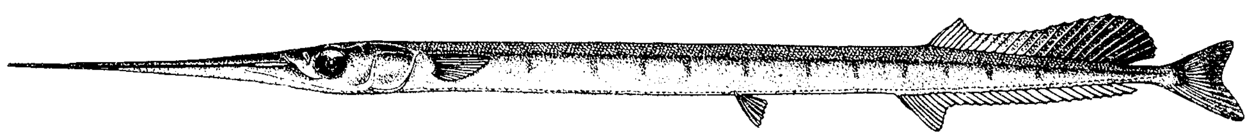
Larval belonids usually will not be confused with those of any other family in the California Current vicinity, although larvae of other Beloniformes do share some characters with the belonids. Larval exocoetids in the CalCOFI area are much stockier than larval belonids, quickly develop much longer pectoral and pelvic fin rays, lack a beak (except *Fodiator acutus rostratus*), and have fewer myomeres. Larval hemiramphids (except *Hemiramphus saltator*) are more lightly pigmented than the belonids, most have distinct melanophore bands rather than the more or less uniform pigmentation of the belonids, and most have fewer myomeres, fewer anal fin rays (Table Beloniformes 1), and a more anterior dorsal fin origin than the belonids. Larval scomberesocids are compressed rather than cylindrical as the belonids are, develop dorsal and anal finlets which the belonids lack, and do not acquire a pronounced beak.

The following description of *S. exilis* is taken from Ambrose and Moser (1988), supplemented with additional meristic data collected during the present study. *Ablennes hians* is shown in Figure Belonidae 1 but is not described separately, and the other three species are neither figured nor described because no specimens were available. Some descriptions and additional illustrations of *A. hians* are available in Parin (1967), Hardy (1978a), Collette et al. (1984a), and Chen (1988).



12.3 mm

36.1 mm



206 mm

Figure Belonidae 1. *Ablennes hians*: Early larva, 12.3 mm (Chen 1988); "halfbeak" stage larva, 36.1 mm (Collette et al. 1984a); juvenile, 206 mm (Parin 1967).

MERISTICS

	Range	Mode
Vertebrae:		
Total	67–74	69–72
Precaudal	41–46	43–46
Caudal	24–29	26–27
Fins:		
Dorsal spines	0	0
Dorsal rays	13–17	15
Anal spines	0	0
Anal rays	16–19	18
Pelvic	5–6	6
Pectoral	11–13	12
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	5–6	6
Lower	5–6	6
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	11–12	12

LIFE HISTORY

Range: San Francisco, California to the Galápagos Islands & Peru

Habitat: Neritic, usually at or near surface close to shore & in bays & harbors

Spawning season: Summer (California)

ELH pattern: Oviparous; eggs attach via long filaments to vegetation & floating objects; larvae are neustonic

LITERATURE

Ambrose & Moser 1988
Collette et al. 1984a

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.3–2.8 mm **Yolk:** Homogeneous; ca. 2.2–2.7 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: 18–40 long filaments distributed evenly over chorion
Pigment: None initially; embryo becomes completely pigmented with melanophores & xanthophores except on P_1, C, & median finfold
Diagnostic features: Filaments attached to chorion; late embryo nearly completely pigmented.

LARVAE

Hatching length: 6.2–9.3 mm
Flexion length: before hatching
Transformation length: ca. 32–68 mm*
Fin development sequence: C_1, D & A & P_1, C_2, P_2
Pigmentation: Larvae—Completely pigmented initially except on branchiostegal membrane, P_1 blades, median finfold, & end of gut; decreasing lateral melanistic pigment on trunk after ca. 27 mm.
Diagnostic features: Larvae nearly completely pigmented; very elongate & slender with long preanal length; lower jaw begins to elongate into beak by end of yolk absorption (ca. 7–10 mm) & upper jaw begins to elongate by ca. 16 mm; D rays 13–17, A rays 16–19.

MORPHOMETRICS (range & mean in %)†

	Y-S	PoF	Tr	Juv
Sn-A/BL		68–72 69	67–70 69	68–70 69
BD/BL		6–14 9	5–7 6	6–7 7
HL/BL		14–16 15	16–17 17	15–17 16
SnL/HL		11–128 50	175–193 182	214–264 247
ED/HL‡		30–56× 28–44 40×34	29–34× 23–28 31×26	30–34× 29–34 32×30
P_1L/BL		6–10 8	9–9 9	9–11 10
P_2L/BL		0–3 1	4–5 5	4–5 5
ML/HL		0–260 130	202–267 232	184–291 265

* Juvenile form, pigmentation, & full fin ray complements present by ca. 32–40 mm; scales form at ca. 58–68 mm
† Morphometrics calculated from Ambrose & Moser (1988), Table 2. Body length, preanal length, & head length were measured from the anterior margin of the eye, owing to the allometric growth of the snout during development.
‡ Eye is oval; horizontal axis is given first, vertical second.

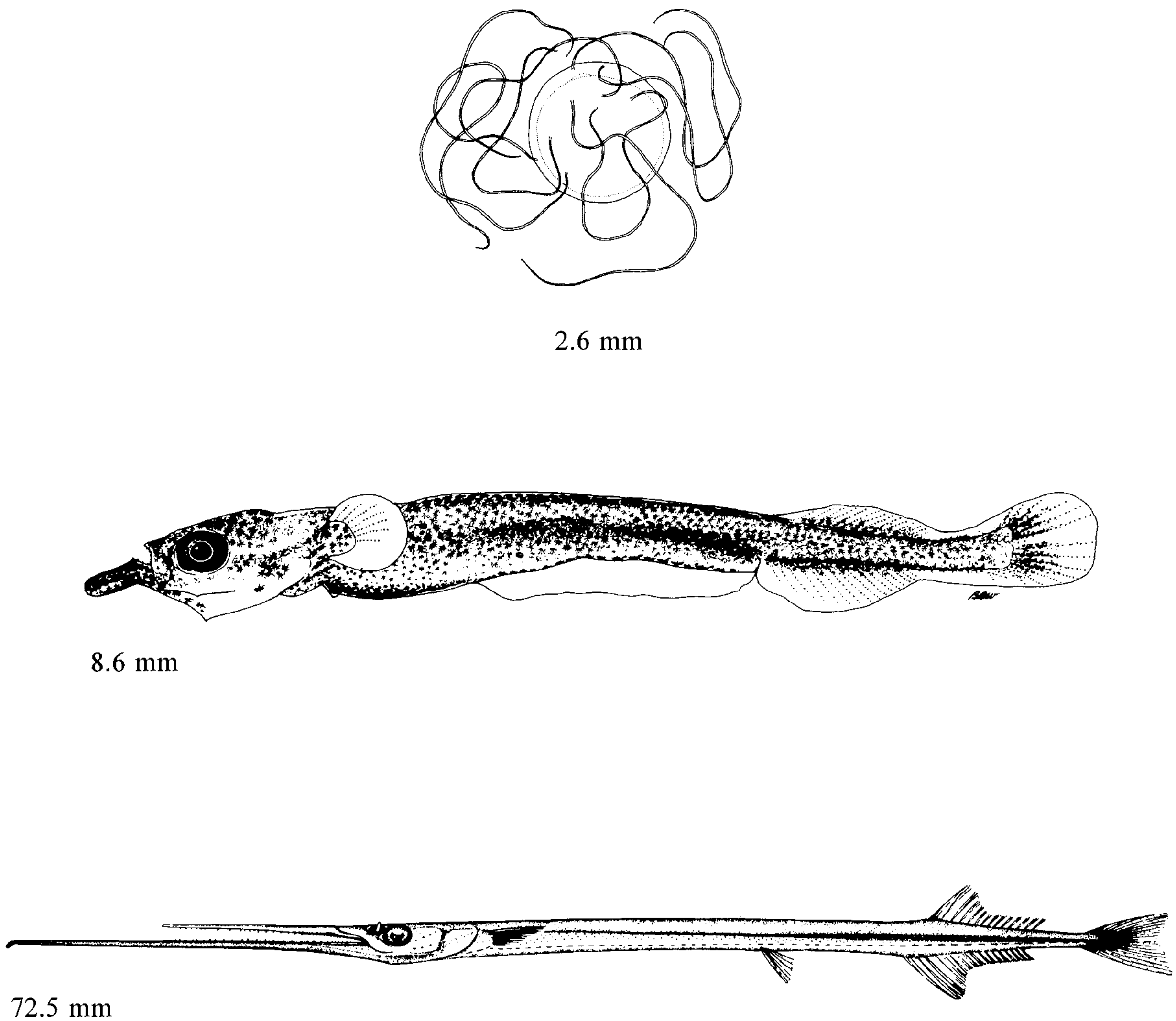


Figure Belonidae 2. Egg, ca. 2.6 mm; early "halfbeak" stage larva, 8.6 mm; juvenile, 72.5 mm (Collette et al. 1984a).

HEMIRAMPHIDAE: Halfbeaks

W. Watson

Hemiramphidae contains about 85 species in 12 genera (Nelson 1994); six species in four genera range into the CalCOFI study area (Collette 1995b): *Euleptorhamphus viridis*, *Hemiramphus saltator*, *Hyporhamphus gilli*, *Hy. rosae*, *Hy. unifasciatus* and *Oxyporhamphus micropterus micropterus*. The distributions of all except *Hy. rosae* are primarily south of the CalCOFI study area. *E. viridis* and *O. m. micropterus* are primarily epipelagic, *He. saltator*, *Hy. gilli*, and *Hy. unifasciatus* are primarily neritic, and *Hy. rosae* occurs primarily in bays, estuaries, and close to shore along the open coast. Larval *O. m. micropterus* have been collected in small numbers at CalCOFI stations off southern Baja California, while only single specimens of *E. viridis*, *He. saltator*, and *Hy. rosae*, and no *Hy. gilli* or *Hy. unifasciatus*, have been recognized in CalCOFI collections.

Halfbeaks are small to medium-size (ca. 5–50 cm, depending on species) surface-living marine, estuarine, and freshwater fishes. They are elongate and (usually) compressed, with posterior dorsal and anal fins, emarginate or forked caudal fin with elongate lower lobe, and with the lower jaw produced to form a beak. Some species support commercial bait or food fisheries.

Marine halfbeaks are oviparous, spawning planktonic eggs, or eggs that are attached via filaments to macroalgae and floating objects. The spherical eggs are ca. 1.1–3.1 mm in diameter (typically ca. 2–2.5 mm) and contain a colorless or pale orange to pink yolk, which typically lacks oil globules. The chorion is ornamented with evenly distributed small spinules or tendrils (*Oxyporhamphus* species), or with long filaments distributed evenly, randomly, or in groups (e.g., Breder and Rosen 1966; Collette et al. 1984a). Larvae are ca. 3–8 mm and well developed at hatching, with partially to fully pigmented eyes, an open mouth, fully flexed notochord, developing rays in the dorsal, anal, and caudal fins, and a small to moderate yolk sac (e.g., Sudarsan 1966; Talwar 1967). Halfbeak larvae are elongate, slender, cylindrical to compressed, with a long gut (preanal length ca. 70–80% BL). A preanal finfold typically is present through much of the larval stage. The beak and the pectoral fin rays typically begin developing soon after yolk absorption, followed quickly by the pelvic fin rays. The lower lobe of the caudal fin elongates and scales form during the gradual transformation to the juvenile stage. Larval pigmentation ranges from moderately light to heavy. There typically are 2–4 longitudinal rows of melanophores on the dorsum, a row along the lateral midline which often expands into a broad stripe, at least on the tail, two or more rows along the ventral margin of the tail, and in some species along the ventral surfaces of the head and gut. The beak is heavily pigmented and often the gill cover is, as well. The gut is heavily pigmented, at least dorsally. Some species have considerable additional pigment, especially ventrolaterally along the trunk and on much of the tail. All acquire more dorsolateral pigment during late larval or transformation stages, and many develop a barred pattern during transformation or juvenile stages. Fin pigmentation during the larval stage typically is limited to the dorsal, anal, and caudal fins.

Among the larval fishes in the CalCOFI study area, only belonids in the "halfbeak" stage superficially resemble the hemiramphids. The belonids are much more heavily pigmented than all the hemiramphids except *He. saltator*, and are more elongate and slender, with more myomeres, than all except *E. viridis*. The anal fin originates well ahead of the dorsal fin origin in the belonids, in contrast to under or behind the dorsal origin in all the hemiramphids except *Hy. rosae*. Among the hemiramphids, *E. viridis* is much more elongate and slender, with much higher dorsal and anal fin ray and myomere counts than any of the others (Table Beloniformes 1). *He. saltator* is more heavily pigmented (especially ventrolaterally) than the others, has more myomeres and a more posterior anal fin origin than any except *E. viridis*, and has fewer anal fin rays than the others (Table Beloniformes 1). Pigmentation and myomere counts are similar between *Hy. rosae* and *O. m. micropterus*, except that *O. m. micropterus* has prominent dorsal and anal fin pigmentation, which *Hy. rosae* lacks. The anal fin origin is below dorsal ray 2 or 3 in *O. m. micropterus*, in contrast to ahead of the dorsal fin origin in *Hy. rosae*.

The following descriptions are based on literature and on detailed examinations of 24–36 specimens of each species (Table Hemiramphidae 1). Because only one larval *E. viridis* and no *Hy. gilli* or *Hy. unifasciatus* were available, these are not described. The larval *E. viridis* is shown in Figure Hemiramphidae 1; additional descriptions and illustrations are available in Chen (1988). Meristic data were obtained from literature sources (Meek and Hildebrand 1923; Imai 1959; Parin 1964; Miller and Lea 1972; Collette 1995b), from Clothier and Baxter (unpublished manuscript), and from counts made during this study. Ecological information was obtained primarily from Eschmeyer et al. (1983) and Collette (1995b).

Table Hemiramphidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the hemiramphid descriptions. Preflexion and flexion stages are completed before hatching. An "L" indicates literature used for the description.

Species	Egg	Yolk-sac	Larvae	Transformation	Juvenile
Hemiramphus saltator	0	1 5.2	18 5.9–14.4	0	17 26.2–34.9
Hyporhamphus rosae	0	0	L[a], 3 18.0–19.7	13 19.0–26.2	8 31.3–44.6
Oxyporhamphus micropterus micropterus	L[a,b,c]	L[c], 10 3.2–3.6	L[c], 15 3.8–19.0	L[c], 5 21.0–28.4	L[c], 5 25.0–37.1

[a] Collette et al. 1984a
[b] Imai 1959
[c] Khrapkova-Kovalevskaya 1963

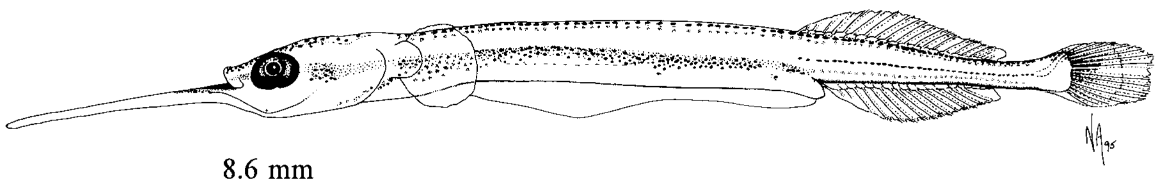


Figure Hemiramphidae 1. Larval *Euleptorhamphus viridis*, 8.6 mm (CalCOFI 5810, station 140.30; original illustration by N. Arthur).

MERISTICS

	Range	Mode
Vertebrae:		
Total	54–58	56
Precaudal	36–41	40
Caudal	16–18	16
Fins:		
Dorsal spines	0	0
Dorsal rays	12–15	13–14
Anal spines	0	0
Anal rays	11–13	12–13
Pelvic	6	6
Pectoral	10–12	11
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	4–6	5
Lower	5–6	6
Gill rakers:		
Upper	9–14	
Lower	23–32	
Branchiostegals	13–15	14

LIFE HISTORY

Range: Southern Baja California Sur to Ecuador

Habitat: Neritic, near surface

Spawning season:

ELH pattern: Oviparous; presumably, eggs attached to floating objects via filaments; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Larvae, 5.2 mm, 8.2 mm (M. T. Vona)
Larva, 14.1 mm, lateral & dorsal views (M. T. Vona)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatchiug length: Probably ca. 5 mm
Flexion length: Before hatching
Transformation length: >14.5 mm, <26 mm
Fin development sequence: C, D & A & P_1, P_2
Pigmentation: *Larvae*—Heavy dorsally on head; on mandible & beak; on gill cover after ca. 7 mm; internally on & under brain; 2 longitudinal rows on dorsum from nape to caudal peduncle; internal series along notochord; laterally on trunk & tail, usually light dorsolaterally on trunk; heavy on upper half of gas bladder & gut, spreading ventrad; light on ventrum except heavy on gular area & along A base; at end of D, spreading over last 5–6 rays by ca. 11 mm; on first 2–3 D rays by ca. 13 mm; on last 1–2 A rays by ca. 11 mm; light on C rays, light on P_1 by ca. 11 mm. *Juvenile*—7 bars; heavy on P_2.
Diagnostic features: Myomeres usually 36–39+16–19=53–55; A rays 11–13; A ray 1 under D 3–6 (usually 4–5); much lateral pigment, especially ventrolaterally & on tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL		73–79		76–79
	74	76		78
BD/BL		12–18		10–12
	17	14		11
HL/BL		23–29		20–26
	26	25		23
HW/HL		43–54		31–39
	65	49		34
SnL/HL		13–18		19–26
	9	16		22
ED/HL*		31–38×		22–29×
		25–33		20–27
	39×32	34×28		26×23
P_1L/BL		10–14		13–17
	10	13		15
P_2L/BL		0–7		7–10
	0	3		9
BkL/HL		4–54		88–128
	0	20		112

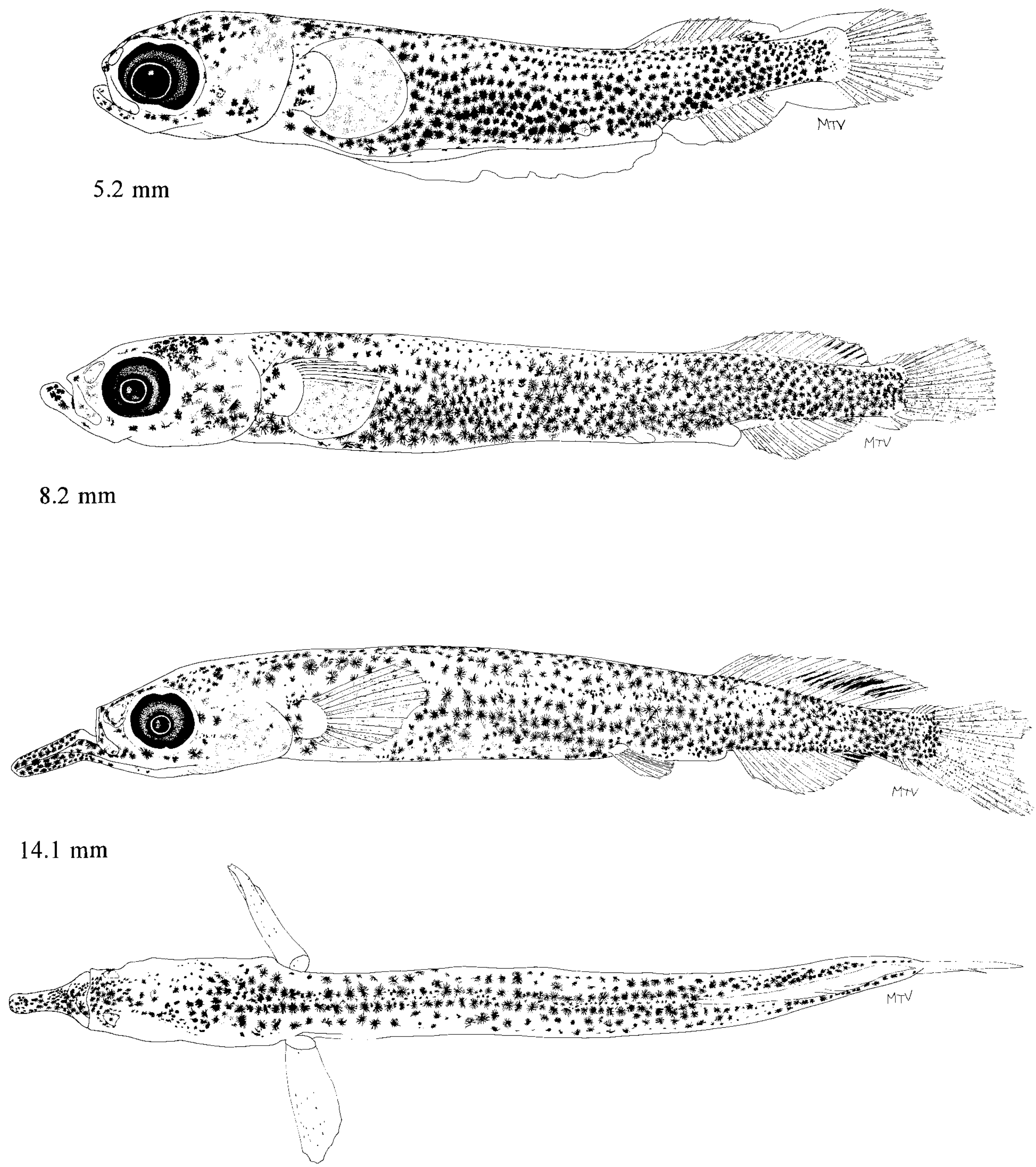


Figure Hemiramphidae 2. Larvae, 5.2 mm, 8.2 mm, 14.1 mm (lateral and dorsal views) (PODS 9210M4, station 12).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–50	48
Precaudal	30–33	31
Caudal	17–18	17
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	14
Anal spines	0	0
Anal rays	14–16	15–16
Pelvic	6	6
Pectoral	9–11	10
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	4–5	5
Lower	3–5	5
Gill rakers:		
Total	28–36	
Upper		
Lower		
Branchiostegals	10–12	10

LIFE HISTORY

Range: Santa Ana River, Los Angeles County, California to Panama

Habitat: At & near surface near shore, primarily in bays & estuaries; enters fresh water

Spawning season:

ELH pattern: Presumably oviparous with eggs attached to spawning substrate via filaments; larvae are planktonic

LITERATURE

Collette et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Juvenile, 23.4 mm, lateral & dorsal views (N. Arthur)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: Before hatching
Transformation length: 19–20 through ca. 30 mm
Fin development sequence:
Pigmentation: *Larvae*—Dorsally on head; on beak & dentary; on gill cover; 2 rows of large melanophores along dorsal margin, 2 rows of small melanophores between these rows by 18 mm; nearly continuous around hypural margin by 19 mm; series along lateral midline; dorso- & ventrolateral series near midlateral region on tail by 18 mm; heavy dorsally on gut, spreading ventrad; on ventral margin of gut, anteriorly initially, then spreading caudad; 2 rows on ventral margin of tail; proximally on C rays. *Juvenile*—Heavier on dorsum; broader lateral stripe on tail; on proximal half of most of dorsal fin.
Diagnostic features: Myomeres 29–33+16–18=46–50 (usually 32+17); first D ray above A ray 1–3 (usually A2 or 3); pigment on trunk & tail largely limited to dorsal & ventral margins & along lateral midline; no D or A pigment before end of larval stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL		70–73 72	69–73 72	71–75 73
BD/BL		10–11 10	10–11 11	10–12 11
HL/BL		20–22 21	21–24 23	22–23 23
HW/HL		40–60 45	36–45 38	34–37 35
SnL/HL		15–21 19	21–26 23	22–29 26
ED/HL*		28–40× 23–30 32×26	24–30× 21–27 27×23	25–28× 22–24 27×23
P_1L/BL		5–11 6	10–12 11	10–11 11
P_2L/BL		0–6 4	5–6 6	6–6 6
BkL/HL		0–113 76	104–140 120	129–144 136

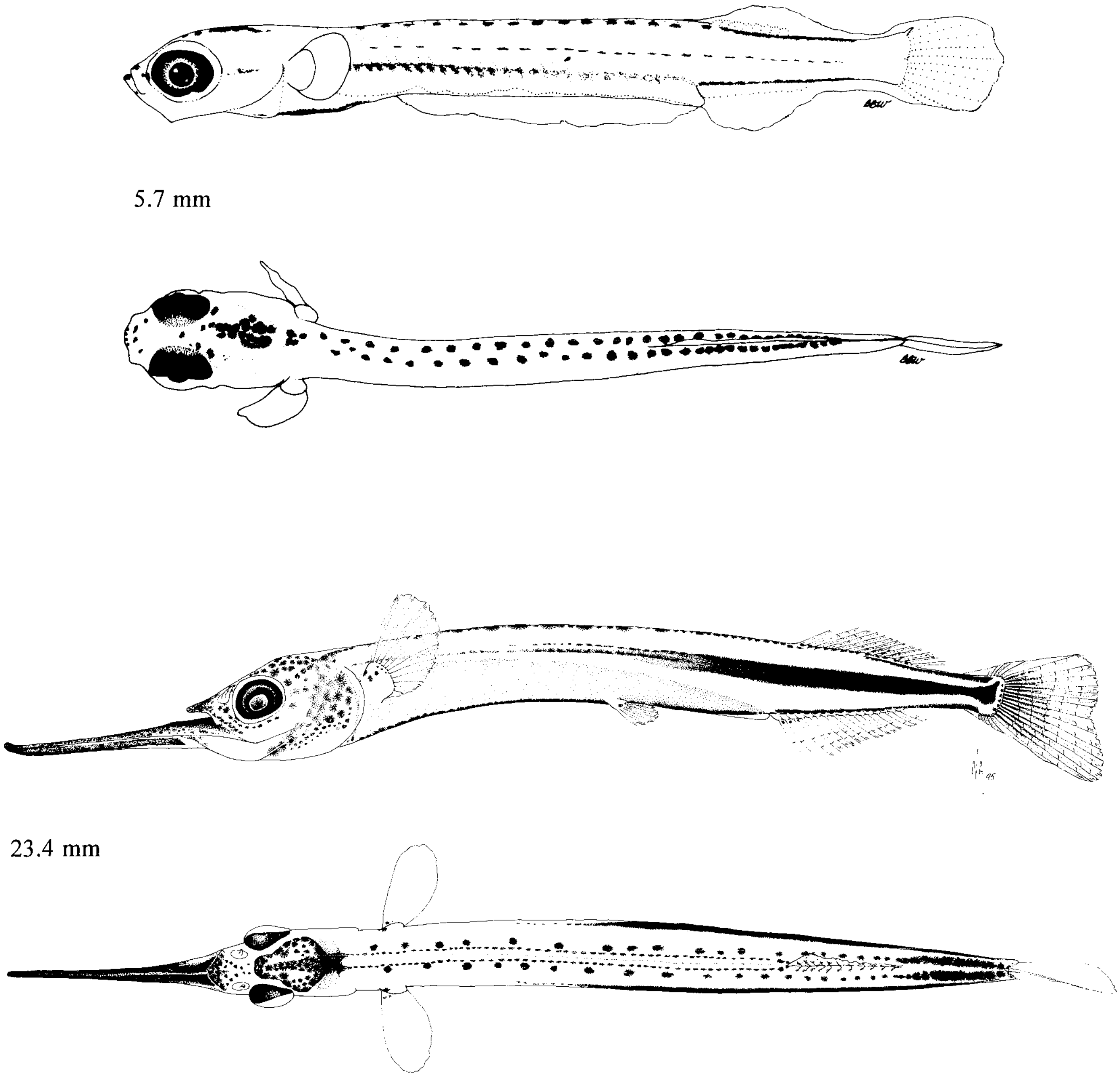


Figure Hemiramphidae 3. Larva, 5.7 mm, lateral and dorsal views (Collette et al. 1984a); juvenile, 23.4 mm, lateral and dorsal views (CFRD Ref. Coll., Panama).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–50	49
Precaudal	30–32	31
Caudal	17–19	18
Fins:		
Dorsal spines	0	0
Dorsal rays	13–15	13–14
Anal spines	0	0
Anal rays	13–16	14–15
Pelvic	6	6
Pectoral	11–13	11–12
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	3–4	4
Lower	3–5	4
Gill rakers:		
Upper	7–9	
Lower	21–26	
Branchiostegals	11–14	12–13

LIFE HISTORY

Range: Warm waters of the Indian & Pacific Oceans; in the CalCOFI area, off southern Baja California Sur

Habitat: Epipelagic, at surface

Spawning season: Year-round in tropics, only during summer near poleward range limits

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Chen 1988
Collette et al. 1984a
Imai 1959
Khrapkova-Kovalevskaya 1963
Kovalevskaya 1965
Mito 1961a
Parin & Gorbunova 1964

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.4 mm (N. Arthur)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.8–2.1 **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Uniformly covered with 74–200 spinules, 0.07–0.12 mm long
Pigment: Melanophores develop on embryo, primarily on dorsum & ventrally on tail; melanophores simultaneously develop on yolk adjacent to embryo.
Diagnostic features: Diameter, spinules

LARVAE

Hatching length: ca. 3.5 mm
Flexion length: Before hatching
Transformation length: 20 mm through ca. 25–28 mm
Fin development sequence: C_1, D & A, P_1, C_2, P_2
Pigmentation: *Larvae*—Dorsally above brain, increasing & spreading forward after 6 mm; internally on brain; on dentary, gular area & gill cover after ca. 5 mm; on beak after ca. 9 mm; 2 rows along dorsal margin; dorsolaterally on caudal peduncle after 4 mm; longitudinal series along lateral midline after ca. 9 mm; 2 rows along ventral margin of tail; heavy dorsal pigment over entire length of gut, spreading ventrad; scattered on yolk sac, condensing onto anterolateral part of gut; usually none ventrally on gut until ca. 6 mm when it forms anteriorly, then spreads along length of gut by ca. 10 mm; distal on last 3–5 D & A rays by ca. 8 mm, spreads forward; scattered along C rays by ca. 12 mm. *Juvenile*—Heavy on upper half & all of tail, along full length of D & A.
Diagnostic features: Myomeres 29–33+17–19=48–50; A ray 1 under D2–3; pigment on body largely limited to dorsal margin, lateral midline, & ventral margin of tail during larval stage; prominent D & A pigment.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL	67–76 73	67–72 70	71–74 72	69–75 73
BD/BL	17–24 20	9–15 11	10–12 11	10–13 12
HL/BL	30–35 33	20–33 24	20–22 21	20–22 21
HW/HL	47–53 51	36–51 43	36–38 37	35–38 37
SnL/HL	12–19 13	11–26 19	22–24 24	24–26 25
ED/HL*	37–41× 26–32 39×29	30–40× 25–33 34×28	27–29× 24–26 28×25	26–28× 24–26 28×25
P_1L/BL	5–10 7	6–12 10	12–14 13	12–17 15
P_2L/BL	0–0 0	0–6 3	6–7 7	6–9 8
BkL/HL	0–0 0	0–58 12	60–74 69	67–75 72

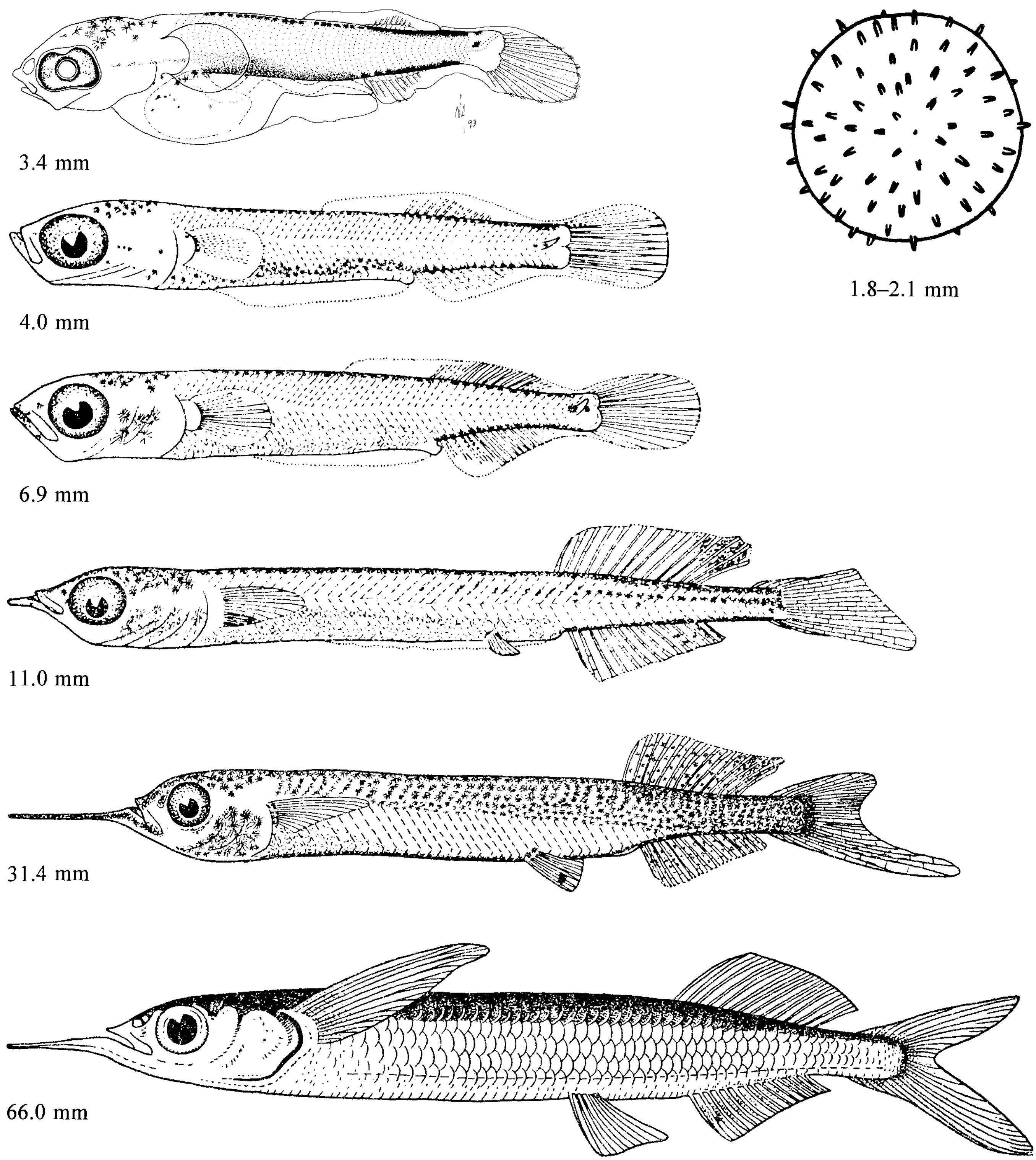


Figure Hemiramphidae 4. Egg, 1.8–2.1 mm (Imai 1959); yolk-sac larva, 3.4 mm (MOPS 8710JD, station III–74); larvae, 4.0 mm, 6.9 mm, 11.0 mm; transformation or early juvenile, 31.4 mm; juvenile 66.0 mm (Khrapkova-Kovalevskaya 1963).

EXOCOETIDAE: Flyingfishes

W. WATSON

Exocoetidae contains at least 52 species in seven or eight genera (Nelson 1994); at least 11 species in six genera occur in the CalCOFI study area (Parin 1995a; Table Beloniformes 1). Although all have primarily tropical and/or subtropical distributions, *Cheilopogon pinnatibarbatus californicus* ranges northward to northern Oregon, while *C. heterurus hubbsi* and *Fodiator acutus rostratus* reach southern California. The others range no farther north in coastal waters than southern Baja California.

Flyingfishes are small to medium-size (most species no larger than ca. 10–50 cm, largest to 70 cm or more) neustonic inhabitants of the neritic and epipelagic zones. Some of the neritic species support local fisheries. All flyingfish species are cylindrical to compressed, and have greatly enlarged pectoral fins. The "four-winged" species also have enlarged pelvic fins. All have an elongate lower caudal fin lobe, and in all species the dorsal and anal fins, which lack spines, are placed far posteriorly. Some taxa develop beaks or barbels during the larval and juvenile stages.

Exocoetids are oviparous, spawning planktonic eggs with unornamented chorions (e.g., *Exocoetus volitans*), or eggs variously ornamented with filaments that serve to attach them to one another, floating objects, kelp, etc. The filaments may be evenly distributed over the chorion or grouped at opposing poles. Eggs range between about 1–3 mm (commonly 1.5–2 mm) in diameter, have a narrow perivitelline space, homogeneous yolk, and usually lack oil globules. The yolk may be transparent, or may range in color from pale yellow to orange. During the latter part of embryonic development the surface of the yolk and/or embryo typically become moderately to heavily covered with melanophores.

Larvae are ca. 3–6 mm long and well developed at hatching, with pigmented eyes, a functional mouth, notochord fully flexed (or nearly so), and caudal fin rays forming (e.g., Parin and Gorbunova 1964; Kovalevskaya 1982). Depending on species, rays may be forming in some or all of the other fins as well. Larvae initially are cylindrical, with large eyes, short fins, and preanal length ca. 66–75% BL. Larval development is gradual, without large changes in proportions apart from the marked elongation of the pectoral fins, and of the pelvic fins in "four-winged" species, and the elongation of the lower caudal fin lobe. Some taxa develop specialized larval and juvenile structures, such as the beak of *Fodiator* and *Parexocoetus*, the mandibular barbels of *Cheilopogon*, *P. brachypterus* and *E. monocirrhus*, and the elongate pigmented dorsal fin lobe of some *Cheilopogon* species (e.g., Collette et al. 1984a). Flyingfish larvae typically are moderately to heavily pigmented at hatching and become more heavily pigmented with development. Larval *Hirundichthys*, in contrast, typically become more lightly pigmented on the trunk, and only a little more heavily pigmented elsewhere. Transforming and juvenile *Exocoetus* and *Cheilopogon* develop a barred pattern on the trunk and/or tail. Live larvae and juveniles often are brightly pigmented with cyanophores and erythrophores; however, these pigments quickly fade in alcohol or formalin preservative.

Larval flyingfishes are easily distinguished from all others by their usually heavy pigmentation, long preanal length, elongate pectoral (and pelvic, in some) fins, and posterior placement of pelvic, dorsal, and anal fins. Among the flyingfishes most likely to be encountered in the CalCOFI area, the two *Cheilopogon* species (*C. h. hubbsi*, *C. p. californicus*) can be distinguished from the others by having mandibular barbels (after ca. 9 mm) and by having the first anal fin ray located under dorsal ray 3–6 (usually 4 or 5). The two species are distinguished from one another primarily by pectoral fin pigment and structure of the barbels. Juvenile *Exocoetus monocirrhus* (≥ ca. 18–20 mm) have a medial chin barbel, but have their dorsal and anal fin origins opposite one another and more anteriorly placed pelvic fins than *Cheilopogon*. *Prognichthys tringa* has the first anal fin ray under D3–5 (usually 3 or 4), but always lacks barbels and has shorter and more rounded pectoral fins than *Cheilopogon* of similar size. *Exocoetus volitans* and *Fodiator acutus rostratus* have the first anal fin ray under D1–3 (usually 2 or 3), but in *E. volitans* the pelvic fin placement is farther forward. *F. a. rostratus* develops a beak after ca.

6 mm; none of the others does. In *Hirundichthys* the first anal fin ray ranges from just ahead of the level of D 1 to under D 1–2. Larval *Hirundichthys* are lightly pigmented, except on the gut, in comparison with the other species. The *Hirundichthys* species presently cannot be identified with certainty because their pigment patterns are similar and diagnostic pectoral fin and tooth characters are not developed. Larvae tentatively identified here as *H. speculiger* have the first anal fin ray ahead of or under D1, and only the first pectoral fin ray is markedly shorter than the longest pectoral ray. The first anal fin ray is under or slightly ahead of D2 in larvae tentatively identified as *H. rondeletii*, and their first two or three pectoral fin rays are markedly shorter than the longest pectoral ray. No larvae in CalCOFI collections were identified as *H. marginatus*, although based on adult distributions *H. marginatus* would be expected to be the *Hirundichthys* species best represented in CalCOFI collections.

The following descriptions are based on literature and on detailed examinations of 25–36 specimens of ach taxon (Table Exocoetidae 1). Separate descriptions are not given for the *Hirundichthys* species owing to the small number of specimens and the uncertainty of the identifications; instead they are described as the genus and literature illustrations (Parin and Gorbunova 1964; Kovalevskaya 1972) are shown for each species. Larval *Cheilopogon papilio*, *C. xenopterus*, *Cypselurus callopterus*, and *Exocoetus monocirrhus* have not been collected during CalCOFI surveys and are not described here. (Very lightly pigmented *Cheilopogon* larvae collected from the lower Gulf of California during CalCOFI Gulf of California surveys may prove to be *C. papilio*.) Early life history stages of *E. monocirrhus* are shown in Figure Exocoetidae 1; refer to Imai (1959), Kovalevskaya (1964) and Chen (1988) for descriptions and additional illustrations of *E. monocirrhus*. Meristic data were obtained from a variety of literature sources (Hubbs and Kampa 1946; Imai 1959, 1960; Parin 1961; Miller and Lea 1972) and from counts made during this study.

Table Exocoetidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the exocoetid descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Larvae	Transformation	Juvenile
Cheilopogon heterurus hubbsi	L[a,b], 16 1.8–2.1	9 4.8–5.4	15 5.5–15.5	5 17.7–20.3	4 21.3–35.0
C. pinnatibarbatus californicus	L[b]	L[b]	22 6.0–14.6	5 18.1–22.3	2 21.3–24.1
Exocoetus volitans	L[c,d]	L[c,d]	20 4.4–12.9	3 13.3–15.7	5 23.5–29.9
Fodiator acutus rostratus	0	6 3.4–4.4	20 4.4–12.4	6 13.3–29.0	4 25.3–48.4
Hirundichthys spp.	0	0	16 6.2–20.6	3 16.4–22.9	0
H. rondeletii	L[e]	L[e]	0	0	3 49.0–49.3
H. speculiger	L[f]	L[f]	0	0	3 36.3–47.1
Prognichthys tringa	0	1 3.5	20 2.8–9.4	10 10.4–12.2	5 12.5–18.6

[a] Barnhart 1932
[b] Hubbs and Kampa 1946
[c] Kovalevskaya 1964
[d] Parin and Gorbunova 1964
[e] Kovalevskaya 1972
[f] Munro 1954

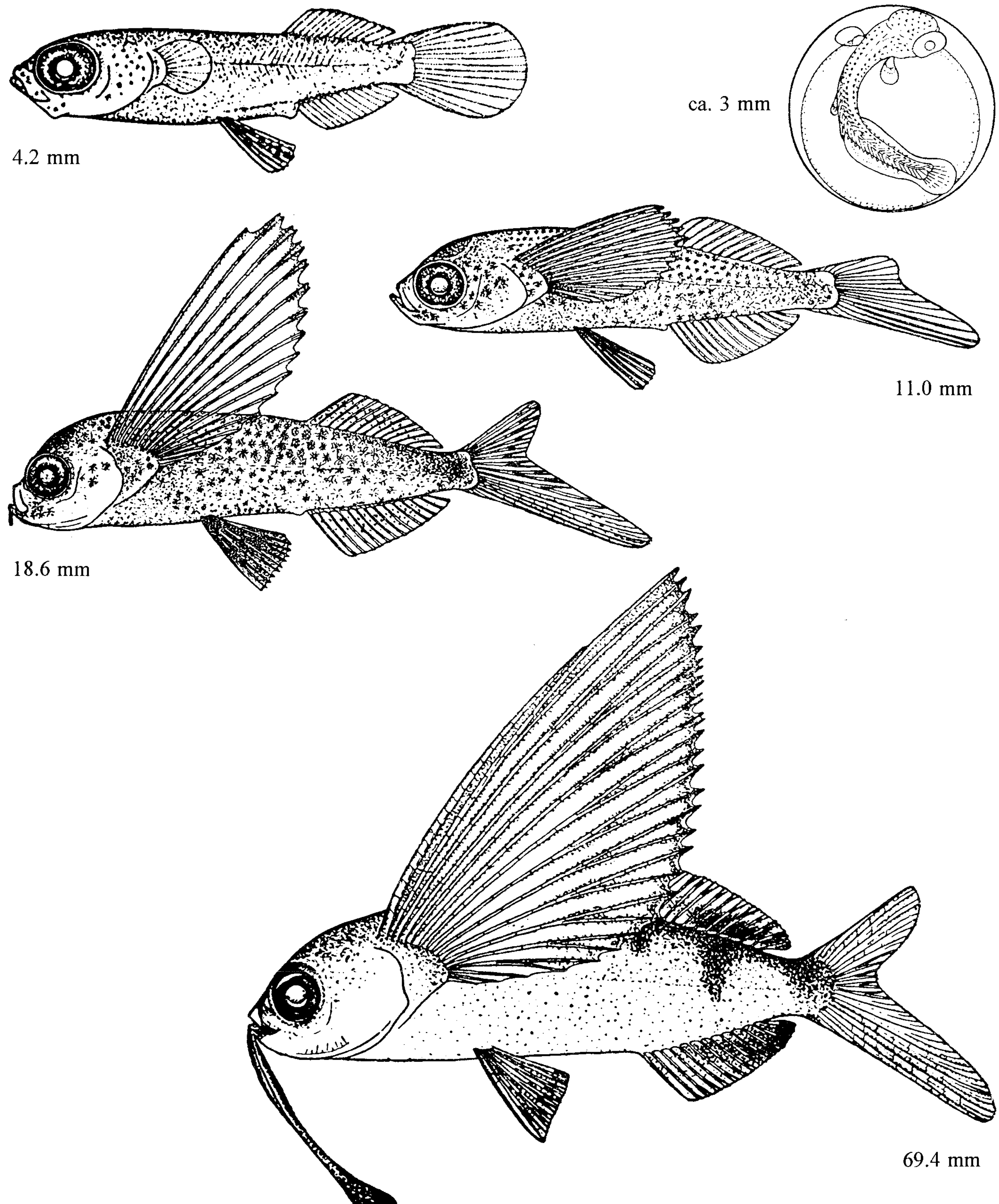


Figure Exocoetidae 1. *Exocoetus monocirrhus*: Egg, ca. 3 mm (size not given); larvae, 4.2 mm, 11.0 mm, 18.6 mm; juvenile, 69.4 mm (Kovalevskaya 1964).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–49	48
Precaudal	31–32	31–32
Caudal	15–17	16–17
Fins:		
Dorsal spines	0	0
Dorsal rays	12–14	13
Anal spines	0	0
Anal rays	8–11	11
Pelvic	6	6
Pectoral	14–16	15
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	6–7	6
Lower	7	7
Gill rakers:		
Upper	5–7	
Lower	15–17	
Branchiostegals	10–12	11

LIFE HISTORY

Range: Eastern North Pacific; in CalCOFI area ranges from Santa Catalina Island, California to central Baja California Sur

Habitat: At surface, usually epipelagic but enters neritic zone as well

Spawning season: Larvae collected during summer in CalCOFI area

ELH pattern: Oviparous; eggs attached via long filaments to one another & to kelp & floating objects; larvae are planktonic

LITERATURE

Barnhart 1932
Hubbs & Kampa 1946

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 5.2 mm (W. Watson)
Postflexion larvae, 5.6 mm, 11.2 mm (W. Watson)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.9–2.2 mm × 1.8–2.0 mm **Yolk:** Homogeneous; ca. 1.8–2.2 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth; 2 groups of ca. 15–18 filaments each attached at opposite poles.
Pigment: Yolk amber; late embryos with pigmented eyes; yolk & body largely covered with melanophores
Diagnostic features: Filaments in groups at opposite poles, thinner & more fragile at one pole than at opposite pole

LARVAE

Hatching length: ca. 4.8–6 mm
Flexion length: Before hatching
Transformation length: ca. 17.5–20.5 mm
Fin development sequence: C_1 & D & A & P_1 & P_2, C_2
Pigmentation: *Larvae*—Heavy on trunk & tail, except little on caudal peduncle before ca. 12 mm; series along lateral midline of tail; up to 6 bars form during transformation; heavy on gut except little ventrally before ca. 11 mm; heavy on head except sparse ventrally & on snout; on D base, extending onto anterior rays by ca. 11 mm & covering fin by ca. 18 mm; on most C rays, heavier ventrally; heavy on P_2; primarily on upper half of P_1, spreading ventrad to cover fin by 11 mm; clear band proximally on P_1 at ca. 12–20 mm, clear patch distally by ca. 12 mm, forms band by ca. 20 mm.
Diagnostic features: Little external pigment on caudal peduncle before ca. 12 mm; larvae ca. 12–20 mm with clear band proximally, & clear patch which develops into a band distally on P_1; pair of barbels form on mandible at ca. 9 mm; each is round to oval in cross-section, with a pigmented fringe developing along the posterior margin by ca. 18 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL	66–69 68	66–73 69	70–76 73	71–75 72
BD/BL	23–27 25	15–21 18	16–19 18	15–18 17
HL/BL	21–25 23	20–26 23	21–22 22	19–21 20
HW/HL	85–94 88	69–83 76	73–86 79	71–81 76
SnL/HL	4–10 6	9–16 12	8–14 11	11–23 16
ED/HL*	48–53× 42–46 51×44	41–50× 36–43 46×39	45–52× 46–52 49×48	43–52× 43–46 47×45
P_1L/BL	9–13 11	12–36 28	38–58 48	54–65 57
P_2L/BL	5–7 6	10–28 19	30–41 35	38–40 39
BbL/HL	0–0 0	0–38 10	27–40 33	15–80 35

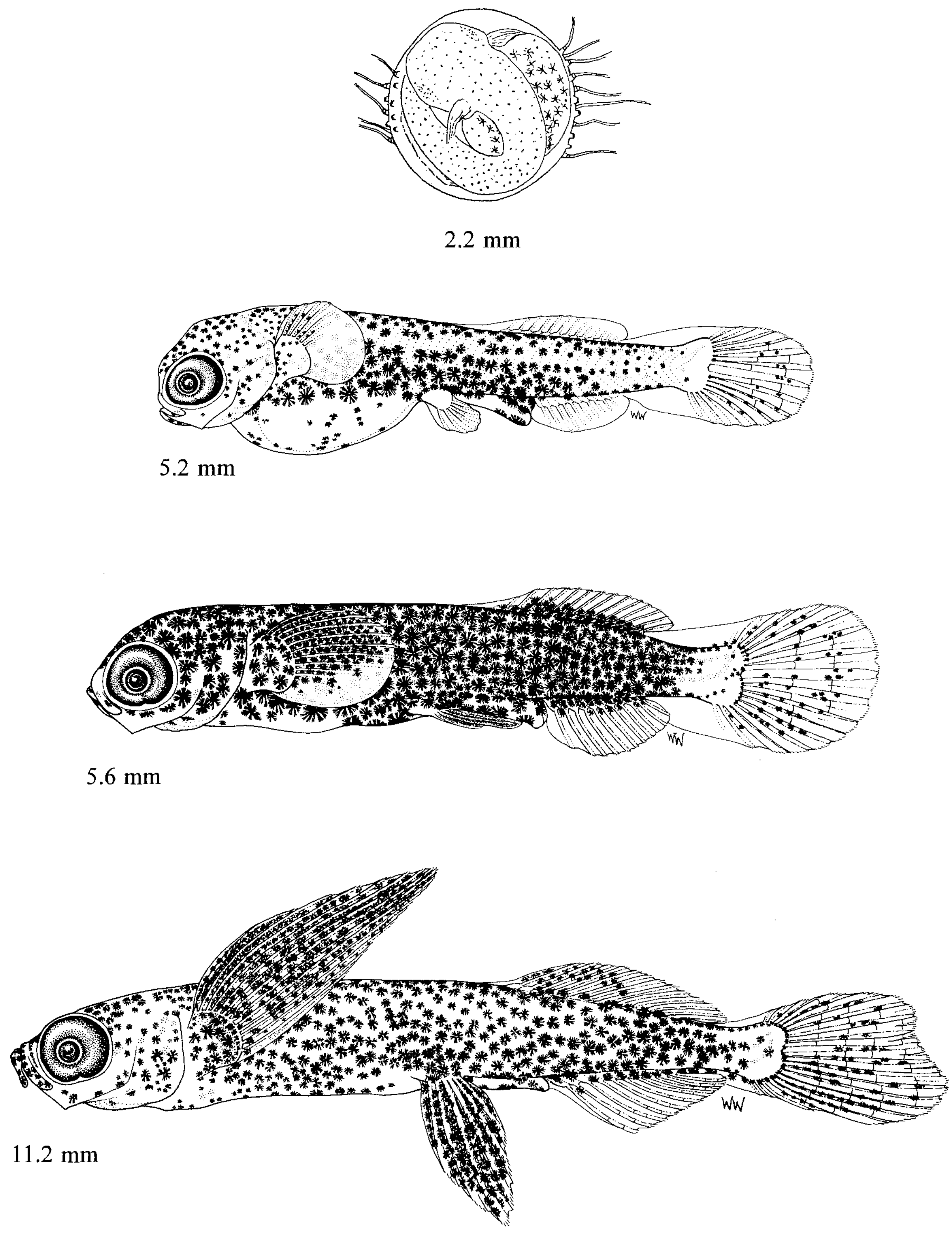


Figure Exocoetidae 2. Egg, ca. 2.2 mm (Barnhart 1932); yolk-sac larva, 5.2 mm; postflexion larva, 5.6 mm (CFRD Ref. Coll., reared at SWFSC, July 23, 1976); postflexion larva, 11.2 mm (CFRD Ref. Coll.).

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–51	50
Precaudal	31–35	34
Caudal	16–17	16
Fins:		
Dorsal spines	0	0
Dorsal rays	9–13	12
Anal spines	0	0
Anal rays	9–12	11
Pelvic	6	6
Pectoral	14–15	15
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	5–6	6
Lower	6–8	6–8
Gill rakers:		
Upper	4–8	
Lower	13–16	
Branchiostegals	10–12	11

LIFE HISTORY

Range: Astoria, Oregon, to Cabo San Lucas, Baja California Sur

Habitat: At surface, epipelagic & neritic

Spawning season:

ELH pattern: Oviparous; eggs attached to one another & to kelp & floating objects via long filaments; larvae are planktonic

LITERATURE

Hubbs & Kampa 1946

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 9.0 mm (R. C. Walker)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.57–1.70 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth; ca. 60 long filaments approximately evenly distributed over surface
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 4–5 mm
Flexion length: Before hatching
Transformation length: ca. 18 mm to ca. 21–22 mm
Fin development sequence: C & D & A & P_1 & P_2
Pigmentation: *Larvae*—Heavy on trunk & tail except slightly lighter on caudal peduncle; series along lateral midline; heavy on gut; heavy on head except lighter ventrally; none on D before ca. 10 mm, then distal blotch in middle of fin, spreading to cover fin by ca. 18 mm; none on A until ca. 18 mm, then proximally only; distal on P_2, covering fin by ca. 10 mm; initially only on upper P_1 rays, spreading ventrad, primarily distally, to cover upper 75% by ca. 10 mm; more or less clear band persists proximally.
Diagnostic features: External pigment about uniform on trunk & tail, caudal peduncle only slightly less pigmented; P_1 with clear band proximally only, clear distal patch or band lacking; pair of barbels form on mandible at 9–11 mm, initially as flat, broad-based simple flaps, meet & fuse mesially by ca. 21 mm, become fimbriate.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL		65–76 68	69–73 71	69–70 70
BD/BL		15–20 17	14–15 15	14–15 14
HL/BL		20–24 22	21–22 21	22–22 22
HW/HL		63–85 72	58–63 61	54–59 57
SnL/HL		6–21 13	15–19 17	16–17 17
ED/HL*		35–44× 33–38 40×36	36–38× 33–38 37×35	38–41× 37–38 40×37
P_1L/BL		13–35 23	37–42 40	46–46 46
P_2L/BL		12–29 22	28–35 31	32–34 33
BbL/HL		0–10 2	17–29 23	11–23 17

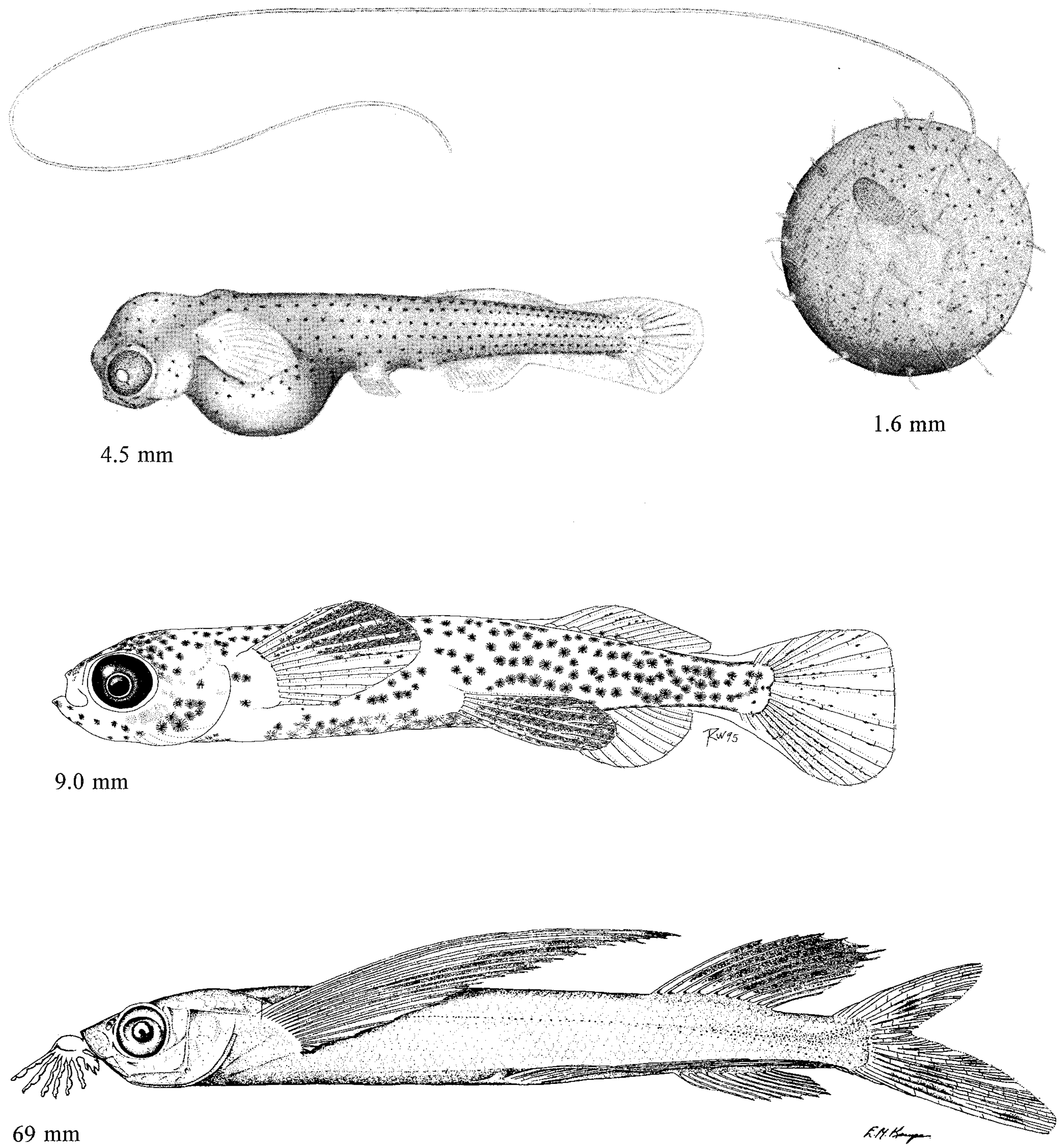


Figure Exocoetidae 3. Egg, ca. 1.6 mm; yolk-sac larva, ca. 4.5 mm (Hubbs and Kampa 1946); postflexion larva, 9.0 mm (reared at SWFSC, day 7, August 22, 1965); juvenile, 69 mm (Hubbs and Kampa 1946).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–46	45
Precaudal	24–26	25–26
Caudal	19–20	19
Fins:		
Dorsal spines	0	0
Dorsal rays	12–15	14
Anal spines	0	0
Anal rays	12–14	13
Pelvic	6	6
Pectoral	14–16	15
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	5	5
Lower	5–7	6
Gill rakers:		
Total	20–37	29–34
Upper	7–8	
Lower	22–24	
Branchiostegals	9–11	10

LIFE HISTORY

Range: Worldwide in warm seas; ranges northward to southern Baja California in the eastern Pacific Ocean

Habitat: At surface, primarily epipelagic but may enter neritic zone as well

Spawning season: Throughout the year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Bruun 1935
Collette et al. 1984a
Imai 1959
Kovalevskaya 1964, 1982
Chen 1988
Parin & Gorbunova 1964

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.7–3.0 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth, lacks filaments
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3.5–4 mm
Flexion length: Before hatching
Transformation length: ca. 13–16 mm
Fin development sequence:
Pigmentation: *Larvae*—On upper half of head except little or none on snout before ca. 8.4 mm; covering trunk & gut except none ventrally on gut until 8–10.5 mm; on dorsal & ventral margins & lateral midline of tail to middle of caudal peduncle, extending to last 12 myomeres by 7 mm; dorso- & ventrolaterally on anterior 60% of tail, extending to end by 8 mm; bar at level of last half of D & A after 12 mm; blotch forms on distal 30–40% of upper P_1 (rays 1–2 to 5–7) after 8 mm; C pigment principally along lower rays, forms after 16 mm; D, A, & P_2 usually unpigmented. *Juvenile*—Heavy pigment on upper part of head & trunk; bar at midtail may extend onto D & A; distal blotch on upper part of P_1; proximal blotch on middle of P_2.
Diagnostic features: P_2 origin far forward, midway between P_1 & A or nearer P_1; P_1 much longer than P_2 after ca. 7 mm; A origin under 1st–3rd dorsal ray (usually D2 or 3); barbels or beak never form; prominent pigment blotch distally on upper P_1 after ca. 8 mm; prominent bar across tail at level of last half of D & A after ca. 12 mm; more upper gill rakers (7–8) than *E. monocirrhus* (4–6).

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL		62–73 67	63–66 65	63–64 63
BD/BL		18–27 21	18–20 19	18–19 19
HL/BL		24–36 29	24–26 25	22–25 24
HW/HL		66–82 71	60–67 65	62–70 66
SnL/HL		13–20 16	17–20 18	19–21 20
ED/HL*		38–48× 30–46	38–40× 27–36	34–38× 34–41
		43×35	39×32	36×37
P_1L/BL		9–38 22	38–43 40	57–61 59
P_2L/BL		8–21 14	13–15 14	12–13 13

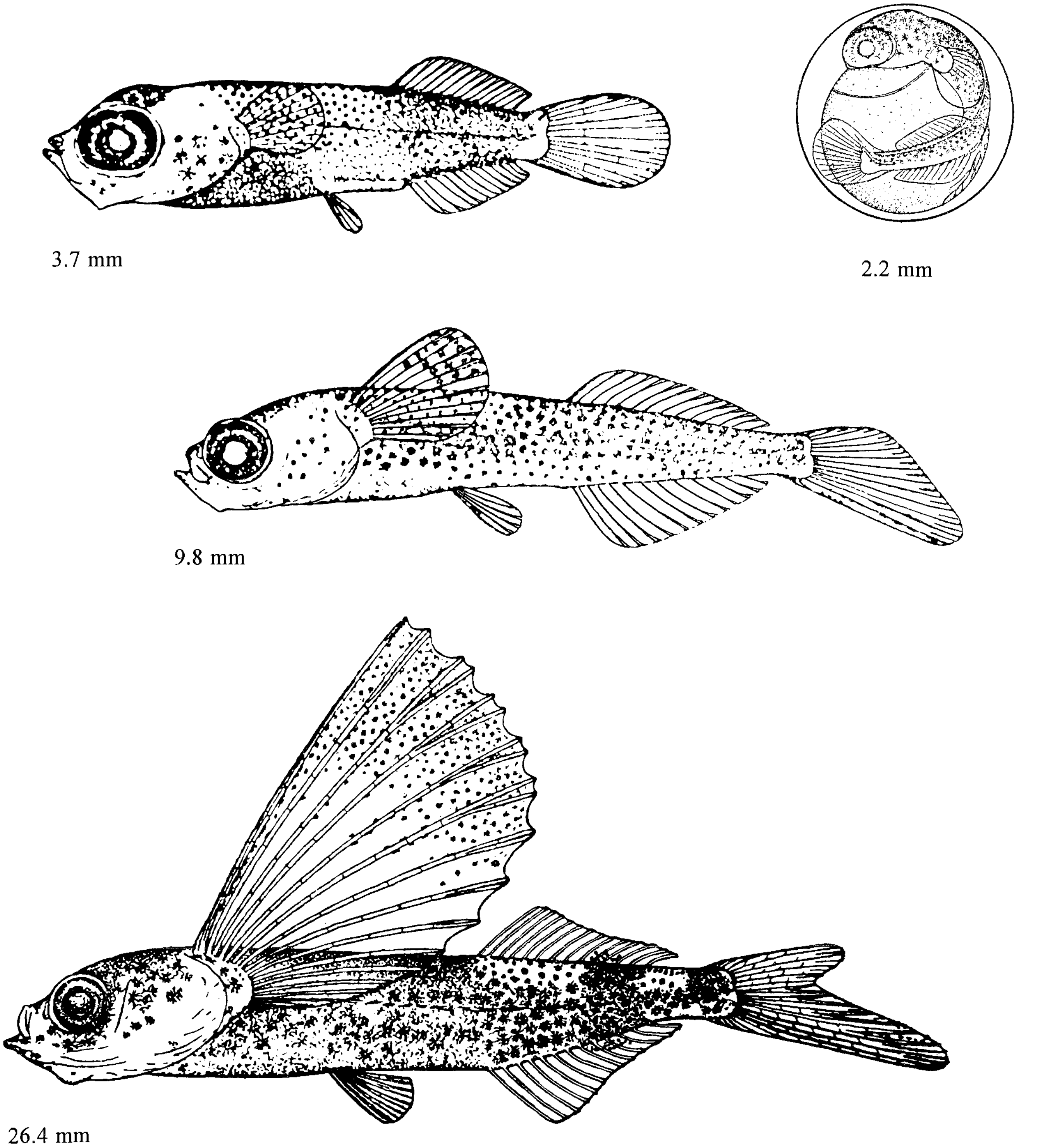


Figure Exocoetidae 4. Egg, ca. 2.2 mm (Parin and Gorbunova 1964); postflexion larvae, 3.7 mm, 9.8 mm; juvenile, 26.4 mm (Kovalevskaya 1964).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	40
Precaudal	24–26	25
Caudal	14–16	15
Fins:		
Dorsal spines	0	0
Dorsal rays	9–11	10
Anal spines	0	0
Anal rays	9–12	11
Pelvic	6	6
Pectoral	12–14	13
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	4–6	5
Lower	5–7	6–7
Gill rakers:		
Upper	7–8	
Lower	21–26	
Branchiostegals	9–11	10–11

LIFE HISTORY

Range: Goleta, California, to Peru

Habitat: Neritic & epipelagic, usually at surface in coastal waters

Spawning season: Summer (southern California)

ELH pattern: Oviparous; eggs attached to floating objects via long filaments; planktonic larvae

LITERATURE

Breder 1928
Collette et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.9 mm (B. Sumida MacCall)
Postflexion larvae, 6.7 mm, 8.4 mm (B. Sumida MacCall)

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* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3.5 mm
Flexion length: Before hatching
Transformation length: ca. 13 mm to ca. 25–29 mm
Fin development sequence: C_1, D & A & P_1 & P_2, C_2
Pigmentation: *Larvae*—Heavy dorsally & dorsolaterally from snout to last 1–3 myomeres, dorsolateral pigmentation initially light on last half of tail, becomes heavy by ca. 8 mm; series along lateral midline; series along ventral margin of tail; external ventrolaterally over gut & first few postanal myomeres, extending to last 1–3 myomeres by ca. 8 mm; pigment completely surrounds gut by ca. 7 mm; light on mandible & opercular area, increasing by 7–8 mm; on P_1 & P_2 bases at ca. 7 mm, on rays at ca. 8 mm. *Transformation*—Heavily pigmented except light ventrally on head & along anterior dorsal midline, none on A rays, upper C rays, or lower 5 P_1 rays.
Diagnostic features: Heavily pigmented except light on tail before ca. 7–8 mm & ventrally on head at all sizes; body pigmentation more or less uniform except lateral midline stripe is prominent in larvae smaller than ca. 8 mm; beak forms on lower jaw after ca. 5.5–6 mm; P_1 rays 12–14.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL	61–67 64	61–75 70	70–72 71	71–73 72
BD/BL	18–25 21	16–21 18	14–18 17	16–18 17
HL/BL	21–25 23	21–28 25	23–25 24	25–28 26
HW/HL	73–85 81	59–84 70	46–58 53	43–49 45
SnL/HL	11–16 13	9–20 16	17–27 21	24–35 30
ED/HL*	39–44× 31–35 41×33	36–44× 31–37 40×34	35–38× 34–36 36×35	29–35× 26–33 32×29
P_1L/BL	9–10 10	9–22 14	27–39 33	38–49 45
P_2L/BL	3–4 4	4–19 13	19–24 22	19–29 24
BkL/HL	0–0 0	0–23 5	47–89 71	71–108 93

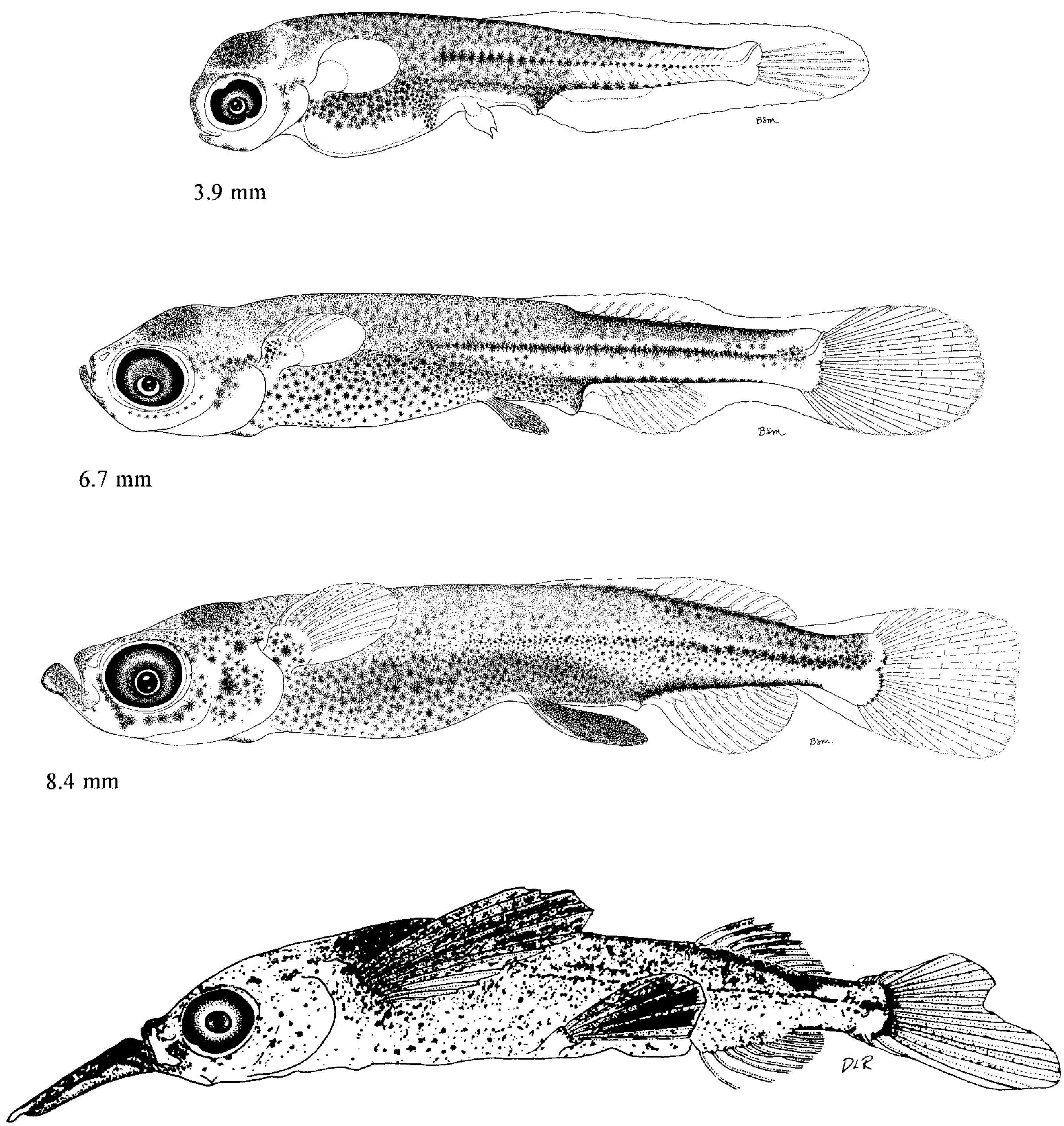


Figure Exocoetidae 5. Yolk-sac larva, 3.9 mm; postflexion larvae, 6.7 mm (MEC I94, station C–N), 8.4 mm (MEC I94, station D–N); transformation specimen, 15.4 mm (Collette et al. 1984a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–47	
Precaudal	27–31	
Caudal	14–19	
Fins:		
Dorsal spines	0	
Dorsal rays	9–12	
Anal spines	0	
Anal rays	10–13	
Pelvic	6	
Pectoral	15–19	
Caudal:		
Principal	7+8	
Procurrent:		
Upper	5–7	
Lower	5–8	
Gill rakers:		
Total	23–29	
Upper		
Lower		
Branchiostegals	9–11	

LIFE HISTORY

Range: Tropical & subtropical, ranging northward in the CalCOFI area to southern Baja California.

Habitat: At surface; *H. speculiger* primarily epipelagic, *H. rondeletii* epipelagic & neritic; *H. marginatus* primarily neritic

Spawning season: *H. rondeletii*: winter–spring; *H. speculiger*: year-round, at least in warmer part of range

ELH pattern: Oviparous; eggs attached to floating objects via long filaments; planktonic larvae.

LITERATURE

Imai 1960
Kovalevskaya 1972, 1982
Munro 1954
Chen 1988
Parin 1961
Parin & Gorbunova 1964

* Three species in CalCOFI area: *H. marginatus*, *H. rondeletii* & *H. speculiger*. All specimens used here were tentatively identified as *H. rondeletii* & *H. speculiger*.

† Means are given separately for specimens tentatively identified as *H. rondeletii* (first) & *H. speculiger* (second); ranges encompass both species.

‡ Eye initially oval, becoming round by transformation; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.53–1.87 mm (*H. speculiger*) **Yolk:** Homogeneous
No. of OG: "Cluster" (*H. speculiger*) **Diam. of OG:** "Minute" (*H. speculiger*)
Shell surface: Cluster of long filaments at one pole, cluster of short hook-like filaments (*H. speculiger*) or single long filament (*H. rondeletii*) at opposite pole.
Pigment: Yolk clear to pale yellow, melanophores on yolk & embryo (*H. speculiger*)
Diagnostic features: Filaments grouped at opposite poles

LARVAE

Hatching length: 3.6–4.5 mm
Flexion length: Before hatching
Transformation length: ca. 16–21 mm to ca. 23–25 mm
Fin development sequence: C_1 & D & A & P_1 & P_2, C_2
Pigmentation: *Larvae*—Initially covered with widely spaced melanophores from P_1 to midtail, pre-P_2 trunk pigment decreases to few dorsolaterally or none by ca. 10 mm; may increase on tail, reaching hypural margin between ca. 9–14 mm; over & on mid- & hindbrain; little or none on forebrain & snout before transformation; usually series under gill cover; along sides of dentary in some; usually present on isthmus; gut completely pigmented; begins on P_1 at ca. 8–10 mm, usually light; on P_2 at ca. 16 mm, usually light; variably present or absent on C; none on D or A before transformation.
Diagnostic features: A origin under or just anterior to D ray 1 (*H. speculiger*) or under D1–2 (*H. rondeletii*, usually); first (*H. speculiger*) or first two (*H. rondeletii*) P_1 rays much shorter than the longest P_1 ray (specimens >ca. 9–10 mm); no barbels or beak; lightly pigmented, except on gut.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv†
Sn-A/BL		65–70 67	64–66 65	64–71 69/65
BD/BL		15–20 16	15–18 17	16–17 17/16
HL/BL		20–40 24	18–21 20	20–20 20/20
HW/HL		71–91 79	74–84 80	78–88 84/81
SnL/HL		9–21 15	15–19 17	11–19 18/15
ED/HL‡		37–49× 32–47 41×38	40–47 43	37–50 39/47
P_1L/BL		22–52 35	42–43 43	56–75 73/63
P_2L/BL		18–31 25	26–31 28	38–43 42/39

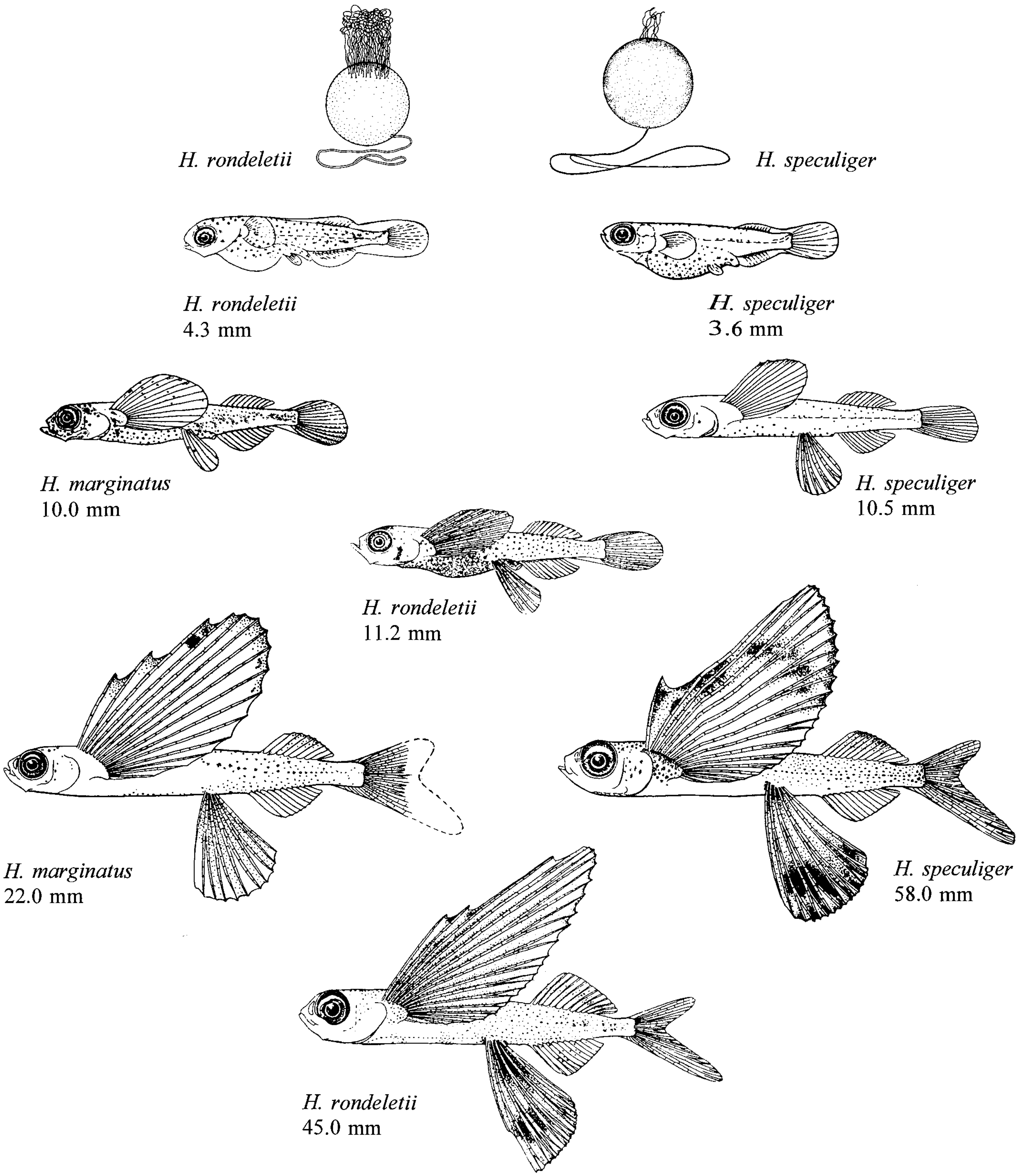


Figure Exocoetidae 6. Eggs of *H. rondeletii* (Kovalevskaya 1972) and *H. speculiger* (Parin and Gorbunova 1964); yolk-sac larvae of *H. rondeletii*, 4.3 mm and *H. speculiger*, 3.6 mm; postflexion larvae of *H. marginatus*, 10.0 mm, *H. rondeletii*, 11.2 mm, and *H. speculiger*, 10.5 mm; juveniles of *H. marginatus*, 22.0 mm, *H. rondeletii*, 45.0 mm, and *H. speculiger*, 58.0 mm (Kovalevskaya 1972).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–43	40–41
Precaudal	27–30	27–29
Caudal	11–14	12–13
Fins:		
Dorsal spines	0	0
Dorsal rays	9–11	10
Anal spines	0	0
Anal rays	7–9	8
Pelvic	6	6
Pectoral	15–17	16
Caudal:		
Principal	7+8	7+8
Procurrent:		
Upper	5–6	5
Lower	5–7	6
Gill rakers:		
Total	17–22	
Upper		
Lower		
Branchiostegals	8–11	9–11

LIFE HISTORY

Range: Tropical & subtropical eastern Pacific Ocean, northward as far as southern Baja California

Habitat: At surface, neritic

Spawning season: Larvae collected primarily January–August

ELH pattern: Oviparous, presumably with eggs attached to one another and/or floating objects via filaments; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.5 mm (N. Arthur)
Postflexion larva, 8.0 mm (N. Arthur)
Juvenile, 11.8 mm (N. Arthur)

* Eye is oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: Probably ca. 2.5–3 mm
Flexion length: Before hatching
Transformation length: ca. 10–12 mm
Fin development sequence:
Pigmentation: *Larvae*—Heavily pigmented except little ventrally before ca. 10–11 mm & none on last 3–4 myomeres before ca. 5 mm; on hypural margin & lateral midline of caudal peduncle after 5 mm, midlateral stripe expands after ca. 8–9 mm; P_1 pigment initially on base only, extends onto upper part of fin after ca. 4 mm, reaches distal margin by ca. 8 mm & nearly covers fin by ca. 10 mm; P_2 pigment initially proximal, spreads distad to cover fin by ca. 8 mm; on D after ca. 9.5–11 mm, primarily anterior; little or none on A; scattered on C, primarily along lower rays.
Diagnostic features: Robust body; P_1 relatively short (compared with *Cheilopogon*) & rounded; A origin under 3rd–5th D ray; barbels or beak never form; small size at transformation; heavily pigmented except last half of caudal peduncle unpigmented before ca. 5 mm & with unpigmented dorsolateral, distal, & ventrolateral areas thereafter.

MORPHOMETRICS (range & mean in %)

	Y-S	PoF	Tr	Juv
Sn-A/BL		69–79	67–74	71–74
	69	73	71	73
BD/BL		20–29	19–24	19–21
	24	24	21	21
HL/BL		23–40	21–24	20–23
	30	29	23	22
HW/HL		77–92	77–91	80–94
	78	84	83	86
SnL/HL		10–20	11–16	12–17
	15	14	14	15
ED/HL*		41–48× 33–44	41–60× 40–52	47–55× 43–53
	36×31	45×38	49×45	51×47
P_1L/BL		9–24	26–31	31–43
	11	16	27	36
P_2L/BL		7–21	14–24	23–29
	6	14	21	25

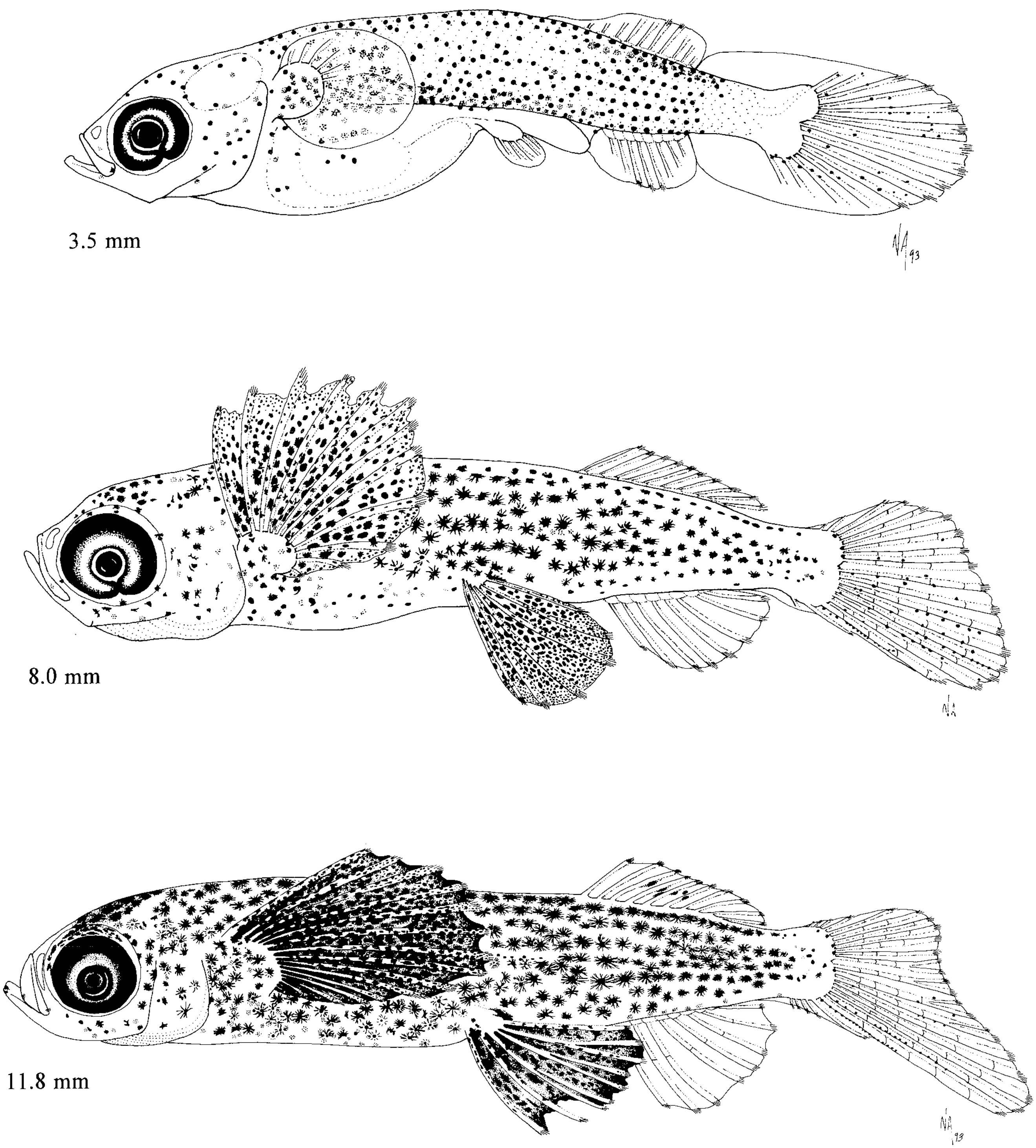


Figure Exocoetidae 7. Yolk-sac larva, 3.5 mm (CalCOFI 5708, station 157.20); postflexion larva, 8.0 mm; juvenile, 11.8 mm (CFRD Ref. Coll., RR61–41, Isla Cerralvo, Baja California Sur).

LAMPRIDIFORMES

S. R. Charter and H. G. Moser

Seven lampridiform families include 21 species in 12 genera (Olney et al. 1993). Eschmeyer (1990) placed Eutaeniophoridae in Lampridiformes, as hypothesized by Rosen and Patterson (1969); however, Moore (1993) suggested that eutaeniophorids belong with the stephanoberycoids and we follow that arrangement in this guide. Olney et al. (1993) demonstrated monophyly for the order on the basis of five synapomorphies, three of which are related to a unique mechanism for jaw protrusion. Patterson and Johnson (1995) place lampridiforms as the sister group of all other acanthomorphs. Lampridiformes is used as the name for the order instead of Lampriformes following the argument of Patterson (Appendix 1, in Olney et al. 1993).

Lampridiforms are among the most spectacular oceanic fishes. Most are relatively large (>40 cm); the oarfish (*Regalecus glesne*) attains a length of 8 m. Lampridiforms are either deep-bodied with symmetrical caudal fins and well developed skeletons or compressed, long and ribbon-like with long dorsal fins, asymmetrical caudal fins, and weak skeletons (Nelson 1994). Most are silvery with crimson or dark fins. They are often skinned during capture. They lack spines in the fins and possess a unique protrusile upper jaw with highly protractile premaxillae (Nelson 1994).

Representatives in this order occur worldwide in epi- to bathypelagic habitats. Some species are rarely captured and range records for some species are from strandings or from individuals swimming feebly close to shore. Planktonic eggs are large with a resilient chorion that may appear amber, pink or red (Olney et al. 1993). Some species' eggs have pigmented yolk and at least one has spinules covering the entire surface of the chorion. Late-stage eggs may be identified by precocious embryos that have pigmented eyes, functional mouths, and elongate anterior rays of the dorsal and pelvic fins with characteristic pigmented swellings. Early-stage lampridiform larvae display many of the unusual morphological features of the adults: compressed deep head, tapering body, large eyes, highly protrusile upper jaw, and a long-based dorsal fin. Anterior dorsal-fin rays of all the lampridiform taxa included in this guide bear lateral spinules visible early in development (Olney et al. 1993). In lampridiforms, particularly trachipterids, development of the posterior part of the dorsal fin is delayed. The caudal peduncle in the late larval stage is too short to accommodate the numerous dorsal-fin rays that will ultimately form. The posterior rays and pterygiophores are formed from a peg-like terminus in the finfold while, simultaneously, the caudal peduncle lengthens to the adult proportion through the elongation of the vertebrae and myomeres. When the details of this process are known, it may provide additional evidence for lampridiform monophyly. Since transformation from larva to juvenile is protracted and there is no distinct metamorphic stage, measurements of transforming specimens were combined with postflexion larvae in the morphometric tables.

Adults of nine species representing six families are known from the California Current region. Ontogenetic stages of six species were available for description (Tables Lampridiformes 1 and 2): *Lophotus lacepede*, *Radiicephalus elongatus*, *Trachipterus altivelis*, *Desmodema lorum*, and *Zu cristatus* from CalCOFI samples and *T. fukuzakii* from other surveys south of the CalCOFI sampling area.

Families included: Lophotidae
Radiicephalidae
Trachipteridae

Table Lampridiformes 1. Meristic characters for the lampridiform species in the California Current vicinity (Olney 1984).

Taxon	Vertebrae			Fin rays				
	PrCV	CV	Total	D	A	P_1	P_2	C_1
Lamprididae								
Lampris guttatus	21	25	46	48–52	33–42	21–24	13–17	30–32
Lophotidae								
Lophotus lacepede			124–153	206–263	5–20	14–17	2–6	16–17
Radiicephalidae								
Radiicephalus elongatus	36–39	77–79	114–121	152–160	6–7	9–10	9–10	4+7
Trachipteridae								
Desmodema lorum	21–25		106–111	197	0	12–14	0	4–7
Trachipterus altivelis	35–40		90–94	165–184	0	10–11	6–7	7–8+6
T. fukuzakii	25–28		69–72	153–174	0	11–13	5	7–9+6–7
Zu cristatus	22–24	39	62–69	120–150	0	10–12	3–7	8–12+1–5
Regalecidae								
Regalecus glesne			143–151	260–412	0	12–13	1	3–4
Stylephoridae								
Stylephorus chordatus			50	115–122	16–17	10–11	1	5–6+2

Table Lampridiformes 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the lampridiform species descriptions. An "L" indicates literature used in the description.

Taxon	Egg	Yolk-sac	Preflexion	Flexion	Postflexion-transformation	Juvenile
Lophotidae						
Lophotus lacepede	L[a], 1 2.5	0	4 5.8–8.0	0	1 25.2	2 45.4–50.1
Radiicephalidae						
Radiicephalus elongatus	0	0	1 7.2	0	4 17.7–20.3	2 33.6–50.4
Trachipteridae						
Desmodema lorum	2 2.4–2.5	0	7 6.0–11.3	0	1 54.3	1 65.9
Trachipterus altivelis	14 2.8–3.1	0	10 7.2–12.8	5 16.2–22.5	10 23.4–54.7	4 59.8–87.5
T. fukuzakii	7 2.0–2.1	0	7 4.8–8.8	6 9.2–34.4	3 57.6–83.4	2 107.4–115.8
Zu cristatus	5 1.9–2.1	0	8 3.7–8.7	5 8.3–13.1	3 18.9–24.7	5 42.8–143.5

[a] Sanzo 1940

LOPHOTIDAE: Crestfishes

S. R. CHARTER AND H. G. MOSER

The crestfish, *Lophotus lacepede*, is widely distributed in temperate and tropical waters of all oceans. It has been reported in the CalCOFI study area from Point Dume, California, south to the Channel Islands and offshore to ca. 1300 km. Specimens have been collected from tuna stomachs, caught on hook-and-line, and captured in nets towed at high speed offshore. Occasionally, individuals have been washed ashore or found swimming feebly at the surface. A single egg and larva were collected off northern Baja California; eggs and larvae are relatively more common in samples from the eastern tropical Pacific (EASTROPAC Expedition).

Adult crestfish inhabit epi- and mesopelagic zones. They are large (102 cm), have a silvery band-like body and a protruding forehead. The dorsal, anal, and caudal fins are crimson; the long-based dorsal fin has a pronounced crest. The short-based anal and caudal fins are near one another. Pelvic bones are present but rays are weakly developed, fragile and often lacking in adults (J. E. Olney, pers. comm.). An ink sac lies above the abdominal cavity and empties through the vent.

Lophotids are oviparous with planktonic eggs and larvae. The chorion of the egg is covered with short spines (0.04–0.06 mm); both the chorion and spines appear amber. Sanzo (1940) illustrated an advanced embryo with snout pigment and a few small dorsal body patches. Larvae hatch with functional mouths, a dorsal fin with elongate anterior rays with pigmented swellings, and pelvic fins with two elongate rays with terminal pigmented swellings.

Larvae of *L. lacepede* resemble those of *Radiicephalus elongatus*. They have overlapping myomere counts (122–137 and 118–131, respectively) but the two species differ in preanal length: snout-anus distance is relatively longer in preflexion *R. elongatus* (61% BL vs. 47% BL) but is relatively longer in the postflexion-transformation stage *L. lacepede* (76% BL vs. 58% BL). Also, *R. elongatus* has an elongate pelvic girdle. Larvae of both species develop an ink sac and anal fin and each species has a characteristic pigment pattern. Larvae of *Zu cristatus* are similar but have fewer myomeres (62–70), a postanal ventral pigment spot and, by 42.8 mm, the ventral profile is characteristically scalloped anterior to the anus.

The following description of *L. lacepede* is based on detailed examination of one egg (2.5 mm), five larvae (5.8–25.2 mm), and two juveniles (45.2–50.1), and on literature (Sanzo 1940; Olney 1984). Additional morphological and ecological information was obtained from Fitch and Lavenberg (1968) and Eschmeyer et al. (1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	124–153	
Precaudal		
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	206–263	
Anal spines	0	
Anal rays	5–20	
Pelvic	2–6	5
Pectoral	14–17	
Caudal:		
Principal	16–17	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	3–4	
Lower	7–9	
Branchiostegals		

LIFE HISTORY

Range: Worldwide in warm seas; in eastern Pacific, north to southern California

Habitat: Surface to at least 92 m depth

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser 1981
Olney 1984
Sanzo 1940

EARLY LIFE HISTORY DESCRIPTION

EGGS

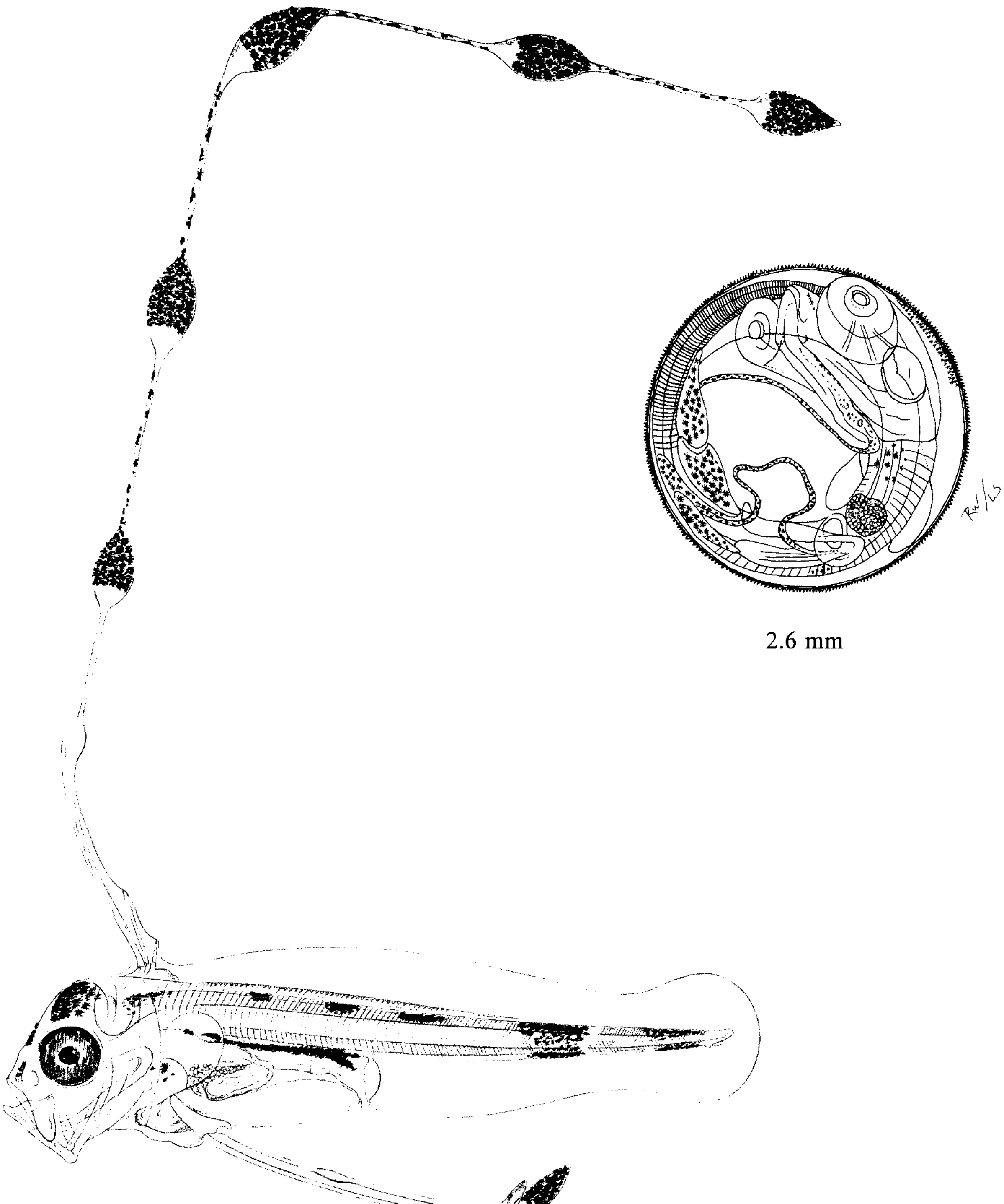
Shell diam.: 2.5–2.6 mm **Yolk:** Homogeneous; ca. 1.9 mm diam.
No. of OG: **Diam. of OG:**
Shell surface: Amber spines (0.04–0.06 mm long) scattered over entire surface
Pigment: Chorion amber; unpigmented yolk; advanced embryo with melanophores in patches on dorsum from snout to end of tail, dorsally on gut, & on swellings on elongate D & P_2 rays
Diagnostic features: Large size; spinous chorion surface; embryo shape; high myomere count; precocious development of D & P_2

LARVAE

Hatching length: <5.8 mm
Flexion length: <25.2 mm
Transformation length:
Fin development sequence: D & P_2, C & A, P_1
Pigmentation: *Preflexion*—Scattered on head; on snout; dorsally over air bladder & hindgut; 3 patches dorsally; 1 dorso-ventral bar on tail; apposing dorsal & ventral patches near tip of tail; swellings on anterior D & P_2 rays (elongate portion of fins generally broken); few internally posterior to cleithrum. *Postflexion-transformation-juvenile*—Increasing along jaw, anterior to cleithrum, & laterally on body.
Diagnostic features: Total myomeres 122–137; myomeres in preflexion larvae 27–34+91–96, in postflexion-transformation larvae 60+69, & in juveniles 109–124+13–19; in preflexion stage, moderate-sized eye (<40% HL) & short preanal length (<50% BL) & in postflexion-juvenile stage, small eye (ca. 33% HL) & long preanal length (>75% BL); by 25.2 mm, ink sac visible & A pterygiophores developing; distinctive pigment.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF-Tr	Juv
Sn-A/BL		44–52 47		 76	84–90 87
BD/BL		20–26 23			13–13 13
HL/BL		18–22 20		 23	14–15 15
HW/HL		33–47 39		 27	32–39 36
SnL/HL		16–29 22			18–21 19
ED/HL		38–41 39			31–35 33
P_1L/BL		3–6 5		 3	5–6 6
P_2L/BL		11–53 26		 7	
JD/HL		50–63 58			38–54 46



2.6 mm

12.1 mm

Figure Lophotidae 1. Egg, 2.6 mm (redrawn from Sanzo 1940); preflexion larva, 12.1 mm (Sanzo 1940).

RADIICEPHALIDAE: Tapertails

S. R. CHARTER AND H. G. MOSER

The rare monotypic lampridiform, *Radiicephalus elongatus*, occurs worldwide in warm and temperate seas. A few adults have been collected from the epi- to bathypelagic zones of the Atlantic and in the Pacific off New Guinea. A total of seven North Pacific specimens were available for examination, six (17.7–50.4 mm) from the SIO/Marine Vertebrates Collection and one larva (7.2 mm) from CalCOFI 7210, station 40.120.

Adults are silvery, elongate, strongly compressed fishes with a tail that tapers to a thin caudal filament. The anus is at ca. 33% BL. The dorsal fin is long-based. The anal fin is rudimentary with small delicate rays. Pelvic rays become reduced or lost with development, although Oelschläger (1983) and Smith and Heemstra (1986) figure specimens (>31 cm) with pelvic rays. The upper jaw is highly protrusible. An ink sac empties through the vent. The lateral line extends posteriorly as a thin-walled tube on the elongate caudal rays.

Planktonic eggs have not been identified. Karrer (1976) described ovarian eggs (2.5 mm diameter) in a female collected from the Gulf of Guinea. The planktonic larvae have a compressed, long, tapering body, a long-based dorsal fin, and a highly protrusible upper jaw.

The pigment pattern of *R. elongatus* larvae is similar to, but distinct from, that of larval *Lophotus lacepede* and *Zu cristatus*. *Z. cristatus* has fewer myomeres than *R. elongatus* (62–70 vs. 118–131). Myomere counts of *R. elongatus* and *L. lacepede* overlap (118–131 and 122–137, respectively). In preflexion *R. elongatus* the pelvic girdle is more elongate, eye diameter is larger (50% HL vs. 39% HL), and the preanal distance is longer (61% BL vs. 47% BL) than in *L. lacepede*. Postflexion-transformation stage *R. elongatus* larvae have a shorter preanal distance than *L. lacepede* (58% BL vs. 76% BL). At 17.7 mm the ink sac is visible and the anal fin is developing; at 50.4 mm the thin-walled lateral line tube in the caudal region is developed.

Adult morphological and ecological information was taken from Harrison and Palmer (1968), Smith and Heemstra (1986), and Nelson (1994). The following description of *R. elongatus* larvae is based on the detailed examination of seven specimens (7.2–50.4 mm) and on literature (Olney 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	114–121	
Precaudal	36–39	
Caudal	77–79	
Fins:		
Dorsal spines	0	
Dorsal rays	152–160	
Anal spines	0	
Anal rays*	6–7	
Pelvic†	9–10	
Pectoral	9	
Caudal:		
Principal	4+7	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2	
Lower	7–8	
Branchiostegals	4–6	

LIFE HISTORY

Range: Apparently worldwide in warm & temperate seas; few reported from Atlantic, Indo-West Pacific, & North Pacific Oceans

Habitat: All records from epi- & mesopelagic zones

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Olney 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 7.2 mm (R. C. Walker)
Postflexion-transformation specimen, 20.3 mm (R. C. Walker)

* Rudimentary in adult.
† Absent in adult.

EARLY LIFE HISTORY DESCRIPTION

EGGS

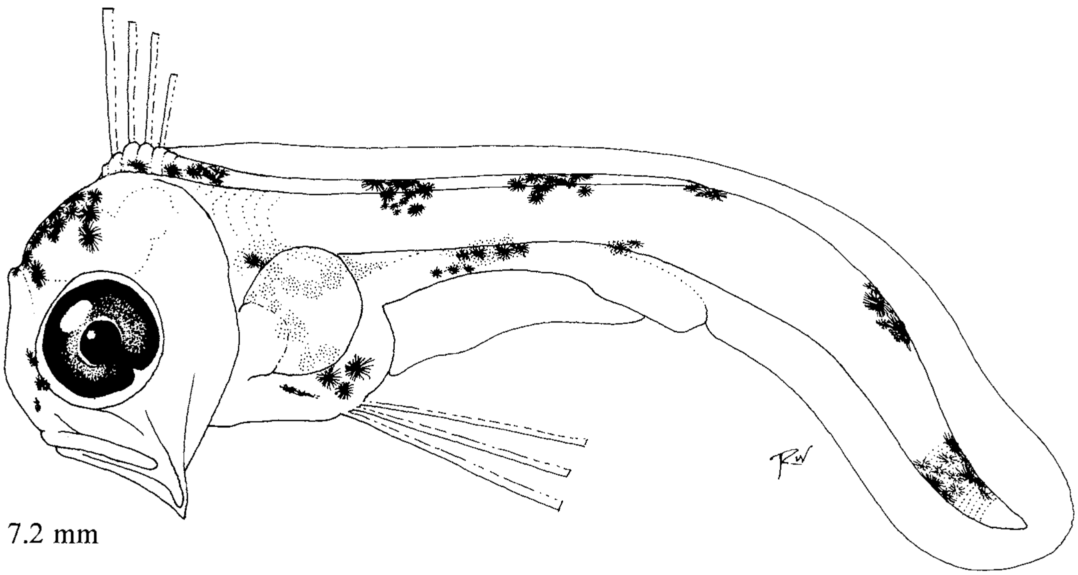
Shell diam.:
No. of OG:
Shell surface:
Pigment:
Diagnostic features:
Yolk: Homogeneous
Diam. of OG:

LARVAE

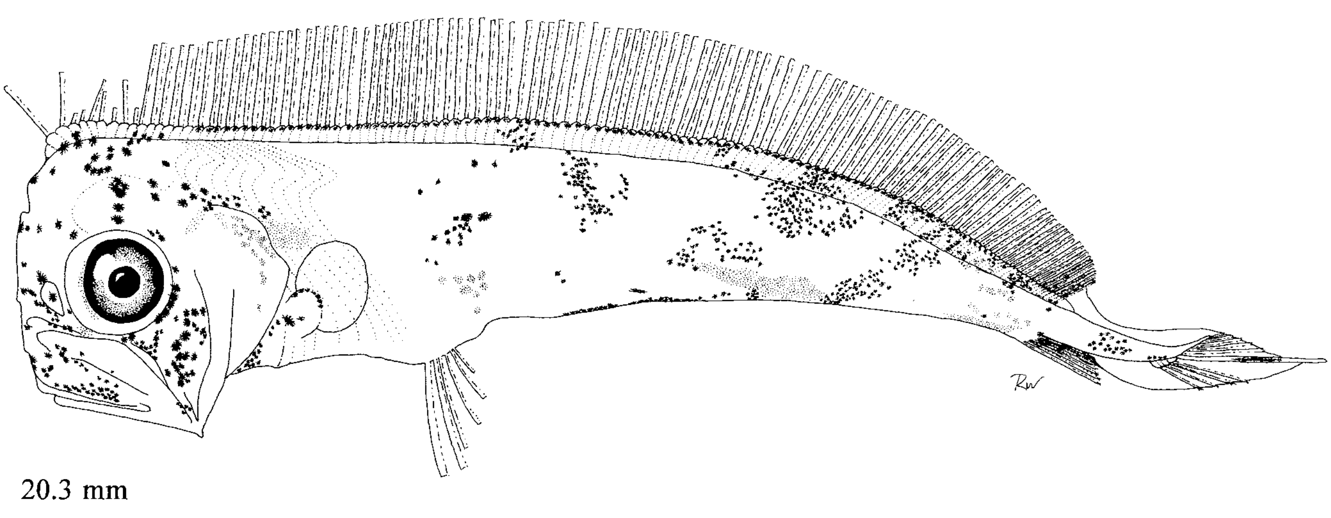
Hatching length: <7.2 mm
Flexion length: ca. 17.7 mm
Transformation length: Protracted & gradual
Fin development sequence: D & P_2, C & A, P_1
Pigmentation: *Preflexion*—Anterior to eye; on forebrain; on snout; 5 patches dorsally, opposing dorso-ventral patches at caudal region; 3 patches above gut; 1 patch over pelvic girdle. *Postflexion-transformation*—Scattered on snout; over jaw; on forebrain; laterally on body & pterygiophores (6 dorsal & 3 ventral patches expanded); in caudal region & between C rays; P_1 base; internally above gut; over anus & anteriorly to A. *Juvenile*—Increasing over body & internally on notochord in caudal region.
Diagnostic features: Total myomeres 118–131; myomeres in preflexion larvae 63+68, in postflexion-transformation larvae 47–52+66–74, & in juvenile 44–50+74–75; in preflexion stage, large eye (diameter ca. 50% HL) & preanal length >60% BL; in postflexion-transformation stage, small eye (ca. 33% HL) & short preanal length (ca. 58% BL); in juvenile, small eye (ca. 24% HL) & short preanal length (ca. 57% BL); slender (BD ca. 18% BL); elongate P_2 girdle; by 17.7 mm, ink sac visible & A developing; by 50.4 mm, tubercles developing ventrally on body & tube in C region.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF-Tr	Juv
Sn-A/BL		61		52–61 58	54–59 57
BD/BL		22		20–22 20	17–19 18
HL/BL		19		19–25 22	21–26 23
HW/HL		50		39–46 42	26–32 29
SnL/HL		24		14–39 29	18–29 24
ED/HL		50		31–35 33	22–26 24
P_1L/BL		7		3–4 3	4–5 5
P_2L/BL		23		7–16 12	5–11 8
JD/HL		66		52–60 57	38–41 40



7.2 mm



20.3 mm

Figure Radiicephalidae 1. Preflexion larva, 7.2 mm (CalCOFI 7210, station 40.120); postflexion-transformation specimen, 20.3 mm, partly skinned, pigment is missing (SIO 74–54).

TRACHIPTERIDAE: Ribbonfishes

S. R. CHARTER AND H. G. MOSER

Four ribbonfish species occur in the CalCOFI study area. *Trachipterus altivelis* ranges from Alaska to Chile; eggs, larvae, and adults occur throughout the CalCOFI region, most commonly in the northern half of the survey pattern. *Trachipterus fukuzakii* ranges from southern California to Chile. Eggs and larvae of *T. fukuzakii* have not been identified from CalCOFI samples but occur frequently in samples from the eastern tropical Pacific (EASTROPAC Expedition). *Zu cristatus* occurs worldwide in warm seas; in the eastern Pacific it ranges from southern California, to Peru and the Galápagos Islands. *Desmodema lorum* probably occurs only in the north Pacific and in the eastern Pacific from central California to southern Baja California. Larvae of *D. lorum* have been taken offshore from central California to central Baja California. Eggs of *D. lorum* and eggs and larvae of *Z. cristatus* occur in the southern portion of the CalCOFI study area but are more common in samples from the eastern tropical Pacific.

Adult trachipterids are epi- to mesopelagic; some have been washed ashore or collected swimming feebly near the shore. They occur in all oceans except the Antarctic. Trachipterids have a spotted juvenile stage that inhabits the euphotic zone. Adults are highly compressed and ribbon-like, with a long-based dorsal fin and highly protrusile upper jaw. They lack anal fins; one genus, *Desmodema,* also lacks pelvic fins. Most have silvery bodies with red fins although some species have a partially or completely dark dorsal or caudal fin. Total vertebral counts separate the species in our study area: *D. lorum* (106–111), *T. altivelis* (90–94), *T. fukuzakii* (69–72), and *Z. cristatus* (62–69). Trachipterids have been observed from submersibles oriented head up at a 45° angle, maintaining position by undulating the dorsal fin (Eschmeyer et al. 1983).

Trachipterids are oviparous with planktonic eggs. The eggs are large, have a resilient chorion and appear amber, pink or red. In our area, *T. altivelis* eggs are the largest (2.8–3.1 mm) and lack yolk pigment. Eggs of *D. lorum* (2.4–2.5 mm), *T. fukuzakii* (2.0–2.1 mm), and *Z. cristatus* (1.9–2.1 mm) have scattered yolk pigment. The pigment pattern of advanced embryos will separate *T. fukuzakii* and *Z. cristatus*; *T. fukuzakii* lacks a ventral postanal pigment patch and has a relatively longer gut than *Z. cristatus* throughout larval development. The precocious larvae hatch with protrusile upper jaws and elongate anterior dorsal and pelvic rays with terminal or serial pigmented swellings. Elongate rays usually are broken in field-caught larvae. Morphology in preflexion larvae is similar among species; however, total myomere counts as well as distinctive pigmentation separate the species. Preflexion *D. lorum* larvae have dorsal and ventral pigment series, *T. altivelis* lack postanal pigment, *T. fukuzakii* have a dorsal pigment series, and *Z. cristatus* have several dorsal patches and a single ventral postanal patch. In *Z. cristatus*, notochord flexion occurs at a smaller size than in the other species and preanal length is relatively shorter in all stages compared to other species. Late larvae may be separated by body morphology: *D. lorum* has a deep, rounded ventral profile, *T. altivelis* has a gradually tapering body profile, *T. fukuzakii* has a steeply tapering, undulating ventral body profile, and *Z. cristatus* has a deep, scalloped ventral profile anterior to the anus. Dorsal and anterior pelvic fin rays bear small, strong lateral spinules. Posterior pelvic, middle caudal, and pectoral fin rays bear weaker spinules. These spinules disappear in older specimens. Lateral line scales develop with one or two spinous ridges. Most species have a specialized juvenile stage with a distinctive pigment pattern and produced pelvic fin rays that are reduced or lost (*Desmodema*) in adults.

Morphological and ecological information was taken from Fitch and Lavenberg (1968), Miller and Lea (1972), Rosenblatt and Butler (1977), Eschmeyer et al. (1983), and Nelson (1994). The following species descriptions were based on detailed examination of a total of 28 eggs, 67 larvae, and 11 pelagic juveniles (Table Lampridiformes 2), and on literature (Hubbs 1925a; Sparta 1933; Rosenblatt and Butler 1977; Olney and Naplin 1980; Olney 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	106–111	
Precaudal	21–25	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	197	
Anal spines	0	
Anal rays	0	
Pelvic	0	
Pectoral	12–14	
Caudal:		
Principal	4–7	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–3	3
Lower	9–10	9
Branchiostegals		

LIFE HISTORY

Range: North Pacific, 20°–40° N, central California to southern Baja California to 160° E

Habitat: Oceanic; epi- to upper mesopelagic; young near surface

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Amaoka et al. 1992
Rosenblatt & Butler 1977

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 2.5 mm (R. C. Walker)
Preflexion larva, 6.0 mm (R. C. Walker)
Late preflexion larva, 11.3 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.4–2.5 mm **Yolk:** Homogeneous; 2.1–2.3 mm diam.
No. of OG: **Diam. of OG:**
Shell surface: Small pits or other irregularities
Pigment: Chorion amber to pink; melanophores scattered on yolk; on embryo, anterior to eye, over brain, dorsally on epaxial myomeres, & few ventrally on hypaxial myomeres.
Diagnostic features: Large size; embryo shape; pigment on yolk; high myomere count; precocious development of D & P_2

LARVAE

Hatching length: <6.0 mm
Flexion length: >11.3 mm
Transformation length: Protracted & gradual, >54.3 mm, <65.9 mm
Fin development sequence: D & P_2, C, P_1
Pigmentation: *Preflexion*—On forebrain & onto ascending process of premaxilla; on jaw; anterior & posterior to cleithrum; dorsolaterally on gut; series dorsally on epaxial myomeres; postanal series on hypaxial myomeres; a few in C region. *Flexion–postflexion-transformation*—Increasing over brain, anterior & posterior to eye, & laterally on body; on D pterygiophores. *Juvenile*—Finely scattered with concentrated small patches over entire body; 2 large concentrated patches on epaxial myomeres; dorsally on pterygiophores; on ascending process of premaxilla.
Diagnostic features: Total myomeres 106–112 (34–51+59–76); compared to other trachipterids, preanal length greater in postflexion-transformation stage, eye smaller (ED 26% HL vs. 31–34%), & jaw depth shallower (JD 36% HL vs. 51–52%); dorsal epaxial & ventral hypaxial pigment; pigment on D pterygiophores; in later stages, deep body, more rounded anteroventral profile, & narrower, elongate tail.

MORPHOMETRICS (range & mean in %)

	PrF	F	PoF-Tr	Juv
Sn-A/BL	51–68			
	58		66	64
BD/BL	20–32			
	26		23	25
HL/BL	20–26			
	23		23	17
HW/HL	42–51			
	47		28	41
SnL/HL	19–39			
	28		23	20
ED/HL	34–46			
	41		26	35
P_1L/BL	5–8			
	6		10	10
P_2L/BL	5–119			
	29		50	66
JD/HL	56–77			
	65		36	54

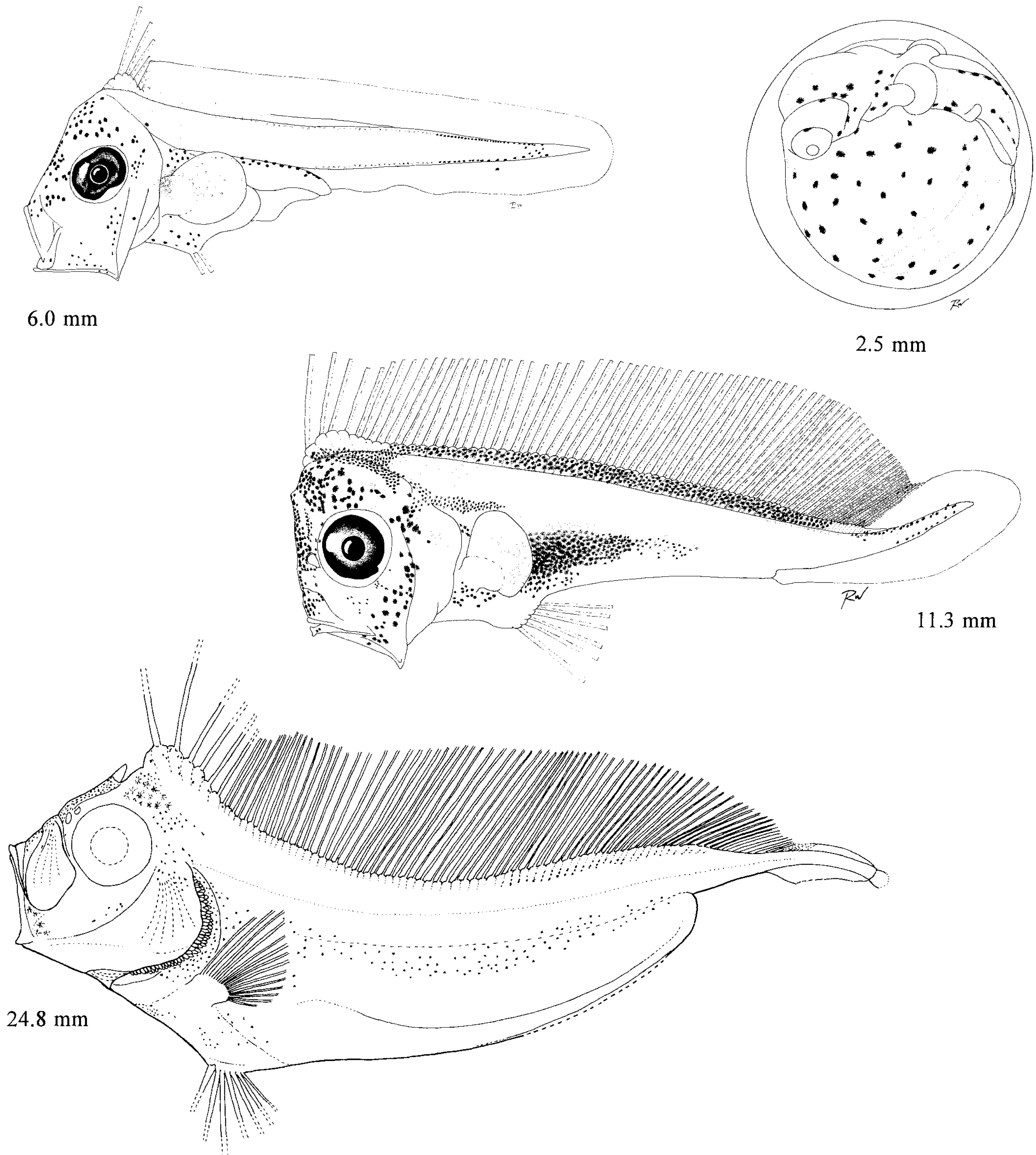


Figure Trachipteridae 1. Egg, 2.5 mm (CalCOFI 7807, station 107.60); preflexion larva, 6.0 mm (CalCOFI 6110, station 90.160); late preflexion larva, 11.3 mm, partly skinned, pigment is missing (CalCOFI 5408, station 120.60); postflexion-transformation specimen, 24.8 mm (Amaoka et al. 1992).

MERISTICS

	Range	Mode
Vertebrae:		
Total	90–94	
Precaudal	35–40	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	165–184	
Anal spines	0	
Anal rays	0	
Pelvic	6–7	
Pectoral	10–11	
Caudal:		
Principal	7–8+6	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	3–5	
Lower	9–11	
Branchiostegals		

LIFE HISTORY

Range: Alaska to Chile

Habitat: Oceanic; surface to 900 m depth; large adults sometimes bottom feeders

Spawning season: Larvae collected throughout the year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fitch 1964
Hubbs 1925a
Matarese et al. 1989
Matarese & Sandknop 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Embryo, 7.4 mm, dissected from a 3.1 mm egg (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.8–3.1 mm **Yolk:** Homogeneous; 2.2–2.6 mm diam.
No. of OG: **Diam. of OG:**
Shell surface: Fine striations or other irregularities
Pigment: Chorion amber to pinkish amber; melanophores on embryo over brain, anterior to cleithrum, dorsally on gut, over P_2 girdle, & on D & P_2 serial swellings.
Diagnostic features: Large size; embryo shape; unpigmented yolk, often with vesicles; high myomere count; precocious development of D & P_2.

LARVAE

Hatching length: ca. 7.2–7.4 mm
Flexion length: >12.8, <16.2 mm
Transformation length: Protracted & gradual, >54.7 mm
Fin development sequence: D & P_2, C, P_1
Pigmentation: *Preflexion*—On forebrain; anterior to cleithrum; anteriorly & dorsally on gut. *Flexion*—Increasing over ascending process of premaxilla; increasing laterally on gut. *Postflexion-transformation*—Increasing on jaw & laterally on body; on D pterygiophores; series above anterior 75% of notochord; few in caudal region. *Juvenile*—Very fine, widely spaced over entire body; heavy over ascending process of premaxilla; around maxilla & under eye; heavy spots over P_2 & posterior to P_2; 3 large spots on epaxial myomeres & dorsally posteriad from 3rd spot to C; on D pterygiophores; sometimes light spot in D pterygiophores at ca. anterior 20% BL.
Diagnostic features: Total myomeres 92–103; myomeres in preflexion stage 40–47+46–58, in flexion stage 52–56+36–49, in postflexion-transformation stage 52–62+36–42, & in pelagic juveniles 54–57+39–41; lack of postanal pigment in preflexion & flexion stages; gradually tapering body profile in postflexion-transformation stage & pelagic juvenile.

MORPHOMETRICS (range & mean in %)

	PrF	F	PoF-Tr	Juv
Sn-A/BL	49–57 53	58–68 64	61–71 65	62–68 64
BD/BL	18–24 21	21–24 23	18–24 21	16–20 18
HL/BL	18–24 20	19–23 21	17–22 19	16–18 16
HW/HL	33–68 45	33–44 39	30–54 40	23–36 32
SnL/HL	13–32 21	17–32 24	14–25 19	19–30 24
ED/HL	32–49 41	34–42 38	24–38 34	27–34 30
P_1L/BL	5–8 6	3–8 5	3–7 5	6–11 8
P_2L/BL	9–46 23	17–76 39	12–99 46	23–60 43
JD/HL	47–73 63	46–60 55	47–57 52	39–55 48

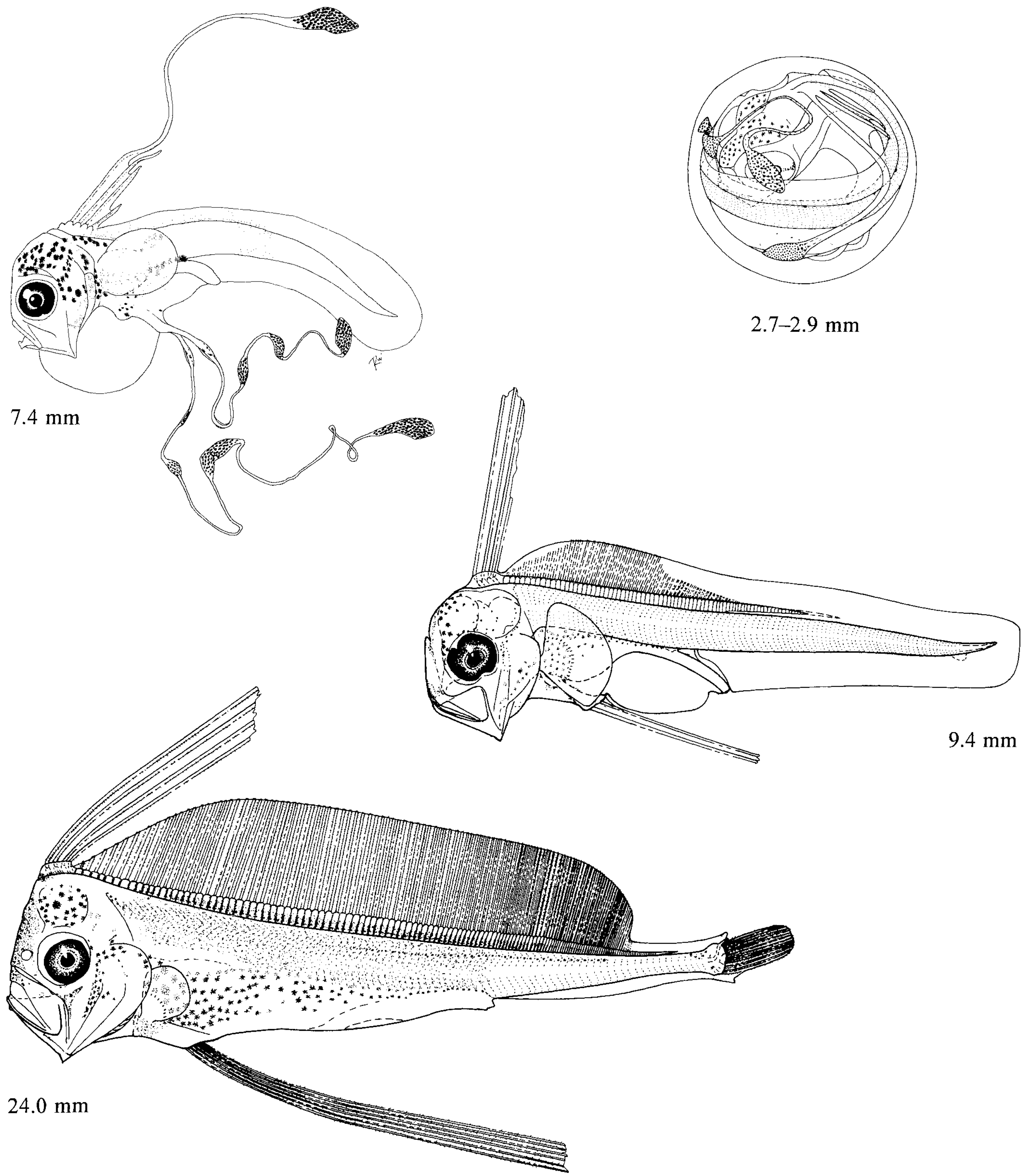


Figure Trachipteridae 2. Egg, 2.7–2.9 mm (Matarese and Sandknop 1984); embryo, 7.4 mm, dissected from 3.1 mm egg (CalCOFI 7501, station 87.80); preflexion larva, 9.4 mm; postflexion-transformation specimen, 24.0 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	69–72	
Precaudal	25–28	
Caudal		
Fins:		
Dorsal spines	0	
Dorsal rays	153–174	
Anal spines	0	
Anal rays	0	
Pelvic	5	
Pectoral	11–13	
Caudal:		
Principal	7–9+6–7	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Southern California to Chile

Habitat: Epi- to mesopelagic

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Olney 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Embryo, 5.6 mm, dissected from a 2.1 mm egg (R. C. Walker)
Flexion larva, 13.3 mm (R. C. Walker)

* Two of the postflexion-transformation specimens had both eyes missing—snout & eye & jaw depth measurements were not taken.
† One juvenile had lower jaw broken, measurement not taken.

EARLY LIFE HISTORY DESCRIPTION

EGGS

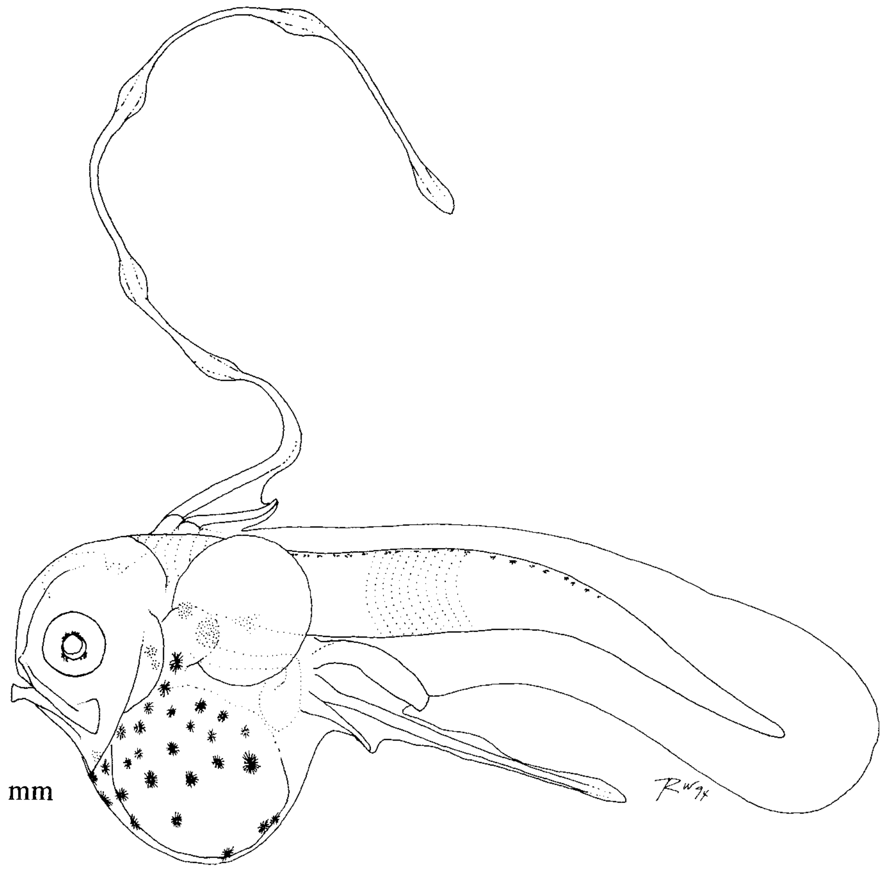
Shell diam.: 2.0–2.1 mm **Yolk:** Homogeneous; 1.6–1.8 mm diam.
No. of OG: **Diam. of OG:**
Shell surface: Small shallow pits on most eggs
Pigment: Chorion light amber to light pink; melanophores scattered on yolk, on embryo anterior to gut, & dorsally on myosepta
Diagnostic features: Size; embryo shape; pigment on yolk; precocious development of D & P_2; low myomere count; dorsal myosepta pigment.

LARVAE

Hatching length: ca. 4.8–5.6 mm
Flexion length: ca. 9.2 mm
Transformation length: Protracted & gradual
Fin development sequence: D & P_2, C, P_1
Pigmentation: *Preflexion–flexion*—Anteriorly on gut; dorsally on myosepta; some have snout pigment; by 8.8 mm, on forehead & between eye & cleithrum; on D pterygiophores; dorsolaterally on gut. *Postflexion-transformation*—On caudal peduncle; by 83.4 mm, on lips & posteriorly on eye socket. *Juvenile*—On lower jaw angle; on ventral body edge below cleithrum; 2–3 patches laterally on body.
Diagnostic features: Total myomeres 70–86; myomeres in preflexion larvae 29–39+36–52, in flexion stage 39–50+28–37, in postflexion-transformation stage 49–53+30–31, & in pelagic juveniles 43–44+31–33; gut elongate; dorsal pigmentation; lack of ventral pigmentation; low myomere count; by 13.3 mm, ventral profile tapers more steeply then in *T. altivelis* & postanal region of body is strap-like.

MORPHOMETRICS (range & mean in %)

	PrF	F	PoF-Tr*	Juv†
Sn-A/BL	50–60 55	64–74 69	65–72 68	66–68 67
BD/BL	20–30 27	21–32 27	16–20 18	16–17 17
HL/BL	17–22 20	18–27 22	19–20 20	19–20 20
HW/HL	38–62 47	28–45 36	20–26 24	20–22 21
SnL/HL	11–30 20	13–19 17	22	31–31 31
ED/HL	39–57 45	33–41 37	24	19–21 20
P_1L/BL	4–8 5	3–6 5	4–6 5	6–7 7
P_2L/BL	8–31 14	6–47 21	8–24 13	5–5 5
JD/HL	49–74 65	46–63 57	37	41



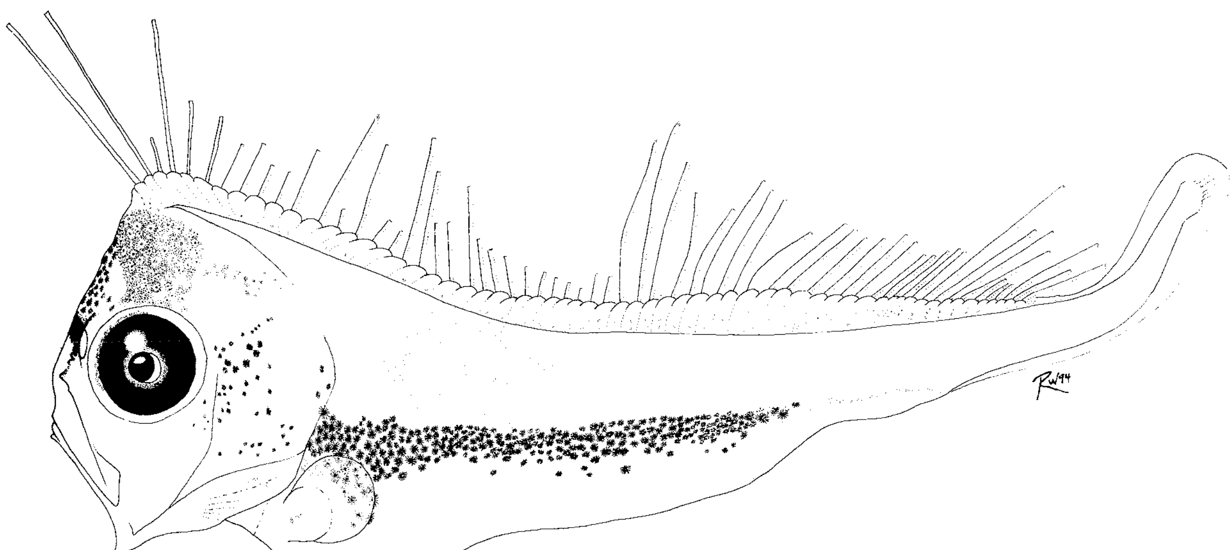


Figure Trachipteridae 3. Embryo, 5.6 mm, dissected from 2.1 mm egg (EASTROPAC II, station 60.48); flexion larva, 13.3 mm, partly skinned, pigment is missing (EASTROPAC II, station 60.295).

MERISTICS

	Range	Mode
Vertebrae:		
Total	62–69	
Precaudal	22–24	
Caudal	39	
Fins:		
Dorsal spines	0	
Dorsal rays	120–150	
Anal spiues	0	
Anal rays	0	
Pelvic	3–7	5–6
Pectoral	10–12	
Caudal:		
Principal	8–12+1–5	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–3	
Lower	8–9	
Branchiostegals		

LIFE HISTORY

Range: Worldwide in warm seas; in eastern Pacific, southern California to Peru & Galápagos Islands

Habitat: Shallow water to 90 m depth

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser 1981
Olney & Naplin 1980
Sparta 1933

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.8 mm (M. T. Vona)
Flexion larva, 13.7 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.9–2.1 mm **Yolk:** Homogeneous; 1.4–1.8 mm diam.
No. of OG: **Diam. of OG:**
Shell surface: Uneven striations; small pits or other irregularities
Pigment: Chorion amber to dark pink; melanophores scattered on yolk; on embryo, double row of dashes on dorsum, 1 ventral postanal melanophore, & melanophores on serial swellings of D & P_2
Diagnostic features: Size; embryo shape; pigment on yolk; low myomere count; precocious development of D & P_2

LARVAE

Hatching length: <3.7 mm
Flexion length: ca. 8.3–9.6 mm
Transformation length: Protracted & gradual, >67.5 mm
Fin development sequence: D & P_2, C, P_1
Pigmentation: *Preflexion*—By 3.7 mm, eye becoming pigmented, a few over brain, 3 dorsally, & 1 ventral postanal melanophore. *Flexion*—Increasing over forehead to snout; increasing on head to nape; 5 dorsal patches; 2 ventral patches; over P_2 girdle; dorsally on gas bladder & gut. *Postflexion-transformation*—Very fine over entire body surface; dorsal & ventral patches increase to 9–15 & 5–7, respectively; on C rays; on jaw; on cleithrum; increasing around anus. *Juvenile*—Ventral to cleithrum; postanal dorsal & ventral patches form bars; pelagic juvenile pigment persists to at least 321 mm.
Diagnostic features: Total myomeres 62–70; myomeres in preflexion larvae 24–32+36–42, in flexion stage 28–37+30–38, & in postflexion-transformation stage 32–37+29–35; low myomere count; short gut; notochord flexion begins at a small size; by 42.8 mm, deep & scalloped ventral profile anterior to anus; spinous lateral line scales; characteristic pigment pattern throughout all stages.

MORPHOMETRICS (rauge & mean in %)

	PrF	F	PoF-Tr	Juv
Sn-A/BL	47–59 51	47–60 56	55–62 59	45–50 47
BD/BL	19–30 24	26–33 28	20–29 25	23–26 25
HL/BL	18–22 20	20–25 24	23–24 24	15–20 18
HW/HL	33–53 43	35–47 38	38–50 43	32–38 34
SnL/HL	15–31 23	21–31 25	15–26 21	25–31 27
ED/HL	37–46 41	34–39 37	29–35 31	27–35 32
P_1L/BL	3–10 6	4–6 5	7–13 10	7–10 9
P_2L/BL	16–629 125	15–150 46	14–14 14	14–78 40
JD/BL	52–76 64	52–70 60	49–54 51	50–60 56

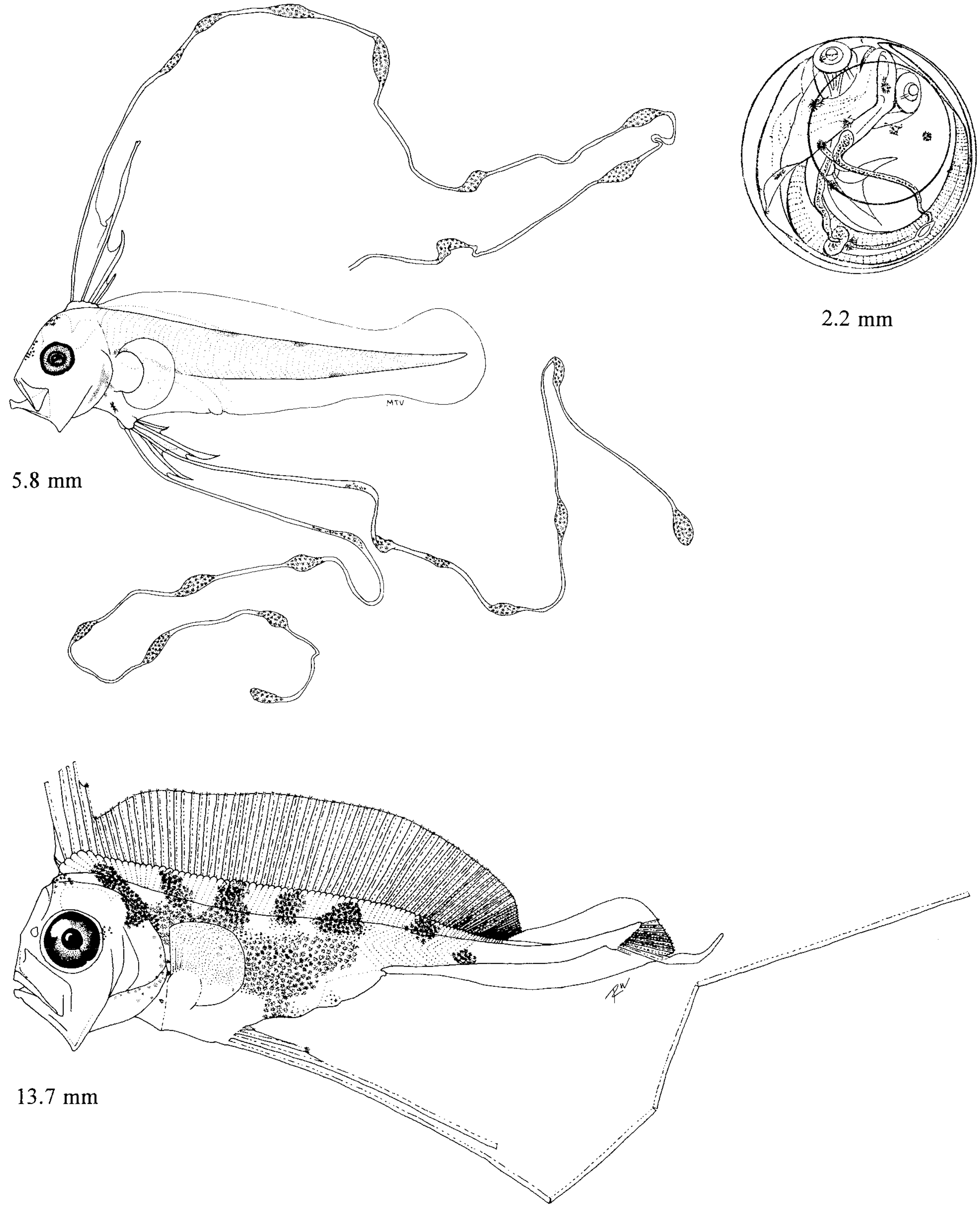


Figure Trachipteridae 4. Egg, 2.2 mm (from Sparta 1933 as *Trachipterus cristatus*); preflexion larva, 5.8 mm (CFRD Ref. Coll., R. Harbison, station 2061–15); flexion larva, 13.7 mm (CFRD Ref. Coll., R. Harbison, station 548–16).

BERYCIFORMES

W. WATSON

Beryciformes is a morphologically and ecologically diverse assemblage of fishes generally accepted as basal acanthomorphs; however, the composition of the order is uncertain and monophyly is questionable in traditional treatments of the group (e.g., Keene and Tighe 1984; Nelson 1984; Johnson and Patterson 1993; Moore 1993). Based primarily on examination of several skeletal features, Moore (1993) transferred most of the beryciforms to Trachichthyiformes, placing the berycoid families Diretmidae, Anoplogastridae, Anomalopidae, and Monocentridae in the Trachichthyoidei, and including the stephanoberycoids with the rondeletiids, barbourisiids, megalomycterids and cetomimids (and probably the mirapinnids) in the trachichthyiform suborder Stephanoberycoidei. In contrast, Johnson and Patterson (1993) argued that the berycoids (including Holocentridae, which Stiassny and Moore [1992] excluded from the Beryciformes on the basis of pelvic girdle morphology) and stephanoberycoids each are a monophyletic group that should be accorded ordinal status. Monophyly was proposed for the berycoids primarily on the basis of innervation of the last neuromast in the supraorbital sensory canal by the buccal nerve (Jakubowski 1974; Freihofer 1978); differences in several skeletal features were cited as the basis for separating the berycoids and stephanoberycoids and as additional evidence of berycoid monophyly. Stephanoberycoid monophyly was less clearly established in that it was based mainly on plesiomorphous (or perhaps reversed) character states, except that the enlarged extrascapulars and the pattern of frontal crests might represent an apomorphic condition. Nelson (1994) provisionally accepted Johnson and Patterson's (1993) arrangement. Here, in part because "beryciform" phylogeny remains unsettled, but primarily as a convenience, we follow Eschmeyer's (1990) more traditional scheme with the berycoids (including Holocentridae) and stephanoberycoids retained as beryciform suborders and the rondeletiids, barbourisiids and cetomimids placed in a separate order, Cetomimiformes (because none of these cetomimiform fishes has been collected during CalCOFI surveys, the order is not included in this guide). We differ from Eschmeyer's (1990) classification by including the mirapinnids in the stephanoberycoids rather than placing them in their own lampridiform suborder.

Little is known of beryciform reproduction and early life history, except that larvae are known for several species in both suborders. The larvae are morphologically diverse, ranging from very deep-bodied and robust with moderate preanal length to slender and elongate with long preanal length. Head spination, often very elaborate and/or with greatly enlarged spines, appears to be the norm among berycoids, while the stephanoberycoids more commonly have fewer, smaller spines or none at all. Larval pigmentation ranges from light to heavy in both suborders.

At least 18 species in five beryciform families occur in the California Current vicinity; larvae of nine or ten of these, representing three families, have been identified in CalCOFI ichthyoplankton samples.

Suborders and families included: Berycoidei
- Diretmidae
- Anoplogastridae
- Holocentridae

Stephanoberycoidei
- Melamphaidae
- Mirapinnidae

DIRETMIDAE: Spinyfins

W. Watson

The spinyfin family contains four species in three genera (Kotlyar 1988; 1990) of primarily tropical and subtropical fishes. None has been recorded from the California Current but *Diretmus argenteus* is known from the eastern tropical Pacific and might reach the southern end of the CalCOFI study area, although it seems unlikely that it would reproduce there. *Diretmichthys parini* has been recorded east of Hawaii (Kotlyar 1988) and might reach the southwestern margin of the California Current vicinity although again it seems unlikely that its reproductive range would extend so far.

Adult diretmids are small to medium-size (ca. 15–40 cm) meso- and bathypelagic residents of warm oceans. They are deep-bodied, strongly compressed, with a large head and large eyes. Small juveniles may be nearly circular in profile. The relatively long dorsal and anal fins each contain a single spine, and all elements in the dorsal and anal fins bear small spinules basally. Diretmids are dark brown to black, usually darkest dorsally. *Diretmus argenteus* is silvery on the flanks.

Spawning and eggs are unknown, but larvae have been described (Post 1976; Post and Quero 1981). Larvae are deep-bodied, compressed, with long preanal length, large head, large eyes, and a pair each of greatly enlarged parietal and preopercular spines, in addition to many smaller head spines. Fin rays begin to form in the pectoral, dorsal and anal fins before notochord flexion. Larval pigmentation, usually relatively light before transformation, occurs primarily on the dorsum, jaws and opercle, internally over the gut, and on the caudal peduncle and above the anal fin base during the postflexion stage. An anterior saddle often is present and a posterior saddle usually is present.

Larval diretmids superficially resemble larval *Anoplogaster*, with which they may co-occur, but are easily separated by their higher dorsal and anal fin ray counts (complements incomplete, but already higher than *Anoplogaster* during notochord flexion). In addition, the diretmids are more compressed, have a smaller eye, somewhat shorter preanal length, and usually are more lightly pigmented than larval *A. cornuta*. The saddle-like pigment pattern often visible on larval diretmids does not occur on larval *A. cornuta*. Larvae of the diretmid genera are distinguished by relative positions of the pelvic and pectoral fins: the pelvics are ahead of, or below, the pectoral insertion (usually ahead) in *Diretmoides* and *Diretmichthys*, and below or behind the pectoral insertion (usually behind) in *Diretmus*. The parietal spines typically are less steeply inclined toward the caudal and the preopercular spines are directed posteroventrally rather than anteroventrally in *Diretmus*, compared with *Diretmoides* and *Diretmichthys*. In postflexion *Diretmus* larvae larger than ca. 9–13 mm, the presence of the prepelvic abdominal keel and position of the anus immediately adjacent to the first anal fin ray (vs. keel absent and anus separated by a short distance from the anal fin base in *Diretmoides* and *Diretmichthys*) will facilitate identification. *Diretmoides* and *Diretmichthys* are distinguished primarily by pigmentation (e.g., Post and Quero 1981).

The following description is based on literature (Post 1976; Post and Quero 1981; Keene and Tighe 1984) and on detailed examination of 12 postflexion larvae (6.0–13.5 mm) and 5 juveniles (21.2–31.2 mm) of *D. argenteus*. Meristic and ecological data were obtained from Post (1976), Post and Quero (1981), and Kotlyar (1988). Additional counts were made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	27–29	28
Precaudal	11–14	13
Caudal	15–17	15
Fins:		
Dorsal spines	I	I
Dorsal rays	25–29	27
Anal spines	I	I
Anal rays	18–24	21–22
Pelvic	I,6	I,6
Pectoral	17–20	18–19
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	4	4
Gill rakers:		
Upper	5–9	7
Lower	10–14	11–12
Branchiostegals	7–8	

LIFE HISTORY

Range: Warm waters in all oceans, primarily tropical

Habitat: Young epi- & mesopelagic, primarily 50–250 m depth; adults meso- & bathypelagic, primarily 300–1000 m depth

Spawning season:

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

Baldwin & Johnson 1995
Keene & Tighe 1984
Post 1976
Post & Quero 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 6.2 mm (W. Watson)

* P_2 rays broken & incomplete in all specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4 mm
Flexion length: ca. 6 m
Transformation length: ca. 15–20 mm
Fin development sequence: D & A & P_1, P_2, C
Pigmentation: *Larvae*—Internally on midbrain, spreading onto fore- & hindbrain by 7 mm; externally on top of head after 12 mm; light on premaxillary, dentary, & preopercle, increasing with growth but remaining relatively light on jaws; saddle under last 11–12 D rays, often anterior saddle present between parietal spines & D origin, few dorsolateral melanophores to strong stripe between saddles in postflexion stage; bar across end of caudal peduncle by ca. 7 mm; few ventrolaterally to strong stripe above A base; few on A base; internally over upper third of gut, spreading ventrad; series along isthmus & ventral margin of gut. *Juvenile*—Becoming completely pigmented except on fins by ca. 30 mm, darkest dorsally, lightest ventrolaterally over gut area.
Diagnostic features: Parietal spines usually less inclined caudally than in *Diretmoides* & *Diretmichthys*; preopercular spine directed posteriorly rather than anteriorly as in *Diretmoides* & *Diretmichthys*; P_2 origin below or behind P_1 insertion (usually ahead in *Diretmoides* & *Diretmichthys*); keeled abdominal scutes form between ca. 9–13 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				61–79 70		62–73 69
BD/BL				57–71 63		71–82 74
HL/BL				34–50 41		38–42 40
HW/HL				36–81 55		39–59 51
SnL/HL				14–33 23		13–19 16
ED/HL				28–43 36		37–49 40
P_1L/BL				29–37 32		32–40 36
P_2L/BL				8–30 20		*
PaSL/HL				1–32 14		0–1 0.3
PrSL/HL				5–34 16		0–9 4

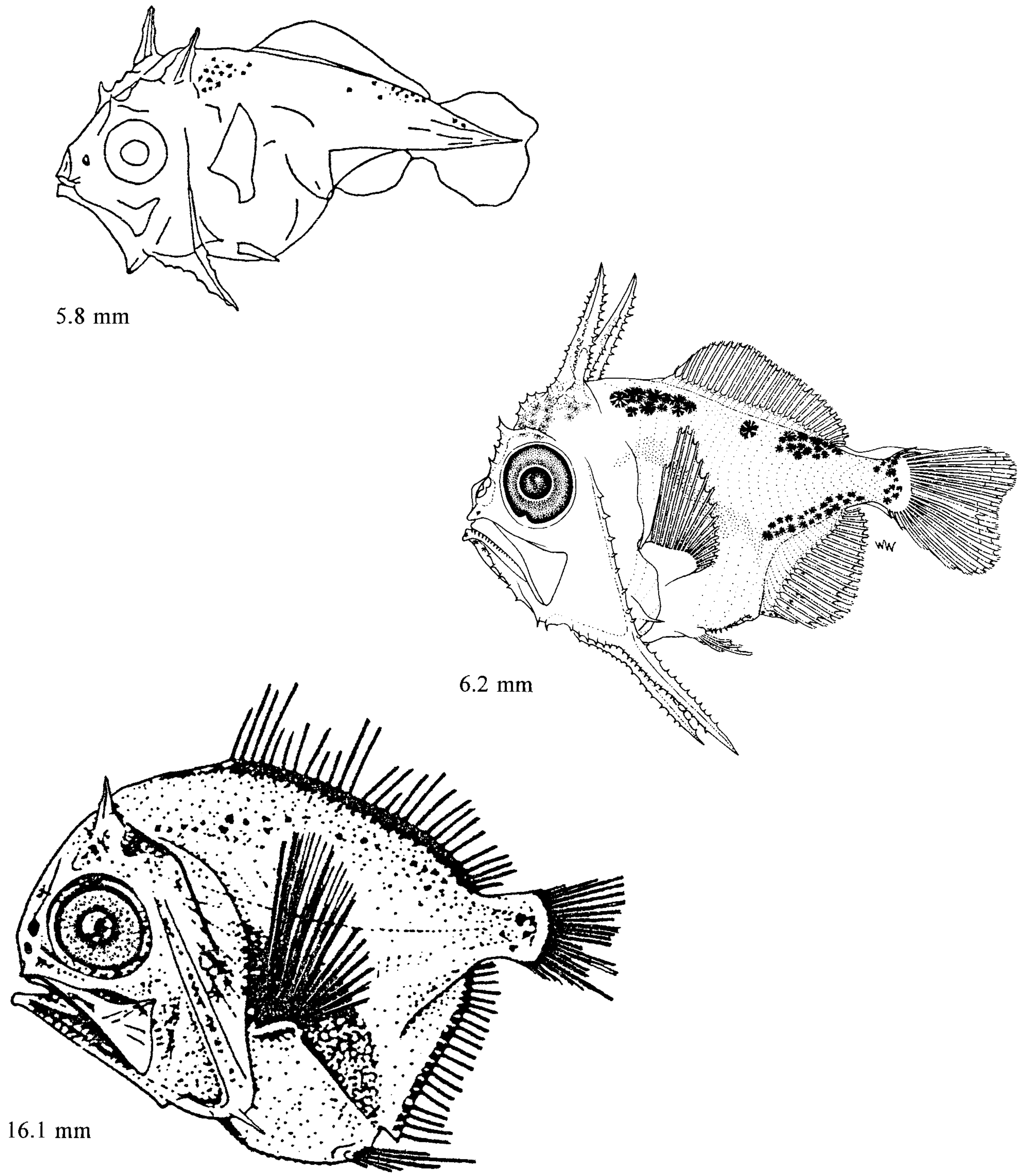


Figure Diretmidae 1. Preflexion larva, ca. 5.8 mm (Post 1976); postflexion larva, 6.2 mm (SIO 73–146); late postflexion larva, ca. 16.1 mm (Post and Quero 1981).

ANOPLOGASTRIDAE: Fangtooths

W. WATSON

Anoplogaster cornuta, one of the two species in the family Anoplogastridae, occurs worldwide in meso- and bathypelagic waters between about 46° N and 46° S (Woods and Sonoda 1973; Kotlyar 1986). Although fangtooths are present in the CalCOFI study area, their larvae have not been taken in CalCOFI ichthyoplankton samples.

Adult fangtooths are small (to ca. 15 cm) deep-water predators on crustaceans, cephalopods, and fishes. They are compressed, deep-bodied anteriorly with a tapering tail, have preanal length about two-thirds of body length, and have a large, sculptured head with small eyes and a large mouth armed with very long fang-like teeth. Juveniles (≤7–9 cm) have prominent parietal and preopercular spines. The juveniles are grey to brown, usually with one or more black patches on the ventrum, while adults are evenly dark brown to black.

Spawning and eggs are unknown, but planktonic larvae of *A. cornuta* 4 mm (late preflexion stage) and larger are well known (Keene and Tighe 1984; Okiyama and Hirano 1988; this study). Larvae are characterized by their long preanal length (usually 75–80% BL), deep body (usually 60–80% BL), and large head (usually 37–43% BL) with large eyes, large mouth, and a pair each of prominent parietal and preopercular spines. Although these spines are relatively small (ca. 9–12% BL) and simple in the smallest preflexion stage larvae, they become enormous (maximum 55–60% BL) and strongly serrate in flexion and postflexion stages. Fins develop early: in a 4 mm preflexion stage *A. cornuta* full complements of dorsal and anal rays are present, the pectoral fins are nearly complete, and caudal fin rays are forming. Notochord flexion usually is completed between 4.4–5.1 mm. By 6 mm full ray complements are present in all fins and scales are forming just anterior to the pelvic fin bases. Young larvae are moderately pigmented over the midbrain area and on the gill cover, trunk, and gut. Melanophores gradually proliferate in all these areas, spreading from the trunk onto the tail during the flexion or postflexion stage. The abdominal scale patch becomes intensely pigmented. Development is direct; there is no distinct transformation stage.

Larval *A. cornuta* superficially resemble larval diretmids but are easily distinguished by their early forming dorsal and anal fins (full ray complements present in preflexion stage vs. complements incomplete until postflexion stage) with low fin ray counts (D 17–20 vs. 26–29 and A 7–10 vs. 18–24). In addition, larval *A cornuta* are less compressed, have larger eyes, a somewhat longer preanal length, and are more heavily pigmented than larval diretmids (see Diretmidae).

The following description is based on detailed examination of 19 larvae (4.0–9.9 mm, preflexion through transformation stage) and five juveniles (10.8–17.8 mm). Meristic data were obtained from the literature (Woods and Sonoda 1973; Keene and Tighe 1984; Kotlyar 1986; Matarese et al. 1989) and from counts made during this study. Ecological information is from Fitch and Lavenberg (1968), Woods and Sonoda (1973), and Kotlyar (1986).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25–29	28
Precaudal	11–14	12
Caudal	14–17	16
Fins:		
Dorsal spines	0	0
Dorsal rays	17–20	18
Anal spines	0	0
Anal rays	7–10	8–9
Pelvic	I,6	I,6
Pectoral	13–16	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–7	7
Lower	5–9	7
Gill rakers:		
Upper	5–11	
Lower	7–13	
Branchiostegals	8–9	8

LIFE HISTORY

Range: Circumglobal between ca. 46° N & S; in eastern Pacific from Oregon to Chile

Habitat: Young epi-, meso-, & bathypelagic; adults meso- & bathypelagic

Spawning season: Summer

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

Baldwin & Johnson 1995
Keene and Tighe 1984
Matarese et al. 1989
Okiyama and Hirano 1988
Woods and Sonoda 1973

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.0 mm (W. Watson)
Flexion larva, 4.3 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 4.3–4.5 mm through 4.4–5.1 mm
Transformation length: ca. 5.5–6.5 mm through ca. 10 mm
Fin development sequence: D & A & P_1, C_1, P_2, C_2
Pigmentation: *Preflexion–postflexion*—Light to heavy over midbrain area, becoming consistently heavy by ca. 4.5 mm; none to few on forebrain, becoming light to moderate by 4.6 mm; on preopercle, spreading over most of gill cover by 5.2 mm; externally over trunk myomeres, spreading onto tail, primarily ventrolaterally, after 4.6 mm; internally over notochord anteriorly, spreading caudad to level of D insertion by 5.2 mm; heavy over upper half of gut, spreading ventrad to surround all but ventral midline by 5.2 mm; present or absent on P_1 base. *Transformation*—Increasing on head, gut, trunk & tail; black patch forms on ventrum just anterior to P_2 bases.
Diagnostic features: Prominent parietal & preopercular spines that become relatively enormous from flexion through transformation stages (ca. 4.5–10 mm); D usually 18 & A usually 8 (full complements present by 4 mm); long preanal length; large head; deep body.

MORPHOMETRICS (range & mean in %)

	YS	PrF	F	PoF	Tr	Juv
Sn-A/BL		77–80 79	65–78 73	75–82 79	73–81 75	70–82 78
BD/BL		55–60 57	60–75 67	65–90 73	73–87 78	69–76 72
HL/BL		37–43 40	37–47 43	36–56 43	39–47 43	32–39 36
HW/HL		74–78 77	83–90 87	83–104 93	88–106 96	81–107 91
SnL/HL		7–13 11	8–11 10	4–11 7	2–14 8	8–15 11
ED/HL		44–54 49	41–53 45	46–60 53	45–60 53	40–57 48
P_1L/BL		24–32 28	31–40 36	37–51 42	38–49 42	36–41 39
P_2L/BL		0–0 0	0–3 1	1–7 4	4–15 11	14–22 18
PaSL/BL		9–13 11	21–35 25	23–60 36	31–60 45	20–41 29
PrSL/BL		10–12 11	14–37 26	20–55 31	31–55 43	21–40 32

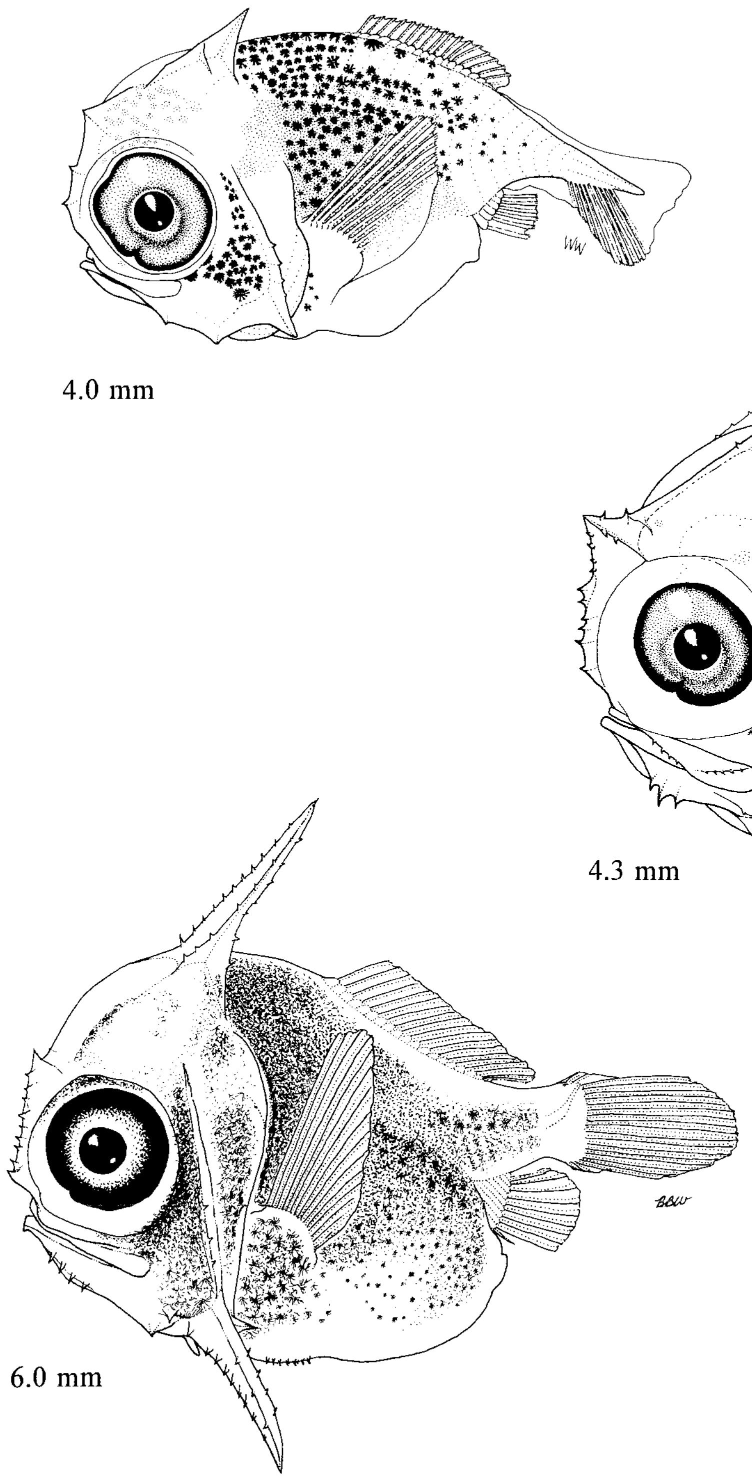


Figure Anoplogastridae 1. Late preflexion larva, 4.0 mm (SIO 73–146); flexion larva, 4.3 mm (CFRD Ref. Coll., TC 47, station 58); postflexion larva, 6.0 mm (Keene and Tighe 1984; although pelvic fins are not shown in this illustration, they normally form between 4 and 5 mm and are complete or nearly complete by 6 mm).

HOLOCENTRIDAE: Squirrelfishes

W. WATSON

Holocentridae contains about 65 species in eight genera, usually separated into two subfamilies, Holocentrinae and Myripristinae. One holocentrine and two or three myripristine species occur in the California Current vicinity (Allen and Robertson 1994; Schneider and Krupp 1995a) but only two species, the myripristine *Myripristis leiognathos* and the holocentrine *Sargocentron suborbitalis* occur in the CalCOFI study area. The distributions of both species are primarily tropical and subtropical; *M. leiognathos* ranges northward as far as Bahía Magdalena and the northern Gulf of California, while *S. suborbitalis* ranges to the Cabo San Lucas area and the central Gulf, but has not been reported from the west coast of Baja California. Larval *M. leiognathos* have been collected off southern Baja California Sur during CalCOFI surveys and larval *S. suborbitalis* have been collected during other surveys along the Pacific coast of mainland Mexico and Central America.

Squirrelfishes are small to medium-size (ca. 10–60 cm, depending on species) nocturnally active residents of coastal reefs (intertidal zone to ca. 400 m depth, most commonly ≤100 m). They typically are compressed, moderately deep-bodied, with large eyes, large ctenoid scales, a continuous dorsal fin deeply notched between the spinous and ray portions, and four anal fin spines. They range in color from silvery to bright red.

Neither spawning nor eggs have been described for squirrelfishes. Larval size and developmental state at hatching are unknown; McKenny (1959) described a 1.8 mm larva of *Holocentrus vexillarius* with a small yolk sac, an open mouth, pigmented eyes, long preopercular spines, and developing supraoccipital crest and spines. Squirrelfish larvae are moderately deep-bodied and compressed, with preanal length increasing from about 50% (preflexion stage) to about 67% (postflexion stage) of body length. The head and eyes are large and the gut is coiled. Pelvic fins develop early in *Myripristis*. The most striking features of larval holocentrids are the large, ridged and serrate spines on the rostrum, preopercle, opercle, and supraoccipital crest. These spines reach their maximum relative lengths during, or just after, notochord flexion. Additional small spines may develop on the frontals, supracleithra, and posttemporals; oblique serrate ridges form on the frontals and on the pterotics and parietals in some species. Larval pigmentation initially is rather light, with melanophores dorsally on the gas bladder and gut, usually a few dorsally on the head, and few to none on the dorsal and/or ventral margins of the tail, on the rostrum, and on the pelvic fins. Pigmentation increases rapidly, first primarily on the head and gut through notochord flexion, then spreading caudad to cover all but the caudal peduncle and the pectoral, anal, soft dorsal, and caudal fins (and the pelvic fins in some species) during the postflexion stage. Holocentrids pass through a pelagic juvenile "rhynchichthys" stage, characterized by the presence of the large rostral, preopercular, opercular, and supraoccipital spines. Rhynchichthys stage *M. leiognathos* and *S. suborbitalis* are bright silver in life.

Among the larval fishes in the CalCOFI study area, only priacanthids superficially resemble the holocentrids. Larval priacanthids lack the rostrum, have no vertical spines on the supraoccipital crest (1 or 2 in the holocentrids), and have 23–24 (usually 23) myomeres versus 25–27 (usually 26) in the holocentrids. The two squirrelfish species are easily distinguished by the rostral spine, which is bifurcate in *M. leiognathos* (and in the other larval *Myripristis* described to date, e.g., Jones and Kumaran 1964; Leis and Rennis 1983) but single in *S. suborbitalis* (and in the other larval Holocentrinae described to date, e.g., Jones and Kumaran 1964; Leis and Rennis 1983; McKenny 1959). *M. leiognathos* has pigmented pelvic fins that develop rays early in the preflexion stage, while *S. suborbitalis* has unpigmented pelvic fins that develop rays after the preflexion stage. *M. leiognathos* has rostral pigment (rarely absent), while *S. suborbitalis* does not. *M. leiognathos* has 11–13 anal fin rays, while *S. suborbitalis* has 8–9 (present in the postflexion stage; the first ray becomes the fourth spine after ca. 14 mm).

The following descriptions are based on detailed examinations of 29 *M. leiognathos* and 30 *S. suborbitalis* (Table Holocentridae 1). Meristic data were obtained from Greenfield (1965, 1974), Clothier and Baxter (unpublished manuscript), and counts made during this study. Ecological information was obtained from Greenfield (1965), Thompson et al. (1979), Allen and Robertson (1994), and Schneider and Krupp (1995a).

Table Holocentridae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the holocentrid species descriptions.

Species	Preflexion	Flexion	Postflexion	Rhynchichthys
Myripristis leiognathos	12 2.6–3.8	4 3.6–4.3	3 4.3–5.9	10 8.2–27.6
Sargocentron suborbitalis	15 1.6–4.4	1 4.8	4 5.6–6.2	10 8.1–34.8

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XI	XI
Dorsal rays	12–15	14
Anal spines	IV	IV
Anal rays	11–13	12
Pelvic	I,7	I,7
Pectoral	14–16	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–6	5
Lower	4–5	4
Gill rakers:		
Upper	8–10	9–10
Lower	19–24	21–22
Branchiostegals	8	8

LIFE HISTORY

Range: Eastern Pacific, from Bahía Magdalena & Gulf of California to Ecuador, including Islas de Revillagigedo, Isla Cocos, & the Galápagos Islands

Habitat: Shallow (ca. 1–15 m depth) coastal waters; usually aggregate in caves & crevices in reefs during the day, disperse to feed in open waters at night

Spawning season: Larvae collected February–September

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.0 mm (M. T. Vona)
Flexion larva, 4.3 mm (M. T. Vona)
Postflexion larva, 4.3 mm, lateral & dorsal views (M. T. Vona)
Postflexion larva, 5.9 mm (M. T. Vona)

* BL, Sn-A, HL, & SnL all exclude the rostrum, i.e., measurements are from the anterior margin of the upper jaw.
† Rhynchichthys stage.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.6 mm
Flexion length: 3.6–3.8 mm through 4.3 mm
Transformation length: ca. 8–28 mm
Fin development sequence: P_2, C_1, 1D, 2D & A, C_2, P_1
Pigmentation: *Preflexion–postflexion*—Few over mid- & hindbrain, mainly along cranial ridges, increases gradually; internally on hindbrain, spreading onto spinal cord by ca. 3.3 mm; on rostrum at spine base; present or absent near tip of lower jaw; under upper part of opercle by 3.1 mm & lower part of preopercle by 3.6 mm; dorsolaterally on myomeres 1–3 by 3.2 mm, gradually spreading ventrad & caudad; on DI–III by 4.3 mm, spreading to DVII by 5.9 mm; dorsally on gut & gas bladder, spreading ventrad to surround gut by 3.6 mm; on distal 20–50% of P_2. *Rhynchichthys*—Heavily pigmented except little or none on snout, rostrum, jaws, caudal peduncle, fins (P_1, 2D, A, C); sides bright silver in life.
Diagnostic features: Moderate-size rostrum with terminal bifurcate spine; precocious development of P_2 (<2.6 mm, preflexion stage) & scales (ca. 4.3 mm, beginning of postflexion stage); A rays 11–13 (present by postflexion stage; ray 1 becomes spine IV at ca. 14 mm); myomeres 9–11+15–17=25–26 (usually 11+15); pigment on rostrum & P_2, none on tail through flexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr†	Juv
Sn-A/BL		49–61 55	55–59 57	63–67 65	63–68 66	
BD/BL		31–40 36	34–38 36	39–44 41	31–43 37	
HL/BL		33–41 37	34–42 37	39–45 42	34–39 36	
HW/HL		56–69 64	59–71 66	63–68 65	56–70 64	
SnL/HL		24–32 28	19–29 24	23–25 24	13–25 20	
ED/HL		37–44 41	38–47 42	42–45 44	37–46 42	
P_1L/BL		8–11 10	9–11 10	10–11 11	10–18 16	
P_2L/BL		16–21 19	19–21 20	19–21 20	16–20 18	
RL/HL		19–56 34	39–50 46	41–55 47	7–37 20	

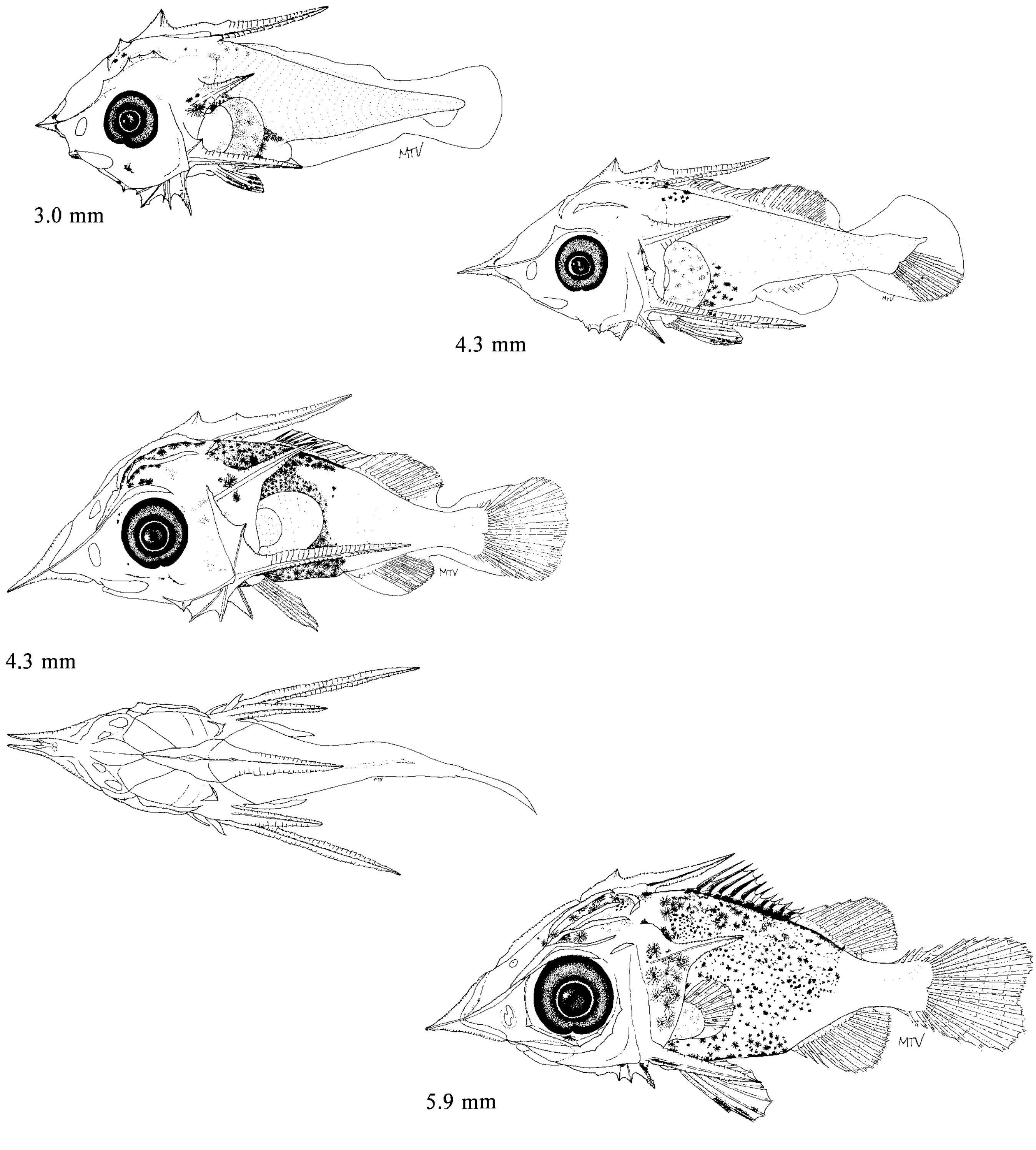


Figure Holocentridae 1. Preflexion larva, 3.0 mm (CalCOFI 5209, station 144.5G.26); flexion larva, 4.3 mm (TO 59–1, station 33); early postflexion larva, 4.3 mm, lateral and dorsal views, scales on trunk are not shown, pigment is not shown on dorsal view (IATTC Mazatlán Project, station 1–13–5); late postflexion larva, 5.9 mm, scales covering most of body are not shown (IATTC Mazatlán Project, station 1–13–5).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27	27
Precaudal	11	11
Caudal	16	16
Fins:		
Dorsal spines	XI	XI
Dorsal rays	13–14	13
Anal spines	IV	IV
Anal rays	8–9	8–9
Pelvic	I,7	I,7
Pectoral	15	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	5–6	6
Lower	4–6	5
Gill rakers:		
Upper	6	6
Lower	12	12
Branchiostegals	8	8

LIFE HISTORY

Range: Gulf of California to Ecuador including offshore islands

Habitat: Rocky intertidal & shallow coastal zone; shelters in rocky caves & crevices during the day, disperses to forage near bottom at night

Spawning season: Larvae collected in spring & summer

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.2 mm, 4.2 mm (M. T. Vona)
Postflexion larva, 5.8 mm, lateral & dorsal views (M. T. Vona)

* BL, Sn-A, HL, & SnL all exclude the rostrum, i.e., measurements are from the anterior margin of the upper jaw.
† Rhynchichthys stage.
‡ Rostrum intact in only one specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <1.6 mm
Flexion length: ca. 4.5–5 mm
Transformation length: ca. 8–35 mm
Fin development sequence: C_1, D & A & P_2, P_1, C_2
Pigmentation: *Preflexion–postflexion*—Few over midbrain beginning at ca. 2.4 mm, mainly along cranial ridges, increases gradually; internally over (after ca. 2.4 mm) & under hindbrain, extending dorsally over spinal cord anteriorly; internally above, below & along vertebral column in postflexion stage; under opercle in postflexion stage; externally on trunk in postflexion stage, spreading caudad to level of DVII or VIII by end of stage; gut completely pigmented except end of hindgut; few posteriorly on ventral margin & above & below notochord tip, decreasing to 0–3 by ca. 6 mm. *Rhynchichthys*—Completely pigmented except none on snout, rostrum, jaws, end of caudal peduncle, P_1 & P_2 (except bases), A, 2nd D, C; sides bright silver in life.
Diagnostic features: Large rostrum with long single terminal spine after ca. 2 mm; very long spines at angle of preopercle & on supraoccipital crest after 1.8–2.2 mm; A rays 8–9 (present by postflexion stage; ray 1 becomes spine IV by ca. 14 mm); preanal myomeres 7–8 (preflexion stage) or 14 (postflexion stage), 26 total; pigment on last half of tail at least through preflexion stage; rostrum & P_2 unpigmented.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr†	Juv
Sn-A/BL		41–56 48	 52	60–70 66	66–68 67	
BD/BL		25–38 30	 33	37–39 38	36–39 38	
HL/BL		24–39 30	 33	39–44 41	33–40 36	
HW/HL		55–83 71	 72	63–73 68	62–73 66	
SnL/HL		15–35 26	 23	19–22 21	15–20 18	
ED/HL		36–57 45	 52	42–50 46	37–49 44	
P_1L/BL		7–12 9	 10	14–15 15	17–18 18	
P_2L/BL		0–4 1	 4	11–16 13	17–20 18	
RL/HL		0–177 100	 135	 129‡	6–78 43	

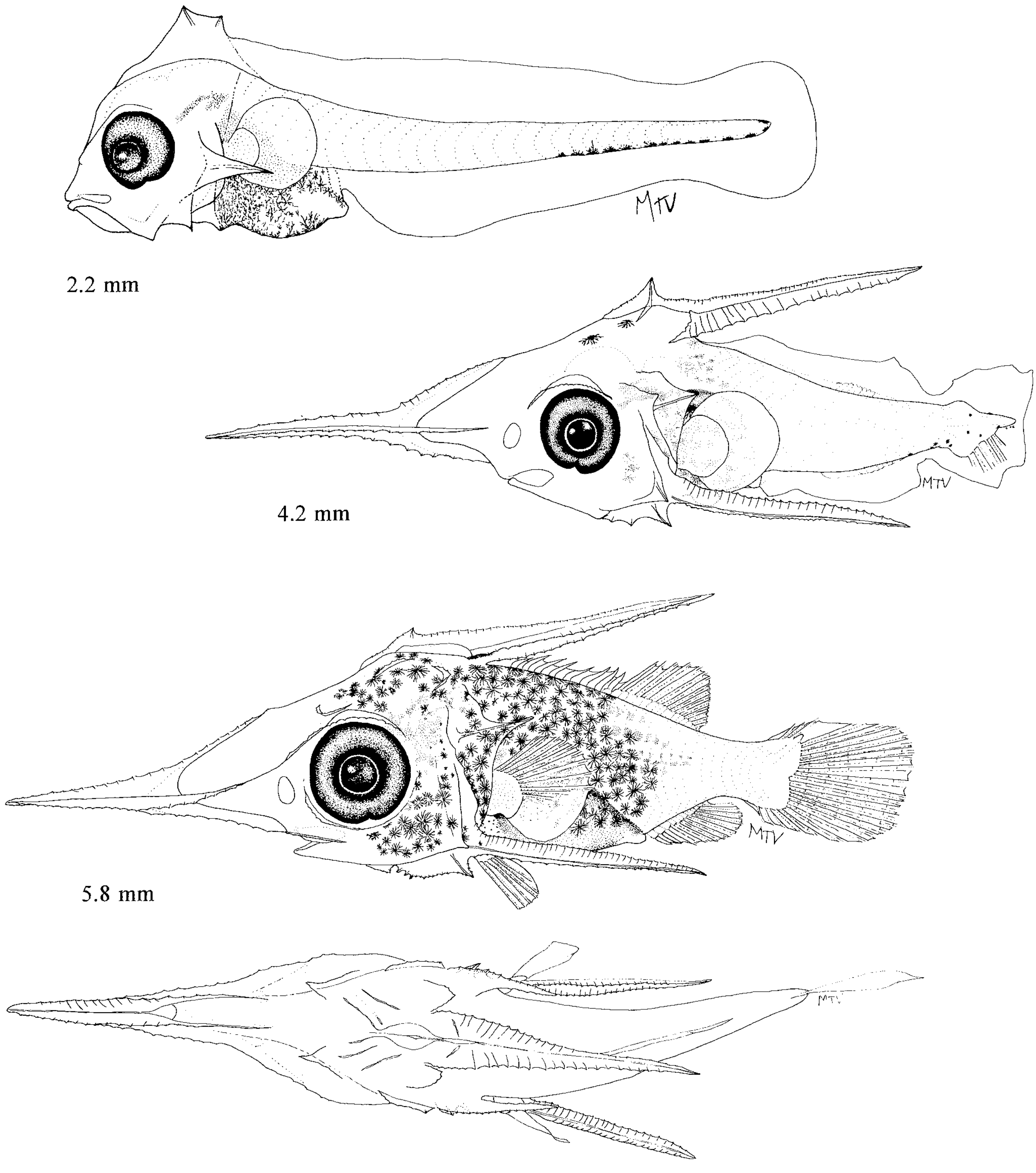


Figure Holocentridae 2. Preflexion larvae, 2.2 mm (IATTC 89022, station PSL1 Red), 4.2 mm (TO 58–1, station 71); postflexion larva, 5.8 mm, lateral and dorsal views, scales on trunk are not shown, pigment is not shown on dorsal view (CFRD Ref. Coll., IATTC Survey 67–2, station N18).

MELAMPHAIDAE: Bigscales

E. M. SANDKNOP AND W. WATSON

At least 15 of the approximately 34 melamphaid species, representing four of the five genera, occur in the California Current vicinity (Table Melamphaidae 1). *Melamphaes parvus* is endemic to the California Current, *M. acanthomus* ranges from about 6° N to 33° N (west to ca. 80–120° W) and *M. macrocephalus* and *M. spinifer* range from about 15° S to 27° N (west to ca. 130° W) in the eastern Pacific, while *M. lugubris* ranges across much of the North Pacific (ca. 32–56° N). *Melamphaes longivelis* and *M. suborbitalis* are widely distributed in the Atlantic and Pacific oceans and have been recorded in the CalCOFI study area off southern and central California, respectively (Berry and Perkins 1966), while *M. simus* is widely distributed in the Atlantic, Indian and Pacific Oceans, reaching the California Current vicinity off the southern Baja California peninsula (Ebeling 1962). *Melamphaes indicus* is a tropical Indo-Pacific and eastern Pacific species that has been recorded off southern California at CalCOFI station 90.160 (Berry and Perkins 1966) and *M. laeviceps* is primarily an eastern tropical Pacific species that has been recorded far offshore from northern Baja California to central California (Berry and Perkins 1966). *Scopelogadus bispinosus* ranges throughout much of the eastern Pacific (ca. 20° S – 40° N) and the tropical central Pacific (Ebeling and Weed 1963). *Poromitra oscitans* ranges from about 10° S to 33° N in the eastern Pacific and across the tropical Indo-Pacific (Ebeling 1975). *Poromitra megalops* is circumtropical and *P. crassiceps* and *Scopeloberyx robustus* are nearly cosmopolitan (Ebeling and Weed 1973).

Larvae of nine melamphaid species have been identified in CalCOFI ichthyoplankton collections, primarily from the more offshore stations during spring and summer cruises. Larval *Melamphaes lugubris, M. parvus, M. simus, Scopelogadus bispinosus*, and an unidentified *Melamphaes* species are relatively common. The unidentified *Melamphaes* larvae have meristic characters consistent with *M. indicus, M. laeviceps* and *M. macrocephalus* but are quite different from the larval *M. indicus* and larval or transformation *M. macrocephalus* shown by Ebeling (1962). We suspect the unidentified larvae are *M. laeviceps* but lack the late larval and transformation specimens that would link the larval series with identifiable adults. Larvae of a *Poromitra* species occasionally collected at offshore southern CalCOFI stations closely resemble larval *P. capito* described by Ebeling and Weed (1973); however, *P. capito* is endemic to the north Atlantic Ocean (Parin and Borodulina 1989). Parin and Borodulina (1989) described a *capito*-like *Poromitra* species, *P. gibbsi*, from the southeastern Pacific; the CalCOFI specimens might be this species although they differ somewhat in pigmentation and have smaller preopercular spines than the larval *P. gibbsi* described (as *Poromitra* sp.) by Belyanina (1987).

Adult melamphaids are small (ca. 3–15 cm) meso- and bathypelagic residents of tropical and temperate seas. They are slightly to moderately compressed, moderately deep-bodied to moderately elongate, with large heads typically ornamented with ridges and/or spines covered with a thin skin. Preanal length is about half of body length. The thin, deciduous, cycloid scales are large (especially in *Scopelogadus*), hence the common name. Melamphaids typically are brown or black.

Eggs and yolk-sac larvae are poorly known, but later larval stages are well known for several species (e.g., Keene and Tighe 1984). *Melamphaes lugubris* spawns spherical planktonic eggs that are ca. 0.8–1.0 mm in diameter with a segmented yolk and one to several oil globules (Matarese et al. 1989). Recently hatched *S. bispinosus* are just under 2 mm long with unpigmented eyes, a partially formed mouth, and moderate yolk sac containing a homogeneous yolk without an oil globule. Preanal length ranges from about 30–50% BL in early melamphaid larvae to about 50–60% BL in late larvae. Larvae typically are moderately slender during the preflexion stage but commonly become moderately deep-bodied by, or during, the postflexion stage. The head is moderately large. Spines and/or spiny ridges form on the head and pectoral girdle during the flexion or postflexion stage; these range from one or two weak opercular spines in *Melamphaes* to numerous large spines on the nasal, frontal, pterotic, preopercular, opercular, cleithral, supracleithral, and posttemporal bones in *Poromitra*.

Pelvic fin rays form before the segmented dorsal and anal fin rays in most species. Larval pigmentation is light initially; melanophores are located primarily dorsally on the gut and species- or genus-specific patterns occur on the trunk, tail, and fins. Pigmentation increases during development; late larvae are barred, spotted, pigmented primarily on the dorsum, or are nearly completely pigmented, depending on species.

Larval melamphaids are recognized by a combination of characters including 25–31 myomeres (commonly 26–28); large head, often with large eyes; precocious development of pelvic fins; and distinctive pigment patterns. Although larvae of the genera and many of the species can be identified on the basis of morphometric (primarily preanal length and body depth), morphological (primarily spination of the head and pectoral girdle), meristic (primarily myomere and dorsal fin ray counts), and pigment characters, some of the *Melamphaes* species are difficult to distinguish from one another. Damaged or small larvae often cannot be unequivocally identified to species.

The following descriptions are based on detailed examinations of 18–37 specimens of each species (Table Melamphaidae 1). *Poromitra oscitans* is not described separately but is shown in Figure Melamphaidae 1, as is an example of the unidentified *Poromitra* sp. (possibly *P. gibbsi*) larvae. Meristic data were obtained from Ebeling (1962, 1975), Ebeling and Weed (1963, 1973), Parin and Ebeling (1980), and counts made during this study. Ecological information was obtained from the same literature sources and Clarke and Wagner (1976).

Table Melamphaidae 1. Meristic characters for the melamphaid species in the California Current vicinity. All have 10+9 principal caudal fin rays (9–10+8–9 in *Melamphaes simus*) and 8 branchiostegal rays.

Species	Vertebrae			Fin rays					Gill rakers
	PrCV	CV	Total	D	A	P_1	P_2	C_2	
Melamphaes acanthomus	11	15–16	26–28	III,14–16	I,7–9	14–16	I,7	3–5+4–5	6–7+15–17
M. indicus	12–13	13–15	26–27	III,14–15	I,8	15	I,7	4+4	3–4+11–13
M. laeviceps	11	16–17	27–28	III,16–18	I,8–10	15–16	I,7	4+4	4–5+13–15
M. longivelis	11–13	16–18	28–30	III,15–18	I,8–9	15	I,7	4+4	4–5+13–15
M. lugubris	11–12	16–19	28–31	III,14–16	I,7–9	15–17	I,7	3–5+4–5	5–6+15–18
M. macrocephalus	11	15–16	26–28	III,13–16	I,8–9	14–15	I,7	4+4–5	5–7+14–16
M. parvus	11–12	16–17	27–29	III,13–15	I,7–9	14–15	I,7	3–5+3–4	4–5+13–15
M. simus	11–13	16–18	28–30	III,15–17	I,8–10	14–16	I,7	3–5+4–5	3–4+12–15
M. spinifer	11–12	14–17	26–29	III,14–16	I,7–9	14–15	I,7	4+3–5	3–5+13–14
M. suborbitalis	11	17–18	28–29	III,15–16	I,7–8	15–16	I,7	4+4	5–7+15–17
Poromitra crassiceps	10	16–19	26–29	III,11–14	I,8–11	13–15	I,7–8	4+4	8–12+18–24
P. megalops	9–11	18–19	26–30	II–III,10–12	I,8–10	13–15	I,7	4+4	6–8+15–20
P. oscitans	9–10	15–16	24–26	III,9–11	I,8	13–14	I,7	4+3–4	6–7+16–18
Scopeloberyx robustus	10–11	14–16	23–27	II–III,10–13	I,7–9	12–14	I,7–8	3–5+3–5	5–7+15–19
Scopelogadus bispinosus	10–11	14–17	24–27	II,10–12	I,7–9	14–15	I,7–8	4+3–4	6–9+15–18

Table Melamphaidae 2. Number of specimens (above) and their size ranges (in mm, below) used in the preparation of the melamphaid species descriptions.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Melamphaes lugubris	3 2.4–3.1	9 2.9–5.2	6 5.3–7.3	10 7.4–15.0	5 15.2–22.5	4 25.0–41.5
M. parvus	0	3 4.5–5.5	4 6.1–7.3	9 7.3–13.5	2 17.2–19.7	5 18.5–41.2
M. simus	0	4 3.2–5.1	5 5.8–7.3	6 7.8–10.8	2 12.2–12.7	4 13.8–21.5
Melamphaes sp.	0	7 3.0–5.4	4 7.1–7.9	4 9.0–13.2	0	3 17.2–25.0
Poromitra crassiceps	1 3.0	8 3.3–7.3	6 7.2–10.7	6 9.9–14.2	4 18.3–21.6	4 21.2–30.7
P. megalops	1 2.4	6 3.7–4.5	5 5.2–6.8	5 6.4–11.5	0	5 14.0–25.9
Scopeloberyx robustus	0	8 2.2–3.4	6 3.3–4.1	10 4.1–10.2	4 10.7–14.3	2 12.6–13.8
Scopelogadus bispinosus	3 1.8–2.5	9 2.5–4.4	6 4.2–4.9	9 5.3–8.8	3 13.2–13.5	3 14.3–29.2

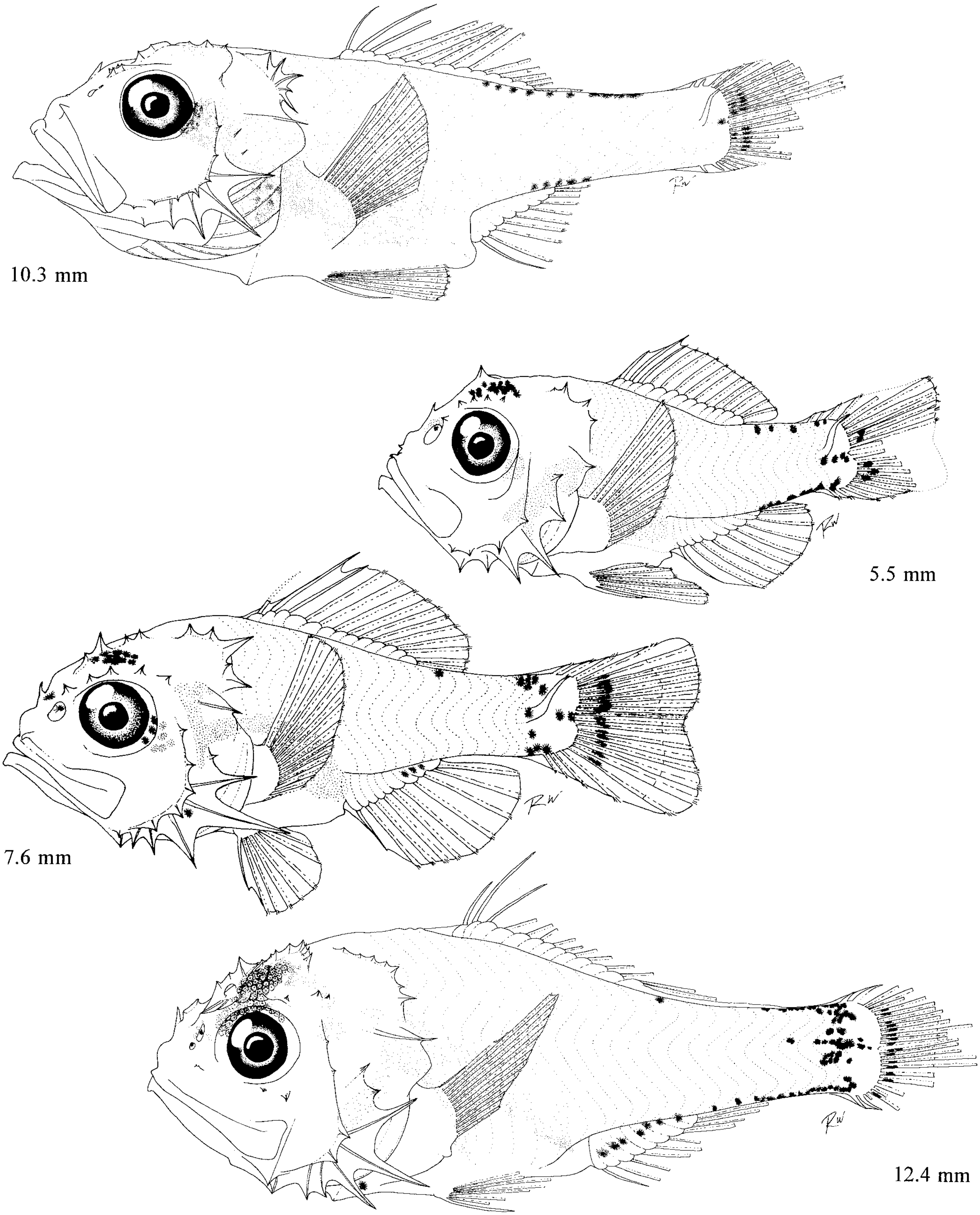


Figure Melamphaidae 1. *Poromitra* sp. (possibly *P. gibbsi*), postflexion larva, 10.3 mm (CalCOFI 7205, station 24.137); *Poromitra oscitans*, postflexion larvae, 5.5 mm, 7.6 mm, 12.4 mm (SIO 73–146). Original illustrations by R. C. Walker.

MERISTICS

	Range	Mode
Vertebrae:		
Total	28–31	29–30
Precaudal	11–12	12
Caudal	16–19	17–18
Fins:		
Dorsal spines	III	III
Dorsal rays	14–16	15
Anal spines	I	I
Anal rays	7–9	8
Pelvic	I,7	I,7
Pectoral	15–17	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	3–5	4
Lower	4–5	4
Gill rakers:		
Upper	5–6	5–6
Lower	15–18	16–17
Branchiostegals	8	8

LIFE HISTORY

Range: North Pacific from Bering Sea to central Baja California

Habitat: Epi- and mesopelagic; 50–1200 m depth, primarily in 200–500 m depth range

Spawning season: Larval *Melamphaes* spp. collected throughout the year with March–June maximum & October–December minimum in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Baldwin and Johnson 1995
Ebeling 1962
Keene & Tighe 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.90 mm (R. C. Walker)
Yolk-sac larva, 2.7 mm (R. C. Walker)
Preflexion larva, 4.8 mm (R. C. Walker)
Transformation specimen, 18.2 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.81–0.96 mm **Yolk:** Segmented
No. of OG: 1–several **Diam. of OG:**
Shell surface: Smooth
Pigment: Late embryo with melanophores on snout, on dorsal margin near midtail, & ventral margin near end of tail; few scattered on yolk near head
Diagnostic features: Embryonic pigmentation

LARVAE

Hatching length: <2.4 mm
Flexion length: 5.3–7.3 mm
Transformation length: ca. 15.2 mm – ca. 22.5 mm
Fin development seqnence: P_2, D, C_1, P_1, A, C_2
Pigmentation: *Yolk-sac–preflexion*—On dorsal margin at myomeres 12–13 through 15–19 & on ventral margin at myomeres 13 through 16–17 (16–18 through 19–22 by 5 mm); on yolk; dorsally on gut; distally on P_2, often absent after 4 mm; under hindbrain at 4 mm, spreading onto dorsum by 4.5 mm; posteriorly over midbrain at 4.5 mm. *Flexion–postflexion*—Increasing over brain; row on each side of D base; extending onto caudal peduncle after 7 mm; double row along ventral margin after 7 mm; between hypurals 2–3 by 5.7 mm; bar over hypural area by 9–11 mm, spreading forward as dorso- & ventrolateral stripes by ca. 15 mm; increasing on gut; usually distally on P_2 after 6 mm, covering fin after ca. 16 mm; internally over notochord in postflexion stage (difficult to see). *Transformation*—Completely pigmented except little or none on P_1 & C rays; gut darkest.
Diagnostic features: Myomeres 28–30 (usually 30; 9+21 in preflexion stage, 13+17 in postflexion stage); P_1=15–17 (usually 16, complete in postflexion stage); eye slightly smaller compared with *M. parvus*; P_2 pigment (when present) usually on distal half of fin before ca. 16 mm; pigment always present on dorsal & ventral margins.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	37–42 39	38–50 44	50–58 55	55–64 59	58–64 62	64–65 65
BD/BL	12–18 16	12–23 17	15–24 21	22–27 24	24–27 25	26–28 27
HL/BL	19–23 22	21–28 24	29–35 32	29–35 32	30–36 33	35–37 35
HW/HL	53–59 58	34–59 45	34–45 39	34–45 38	40–48 43	47–54 51
SnL/HL	11–18 16	14–39 19	27–33 32	29–38 31	27–30 28	19–24 22
ED/HL	41–48 44	29–40 36	25–31 28	22–30 25	20–25 23	16–20 18
P_1L/BL	4–7 5	3–7 5	8–13 10	11–19 14	17–29 23	28–31 29
P_2L/BL	0–1 1	3–21 9	11–29 19	10–26 19	21–42 27	19–22 20

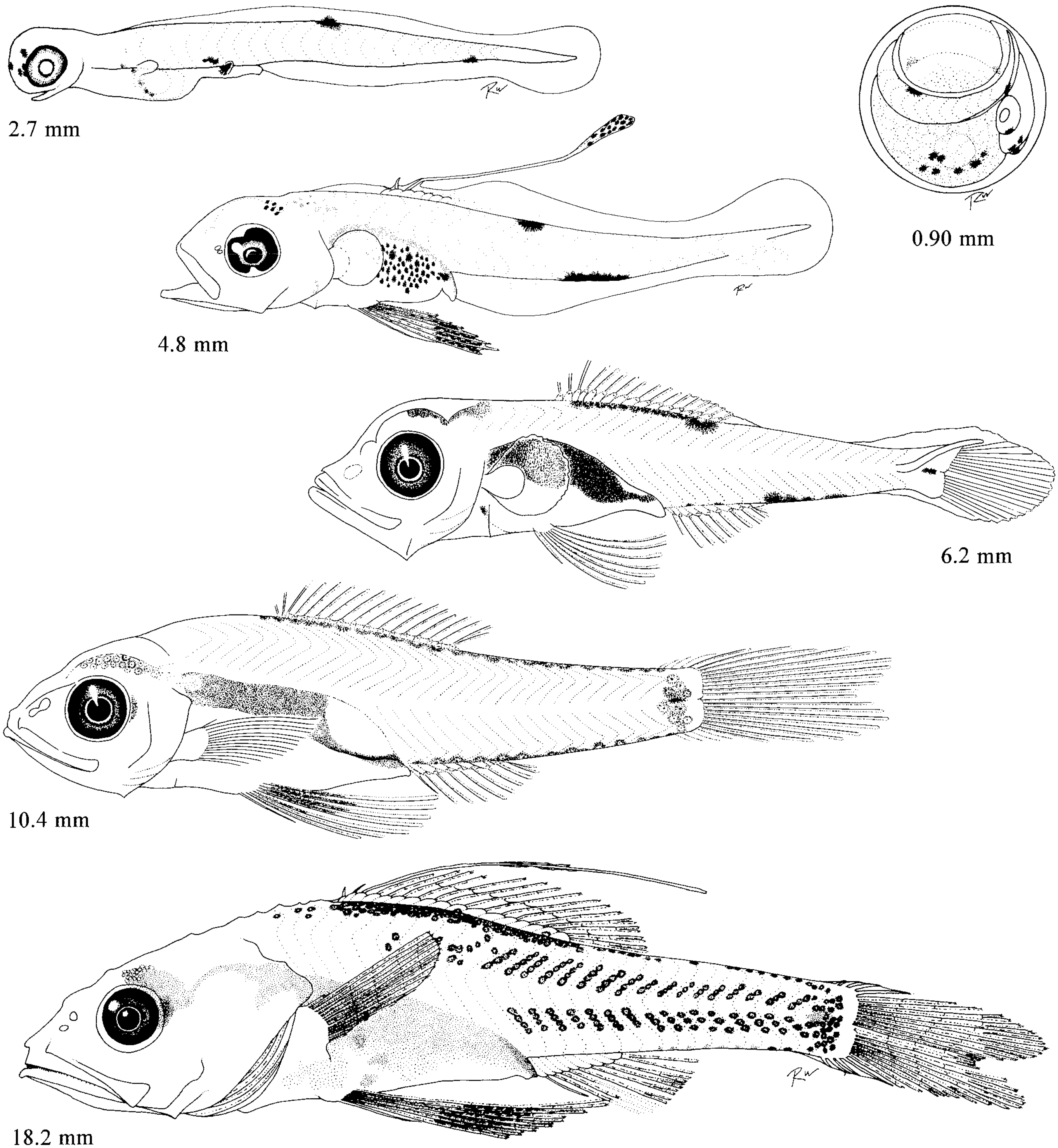


Figure Melamphaidae 2. Egg, 0.90 mm (CalCOFI 8105, station 96.7.100); yolk-sac larva, 2.7 mm (CalCOFI 7205, station 31.131); preflexion larva, 4.8 mm (CalCOFI 7505, station 110.70); flexion larva, 6.2 mm; postflexion larva, 10.4 mm (Keene and Tighe 1984; P_1 rays typically begin to form between ca. 5.0–5.5 mm although none is shown on the 6.2 mm specimen, and P_2 pigmentation typically is denser on the distal half of the fin after ca. 6 mm although it is shown only on the proximal half of the fin in the 10.4 mm specimen); transformation specimen, 18.2 mm (CalCOFI 6407, station 90.70).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27–29	28
Precaudal	11–12	12
Caudal	16–17	16
Fins:		
Dorsal spines	III	III
Dorsal rays	13–15	14–15
Anal spines	I	I
Anal rays	7–9	8
Pelvic	I,7	I,7
Pectoral	14–15	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	3–5	4
Lower	3–4	3–4
Gill rakers:		
Upper	4–5	4
Lower	13–15	14–15
Branchiostegals	8	8

LIFE HISTORY

Range: California Current, primarily between 25° & 42° N

Habitat: Mesopelagic, primarily below 200 m depth

Spawning season: Larval *Melamphaes* spp. collected throughout the year with March–June maximum & October–December minimum in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ebeling 1962

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.4 mm (R. C. Walker)
Flexion larva, 6.3 mm (R. C. Walker)
Postflexion larva, 8.4 mm (R. C. Walker)
Transformation specimen, 19.7 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: 5.9–7.3 mm
Transformation length: >13.5 mm – ca. 18.5–20 mm
Fin development sequence: P_2, D & P_1, C_1, A, C_2
Pigmentation: *Preflexion*—Under hindbrain, spreading dorsad & extending over notochord to myomere 3–4 by 5.9 mm; over midbrain after 5 mm; anteriorly & dorsally on gas bladder & gut; 0–2 ventrally on tail; few proximally on P_2. *Flexion–postflexion*—Increasing over mid- & hindbrain; usually a patch behind eye by 6.8 mm; over notochord to myomere 19 by 10.5 mm; along D base beginning anteriorly at 6.0–6.3 mm, reaching C by 13.5 mm; dorsolateral stripe below D base at ca. 8.8 mm & ventrolateral stripe above A base at ca. 10.5 mm, both reaching C by 13.5 mm; along A base beginning posteriorly at 5.9 mm, extending caudad & cephalad; between hypurals 2–3 & proximally over urostyle at 6.3–6.8 mm; often covering entire P_2 by 10.5 mm. *Transformation*—Completely pigmented except on P_1; gut darkest.
Diagnostic features: Myomeres 28–29 (usually 28; 8–10+18–20 in preflexion stage, 11–12+16–17 in postflexion stage); P_1=14–15 (usually 15, complete in postflexion stage); eye large compared with *M. lugubris*; P_2 pigment (when present) usually on proximal half of fin before ca. 10.5 mm; no pigment on dorsal margin before 6 mm, little or none on ventral margin before ca. 5.9 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–51 49	52–61 57	60–64 62	60–62 61	61–66 64
BD/BL		21–25 24	22–26 24	24–28 26	26–28 27	26–30 27
HL/BL		26–31 29	28–36 32	33–37 34	33–34 33	34–41 37
HW/HL		47–56 50	41–50 45	39–58 44	39–51 45	38–56 46
SnL/HL		32–35 33	30–37 34	30–39 34	21–27 24	21–25 23
ED/HL		37–40 38	32–41 35	26–32 30	20–22 21	13–20 17
P_1L/BL		5–7 6	6–11 10	10–27 15	19–30 25	17–30 26
P_2L/BL		10–14 13	8–23 15	24–28 26	* 21	14–28 20

* P_2 intact in only one specimen.

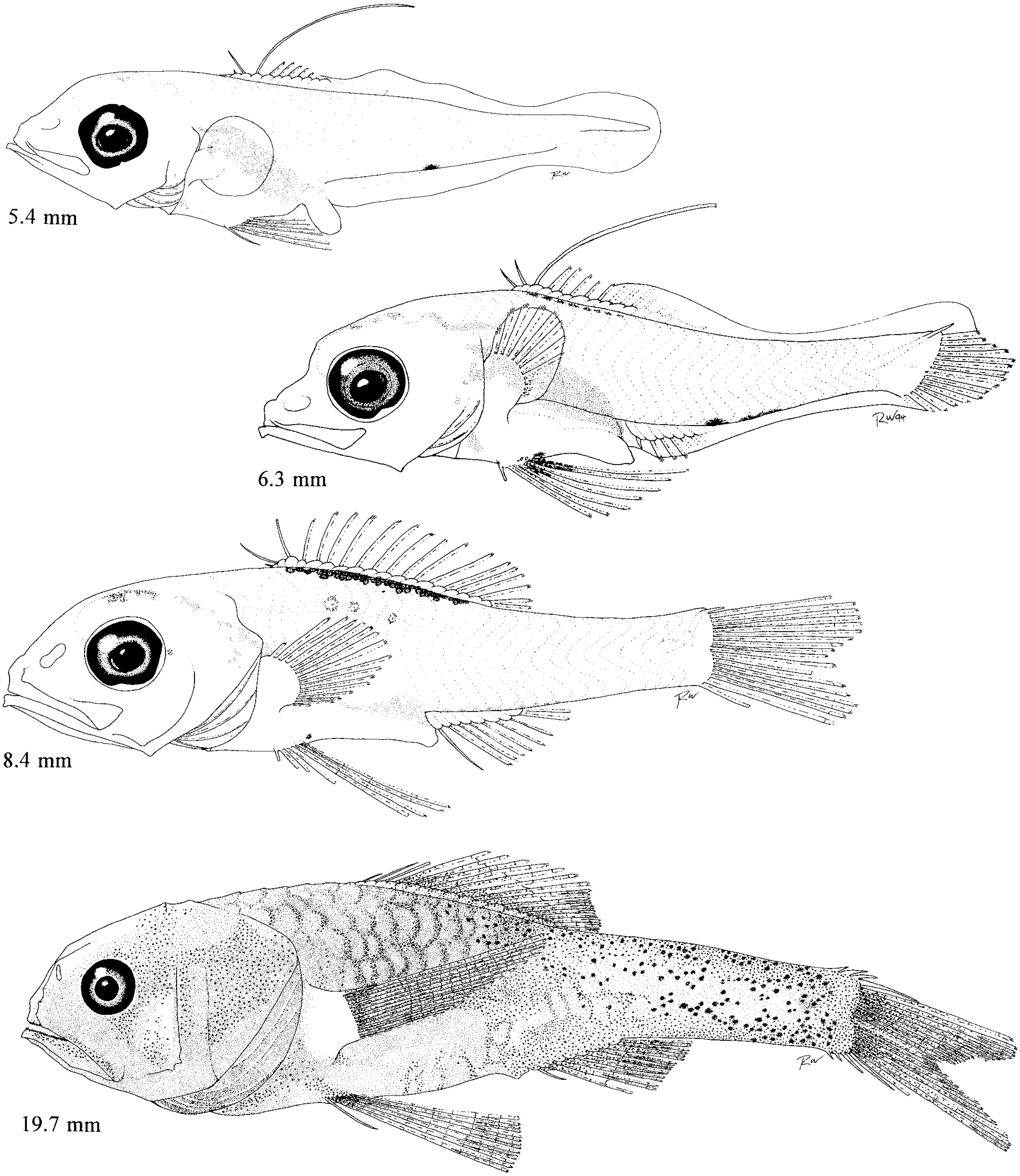


Figure Melamphaidae 3. Preflexion larva, 5.4 mm (CalCOFI 7703, station 83.80); flexion larva, 6.3 mm (CFRD 9104, station 73.3.90); postflexion larva, 8.4 mm (CalCOFI 7505, station 87.70); transformation specimen, 19.7 mm (CalCOFI 5607, station 103.85).

MERISTICS

	Range	Mode
Vertebrae:		
Total	28–30	29
Precaudal	11–13	12
Caudal	16–18	17
Fins:		
Dorsal spines	III	III
Dorsal rays	15–17	16
Anal spines	I	I
Anal rays	8–10	9
Pelvic	I,7	I,7
Pectoral	14–16	15
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	3–5	4
Lower	4–5	4
Gill rakers:		
Upper	3–4	4
Lower	12–15	13–14
Branchiostegals	8	8

LIFE HISTORY

Range: Eastern Atlantic, Indo-Pacific, & Central North Pacific; in eastern north Pacific to ca. 120° W

Habitat: Adults mesopelagic to 800 m depth; larvae & juveniles as shallow as 35–40 m

Spawning season: Larvae occur throughout the year with maximum in spring & summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ebeling 1962
Ebeling & Weed 1973

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.9 mm (R. C. Walker)
Flexion larva, 5.1 mm (R. C. Walker)
Postflexion larvae, 6.6 mm, 11.0 mm (R. C. Walker)

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* P_1 rays intact in only one specimen.
† P_2 rays broken in both specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.2 mm
Flexion length: >5.1–7.3 mm
Transformation length: ca. 12–13 mm
Fin development sequence: P_2, D, C_1, P_1, A, C_2
Pigmentation: *Preflexion*—Initially only dorsally on gas bladder & ventrally in vicinity of myomere 21; under hindbrain after 4 mm; usually dorsolaterally on hindbrain & under forebrain at 4.4 mm; dorsally on hindgut by 4.4 mm; on dorsal margin in vicinity of myomere 13 at 5.1 mm. *Flexion*—Externally over midbrain & internally over hindbrain by 6.6 mm; increasing under brain; dorsally over entire gut; spreading forward, then both cephalad & caudad along dorsal margin; spreading caudad along ventral margin of caudal peduncle; 1–2 between middle hypurals; over urostyle by 6.6 mm; few externally laterally over hypural area by 6.6 mm. *Postflexion–transformation*—Increasing over & under brain & on gut; double row on dorsal margin from myomeres 2–26 & on ventral margin from myomeres 17–27 by 7.8 mm; bar forms across hypural area.
Diagnostic features: Myomeres 28–30 (6–7+22–24 during preflexion stage, 10–12+16–18 in postflexion stage); usually 9 A rays; P_2 pigment distal when present, usually absent; dorsal margin unpigmented in preflexion stage; fully pigmented in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		29–35 32	31–51 43	52–56 54	58–58 58	61–64 62
BD/BL		18–20 19	19–24 21	21–25 24	24–27 26	26–28 27
HL/BL		20–24 22	21–29 27	27–30 28	27–30 29	33–36 35
HW/HL		42–53 46	36–48 41	33–49 39	41–50 46	47–50 49
SnL/HL		20–40 32	32–39 35	31–38 34	26–31 29	20–24 23
ED/HL		40–43 42	32–44 35	26–35 29	20–24 22	12–17 14
P_1L/BL		8–8 8	8–12 9	11–13 12	* 14	23–30 27
P_2L/BL		7–12 10	14–32 23	16–28 22	†	19

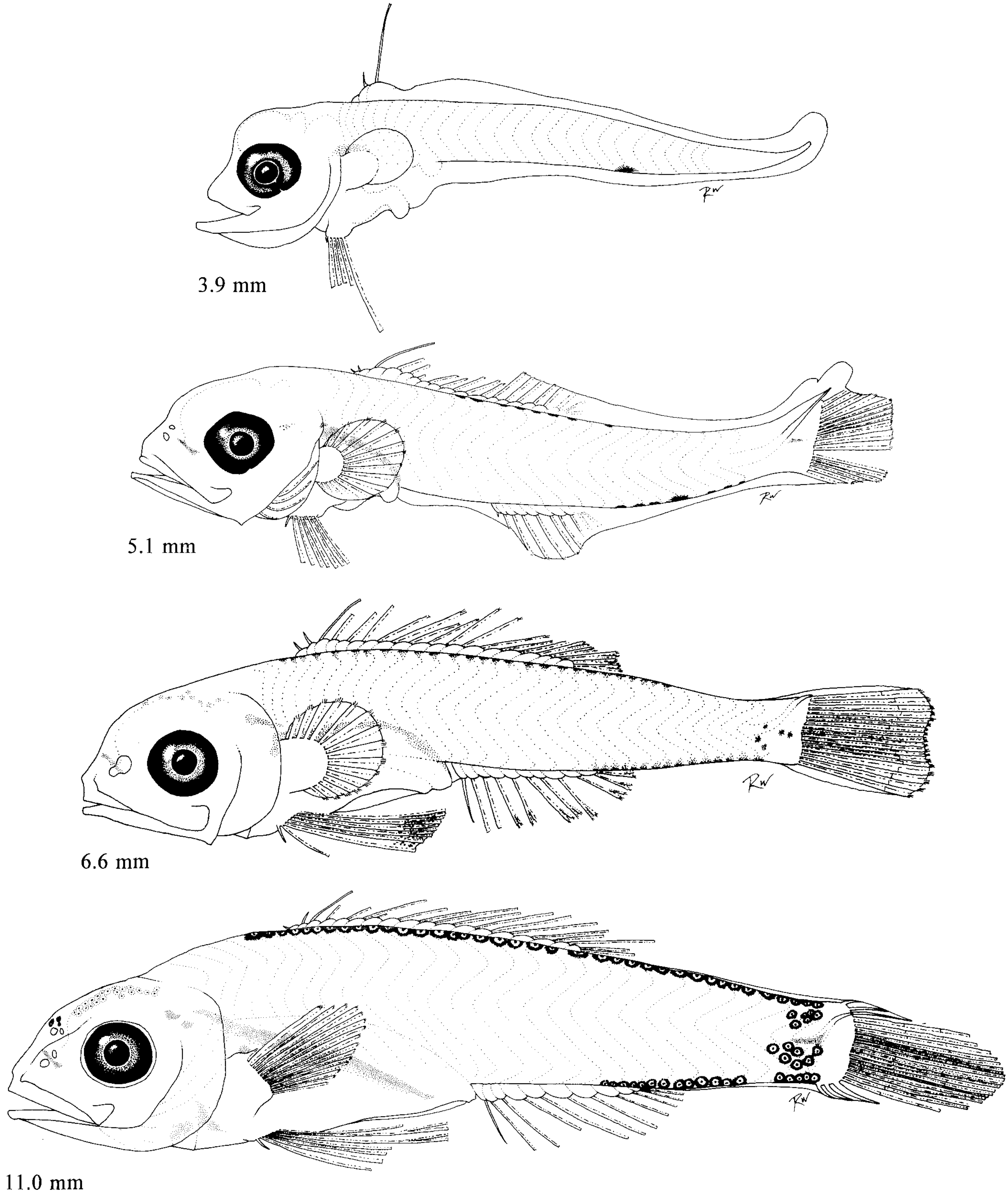

Figure Melamphaidae 4. Preflexion larva, 3.9 mm (CalCOFI 7205, station 31.137); flexion larva, 5.1 mm (CalCOFI 6104, station 80.200); postflexion larva, 6.6 mm (CalCOFI 7205, station 31.137); postflexion larva, 11.0 mm (CalCOFI 7205, station 31.141).

MERISTICS*

	Range	Mode
Myomeres:		
Total	26–28	28
Precaudal	7–12	
Caudal	15–21	
Fins:		
Dorsal spines	III	III
Dorsal rays	15–17	15
Anal spines	I	I
Anal rays	8	8
Pelvic	I,7	I,7
Pectoral	15–16	16
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	4	4
Gill rakers:		
Upper		
Lower		
Branchiostegals	8	8

LIFE HISTORY*

Range: Larvae collected far offshore from southern California, Baja California, & in eastern tropical Pacific

Habitat:

Spawning season: Larvae collected primarily in late spring & summer

ELH pattern: Larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.0 mm, 4.7 mm (R. C. Walker)
Flexion larva, 7.1 m (R. C. Walker)
Postflexion larva, 13.2 mm (R. C. Walker)

* Meristic and life history data refer only to larvae.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 6–8 mm
Transformation length: >13.2 mm, <17.2 mm
Fin development sequence: P_2, D, C_1, P_1, A, C_2
Pigmentation: *Preflexion–flexion*—0–few on ethmoid cartilage; on roof of mouth & under hindbrain, increasing after 6.3 mm; over midbrain & behind eye by 7.1 mm; dorsally on gas bladder & gut; dorsal patch near midtail shifts forward to postanal myomere 6–7 by 5.4 mm; ventral patch near midtail shifts caudad to myomeres 20–24 by 5.4 mm; 0–3 posteriorly on ventral margin of tail; 1 between middle hypurals; 1–3 proximally on lower C rays in flexion stage. *Postflexion*—Increasing on head & gut; on upper part of cleithra by 10.3 mm, spreading onto supracleithra by 13.2 mm; double row along D base, extending laterally as saddle in vicinity of D insertion; light to heavy dorsally on caudal peduncle, usually only posteriorly before 13.2 mm; internally & externally on hypural area; ventral patch behind A insertion.
Diagnostic features: Myomeres 26–28 (5–6+22–23 in preflexion stage, 10–11+16 in postflexion stage); P_2 usually unpigmented, only on base when present; dorsal & ventral margins always with pigment, patches always widely separated in larvae ca. 5–9 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		30–42 34	34–42 39	49–58 55		60–62 61
BD/BL		17–23 19	19–21 20	20–24 23		25–29 27
HL/BL		19–28 22	23–28 26	31–33 32		34–37 35
HW/HL		32–60 46	33–42 38	39–47 43		49–51 50
SnL/HL		25–38 31	33–39 36	29–33 31		25–44 37
ED/HL		27–48 38	32–44 36	25–28 26		15–15 15
P_1L/BL		6–10 8	9–10 9	12–17 15		24–29 26
P_2L/BL		5–22 15	16–18 17	19–57 42		13–17 15

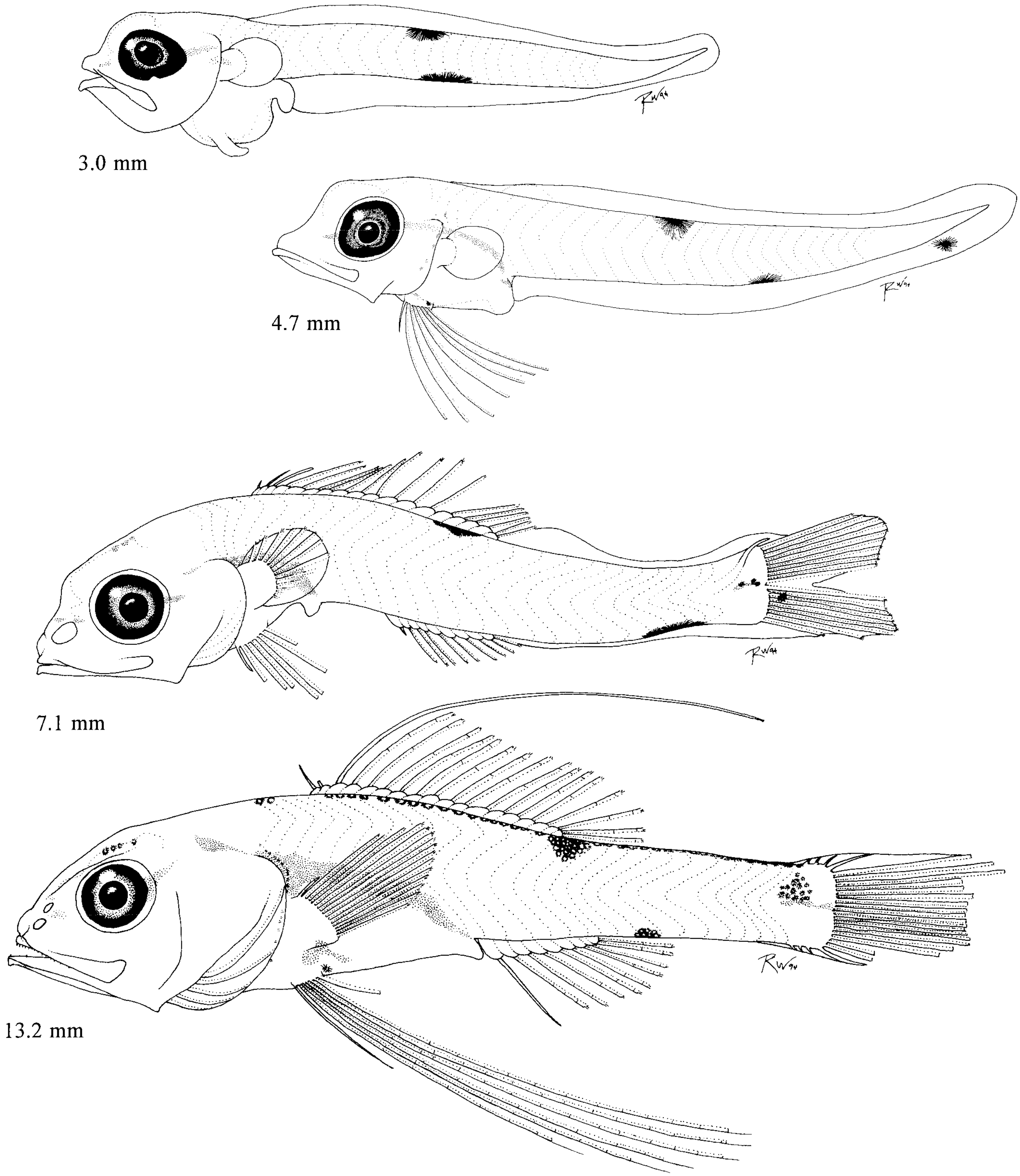

Figure Melamphaidae 5. Preflexion larva, 3.0 mm (CalCOFI 7205, station 31.137); preflexion larva, 4.7 mm (Eastropic, station 1–8, OBL); late flexion larva, 7.1 mm (CalCOFI 7807, station 90.180); postflexion larva, 13.2 mm (Eastropic, station 1–8, OBL).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–29	27
Precaudal	10	10
Caudal	16–19	17
Fins:		
Dorsal spines	III	III
Dorsal rays	11–14	12
Anal spines	I	I
Anal rays	8–11	9
Pelvic	I,7–8	I,7
Pectoral	13–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	4	4
Gill rakers:		
Upper	8–12	9
Lower	18–24	21–22
Branchiostegals	8	8

LIFE HISTORY

Range: Cosmopolitan except absent from Arctic Ocean & Mediterranean Sea

Habitat: Meso- & bathypelagic at 150–1200 m depth, below 750 m during the day, shallower at night

Spawning season: Larval *Poromitra* spp. collected throughout the year, maximum in spring–summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Keene & Tighe 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.2 mm (B. Sumida MacCall)
Flexion larvae, 7.9 mm, 10.7 mm (B. Sumida MacCall)
Postflexion larva, 14.2 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3 mm
Flexion length: 7.2–7.3 mm through 9.9–10.7 mm
Transformation length: ca. 18 mm through 21.2–21.6 mm
Fin development sequence: P_2, P_1, C_1 & D, C_2 & A
Pigmentation: *Yolk-sac*—Few on P_1 finfold. *Preflexion*—Internally under mid- & hindbrain; spreading upward on hindbrain after 4.2 mm; dorsolaterally posteriorly on midbrain by 6.2–7.8 mm; on gas bladder & upper half of gut; few around notochord tip by 4.9 mm; along ventral margin of tail by 6.2 mm; on dorsal margin near insertion of D anlage by 7.8 mm; on P_2 by 6.2 mm. *Flexion–postflexion*—Dorsally on hindbrain & internally near posterior margin of eye by 8.5 mm, increases on brain; increases & spreads ventrad on gut; spreads cephalad & caudad on dorsal margin; laterally on D & A fin bases by 10.5 mm; laterally on last few myomeres by 8.5 mm; dorsally & dorsolaterally on first few myomeres after 14 mm; primarily proximally on C. *Transformation*—Becoming heavy on lower half of head; heavy on trunk, spreading caudad.
Diagnostic features: Myomeres 6–10+17–23=26–29 (usually 7–9+19–21=28 through flexion stage, 10+18 in postflexion stage); preopercular, opercular & posttemporal spines form during flexion stage, frontal, pterotic & nasal spines form early in postflexion stage; eyes become relatively small; large pigmented P_1 & P_2.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–42	38–47	46–50	55–66	61–64
	35	38	41	48	59	62
BD/BL		18–22	21–31	25–28	27–33	28–32
	16	20	24	26	29	30
HL/BL		19–27	26–33	30–31	35–44	41–46
	23	24	29	31	41	44
HW/HL		47–66	42–49	36–47	39–41	32–48
	29	57	47	41	40	40
SnL/HL		23–45	34–47	34–42	26–38	26–30
	12	36	40	37	31	28
ED/HL		31–41	23–33	24–27	11–20	12–14
	47	36	28	25	15	13
P_1L/BL		7–15	13–23	19–29	24–36	31–34
	6	11	17	23	32	33
P_2L/BL		0–14	11–17	21–24	10–18	15–21
	0	7	14	22	14	18

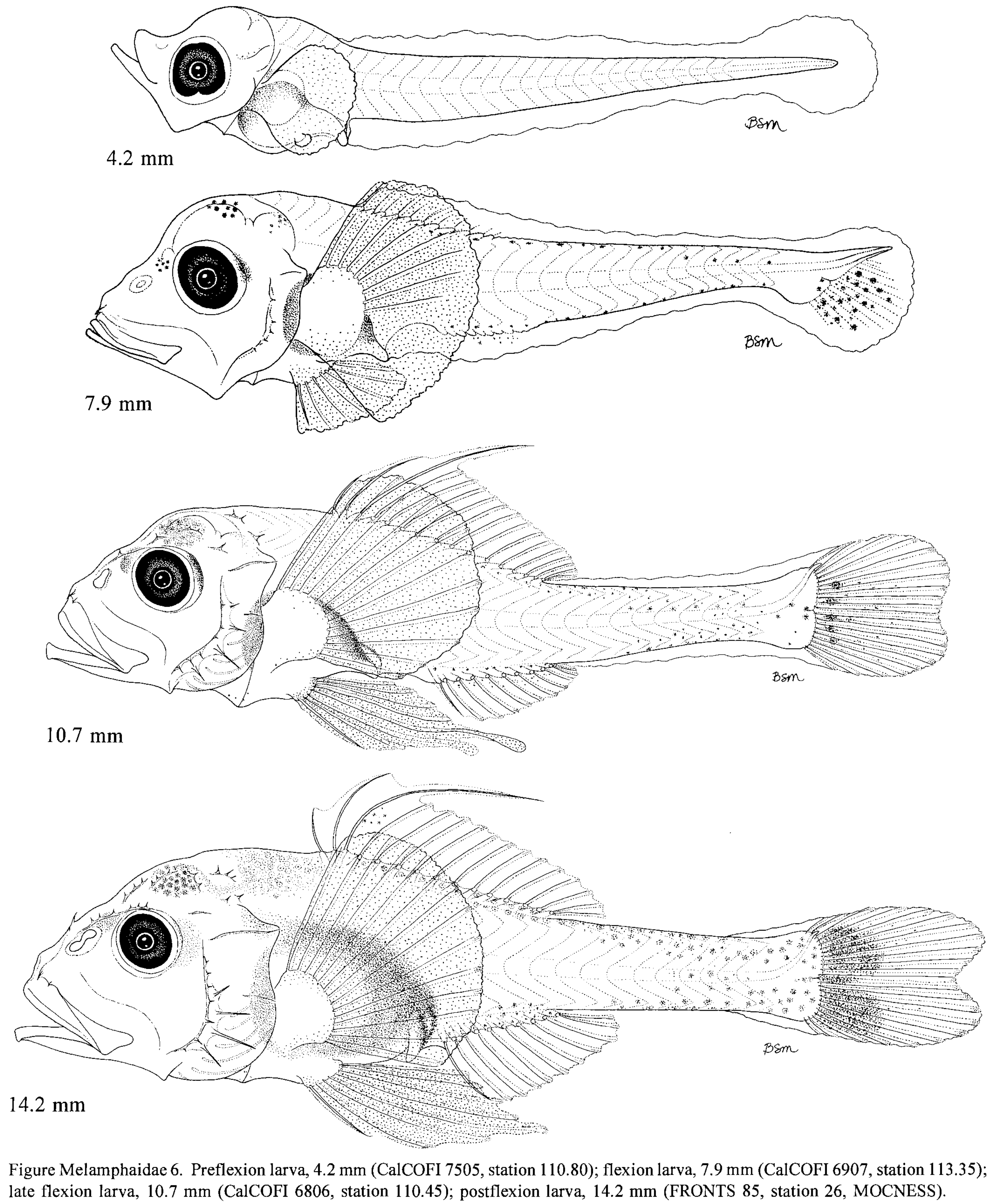

Figure Melamphaidae 6. Preflexion larva, 4.2 mm (CalCOFI 7505, station 110.80); flexion larva, 7.9 mm (CalCOFI 6907, station 113.35); late flexion larva, 10.7 mm (CalCOFI 6806, station 110.45); postflexion larva, 14.2 mm (FRONTS 85, station 26, MOCNESS).

MERISTICS*

	Range	Mode
Vertebrae:		
Total	27–30	28–29
Precaudal	9–11	10
Caudal	18–19	18–19
Fins:		
Dorsal spines	II–III	III
Dorsal rays	10–12	11
Anal spines	I	I
Anal rays	9–10	9
Pelvic	I,7	I,7
Pectoral	13–15	13
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	4	4
Gill rakers:		
Upper	6–8	7
Lower	16–20	17
Branchiostegals	8	8

LIFE HISTORY

Range: Circumtropical

Habitat: Meso- & bathypelagic, primarily at 150–1000 m depth

Spawning season: Larval *Poromitra* spp. collected throughout the year, maximum in spring–summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ebeling & Weed 1973

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.0 mm (B. Sumida MacCall)
Flexion larva, 5.2 mm (B. Sumida MacCall)
Postflexion larva, 6.4 mm (B. Sumida MacCall)

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* Meristic counts for eastern Pacific specimens; full range given in Table Melamphaidae 1.
† Specimen damaged; HW, SnL, & ED could not be measured.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ≤2.4 mm
Flexion length: 4.5 mm through 6.4–6.8 mm
Transformation length: >11.5 mm, <14.0 mm
Fin development sequence: D & P_1 & P_2, C_1, A, C_2
Pigmentation: *Preflexion*—Under mid- & hindbrain; along cleithrum; on gas bladder & upper part of gut; few along ventral margin of tail. *Flexion*—Dorsolaterally posteriorly on midbrain, around lower half of forebrain; internally near posterior margin of eye after 6 mm; longitudinally elongate dashes, primarily near dorsal & ventral margins & along lateral midline initially, filling in laterally from trunk to tail; few on C. *Postflexion*—On frontal above eye; over posterior part of midbrain between 6.4–11.5 mm; proximal bar across principal C rays by 11.8 mm.
Diagnostic features: Myomeres 7–10+18–21=27–29 (usually 7+21 in preflexion stage, 9+19 by postflexion stage); preopercular & opercular spines form at end of flexion stage; posttemporal spines form during mid-postflexion stage (ca. 8 mm); frontal & nasal spines form late in postflexion stage; eyes relatively large; longitudinally elongate dash-like melanophores on trunk & tail beginning in late flexion or early postflexion stage; little or no pigment on P_1 & P_2.

MORPHOMETRICS (range & mean in %)

	Y-S†	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–47	40–48	46–51		53–56
	38	41	44	49		54
BD/BL		25–32	26–34	28–39		25–27
	21	28	30	32		26
HL/BL		26–34	27–35	31–36		34–38
	28	30	31	33		36
HW/HL		36–60	44–55	45–55		42–48
		51	51	50		44
SnL/HL		36–40	33–42	27–39		17–19
		37	36	33		18
ED/HL		34–42	31–39	27–33		20–26
		37	36	30		24
P_1L/BL		5–10	11–20	16–19		24–35
	8	7	15	18		28
P_2L/BL		5–12	7–14	9–15		19–26
	0	8	11	12		21

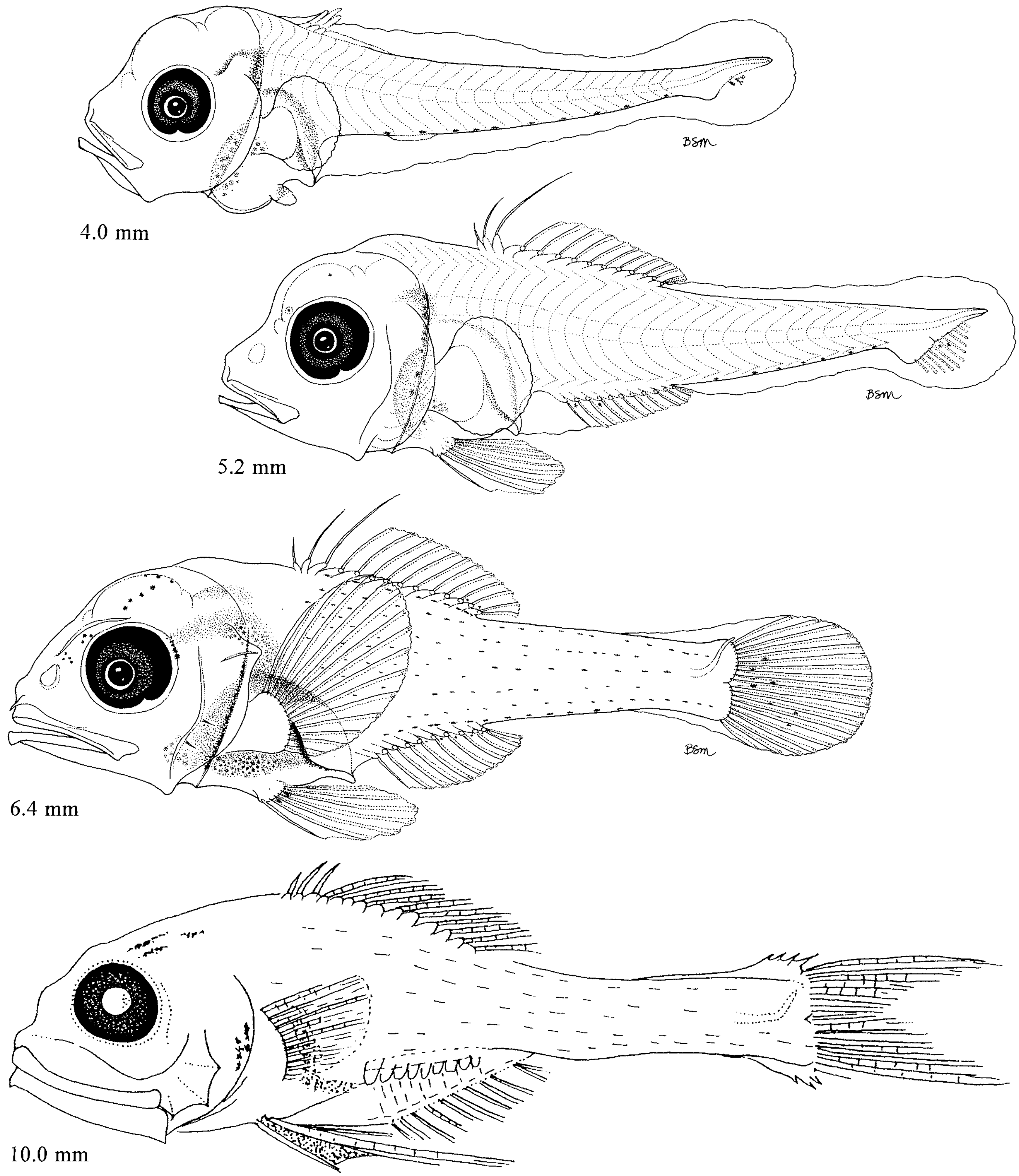


Figure Melamphaidae 7. Preflexion larva, 4.0 mm (EASTROPAC II, station 46.084); flexion larva, 5.2 mm (EASTROPAC II, station 46.094); postflexion larva, 6.4 mm (EASTROPAC II, station OP.664); postflexion larva, 10.0 mm (Keene and Tighe 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	23–27	25
Precaudal	10–11	10
Caudal	14–16	15
Fins:		
Dorsal spines	II–III	II
Dorsal rays	10–13	11–12
Anal spines	I	I
Anal rays	7–9	8
Pelvic	I,7–8	I,7
Pectoral	12–14	13–14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	3–5	4
Lower	3–5	3
Gill rakers:		
Upper	5–7	6
Lower	15–19	16
Branchiostegals	8	8

LIFE HISTORY

Range: Cosmopolitan except absent from Arctic Ocean & Mediterranean Sea

Habitat: Meso- & bathypelagic at 340–1200 m depth, primarily below 500 m

Spawning season: Larvae collected in most months, maximum in July–August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Keene & Tighe 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.4 mm, 2.9 mm (B. Sumida MacCall)
Flexion larva, 3.9 mm (B. Sumida MacCall)
Postflexion larva, 7.8 mm (B. Sumida MacCall)

* P_2 rays intact in only one specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: 3.3–3.4 mm through 4.1 mm
Transformation length: ca. 10.5 mm through 12.6–14.3 mm
Fin development sequence: P_2, D, A & C_1, P_1, C_2
Pigmentation: *Preflexion–flexion*—Few externally, posteriorly over midbrain beginning at ca. 3 mm; internally under mid- & hindbrain; present or absent in floor of otic capsule (usually present); anterodorsally over gut & gas bladder, spreading posteriorly to near anus by 3–3.5 mm; pair present or absent near cleithral symphysis after 3 mm (usually absent); 1–few dorsolaterally in vicinity of last 2–3 preanal & first 2–3 postanal myomeres; 1–few along lateral midline in vicinity of last 1–2 preanal & first 1–2 postanal myomeres, spreading caudad; ventral & ventrolateral blotch near terminus of gut, shifting caudad 2–3 myomeres; few along ventral margin of tail; 0–few along hypural margin in flexion stage; 0–few on P_2. *Postflexion*—On nostril & posterior margin of orbit after 5 mm; increasing on dorsum, laterally, & on P_2 & C; on D & A after 7 mm.
Diagnostic features: Myomeres 9–12+13–16=24–26 (usually 11+14); preopercular spines lacking; prominent hook-like projection present at anterior end of maxillary; precocious P_2 formation; robust form, more compressed than *Scopelogadus*; flexion & transformation at small size; trunk & tail pigment form discontinuous diagonal bar at midbody.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–56 51	58–70 63	65–70 68	66–69 68	61–66 64
BD/BL		17–30 24	31–40 35	31–37 34	31–37 33	33–34 33
HL/BL		23–34 29	29–46 37	30–36 34	32–40 35	39–43 41
HW/HL		41–51 47	37–46 42	42–54 48	43–49 46	46–55 51
SnL/HL		22–43 31	21–35 28	26–32 29	26–30 27	18–20 19
ED/HL		34–43 37	29–39 33	27–34 31	15–22 20	13–15 14
P_1L/BL		4–10 7	10–11 10	11–21 15	19–26 22	30–31 31
P_2L/BL		0–12 6	7–20 11	15–28 20	18–45 26	22*

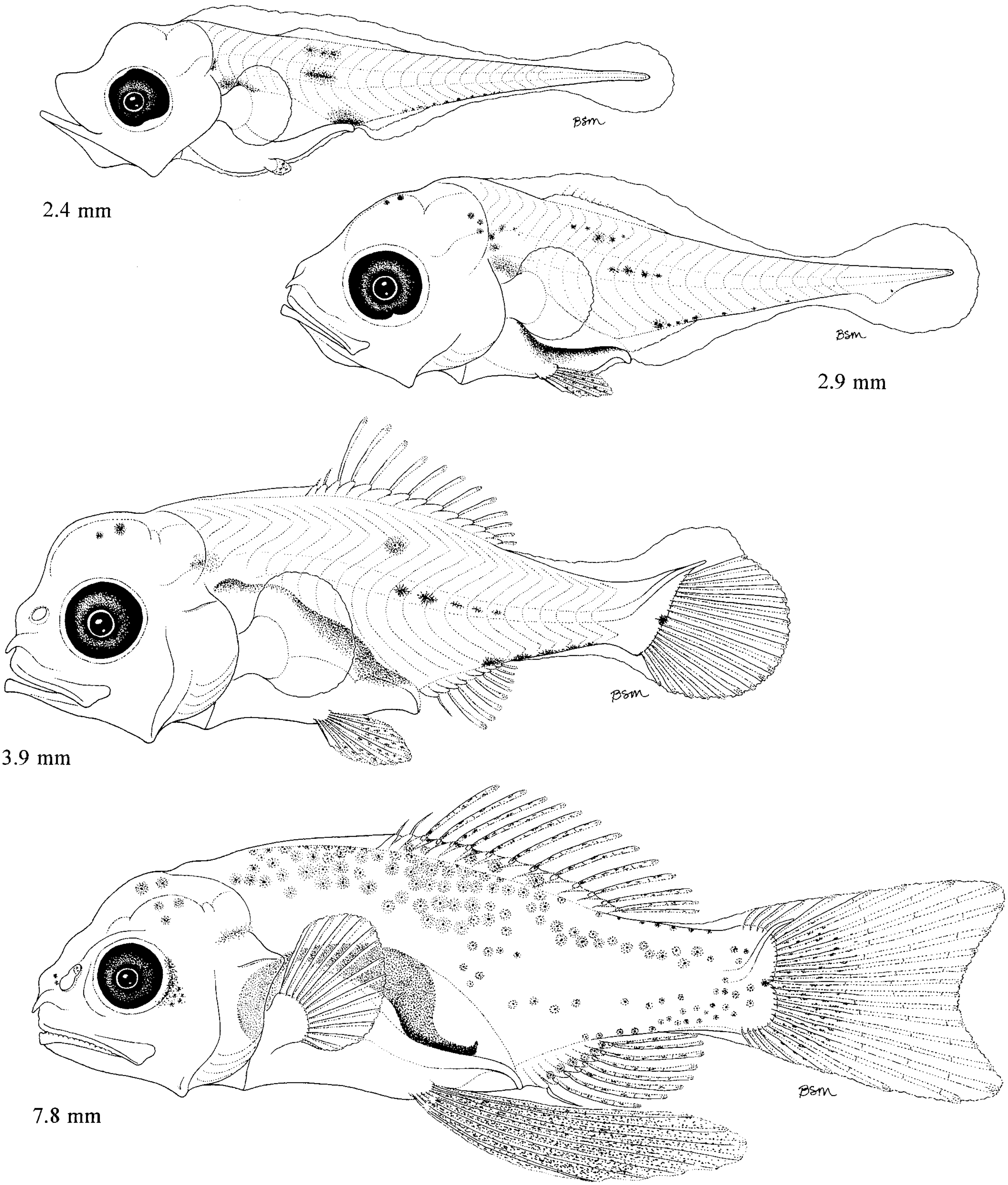


Figure Melamphaidae 8. Preflexion larvae, 2.4 mm (TC 8405, station 81) and 2.9 mm (TC 8505, station 59); flexion larva, 3.9 mm (NORPAC, station 77); postflexion larva, 7.8 mm (TC 8405, station 59).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24–27	25
Precaudal	10–11	10
Caudal	14–17	15
Fins:		
Dorsal spines	II	II
Dorsal rays	10–12	11
Anal spines	I	I
Anal rays	7–9	8
Pelvic	I,7–8	I,7
Pectoral	14–15	14
Caudal:		
Principal	10+9	10+9
Procurrent:		
Upper	4	4
Lower	3–4	4
Gill rakers:		
Upper	6–9	7
Lower	15–18	16–17
Branchiostegals	8	8

LIFE HISTORY

Range: Tropical central Pacific & from ca. 40° N to 20° S in eastern Pacific

Habitat: Meso- & bathypelagic, primarily ca. 200–2000 m depth

Spawning season: Larvae collected year-round, primarily July–November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ebeling & Weed 1963
Keene & Tighe 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.8 mm (B. Sumida MacCall)
Preflexion larva, 2.9 mm (B. Sumida MacCall)
Flexion larvae, 4.0 mm, 4.4 mm (B. Sumida MacCall)
Postflexion larva, 7.8 mm (B. Sumida MacCall)

* P_2 rays intact in only one specimen.
† P_2 rays broken in all specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 1.8 mm
Flexion length: 4.2–4.4 mm through ca. 5 mm
Transformation length: >8.8 mm – ca. 14 mm
Fin development sequence: P_1, D, C_1, A, P_2, C_2
Pigmentation: *Yolk-sac*—Anterodorsally on yolk sac, extending onto cleithra in some; dorsally on intestine posteriorly, extending onto trunk in vicinity of myomeres 5–7; dorsal or dorsolateral patch in vicinity of postanal myomeres 2–6; ventral or ventrolateral patch in vicinity of postanal myomeres 5–15. *Preflexion*—Under midbrain; on anterior margin of midbrain at ca. 3.1 mm; ventrally & ventrolaterally on forebrain & dorsally on hindbrain at 3.5–4 mm; along cleithrum, extending forward onto otic capsule at 3.5–4 mm; anteriorly & dorsally on gut; ventrolaterally in vicinity of myomeres 5–7; diagonal bar across tail in vicinity of postanal myomeres 2–7, spreading cephalad dorsally & caudad ventrally; anteriorly on D at 3.1 mm, on A at 3.5 mm. *Flexion–postflexion*—Increasing on brain & snout, laterally on trunk & tail; present or absent on P_2 after 5 mm.
Diagnostic features: Myomeres 8–11+14–18=25–27 (usually 10+14–16); few, small, late-forming spines on opercular series bones; robust form; distinct diagonal pigment bar across trunk & tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	44–51 47	44–54 50	52–66 57	67–74 69	60–64 62	57–66 62
BD/BL	9–10 10	19–30 25	26–35 30	35–41 38	28–30 29	26–37 31
HL/BL	22–24 23	26–34 30	36–41 37	42–47 43	40–45 43	40–48 44
HW/HL	55–75 62	38–55 50	41–52 48	45–56 48	47–62 54	44–44 44
SnL/HL	10–13 12	21–35 29	32–37 33	30–36 33	30–35 33	29–33 31
ED/HL	37–43 40	32–45 37	30–37 32	21–30 24	14–15 14	11–13 12
P_1L/BL	0–0 0	5–11 8	7–16 12	20–32 25	28–35 31	29–38 35
P_2L/BL	0–0 0	0–0 0	4–7 5	12–18 15	23*	†

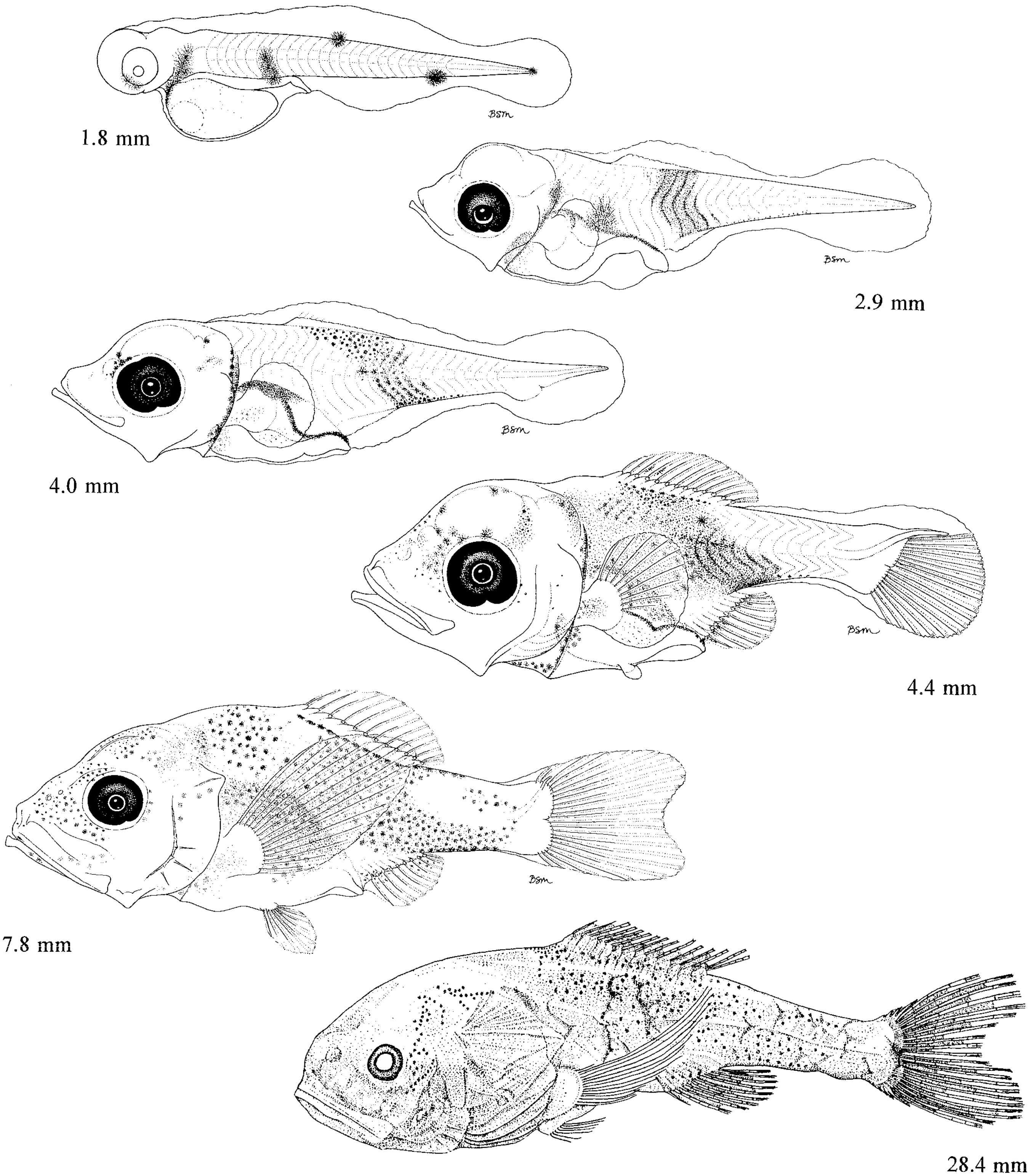


Figure Melamphaidae 9. Yolk-sac larvae, 1.8 mm (EASTROPAC II, station OP.64), 2.9 mm (EASTROPAC II, station 75.196); early flexion larva, 4.0 mm (FRONTS 85, station 18, MOCNESS); late flexion larva, 4.4 mm (CalCOFI 7712, station 97.55); postflexion larva, 7.8 mm (CalCOFI 7210, station 157.25); juvenile, 28.4 mm (Ebeling and Weed 1963).

MIRAPINNIDAE: Ribbontails

S. R. Charter and H. G. Moser

Mirapinnidae is a rare oceanic family (3 genera, 5 species) known only from larvae and juveniles (<55 mm SL). Rosen and Patterson (1969) allied it with the lampridiforms based on apparent similarities of upper jaw morphology, cheek musculature, and caudal skeleton; some classifications, including that of Eschmeyer (1990), follow this hypothesis. Olney et al. (1993) and Moore (1993) concur with Bertelsen and Marshall (1984) that it is a stephanoberyciform (stephanoberycoid in this guide) and that it and its closest relative, the Megalomycteridae, form the sister group of the cetomimids. Mirapinnids occur worldwide in warm and temperate waters in the Atlantic, Indian and Pacific Oceans. *Eutaeniophorus festivus* is the only species whose larvae have been captured on regular CalCOFI surveys, but *Parataeniophorus brevis* is known from the region from one specimen (Herrera and Lavenberg 1995).

Mirapinnids are elongate with a scaleless body; the integument of *Mirapinna* is covered with hair-like outgrowths and *Eutaeniophorus* and *Parataeniophorus* are covered with minute papillae. The opposing dorsal and anal fins are positioned near the caudal fin. Pelvic fins are jugular with their bases oriented horizontally in juveniles. Larval and juvenile eutaeniophorines have a caudal streamer extending from the skin of the caudal fin that may be several times the body length when intact. The mouth is oblique and slightly protrusible.

Mirapinnid eggs are unknown, larvae are uncommon, and only a few post-metamorphic specimens have been captured. Larvae of *E. festivus* have an elongate gut (Sn-A 66–72% BL) and pigmentation on the gut and myosepta. Pigmentation increases with size, becoming finely scattered on the head and body, denser towards the tail and on the caudal streamer. In larger larvae, the caudal streamer has a median stripe and a nearly black border. Juveniles are dark brown. The stomach of the largest *E. festivus* examined (44.4 mm SL) was greatly distended (BD at midgut 26% BL) and contained a large number of copepods belonging to a single species (R. Rosenblatt, pers. comm.).

The following description of *Eutaeniophorus festivus* is based on detailed examination of 12 larval specimens (7 preflexion, 5.9–9.8 mm; 5 flexion, 10.2–19.2 mm), two juvenile specimens (26.2–44.4 mm), and on literature (Bertelsen and Marshall 1956, 1958, 1984). Morphological and ecological information were obtained from Bertelsen (1986), Nelson (1994) and Herrera and Lavenberg (1995).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–55	
Precaudal		
Caudal	7–8	
Fins:		
Dorsal spines	0	
Dorsal rays	16–20	
Anal spines	0	
Anal rays	15–18	
Pelvic	4–5	
Pectoral	20–24	
Caudal:		
Principal	7–8+8–9	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2	
Lower	8	
Branchiostegals	3–5+4	

LIFE HISTORY

Range: Oceanic; in the western & central Pacific, known from the South China Sea, from off New Guinea, from off Hawaii, & in the eastern Pacific, from Oregon to Ecuador

Habitat: Adults probably mesopelagic; pre-transformation individuals epipelagic at 1–200 m depth

Spawning season: Larvae caught throughout the year

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Ahlstrom 1972b
Bertelsen & Marshall 1956, 1958, 1984
Evseenko 1985
Herrera & Lavenberg 1995
Konishi 1988a

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching leugth: <6.5
Flexion length: ca. 10 mm to >19.2 mm
Transformation length:
Fin development sequence: D & A, P_2, C, P_1
Pigmentation: Finely scattered on head & body, increasing slightly with length; slight increase in density toward tail, dorsally on peritoneum, & along ventral myosepta; occasionally a row dorsally along myosepta; denser on C streamer & C rays at base; fully developed streamer has a median stripe & nearly black border.
Diagnostic features: Total myomeres 47–55, predorsal myomeres 31–36; caudal streamer; elongate body; body depth <10% BL; in later stages, lack of pigment patch distally on P_2.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		60–70 66	72–75 72			73–76 74
BD/BL		6–7 7	6–8 7			9–9 9
HL/BL		11–16 13	11–15 14			16–20 18
HW/HL		30–46 40	31–43 39			42–44 43
SnL/HL		7–12 9	11–17 14			23–25 24
ED/HL		27–36 33	26–35 30			15–20 17
P_1L/BL		0–6 3	2–4 3			6–6 6
P_2L/BL		0–0 0	0–1 1			 21

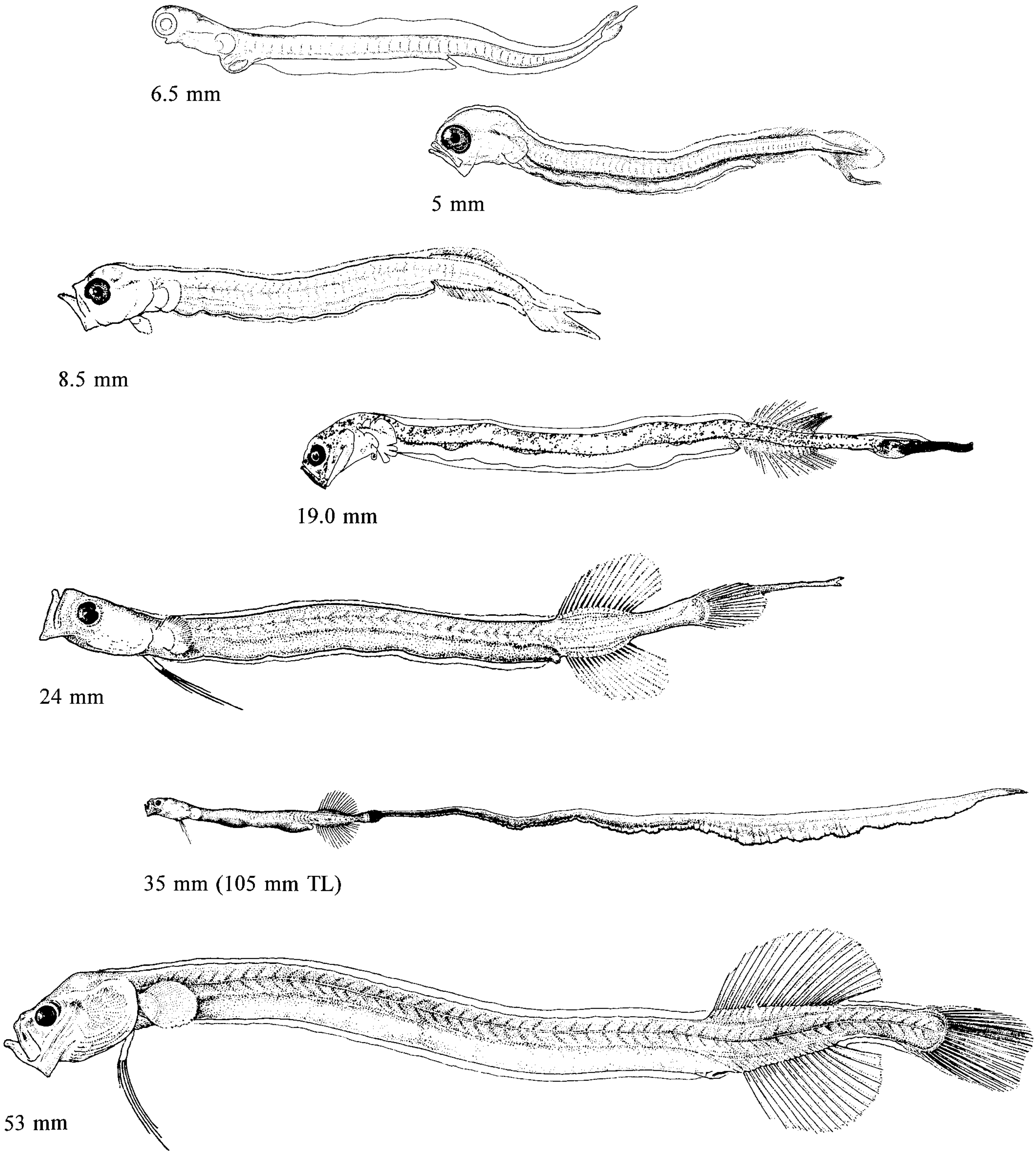


Figure Mirapinnidae 1. Yolk-sac larva, 6.5 mm (Bertelsen & Marshall 1958); preflexion larva, 5 mm; flexion larva, 8.5 mm (Bertelsen & Marshall 1956); flexion larva, 19.0 mm (Konishi 1988a); postflexion larvae, 24 mm, 35 mm, 53 mm (Bertelsen & Marshall 1956).

SYNGNATHIFORMES

W. Watson

Some authors have restricted the Syngnathiformes to the trumpetfishes, cornetfishes, snipefishes, shrimpfishes, ghost pipefishes, and other pipefish and seahorses (e.g., Eschmeyer 1990), or have included the sand-eels, tubesnouts, and sticklebacks in an expanded order (e.g., Gosline 1971). Others have placed most or all of these, sometimes with additional families, in the Gasterosteiformes (e.g., Pietsch 1978; Robins et al. 1991; Johnson and Patterson 1993; Nelson 1994). Johnson and Patterson (1993) reviewed the evidence linking the gasterosteoid and syngnathoid fishes and showed that while it does suggest monophyly for the group as a whole, it does not convincingly demonstrate monophyly for the suborders. Here, primarily for convenience but also because the taxonomic status of these fishes is not fully resolved, we accept Eschmeyer's (1990) restricted Syngnathiformes.

Syngnathiformes contains about 241 species in five families of primarily tropical and subtropical coastal marine fishes. Most are elongate and compressed (cornetfishes are depressed), have a small mouth at the end of a long tubular snout, and are enclosed in bony plates (no plates in cornetfishes and trumpetfishes). The pelvic fins are abdominal and the anal fin and rayed portion of the dorsal fin are far posterior in all but the syngnathids, which lack pelvic fins, may lack the anal fin, and have the dorsal fin near midbody. Many species are rather bizarre in appearance.

The syngnathiform fishes are oviparous. Some spawn spherical planktonic eggs that are ca. 0.6–2.1 mm in diameter and contain an unsegmented yolk with none to many oil globules (Fritzsche 1984). The ellipsoidal eggs of syngnathids are deposited and incubated in a specialized marsupium (or brood patch, in some) on the male, while the spherical eggs of solenostomids are incubated in a marsupium formed by the pelvic fins of the female. Larvae hatch from the planktonic eggs with unpigmented to partially pigmented eyes, unformed to partially formed mouth, and a large to moderate yolk sac (Sparta 1936; Mito 1961a; Leis and Rennis 1983; Leis and Trnski 1989). Syngnathids and solenostomids are more fully developed upon release (Hardy 1978a; Leis and Trnski 1989). Spinules or spiny ridges typically form on the head and body during the larval stage. Larval pigment ranges from light to nearly complete.

Syngnathiformes is represented in the California Current vicinity by about twelve species in three families. Larvae of the slender snipefish and reef cornetfish, and late larvae through adults of three or four pipefish species occur in CalCOFI ichthyoplankton collections.

Families included: Fistulariidae
Centriscidae
Syngnathidae

FISTULARIIDAE: Cornetfishes

W. WATSON AND E. M. SANDKNOP

Two of the four fistulariid species occur in the California Current vicinity (Table Fistulariidae 1; Fritzsche 1976): *Fistularia commersonii* ranges widely throughout the Indo-Pacific and from Bahía Magdalena, Baja California Sur, to Panama in the eastern Pacific, while the endemic eastern Pacific species *F. corneta* ranges from Bahía San Hippolito, Baja California Sur, to Peru. Both species occur at many of the offshore islands and both range throughout the Gulf of California. Only a single larval *F. corneta* has been identified from CalCOFI ichthyoplankton collections off the outer coast of Baja California. Larvae of both species have been taken from the Gulf of California and farther south along the Pacific coast of mainland Mexico and Central America.

Cornetfishes are medium-size to large (maximum 1–2 m), primarily piscivorous fishes commonly associated with coral and rocky reefs in all warm oceans. The fistulariids are very elongate, somewhat depressed, with a long tubular snout bearing a moderately small terminal mouth. The dorsal and anal fins, containing only segmented rays, are far posterior and the caudal fin is forked, with the central rays forming an elongate filament. Cornetfishes typically are green to brown or reddish above, some with spots or stripes, and silvery to white below.

Fistulariids are oviparous with planktonic eggs and larvae (Frizsche 1984). The spherical eggs, 1.5–2.1 mm in diameter, have a smooth chorion, small perivitelline space, unsegmented yolk, and lack oil globules (Mito 1961a; Watson and Leis 1974). Larvae hatch at ca. 4–7 mm with partially pigmented eyes, partially formed mouth, and moderate yolk sac (Mito 1961a; Leis and Rennis 1983). Throughout development the larvae are cylindrical and elongate. Preanal length increases from about 67–75% BL in young larvae to ca. 75–80% BL in late larvae. The snout initially is moderately short and pointed, but the characteristic greatly elongate shape is well established before notochord flexion. A ventrolateral row of spinules forms along each side of the trunk and tail shortly after hatching and a dorsolateral row is added on each side before the end of the yolk-sac stage. Small spines and/or low spiny ridges form on the snout and frontal, preopercular, parietal, supraoccipital, posttemporal, and supracleithral bones beginning mid-way through the preflexion stage. The characteristic elongate caudal filament begins to form shortly before notochord flexion. Development is direct, without a distinct transformation stage. Larvae are pigmented on the dorsum, gut, yolk sac, and caudal finfold at hatching, but the dorsal pigment quickly migrates ventrad so that melanophores are largely restricted to the gas bladder, gut, ventrum, and the caudal finfold until, or through, notochord flexion. Melanophores are added on the head and caudal fin in the postflexion stage and a barred pattern may develop on the trunk and tail near the end of the larval period.

Larval cornetfishes are unlikely to be confused with those of any other family in the California Current vicinity. Distinctive characters include the very elongate body with long preanal length and spinules arranged in four (or more, in larger larvae) longitudinal rows, 74–88 myomeres, elongate snout, and the fins (postflexion stage). The two eastern Pacific species are difficult to distinguish from one another before the full complements of dorsal, anal, and pectoral fin rays are completed during the postflexion stage (Table Fistulariidae 1). Younger larvae are distinguished primarily by myomere counts: 74–78 for *F. corneta* vs. 82–88 for *F. commersonii.*

The following descriptions are based on literature and on detailed examination of 12 *F. commersonii* and 26 *F. corneta* (Table Fistulariidae 2). Meristic data were obtained from Fritzsche (1976), Kimura (1988a), and counts made during this study. Ecological information was obtained from Fritzsche (1976) and Thomson et al. (1979).

Table Fistulariidae 1. Meristic characters for the fistulariid species in the California Current vicinity. Both have 7+7 principal caudal fin rays, 6 pelvic fin rays, and 5 branchiostegal rays. The first four vertebrae are fused (Fritzsche 1976).

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	P_1	C_2
Fistularia commersonii	4+46–49	32–35	83–86	14–17	14–16	13–15	5+5
F. corneta	4+41–43	28–31	75–76	17–20	16–19	15–18	7–8+7–8

Table Fistulariidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the fistulariid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Juvenile
Fistularia commersonii	L[a,b]	L[a,c]	L[c], 6 6.0–11.2	L[c], 1 16.0	L[c], 1 23.3	4 63.2–126.7
F. corneta	0	3 3.4–4.4	8 5.6–9.8	5 11.8–13.3	7 13.5–58.5	3 66.8–101.5

[a] Mito 1961a
[b] Watson and Leis 1974
[c] Leis and Rennis 1983

MERISTICS

	Range	Mode
Vertebrae:		
Total	83–86	85
Precaudal*	4+46–49	4+47
Caudal	32–35	34
Fins:		
Dorsal spines	0	0
Dorsal rays	14–17	16–17
Anal spines	0	0
Anal rays	14–16	15–16
Pelvic	6	6
Pectoral	13–15	15
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	5	5
Lower	5	5
Gill rakers:		
Upper		
Lower		
Branchiostegals	5	5

LIFE HISTORY

Range: Bahía Magdalena, Baja California Sur, & Gulf of California to Panama & offshore islands, & across tropical Indo-Pacific

Habitat: Over shallow reefs & adjacent sandy bottom

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Kimura 1988a
Leis & Rennis 1983
Mito 1961a
Watson & Leis 1974

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 7.6 mm (W. Watson)
Flexion larva, 16.0 mm (W. Watson)
Postflexion larva, 23.3 mm (W. Watson)

* The first four vertebrae are fused (Fritzsche 1976).
† Eye is oval, becoming round to somewhat oval in postflexion & juvenile stages; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.7–2.1 mm
Yolk: Homogeneous
No. of OG: 0
Diam. of OG:
Shell surface: Smooth
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 5.4–7 mm
Flexion length: ca. 13–16 mm
Transformation length: ca. 60 mm
Fin development sequence: C_1, D & A, P_1, C_2, P_2
Pigmentation: *Yolk-sac*—Scattered dorsally on head & along dorsal margin of trunk & tail; scattered on yolk sac; dorsolateral series along each side of gut; on ventral margin of gut posteriorly; on ventral margin of tail; scattered proximally on caudal finfold, may extend onto posterior part of anal finfold. *Preflexion–postflexion*—On lower part of head (dentary, gular area, preopercular, branchiostegal membrane); on hypobranchial & basibranchials after ca. 6 mm; on isthmus; dorsolateral & ventral margin series along gut; on ventral margin of tail, extending along elongate central caudal rays after ca. 11 mm; usually some on anal finfold; internally on hindbrain, extending onto midbrain by ca. 11 mm; on D bases by ca. 16 mm; dorsally on caudal peduncle by ca. 23 mm.
Diagnostic features: Myomeres 50–52+31–36=82–88 (most commonly 51+36); D rays 14–17, A rays 14–16 (all present by ca. 25 mm); hypobranchial & basibranchial pigment present by 6–7 mm; compared with *F. corneta*, more slender, notochord flexion & fin development begin at larger size.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		72–79 75	 76	 74		76–79 77
BD/BL		5–7 6	 4	 4		2–3 3
HL/BL		17–23 20	 27	 27		34–39 37
HW/HL		17–30 24	 9	 11		7–10 8
SnL/HL		36–57 48	 63	 67		73–76 74
ED/HL†		13–24× 13–20 19×16	 10×8	 7×7		6–8× 5–8 7×6
P_1L/BL		3–4 3	 3	 2		3–4 3
P_2L/BL		0–0 0	 0	 0		1–2 1

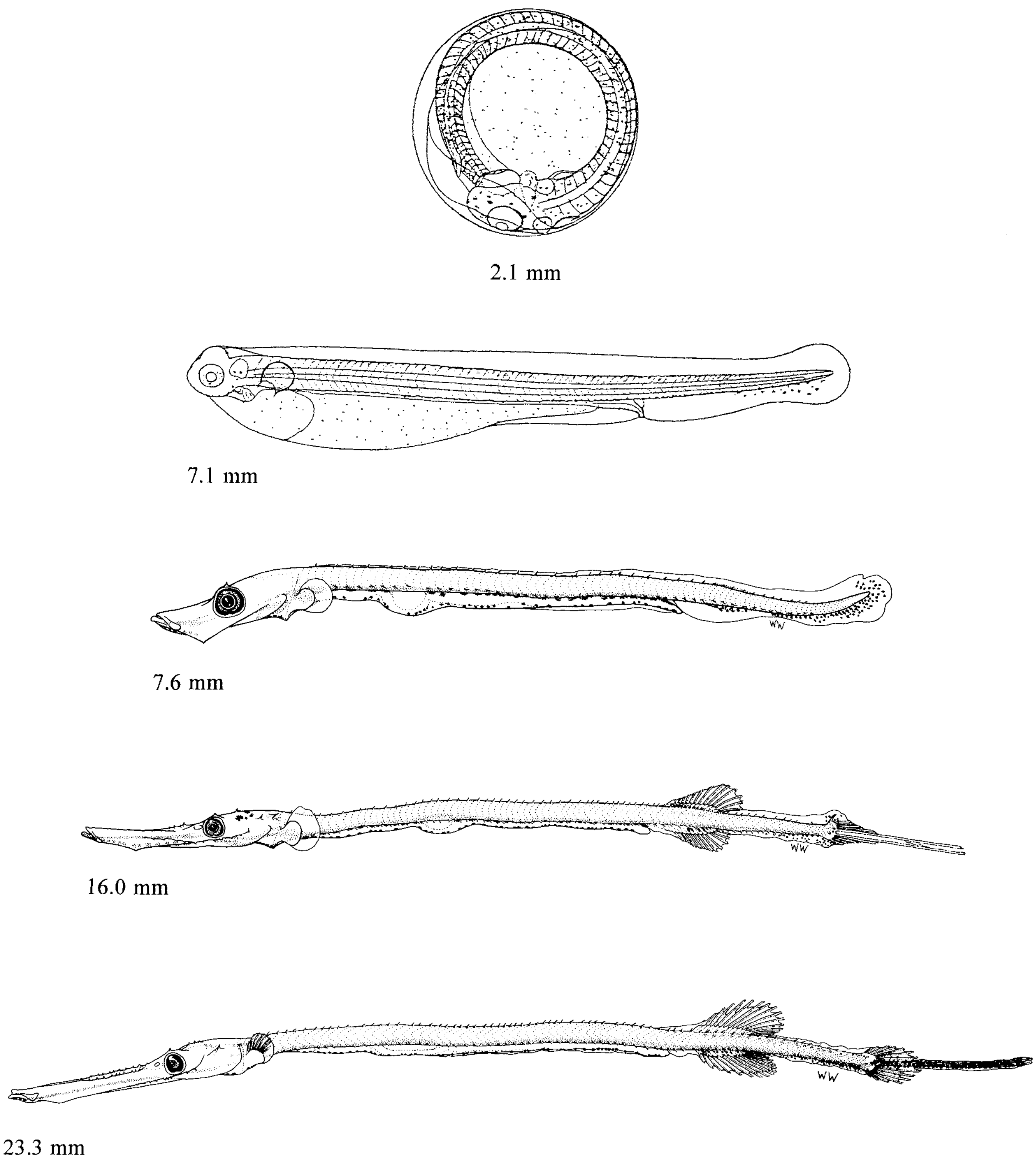


Figure Fistulariidae 1. Egg, ca. 2.1 mm; newly hatched yolk-sac larva, 7.1 mm (Mito 1961a); preflexion larva, 7.6 mm (IATTC 90001, station ASHA #2 Grn); late flexion larva, 16.0 mm (IATTC 91002, station T–7); postflexion larva, 23.3 mm (CalCOFI 5209, station 145.5G.27).

MERISTICS

	Range	Mode
Vertebrae:		
Total	75–76	76
Precaudal*	4+41–43	4+42
Caudal	28–31	30
Fins:		
Dorsal spines	0	0
Dorsal rays	17–20	18–19
Anal spines	0	0
Anal rays	16–19	17–18
Pelvic	6	6
Pectoral	15–18	17
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	7–8	8
Lower	7–8	7–8
Gill rakers:		
Upper		
Lower		
Branchiostegals	5	5

LIFE HISTORY

Range: Bahía San Hippolito, Baja California Sur, & Gulf of California to Bahía Chilco, Peru

Habitat: Pelagic & epibenthic, usually at depths >30 m along continental & insular margins

Spawning season: Larvae collected in summer & fall

ELH pattern: Oviparous; presumably, eggs planktonic; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 4.0 mm (N. Arthur)
Preflexion larva, 8.6 mm (N. Arthur)
Flexion larva, 13.0 mm (N. Arthur)
Postflexion larva, 19.4 mm (N. Arthur)

* The first four vertebrae are fused (Fritzsche 1976).
† Eye is oval, becoming round in flexion stage & oval again in postflexion stage; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3.5–4 mm
Flexion length: ca. 10–13 mm
Transformation length: ca. 60 mm
Fin development sequence: C_1, D & A, P, C_2, P_2
Pigmentation: *Yolk-sac–postflexion*—Laterally on dentary; on lower margin of preopercle; on branchiostegal membrane; double row from tip of lower jaw along gular membrane & isthmus continuing along sides of gut & along ventral margin of tail; row along ventral margin of gut; none to few on caudal finfold; on basibranchials & hypobranchial between 8–10 mm (usually none on hypobranchial before 10 mm); internally on hindbrain by 12 mm; on elongate central C rays by 12 mm; present or absent along A base & on anal finfold after ca. 12 mm.
Diagnostic features: Myomeres 44–47+30–32=74–78 (usually 46+30); D rays 17–20, A rays 16–19 (all present by ca. 20 mm); usually no hypobranchial pigment & little or no basibranchial pigment before 10 mm; compared with *F. commersonii*, more robust, notochord flexion & fin development begin at slightly smaller size.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	71–72 72	67–83 71	71–77 74	76–77 76		72–78 76
BD/BL	6–8 7	5–8 6	5–6 5	3–5 4		2–3 3
HL/BL	13–15 14	14–23 17	19–28 22	26–36 30		28–36 33
HW/HL	43–59 49	19–33 27	14–20 18	8–14 11		7–9 8
SnL/HL	22–38 28	22–56 38	48–58 50	59–72 67		72–87 80
ED/HL†	33–46× 23–32	15–27× 15–26	11–13	6–10× 5–9		7–8× 5–6
	38×28	20×18	12	7×7		7×6
P_1L/BL	2–3 3	2–4 3	2–4 3	2–4 3		4–4 4
P_2L/BL	0–0 0	0–0 0	0–0 0	0–2 0.2		1–2 1

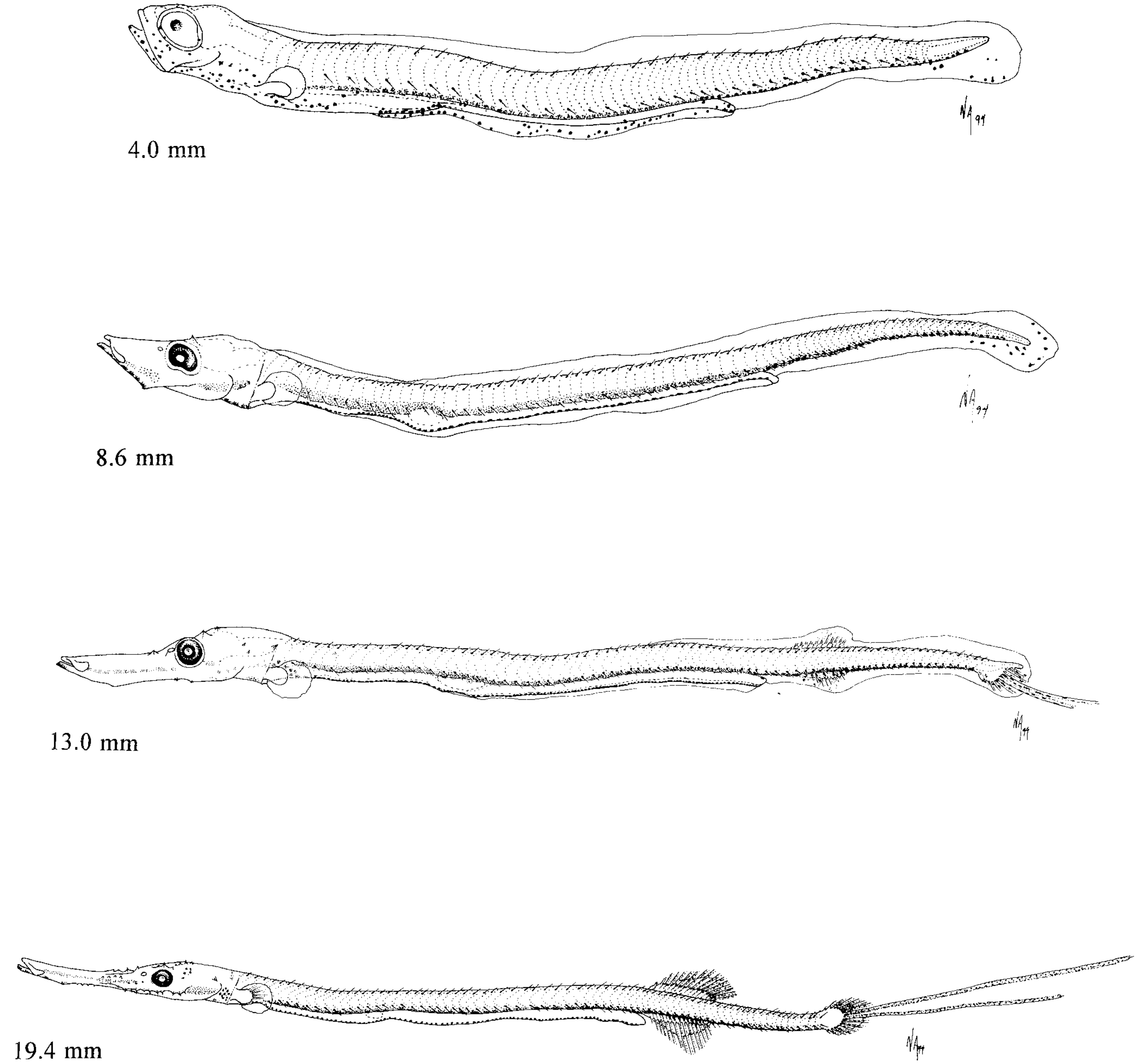


Figure Fistulariidae 2. Yolk-sac larva, 4.0 mm (CalCOFI 5209, 154G.12); preflexion larva, 8.6 mm (IATTC 89025, station PSB #1 Grn); flexion larva, 13.0 mm (CalCOFI 5209, 143.5G.21); postflexion larva, 19.4 mm (EASTROPAC II, station 50.247).

CENTRISCIDAE: Snipefishes and shrimpfishes

W. WATSON

The shrimpfishes and snipefishes commonly are placed in separate families (e.g., Heemstra 1986a; Nelson 1994) although Mohr (1937) considered them to be centriscid subfamilies. Eschmeyer (1990) likewise placed them in the centriscid subfamilies Centriscinae and Macroramphosinae, and we follow that arrangement here. The family is represented in our area by the slender snipefish, *Macroramphosus gracilis*. Mohr (1937) placed all slender-bodied *Macroramphosus* in *M. gracilis*, and the deeper-bodied species in *M. scolopax*. Ehrich (1976) subsequently argued that *M. gracilis* is merely the immature stage of *M. scolopax*; however, Clarke (1984) suggested that not only is *M. gracilis* distinct from *M. scolopax*, but *M. scolopax* itself may contain more than one species.

The slender snipefish occurs worldwide in warm seas; in the eastern North Pacific it ranges southward from Santa Monica Bay, California (Miller and Lea 1972). Larvae and juveniles occur throughout the year in CalCOFI ichthyoplankton samples from the vicinity of San Diego, California, to near Cabo San Lazaro, Baja California Sur. Adult *M. gracilis* are small (to ca. 16 cm) epi- and mesopelagic (to ca. 350 m) planktivores. They are compressed, with a long, tubular snout and small terminal mouth. The spinous dorsal fin originates just behind midbody. Its second spine is thicker and longer than the others. The segmented ray portion of the dorsal fin is far posterior. Slender snipefishes usually are blue to green dorsally and silvery below.

Snipefishes are oviparous with planktonic eggs and larvae. Eggs of *M. scolopax* are spherical, 1.0 mm in diameter, with a single dark rose-colored oil globule 0.2 mm in diameter, and a rose- to violet-colored yolk (Fage 1918; Sparta 1936). Newly hatched Atlantic *M. scolopax* are 3.0 mm long, with partially formed mouth, partially pigmented eyes, and moderate yolk sac with posterior oil globule (Sparta 1936). Recently hatched eastern Pacific *M. gracilis* are ca. 2.5 mm and similarly developed. Larvae initially are moderately elongate, slightly compressed, with a straight gut extending to 55–60% BL. The snout is short and the eye somewhat oval. The body becomes deeper and more compressed, preanal length increases to ca. 75% BL, the eye becomes round, and the snout elongates slowly through the postflexion stage, then rapidly during transformation. The body is covered with spinules, beginning with a single row along the lateral midline of the tail during the preflexion stage. Spinules are added cephalad in this row and a ventrolateral row is added along each side of the gut. Next, spinules spread over the abdominal area and onto the tail and a dorsolateral row is added on each side. Lastly, the dorsal and dorsolateral areas between rows are filled. Frontal, epiotic, and pterotic crests and spines, as well as preopercular spines form during the preflexion and flexion stages. The enlarged second dorsal fin spine is first to form and always is largest. Larval pigmentation initially occurs on the snout, under the brain, above the gut, on the oil globule, and on the dorsal and ventral margins of the tail. Melanophores form along the lateral midline of the tail concurrently with spinule formation. The dorsal pigment spreads cephalad and ventrad, and melanophores form on the head and spread ventrad on the gut during the preflexion stage. Larvae are heavily pigmented by the postflexion stage. Eastern Pacific *M. gracilis* may develop more rapidly than *M. scolopax*; for example, rays are present in all fins by 8 mm and transformation is complete by about 13 mm in *M. gracilis*, but pelvic fin rays do not develop until after 13 mm in *M. scolopax* (D'Ancona 1933).

Larval snipefishes should not be confused with any other larvae in the CalCOFI study area. The body spinules, spines and ridges on the head, elongate tubular snout, and enlarged second dorsal fin spine, all of which are at least partially formed during the preflexion stage, should allow positive identification.

The following description is based on detailed examination of 23 larvae (2 yolk-sac, 2.5 and 2.6 mm; 9 preflexion, 2.8–4.7 mm; 3 flexion, 4.9–5.4 mm; 5 postflexion, 5.6–7.2 mm; 4 transformation, 8.3–12.3 mm) and 3 juveniles (14.2–16.8 mm). Meristic data were obtained from Miller and Lea (1972) and from counts made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	23–24	23
Precaudal	8–9	8
Caudal	14–16	15
Fins:		
Dorsal spines	IV–VIII	V
Dorsal rays	10–13	11
Anal spines	0	0
Anal rays	18–19	18–19
Pelvic	I,4–5	I,4
Pectoral	15–17	15
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	10–12	11–12
Lower	10–12	11–12
Gill rakers:		
Total	17–23	
Upper		
Lower		
Branchiostegals	4	4

LIFE HISTORY

Range: Worldwide in warm seas; Santa Monica Bay, California, & southward in CalCOFI study area.

Habitat: Epi- & upper mesopelagic (to ca. 350 m depth), may range into coastal waters.

Spawning season: Larvae collected throughout the year with largest catches October–March

ELH pattern: Oviparous; planktonic eggs (*M. scolopax*) & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.6 mm (R. C. Walker)
Preflexion larvae, 4.6 mm, 5.6 mm (H. M. Orr)
Postflexion larva, 7.5 mm (H. M. Orr)

* Eye is oval; horizontal axis is given first, vertical second.

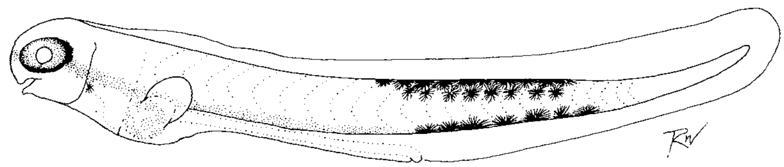
EARLY LIFE HISTORY DESCRIPTION

EGGS *M. scolopax*
Shell diam.: 1.0 mm **Yolk:**
No. of OG: 1 **Diam. of OG:** 0.2 mm
Shell surface:
Pigment: Yolk rose to violet, OG amber-rose; melanophores along sides of embryo & on OG in later stages
Diagnostic features:

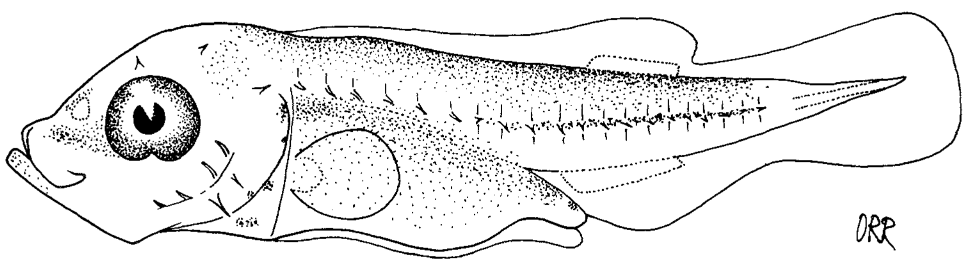
LARVAE
Hatching length: ca. 2.5 mm
Flexion length: 4.8–5.5 mm
Transformation length: ca. 8–13 mm
Fin development sequence: C_1, P_1, D, A, C_2, P_2
Pigmentation: *Yolk-sac*—Heavy on dorsum from myomere 8–9 to 20–21; series beginning under forebrain, continuing above gut & along ventral margin of tail to myomere 21–22; few on yolk sac; few along lower margins of gill covers. *Preflexion–postflexion*—Spreading forward on dorsum to midbrain by 3.2 mm and to tip of snout by 3.6 mm; spreading laterally from dorsum beginning in middle of tail by 3.3 mm; stripe along lateral midline at postanal myomeres 1–10; body becoming completely pigmented by 3.6–4.2 mm, except none on last 2–3 myomeres or ventrally on posterior part of gut or on fin membranes. *Transformation*—Completely pigmented except on P_1, P_2, 2D, A, & C; darker dorsally; stripe along lateral midline of tail remains visible through ca. 10 mm.
Diagnostic features: Myomeres 10–12+14–16=24–26; body becomes covered with spinules, beginning along lateral midline of tail in yolk-sac or early preflexion stage, extending forward to pterotic by 3.6 mm, abdominal series added by 4.2 mm; numerous ridges form on cranium.

MORPHOMETRICS (range & mean in %)

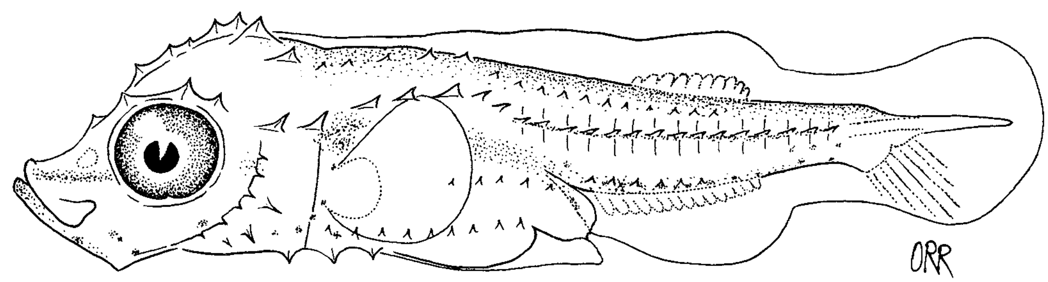
	YS	PrF	F	PoF	Tr	Juv
Sn-A/BL	57–60 59	58–64 61	56–62 60	70–77 73	73–74 73	69–76 73
BD/BL	14–14 14	15–24 20	21–24 22	27–29 28	23–27 25	22–23 23
HL/BL	19–22 21	26–33 29	32–36 33	41–46 43	45–49 46	45–47 46
HW/HL	48–50 49	40–50 45	42–44 43	37–42 39	30–38 34	30–31 31
SnL/HL	16–16 16	16–34 26	31–38 33	39–44 41	44–49 47	51–54 53
ED/HL*	36–36× 28–29	32–38× 27–35	30–34× 30–30	26–31× 24–28	23–27× 21–24	17–22× 17–20
	36×28	35×30	32×30	29×27	24×22	20×19
P_1L/BL	3–4 4	4–9 6	6–9 7	11–14 13	11–15 14	15–16 16
P_2L/BL	0–0 0	0–0 0	0–1 0.2	1–4 2	4–5 4	6–7 6



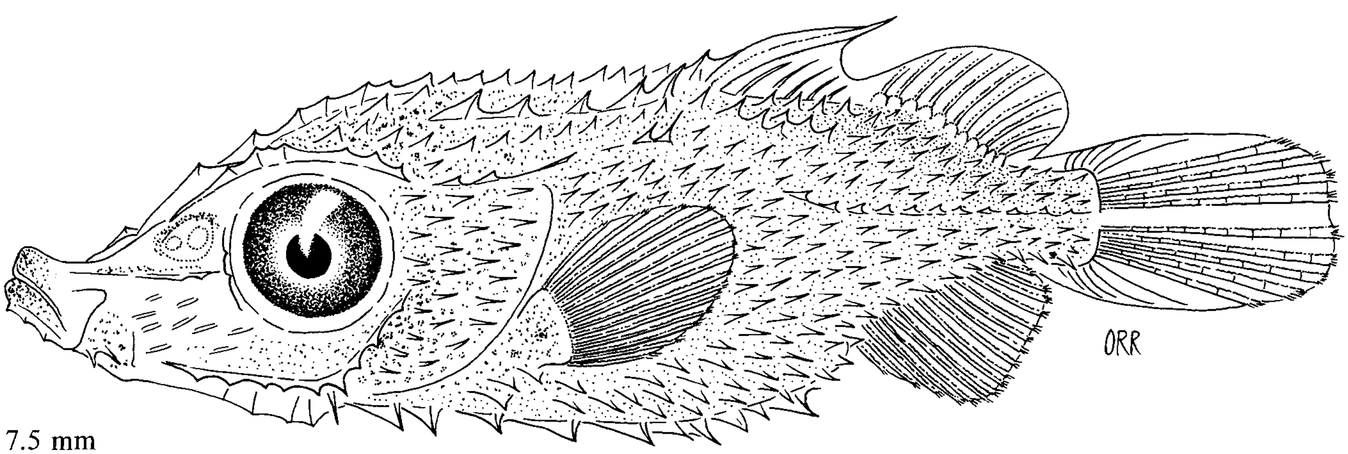
2.6 mm



4.6 mm



5.6 mm



7.5 mm

Figure Centriscidae 1. Yolk-sac larva, 2.6 mm (CalCOFI 6504, station 120.50); preflexion larvae, 4.6 mm, 5.6 mm; postflexion larva, 7.5 mm (CalCOFI). The enlarged second dorsal spine typically is present by 4.5 mm although it is not shown in the 4.6 mm and 5.6 mm specimens above.

SYNGNATHIDAE: Pipefishes and seahorses

W. WATSON AND E. M. SANDKNOP

Syngnathidae is represented in the California Current vicinity by one seahorse and eight pipefish species (Table Syngnathidae 1). Late larvae through adults of a few pipefishes, primarily *Cosmocampus arctus*, *Syngnathus californiensis*, and *S. exilis*, are taken occasionally in CalCOFI ichthyoplankton samples, mainly at inshore stations from summer through early winter.

Adult syngnathids are small to medium-size (maximum ca. 50 cm; most species <30 cm) tropical and temperate marine planktivores (a few species are estuarine and some may enter fresh water). Most are residents of coastal eelgrass and seaweed beds; some prefer rocky or coral reefs and a few are pelagic inhabitants of drift algae. All syngnathids are encased in an armor of bony rings, all have a moderate to long tubular snout with small terminal mouth, dorsal and anal fins composed entirely of segmented rays (anal fin absent in some), and all lack pelvic fins. Pipefishes are elongate, slender, cylindrical to moderately compressed, with the head aligned along the body axis, and they have a caudal fin. Seahorses are deeper-bodied, moderately to strongly compressed, with the head perpendicular to the body axis, and with a prehensile tail lacking a caudal fin. Syngnathid pigmentation typically is cryptic and highly variable, with browns and greens predominating. Some species are brightly colored.

Syngnathids are oviparous, with ellipsoidal to pear-shaped eggs that are incubated in a specialized brood chamber or attached to a broad patch on the male (e.g., Breder and Rosen 1966; James 1970; Hardy 1978a; Fritzsche 1984). Hatching occurs in the brood pouch in the species that have a pouch, and well developed young are released ca. 1–2 weeks after spawning. Commonly, the newly released young have all their body rings, full complements of rays in the dorsal and caudal fins, and often have developing rays in the anal and pectoral fins. Some genera release less developed young, for example, *Doryrhamphus* releases preflexion stage larvae that lack both body rings and fin rays. The young commonly are moderately to heavily pigmented, often with a barred pattern.

Young synganathids are distinctive and will not be confused with the larvae of any family in the CalCOFI area. Young *Hippocampus*, *Cosmocampus*, and *Doryrhamphus* are easily identified; however, the young of most of the *Syngnathus* species are difficult or impossible to distinguish from one another, except that young *S. californiensis* often can be identified by their very high dorsal fin ray and ring counts, while *S. leptorhynchus* often can be identified by their low counts (Table Syngnathidae 1) and habitat (bays and estuaries). The length and shape of the snout and meristics are used to separate most of the *Syngnathus* species (Fritzsche 1980); however, snout features are not useful for young smaller than ca. 50 mm since all have short, oval (in cross-section) snouts. Use of modal ring and dorsal fin ray counts may permit identification to the "most likely" species, but usually does not lead to certain identification. Pigmentation is variable within species and sufficiently similar between species to be of little use in identification.

Detailed descriptions of young syngnathids are not given here. Instead, the seahorse and four pipefish species are illustrated in Figures Syngnathidae 1 and Syngnathidae 2, and morphometric data are summarized in Table Syngnathidae 2. Refer to Fritzsche (1980) and Wang (1981) for additional information.

Table Syngnathidae 1. Meristic characters for the syngnathid species in the California Current vicinity. The pipefishes all have 5+5 caudal fin rays; the seahorse, *Hippocampus ingens*, lacks a caudal fin. All syngnathids lack pelvic fins. Geographic abbreviations: BCS, Baja California Sur; CA, California; Gulf, Gulf of California.

Species	Rings: Trunk	Rings: Tail	Rings: Total	Fin rays: D	Fin rays: A	Fin rays: P_1	Geographic range
Cosmocampus arctus	14–16	36–41	53–56	18–23	2–3	10–11	Tomales Bay, CA to Mazatlán, Mexico, including Gulf
Doryrhamphus excisus excisus	16–19	14–17	35	22–27	4	19–23	Bahía Magdalena, BCS to Ecuador and offshore islands
Hippocampus ingens	11–13	36–41	48–53	17–22	4–5	15–17	San Francisco Bay, CA to Peru, including Gulf
Syngnathus auliscus	14–16	34–39	50–55	26–33	2–3	10–14	Santa Barbara Channel, CA to Peru, including Gulf
S. californiensis	19–22	46–52	66–72	39–48	3–5	12–14	Bodega Bay, CA to Bahía Santa Maria, BCS including offshore islands
S. euchrous	18–20	41–49	60–68	33–45	3	11–14	Redondo Beach, CA to Bahía Ballenas, BCS
S. exilis	17–21	43–50	63–68	35–43	3	11–14	Halfmoon Bay, CA to Bahía Magdalena, BCS, including offshore islands
S. insulae	17–19	40–42	58–60	31–34	2–4	10–12	Isla de Guadalupe, Mexico
S. leptorhynchus	16–21	36–46	53–64	28–43	2–3	11–13	Southeastern Alaska to Bahía Santa Maria, BCS

Table Syngnathidae 2. Morphometric characters for the young of five syngnathid species in the California Current vicinity. Ranges are given above, means are below. L = larvae (full fin ray complements not yet present in all fins); J = juveniles (full fin ray complements present in all fins). Newly released *Hippocampus ingens* and *Syngnathus leptorhynchus* have full fin ray complements in all fins.

Morphometric ratio	*Cosmocampus arctus* L	*Cosmocampus arctus* J	*Doryrhamphus excisus excisus* L	*Doryrhamphus excisus excisus* J	*Hippocampus ingens* L	*Hippocampus ingens* J	*Syngnathus californiensis* L	*Syngnathus californiensis* J	*S. leptorhynchus* L	*S. leptorhynchus* J
Sn-A/BL	42–47 44	35–40 37	67–70 69	68–71 70		46–64 56	37–40 38	38–40 39		40–44 42
BD/BL	4–7 6	3–4 3	6–9 8	6–7 7		8–11 9	3–3 3	2–3 3		3–4 4
HL/BL	16–19 18	12–17 14	24–28 26	26–28 27		21–31 28	13–14 13	12–14 13		14–17 16
HW/HL	23–36 28	19–26 23	20–30 25	26–29 28		21–32 26	23–23 23	20–27 22		24–31 27
SnL/HL	37–49 44	32–45 41	39–41 40	39–43 41		42–55 47	43–46 45	41–49 44		36–44 40
ED/HL	12–25 19	12–15 14	20–27 23	15–19 17		8–21 17	15–17 16	14–17 15		14–21 17
P_1L/BL	2–4 3	2–3 3	4–4 4	4–5 4		4–6 5	2–2 2	2–2 2		2–3 2
Number of specimens	3	10	2	6	0	12	2	7	0	10
Size range (mm)	7.6–15.6	21.6–33.0	4.4–8.1	15.2–22.2		8.2–32.4	21.0–23.4	28.8–49.2		16.0–41.6

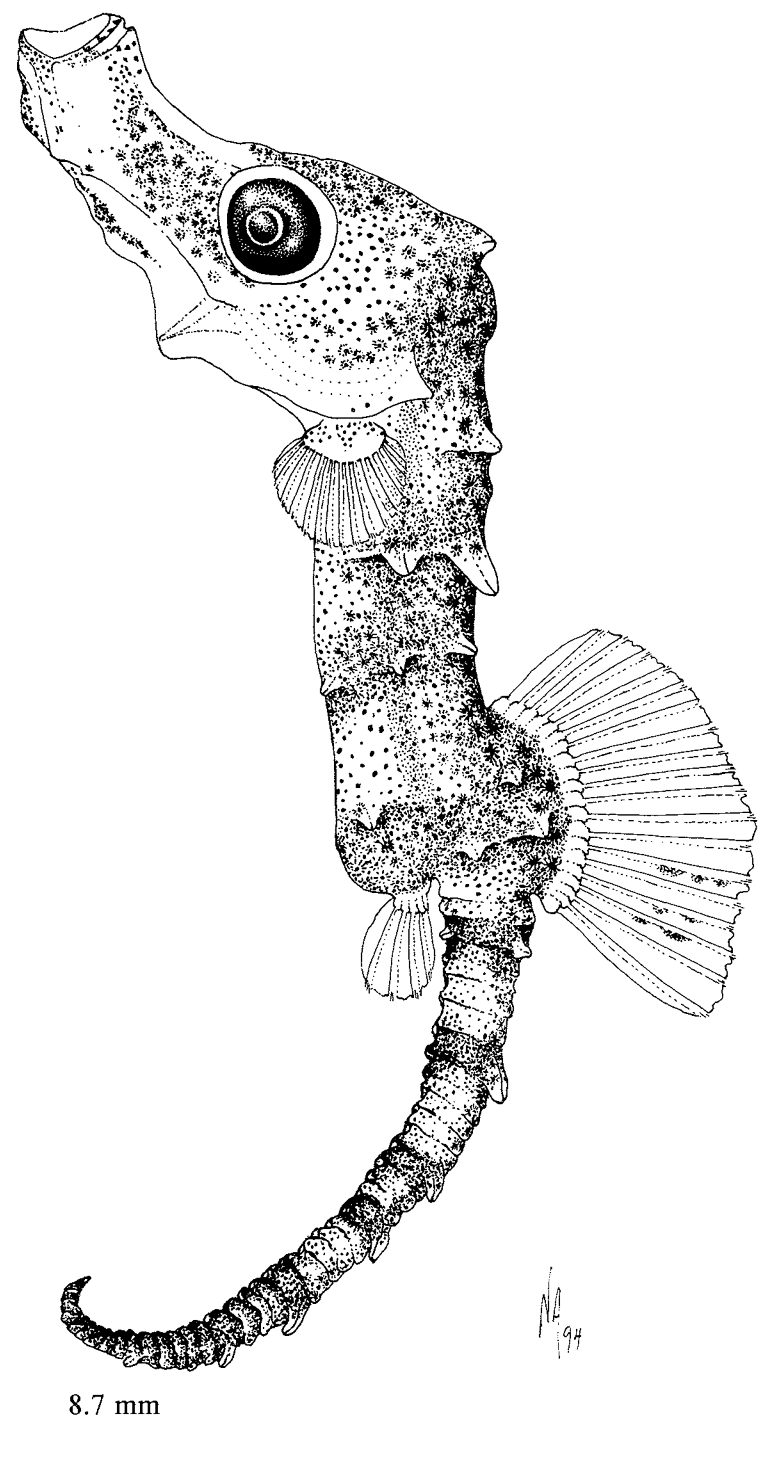


Figure Syngnathidae 1. Newly released *Hippocampus ingens* young; composite of 8.7 mm (body) and 8.8 mm (dorsal and anal fins) specimens (CFRD Ref. Coll., reared at Stephen Birch Aquarium-Museum, July 22, 1994; original illustration by N. Arthur).

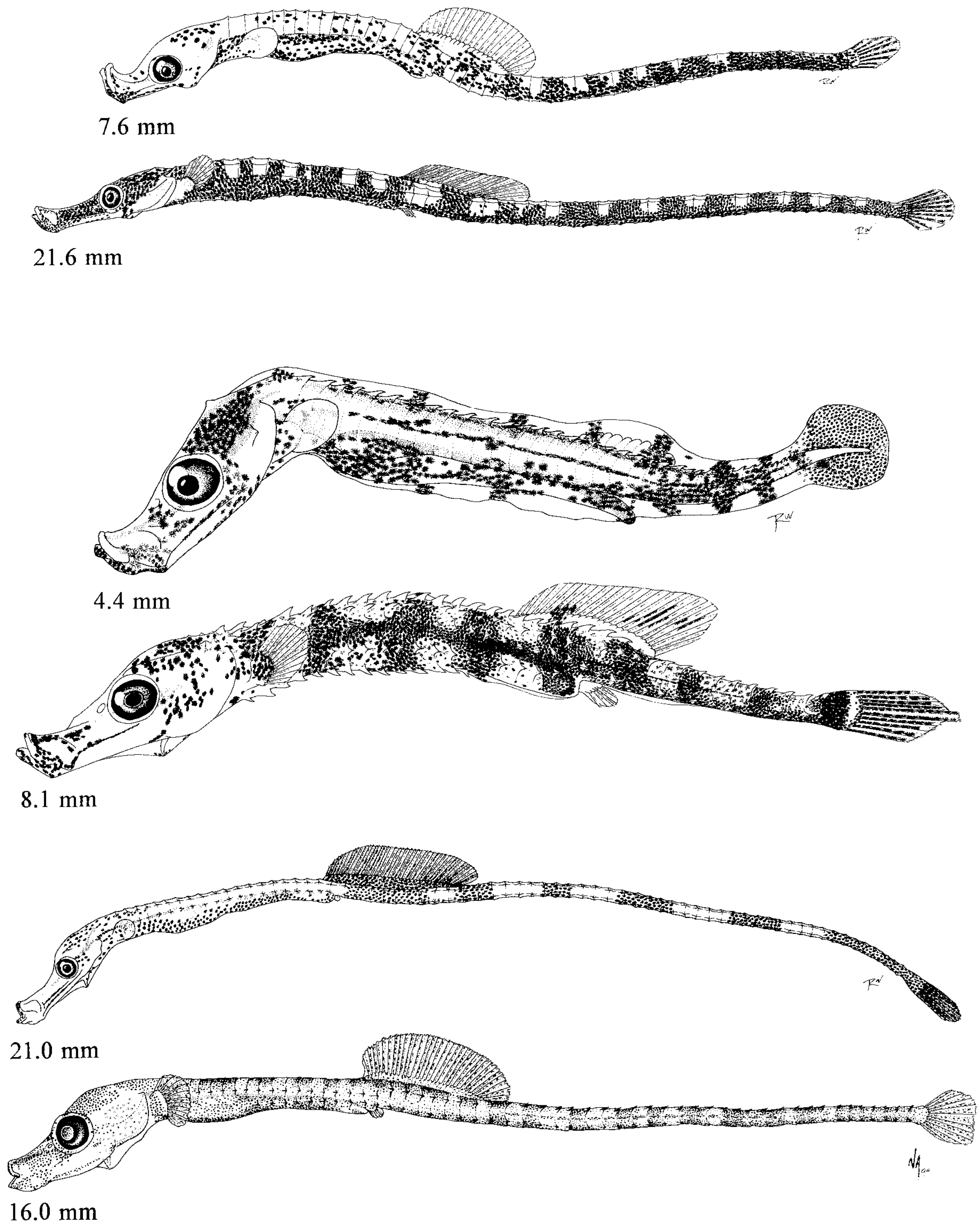


Figure Syngnathidae 2. *Cosmocampus arctus*, recently released 7.6 mm (MEC I–III, station LB–M; original illustration by R. C. Walker), juvenile 21.6 mm (CalCOFI 7808, station 130.35; original illustration by R. C. Walker); *Doryrhamphus excisus excisus*, preflexion larva 4.4 mm (IATTC 90018, station ASL #1 Grn; original illustration by R. C. Walker), late postflexion larva 8.1 mm (IATTC 90017, station B9; original illustration by R. C. Walker); *Syngnathus californiensis*, recently released 21.0 mm (CalCOFI 6601, station 87.33; original illustration by R. C. Walker); *S. leptorhynchus*, newly released 16.0 mm (Reared, SWFSC, 17 June 1974; original illustration by N. Arthur).

SCORPAENIFORMES

H. G. MOSER

Scorpaeniformes, the "mail-cheeked fishes," is a large percomorph group of 25 families, 266 genera, and more than 1,200 species (Nelson 1994). Monophyly is based on the presence of a suborbital stay, formed by an elongation of the third infraorbital bone, that usually is connected to the preopercular bone. Although it has often been suggested that the suborbital stay may have evolved independently and that the order is polyphyletic, the classifications of most workers are based on assumed monophyly with Scorpaeniformes considered either a "pre-perciform" sister group or a perciform derivative (Matsubara 1943; Quast 1965; Greenwood et al. 1966; Poss 1975; Washington et al. 1984a,b; Johnson 1993, Ishida 1994). Johnson and Patterson (1993) questioned a "pre-perciform" position for the group and favored subsuming it in Perciformes as a suborder, if only to stimulate a search for additional characters that might clarify relationships of these fishes. Eschmeyer (1990) and Nelson (1994) list them as an order and differ only in the subordinal status of Normanichthyidae: Eschmeyer (1990) included it in Cottoidei and Nelson (1994) assigned it to its own suborder.

Four suborders, the Scorpaenoidei, Anoplopomatoidei, Hexagrammoidei, and Cottoidei, are represented in the CalCOFI region. All four include species of ecological and commercial importance and the scorpaenoids and cottoids are particularly diverse and abundant. Primarily, scorpaeniforms are demersal fishes although some are semi-pelagic and may make extensive movements. They occupy virtually all habitats, from fresh water and the intertidal zone to the greatest depths of the continental slope. They have a vast array of reproductive modes, from the production of free-floating planktonic eggs or buoyant gelatinous egg masses, to nesting with parental care, to live-bearing, and their early life histories and ontogenetic specializations are equally diverse and complex (Washington et al. 1984b).

Suborders and families included:

- Scorpaenoidei
  - Scorpaenidae
  - Triglidae
- Anoplopomatoidei
  - Anoplopomatidae
- Hexagrammoidei
  - Hexagrammidae
- Cottoidei
  - Cottidae
  - Psychrolutidae
  - Agonidae
  - Cyclopteridae

SCORPAENIDAE: Scorpionfishes and rockfishes

H. G. Moser

Scorpaenids are a highly diverse group of fishes found in the tropical, temperate, and boreal Atlantic and Pacific Oceans, the Indian Ocean, and the Mediterranean Sea. Most of the dozen subfamilies and >56 genera are in the Indo-Pacific (Washington 1984a; Nelson 1994) but three subfamilies (Sebastinae, Scorpaeninae, and Sebastolobinae) inhabit the California Current region (Table Scorpaenidae 1). The temperate-boreal sebastine genus *Sebastes* (rockfishes) has undergone a spectacular radiation in the North Pacific and accounts for about one-third of all scorpaenid species. Of the approximately 110 *Sebastes* species, four are in the North Atlantic, one is found off South Africa and South America, ca. 28 occur in the northwestern Pacific and the remainder are in the northeast Pacific. Approximately 65 species occur in the California Current region and 7 (all endemic, except *S. macdonaldi*) are known from the Gulf of California (Miller and Lea 1972; Chen 1975; Eschmeyer et al. 1983; Poss 1995). *Sebastes* larvae are a major component of CalCOFI ichthyoplankton collections and usually rank third or fourth among all fish larvae taken annually on plankton surveys. They occur throughout the sampling pattern although occurrences and mean abundance diminish sharply off southern Baja California. *Sebastes* larvae rank equally high in occurrence and abundance in plankton surveys north of the CalCOFI area (Doyle 1992). Two sebastolobine (thornyhead) species, *Sebastolobus alascanus* and *S. altivelis*, occur in the CalCOFI region (Moser 1974). Like *Sebastes*, they are temperate-boreal fishes and *S. alascanus* ranges westward to Japan. Their larvae are not abundant in CalCOFI collections. Scorpaenines are tropical-subtropical; three genera (*Pontinus*, *Scorpaena*, and *Scorpaenodes*) are taken relatively rarely in the southern part of the CalCOFI sampling pattern.

Scorpaenids are medium to large (to >90 cm) fishes with a compressed to robust body, large head, and moderate to large eyes. Typically, there are two opercular spines, three to five preopercular spines, and prominent head ridges armed with spines. The dorsal fin is continuous, with a notch posteriorly on the spinous part. In our region, counts for dorsal spines range from 12 to 17 and dorsal rays from 8 to 17. There are 3 anal spines and 3–11 rays. The pelvic fin formula is I,5 and there are 14–24 pectoral rays (Table Scorpaenidae 1). The pectoral fins are rounded to wedge-shaped; in *Sebastolobus* they have a ventral lobe. The caudal fin varies from rounded to slightly forked. Dorsal, anal, and pelvic spines are strong, have venom sacs at their bases, and grooves that conduct the venom to the tips. Scorpaenids are often brightly colored with distinct patterns. Scales may be cycloid or ctenoid and the lateral line scales form a canal that extends onto the caudal fin. *Sebastes* has a prominent gas bladder while *Sebastolobus* and most scorpaenines do not, although all have a gas bladder in the larval stage.

The many *Sebastes* species occupy a variety of habitats from the intertidal zone to mid-slope. Some occupy reefs, others are soft-bottom species, while some are semi-pelagic, forming plumes over bottom features or even moving extensively through midwater. Species that are limited to benthic reef habitats tend to have a robust body and strong head spines whereas semi-pelagic species are compressed to terete and head spination is weak to nearly absent. *Sebastolobus* occupies soft-bottom habitats from the deep shelf to the limits of the continental slope. Scorpaenines are nearshore reef species although some may occur on soft bottom.

Scorpaenids sustain important commercial and sport fisheries throughout the world. Particularly, *Sebastes* is extremely important in the bottom trawl fisheries of both the North Atlantic and North Pacific and is the mainstay of the California sport fishery (Leet et al. 1992; Low 1993). Continental slope populations of the two *Sebastolobus* species have been exploited heavily by trawl and trap fisheries during the past decade (Jacobson 1993).

Scorpaenids have a large array of reproductive specializations. Most of the subfamilies are oviparous and some, like the choridactylines, spawn individual, round eggs. Sebastolobine, scorpaenine, and pteroine species for which information is available are oviparous and spawn bilobed, gelatinous floating egg masses that contain slightly elliptical eggs with homogeneous yolk, with or without an oil globule. The sebastines are live-bearers and the larvae are extruded from the female at a stage of development equivalent to the first-feeding stage of other marine fishes. Brood size is unusually large for live-bearers (up to ca. 2 million in large species) and some species have multiple broods (Phillips 1964; Moser 1967a,b; MacGregor 1970; Love et al. 1990; Boehlert and Yamada 1991). Maternal nutrition has been demonstrated in *Sebastes*, although most of the energy for development is derived from the considerable yolk in the egg (Boehlert and Yoklavich 1984).

In sebastolobines, scorpaenines, and apparently in other scorpaenid subfamilies the integument of newly hatched larvae has an inflated appearance and is vesiculate, while in *Sebastes* inflation is less apparent and vesicles appear on a limited area of the finfold. Also, the pectoral fin base is narrower in sebastines than in the other subfamilies in the region. *Sebastolobus* is unique in having apposing postanal midline blotches rather than a postanal ventral series of melanophores. *Sebastolobus* and *Scorpaenodes* have an enlarged parietal ridge terminating in bifurcate spines with the posterior (nuchal) spine larger than the anterior (parietal) spine. In all other genera in the region the nuchal spine is inserted on the skull and is smaller than the parietal spine. *Sebastolobus* has a higher myomere count than *Scorpaenodes* (28–31 vs. 23–25) and different gut pigment (melanistic shield over the gut vs. pigment only above the gas bladder in *Scorpaenodes*). *Pontinus* and *Scorpaena* have 24 myomeres but the pectoral fin is wing-shaped in *Pontinus* and rounded or fan-shaped in *Scorpaena*. Also, *Scorpaena* has a melanistic shield over the gut whereas *Pontinus* has pigment only above the gas bladder. The same characters useful in species identification of *Sebastes* larvae are applicable to sebastolobine and scorpaenine larvae.

The planktonic larvae of rockfishes live in the upper 80 m of the water column for one to two months, then transform into pelagic juveniles that occupy a variety of habitats for one to several months before settling (Moser et al. 1977; Sumida and Moser 1984; Kendall and Lenarz 1987; Lenarz et al. 1991; Moser and Boehlert 1991; Larson et al. 1994). Rockfish larvae have received much attention because of their abundance in plankton collections, the commercial and ecological importance of the adults, and the potential utility of early and late larval stages in estimating spawning biomass and recruitment. Identification of early larval stages is confounded by a large number of co-occurring species, overlapping meristic characters, and a paucity of morphological and pigment characters. All ontogenetic stages are known for about 13 species: *S. auriculatus* (Stahl-Johnson 1985; Kendall 1989; Matarese et al. 1989), *S. aurora* (Moser et al. 1985), *S. caurinus* (Stahl-Johnson 1985), *S. dallii* (Moser and Butler 1981), *S. diploproa* (Matarese et al. 1989; this study), *S. goodei* (Sakuma and Laidig 1995), *S. jordani* (Moser et al. 1977), *S. levis* (Moser et al. 1977), *S. macdonaldi* (Moser 1972), *S. melanops* (Laroche and Richardson 1980; Kendall 1989; Matarese et al. 1989), *S. melanostomus* (Moser and Ahlstrom 1978), *S. paucispinis* (Moser 1967a), and *S. pinniger* (Waldron 1968; Richardson and Laroche 1979). Complete life histories are known for an additional two species (*S. saxicola*, Sakuma, Laidig, and Nishimoto, in prep.; *S. alutus*, Kendall, in prep.). Descriptions of individual stages and partial series of preflexion and postflexion larvae of many other rockfish species have been based on late intraovarian larvae, post-partum reared larvae, and postflexion larvae traced backward from juveniles (Moser et al. 1977; Richardson and Laroche 1979; Laroche and Richardson 1980, 1981; Kendall and Lenarz 1987; Kendall 1989, 1991; Matarese et al. 1989; Moreno 1993). Matarese et al. (1989) presented an extensive review of rockfish early life histories as well as descriptions of ontogenetic stages of a large number of species. The most useful characters for identification of preflexion larvae are pigment pattern (e.g., the arrangement and composition of postanal dorsal and ventral midline series, pectoral fin, and head pigment) and morphological characters such as pectoral fin shape and head spine development. In addition to these, meristics of developing fins are useful in identification of postflexion larvae and pelagic juveniles. Numbers of lateral line pores and gill rakers are important characters for identifying pelagic juveniles. Pelagic juveniles of most species can now be identified (Matarese et al. 1989) and results from survey cruises show that their distribution and abundance may be useful in predicting year-class strength (Larson et al. 1994; Ralston and Howard 1995).

The arrangement and structure of the head spines are important features of *Sebastes* larvae (Figure Scorpaenidae 1; Phillips 1957; Washington et al. 1984b; Matarese et al. 1989). Pterotic, parietal (usually serrated), and preopercular spines form in preflexion larvae of most species. The pterotics are usually the first to form, followed by the third preopercular spine (the largest and strongest spine in the posterior preopercular series). Other spines form gradually during flexion and preflexion stages and all spines that will be present in the juvenile and adult are present before transformation. Certain spines (e.g., pterotic, anterior preopercular series, lower posttemporal) that develop in *Sebastes* larvae are not present in adults of any species. Remnants of the upper infraorbital series of larvae are present in some species (e.g., *S. aleutianus*) as minute spines below the orbit. Adults of species with weak or obsolete spination on top of the head (e.g., *S. goodei*, *S. jordani*, *S. paucispinis*) typically have a full complement of prominent larval spines. These become reduced late in the larval period and in juveniles. In species with spiny-headed adults, the dorsal head spines continue to develop through transformation and the juvenile stages. Richardson and Laroche (1979) and Laroche and Richardson (1980, 1981) provided detailed descriptions of head spines in postflexion larvae, transformation specimens, and juveniles of seven species (*S. crameri*, *S. entomelas*, *S. flavidus*, *S. helvomaculatus*, *S. melanops*, *S. pinniger*, and *S. zacentrus*) and showed that head spination is useful (along with meristics and pigment patterns) in species separation. The sequence of development and the morphology of head spines in complete developmental series has been described for *S. macdonaldi* (Moser 1972), *S. melanostomus* (Moser and Ahlstrom 1978), *S. dallii* (Moser and Butler 1981), and *S. aurora* (Moser et al. 1985). Interspecific variation in larval head spine complements and structure will be increasingly more useful in identification of earlier larval stages as additional complete series become known.

Progress in identification of larval rockfishes has been slow, owing to the huge species complement, the preponderance of small larvae (ca. 90% <7 mm in length) in collections from standard plankton net tows, and the limited number of taxonomic characters present in these small stages. The rearing of newborn larvae from identified females has been a valuable tool in identification of some species (e.g, Moser and Butler 1981, 1987; Kendall 1989; Moreno 1993); however, rockfish larvae have proven to be difficult to rear and this has limited the utility of this method. Moreover, the early larvae of some closely related species may not be separable by usual taxonomic methods. An example is the subgenus *Sebastomus* which includes 10 species in the CalCOFI region (Chen 1971; Eschmeyer et al. 1983). Seven of these species have been reared to the point of yolk exhaustion (Figure Scorpaenidae 2) and share a distinct suite of characters at this stage (e.g., pigment on the lower jaw and dorsally and ventrally on the gut, a ventral postanal series of melanophores, and pectoral fin pigment that is accentuated at the margin). Later preflexion-postflexion stages retain these characters and develop heavy pigment on the brain and strong parietal (serrated) and preopercular spines (Moser et al. 1977; Richardson and Laroche 1979; Moser and Butler 1987). Late postflexion *Sebastomus* larvae develop a broad pigment saddle below the spinous dorsal fin and a blotch or a saddle on the caudal peduncle (Figure Scorpaenidae 2; Richardson and Laroche 1979; Matarese et al. 1989). The slow progress in identification of preflexion larvae of rockfishes has impeded their use in population estimation; however, this problem may be solved by recent advances in rockfish biochemistry and genetics that could provide new methods for identification of these early stages (Seeb and Kendall 1991; R. D. Vetter and B. J. Eitner, SWFSC, pers. comm.).

Descriptions of 13 complete series and 8 partial series of *Sebastes* species are included in the guide, based largely on the literature (see citations above). Additional specimens were measured for *S. diploproa*, *S. levis*, and *S. melanostomus* (Table Scorpaenidae 3). Descriptions of *Pontinus sierra*, *Pontinus* sp. (adult undescribed), *Scorpaena guttata*, *Scorpaenodes xyris*, *Sebastolobus alascanus*, and *Sebastolobus altivelis* are based mainly on the literature (Moser et al. 1977; Matarese et al. 1989). Eggs of *Scorpaenodes xyris* and additional juvenile specimens of *Pontinus sierra* and *Scorpaena guttata* were measured (Table Scorpaenidae 3). Meristics are from the literature (primarily Miller and Lea 1972; Chen 1986; Matarese et al. 1989) and from counts made during this study. General life history and ecological information were obtained mainly from Miller and Lea (1972), Eschmeyer et al. (1983), Wyllie Echeverria (1987), Love (1991), and Poss (1995).

Table Scorpaenidae 1. Geographic ranges and meristic characters for species of *Sebastes* species in the CalCOFI region. All species have three anal spines, one pelvic spine with five rays, and 8+7 principal caudal fin rays. Data primarily from Miller and Lea (1972), Chen (1986), and Matarese et al. (1989). Abbreviations: AK, Alaska; BCA, Baja California; BRT, British Columbia; C, central; CA, California; G, Gulf; N, northern; OR, Oregon; S, southern; SE, southeast; WA, Washington.

		Fin rays						
		Dorsal						
Species	Distribution	Spines	Rays	A	P_1	Vertebrae	GR (first arch)	Lateral line pores
Sebastinae								
Sebastes aleutianus	Bering Sea to S CA	XIII–XIV	12–15	6–8	17–19	27	28–35	29–34
S. alutus	Bering Sea to S CA	XIII–XIV	13–17	6–9	15–19	27	30–39	44–55
S. atrovirens	N CA to C BCA	XIII	13–15	6–7	16–18	26	28–35	36–45
S. auriculatus	SE AK to C BCA	XIII	12–15	5–8	15–19	26–27	25–30	42–50
S. aurora	S BRT to C BCA	XIII	12–14	5–7	16–19	26	24–28	27–31
S. babcocki	Bering Sea to S CA	XIII	13–15	6–8	17–20	26	29–33	41–51
S. borealis	Bering Sea to C CA	XIII–XIV	12–15	6–8	17–20	27–28	27–31	28–32
S. brevispinis	Bering Sea to S CA	XIII	13–17	7–8	16–18	26	33–36	44–53
S. carnatus	N CA to C BCA	XIII	12–14	5–7	16–18	26	23–30	35–49
S. caurinus	G of AK to C BCA	XIII	11–14	5–7	16–18	25–26	26–32	37–47
S. chlorostictus	WA to C BCA	XIII	11–15	5–7	16–18	26–27	31–36	35–43
S. chrysomelas	N CA to C BCA	XIII	12–14	5–7	17–18	26	25–30	35–46
S. constellatus	C CA to S BCA	XIII–XIV	12–14	5–7	16–18	25–26	25–30	37–47
S. crameri	Bering Sea to S CA	XII–XIII	12–15	6–7	18–20	26	29–34	40–51
S. dallii	C CA to C BCA	XII–XIV	12–14	6–7	16–17	26–27	31–36	37–51
S. diploproa	SE AK to C BCA	XIII	11–14	5–8	17–19	26	32–37	32–43
S. elongatus	G of AK to C BCA	XIII	12–14	5–7	16–18	26	28–33	37–47
S. emphaeus	G of AK to N CA	XIII	13–15	6–8	16–18	27–28	37–43	39–47
S. ensifer	C CA to C BCA	XIII	12–14	5–7	16–18	26	34–40	34–44
S. entomelas	G of AK to N BCA	XIII	14–16	7–9	17–19	26–27	34–47	52–60
S. eos	C CA to C BCA	XIII	11–13	5–7	17–18	26	26–31	34–42
S. flavidus	G of AK to N BCA	XII–XIII	14–16	7–9	17–19	26	33–39	46–60
S. gillii	C CA to N BCA	XIII	13–15	6–8	18–20	26	26–30	40–46
S. goodei	S BRT to S BCA	XIII	13–16	7–9	16–18	26	34–39	48–57
S. helvomaculatus	G of AK to S CA	XII–XIV	12–14	6–7	15–18	26	28–33	34–45
S. hopkinsi	C CA to C BCA	XII–XIV	14–17	6–7	16–18	27	35–43	49–58
S. jordani	S BRT to N BCA	XIII	13–16	8–11	19–22	26	40–47	52–64
S. lentiginosus	S CA to N BCA	XIII	12–13	6–7	16–18	26	34–39	33–41
S. levis	C OR to C BCA	XIII–XIV	12–13	6–7	17–18	26	29–32	45–53
S. macdonaldi	C CA to G of CA	XII–XIV	12–14	7–8	18–20	26	35–42	53–58
S. maliger	G of AK to C CA	XIII	11–14	6–7	16–18	26	29–33	34–48

Table Scorpaenidae 1. Continued.

Species	Distribution	Fin rays: Dorsal Spines	Rays	A	P_1	Vertebrae	GR (first arch)	Lateral line pores
S. melanops	G of AK to S CA	XIII–XIV	13–16	7–9	18–20	26	33–40	45–55
S. melanosema	S CA to C BCA	XIII	11–12	6	17–18	26	34–37	35–43
S. melanostomus	WA to C BCA	XIII	12–15	6–8	17–20	26–27	27–35	28–33
S. miniatus	S BRT to C BCA	XIII	13–15	6–8	16–18	26	35–43	40–48
S. mystinus	G of AK to N BCA	XIII	15–17	8–10	16–19	26–27	32–38	44–56
S. nebulosus	SE AK to S CA	XIII	12–14	6–8	17–19	26	26–31	37–43
S. nigrocinctus	SE AK to C CA	XII–XIV	12–15	6–7	18–20	26	27–32	36–50
S. ovalis	C OR to N BCA	XIII	13–16	7–8	17–19	27	29–34	45–55
S. paucispinis	G of AK to C BCA	XIII–XV	13–16	8–10	14–16	26	27–32	51–70
S. phillipsi	C CA to S CA	XIII–XIV	12–13	5–6	18–19	26–27	36–40	29–33
S. pinniger	G of AK to N BCA	XIII	13–15	7	16–18	26	40–45	39–47
S. proriger	Bering Sea to S CA	XIII	13–16	6–7	16–18	27	36–43	46–55
S. rastrelliger	C OR to C BCA	XIII	12–14	6	18–20	26	17–25	40–49
S. reedi	SE AK to N CA	XIII	13–15	7–8	18–20	26	30–36	47–55
S. rosaceus	N WA to C BCA	XIII–XIV	11–14	5–7	16–18	26–27	29–34	36–46
S. rosenblatti	C CA to C BCA	XIII–XIV	11–13	5–6	16–18	26	28–34	34–42
S. ruberrimus	G of AK to N BCA	XIII	13–16	5–8	18–20	26	25–30	39–46
S. rubrivinctus	C CA to N BCA	XIII	12–15	6–8	16–18	26	26–30	39–49
S. rufinianus	S CA	XIII	14	8	17	27	37–38	30–33
S. rufus	N CA to C BCA	XIII	13–16	8–9	17–19	27–28	32–37	49–56
S. saxicola	SE AK to C BCA	XIII	11–14	5–8	15–18	26	29–35	35–43
S. semicinctus	C CA to C BCA	XIII	12–14	6–8	16–18	26	36–42	40–50
S. serranoides	N CA to C BCA	XII–XIII	15–17	8–10	17–19	26	29–36	50–56
S. serriceps	C CA to C BCA	XIII	13–15	5–7	17–19	26	27–30	44–54
S. simulator	S CA to C BCA	XIII	12–14	5–6	16–18	26	28–33	33–40
S. umbrosus	C CA to S BCA	XII–XIV	11–13	5–7	15–18	26	31–38	33–44
S. variegatus	G of AK to BRT	XIII	14–15	6–7	17–19	27	37–41	43–52
S. wilsoni	G of AK to S CA	XIII–XIV	13–15	5–7	16–18	27–28	37–43	37–47
S. zacentrus	G of AK to S CA	XIII	13–16	6–8	16–19	27–28	31–41	38–50

Table Scorpaenidae 2. Meristic characters for the scorpaenine and sebastolobine species in the CalCOFI region. All species have three anal spines, one pelvic spine with five rays, and 8+7 principal caudal fin rays.

Taxon	Vertebrae			Fin rays				
				Dorsal				
	PrCV	CV	Total	Spines	Rays	A	P_1	C_2
Scorpaeninae								
Pontinus furcirhinus	10	14	24	XII	9	5	17–18	6+6–7
P. sierra	10	14	24	XII	8–9	5–6	16–19	5–7+6–7
Pontinus sp.	10	14	24	XII	8–9	5–6	18–19	5–6+6–7
P. vaughani	10	14	24	XII	9–10	5–6	20	6+6
Scorpaena guttata	10	14	24	XII	8–10	5–6	17–19	6–8+7–9
S. histrio	10	14	24	XII	9–10	5	20–21	6–7+7–8
S. mystes	10	14	24	XII	9	5	19	5+5
S. russula	10	14	24	XII	8–9	5	20–22	5–6+5–6
S. sonorae	10	14	24	XII	9–10	5	20–22	6–7+7
Scorpaenodes xyris	10	13–15	23–25	XIII	9–10	4–6	16–19	4–5+3–5
Sebastolobinae								
Sebastolobus alascanus	12–13	17–21	29–31	XIV–XVII	8–10	3–5	20–23	8–10+8–9
Sebastolobus altivelis	12–13	16–17	28–29	XV–XVI	8–10	4–6	22–24	6–8+7–8

Table Scorpaenidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the scorpaenid species descriptions. An "L" indicates literature used in the description.

Taxon	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Pelagic juvenile	Benthic juvenile
Sebastinae							
Sebastes atrovirens	0	0	L[a]	0	0	0	0
S. auriculatus	0	0	L[b,c,d,e]	L[b,d,e]	L[b,d,e]	L[e]	0
S. aurora	0	0	L[f]	L[f]	L[f]	L[f]	L[f]
S. carnatus	0	0	L[a,c]	0	0	0	0
S. caurinus	0	0	L[b,c,e]	L[b,e]	L[b,e]	L[e]	0
S. constellatus	0	0	L[g]	L[g]	0	0	0
S. dallii	0	0	L[h]	L[h]	L[h]	L[h]	0
S. diploproa	0	0	L[e], 5 4.4–6.5	L[e], 3 6.5–7.7	L[e], 9 9.1–18.6	L[e], 4 20.0–32.6	3 43.7–50.4
S. goodei	0	0	L[i]	L[i]	L[i]	L[i]	0
S. jordani	0	0	L[c,e]	L[c,e]	L[c,e]	L[c,e]	0
S. levis	0	0	L[c], 7 5.0–7.4	L[c]	L[c]	L[c]	L[c]
S. macdonaldi	0	0	L[c,j]	L[c,j]	L[c,j]	L[c,j]	0
S. melanops	0	0	L[d,k]	L[d,k]	L[k]	L[k]	0
S. melanostomus	0	0	L[l], 2 5.2 & 6.6	L[l]	L[l]	L[l]	L[l]
S. mystinus	0	0	L[a,e]	0	L[e]	L[e]	0
S. ovalis	0	0	L[c,g]	0	0	0	0
S. paucispinis	0	0	L[c,m]	L[c,m]	L[c,m]	L[c,m]	0
S. pinniger	0	0	L[n,e]	0	L[e,o]	L[e,o]	L[e,o]
S. rastrelliger	0	0	L[a]	L[a]	0	0	L[e]
S. rufus	0	0	L[g]	L[g]	0	0	L[e]
S. serranoides	0	0	L[g]	0	0	0	0
Scorpaeninae							
Pontinus sierra	0	0	L[c]	L[c]	L[c]	L[c]	2 21.6–27.4
Pontinus sp.	0	0	L[c]	L[c]	L[c]	L[c]	L[c]
Scorpaena guttata	L[c,p]	L[c,p]	L[c]	L[c]	L[c]	0	2 21.4–25.7
Scorpaenodes xyris	10 0.74–0.78× 0.78–0.82	0	L[c]	L[c]	L[c]	L[c]	L[c]
Sebastolobinae							
Sebastolobus alascanus	L[q,r]	L[q,r]	L[c,e,r]	L[c,e,r]	L[c,e,r]	L[c,e,r]	L[c,e,r]
S. altivelis	L[q,r]	L[q,r]	L[c,e,r]	L[c,e,r]	L[c,e,r]	L[c,e,r]	L[c,e,r]

[a] Moreno 1993
[b] Stahl-Johnson 1985
[c] Moser et al. 1977
[d] Kendall 1989
[e] Matarese et al. 1989
[f] Moser et al. 1985
[g] Moser and Butler 1987
[h] Moser and Butler 1981
[i] Sakuma and Laidig 1995
[j] Moser 1972
[k] Laroche and Richardson 1980
[l] Moser and Ahlstrom 1978
[m] Moser 1967a
[n] Waldron 1968
[o] Richardson and Laroche 1979
[p] Orton 1955b
[q] Pearcy 1962
[r] Moser 1974

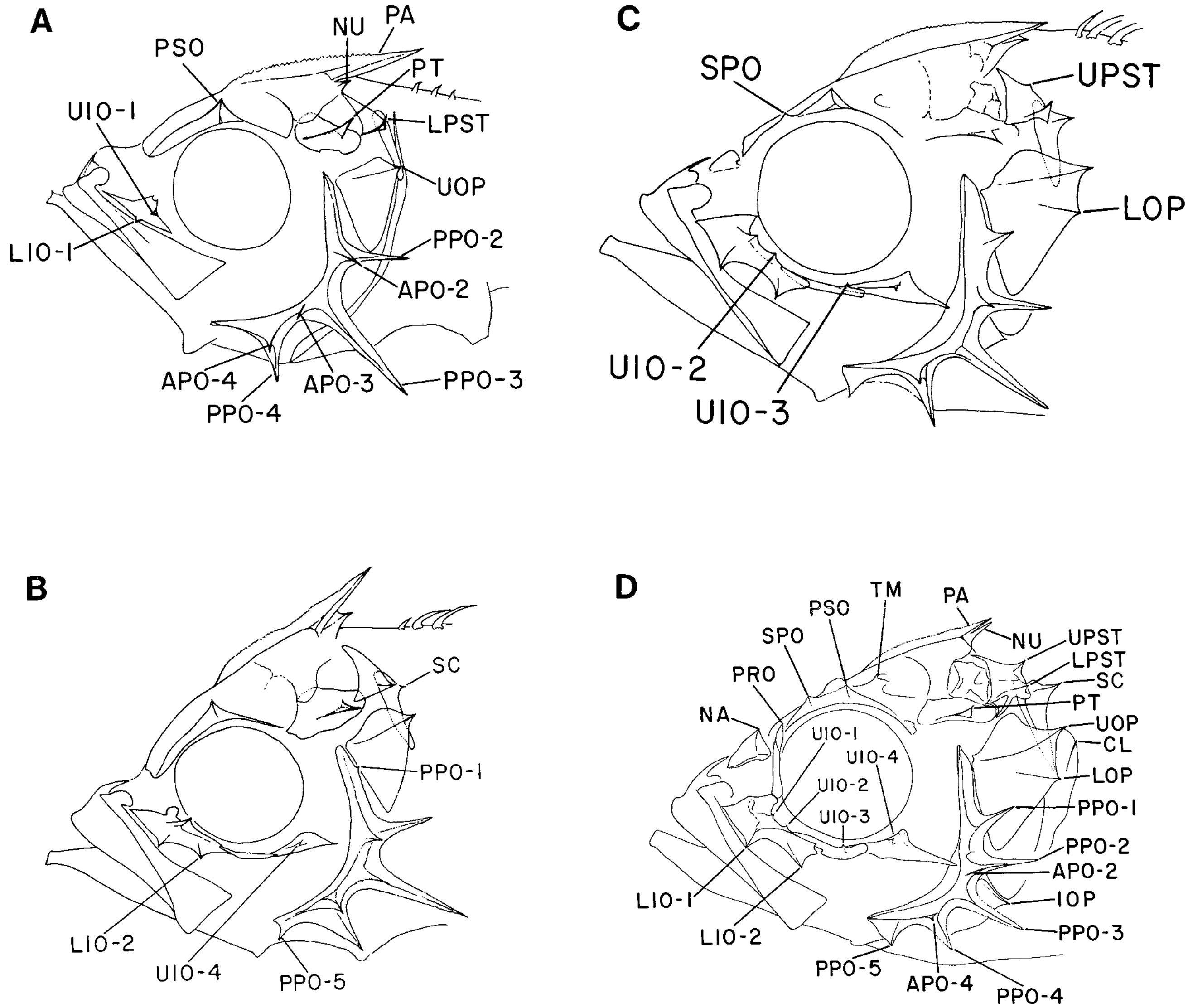


Figure Scorpaenidae 1. Sequence of head spine formation in *Sebastes melanostomus*. (A) Head of 6.2 mm flexion larva; (B) Head of 8.2 mm postflexion larva; (C) Head of 10.0 mm postflexion larva; (D) Head of 16.0 mm pelagic juvenile. Abbreviations of head spines: APO–2, 2nd anterior preopercular; APO–3, 3rd anterior preopercular; APO–4, 4th anterior preopercular; CL, cleithral; IOP, interopercular; LIO–1, 1st lower infraorbital; LIO–2, 2nd lower infraorbital; LOP, lower opercular; LPST, lower posttemporal; NA, nasal; NU, nuchal; PA, parietal; PPO–1, 1st posterior preopercular; PPO–2, 2nd posterior preopercular; PPO–3, 3rd posterior preopercular; PPO–4, 4th posterior preopercular; PPO–5, 5th posterior preopercular; PRO, preocular; PSO, postocular; PT, pterotic; SC, supracleithral; SPO, supraocular; TM, tympanic; UIO–1, 1st upper infraorbital; UIO–2, 2nd upper infraorbital; UIO–3, 3rd upper infraorbital; UIO–4, 4th upper infraorbital; UOP, upper opercular; UPST, upper posttemporal (from Moser and Ahlstrom 1978).

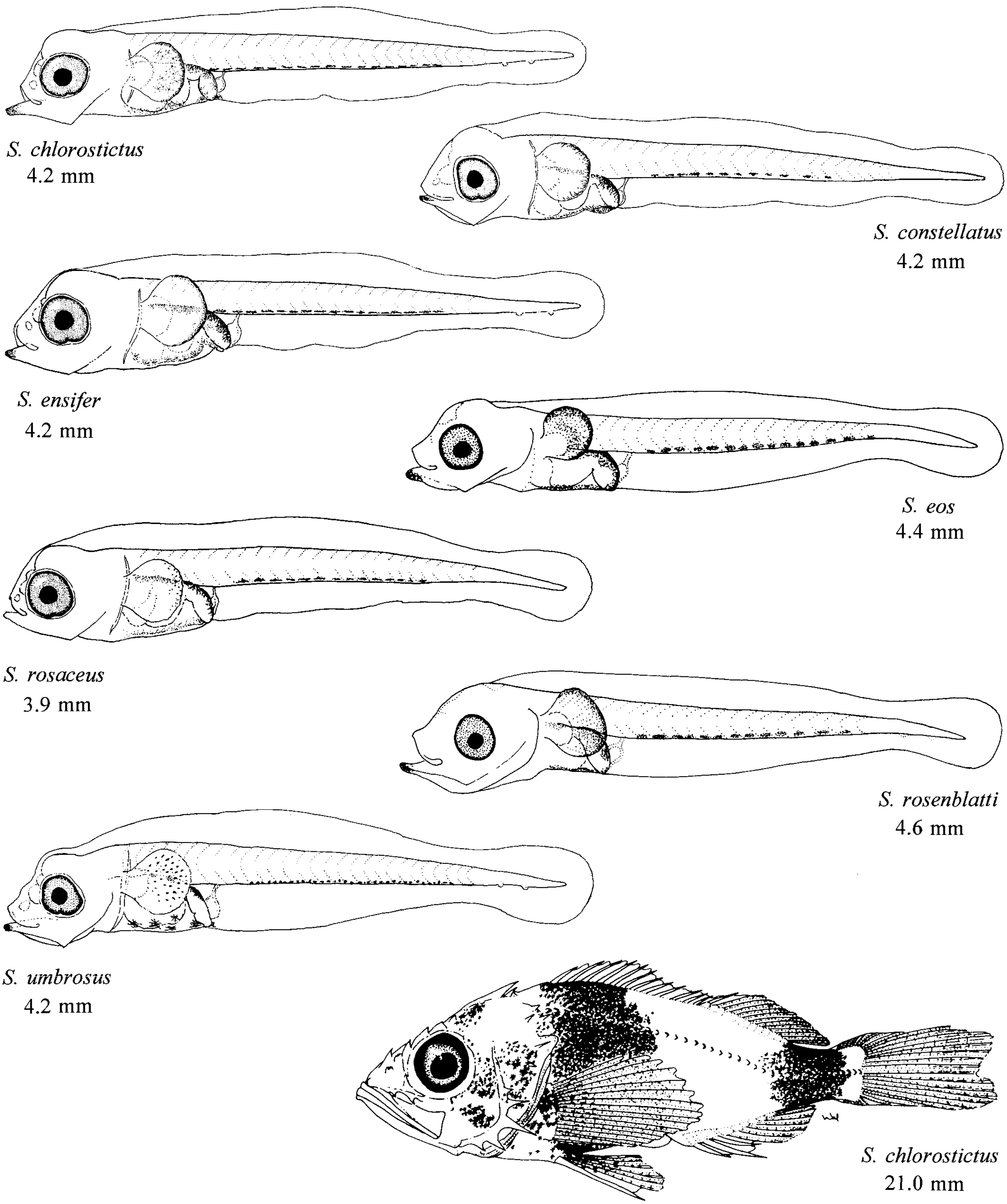


Figure Scorpaenidae 2. Larvae of seven species in the subgenus *Sebastomus*. Early preflexion larvae: *Sebastes chlorostictus*, 4.2 mm; *S. constellatus*, 4.2 mm; *S. ensifer*, 4.2 mm; *S. eos*, 4.4 mm; *S. rosaceus*, 3.9 mm; *S. rosenblatti*, 4.6 mm; *S. umbrosus*, 4.2 mm (Moser et al. 1977). Pelagic juvenile of *S. chlorostictus*, 21.0 mm (Laroche, in prep., from Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	13–15	14
Anal spines	III	III
Anal rays	6–7	7
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper		
Lower		
Gill rakers:		
Total	28–35	32
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Central California to central Baja California

Habitat: Demersal in kelp beds or rocky areas; adults to 46 m depth, common at 10 m

Spawning season: Late winter to spring

ELH pattern: Viviparous; planktonic larvae

LITERATURE

Moreno 1993

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* Based on Moreno (1993).
† Eggs develop in ovaries.
‡ From Moreno (1993); overall ranges are given above & ranges of means for size classes within the preflexion stage are given below.

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: 4.0 mm
Flexion length:
Transformation length:
Fin development sequence:
Pigmentation: *Preflexion*—Initially, dorsally & ventrally on gut, 1 anterior to anus, ca. 9 in series on dorsal midline of tail (from postanal myomere 2 to 11), & ca. 18 in series on ventral margin of tail (from postanal myomere 1 to 18); by 4.9 mm (some specimens), at tip of lower jaw, above midbrain & nape, laterally on gut, at lower cleithral region, & at otic capsule; by 5.9 mm, at tip of lower jaw (all specimens), at angular (some specimens), & more above midbrain & nape.
Diagnostic features: Number & position of melanophores in dorsal & ventral series on tail.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–45 38–42				
BD/BL		11–20 13–18				
HL/BL		14–29 19–25				
HW/HL						
SnL/HL		13–44 24–31				
ED/HL		22–57 38–43				
P_1L/BL						
P_2L/BL						
PrS/HL						

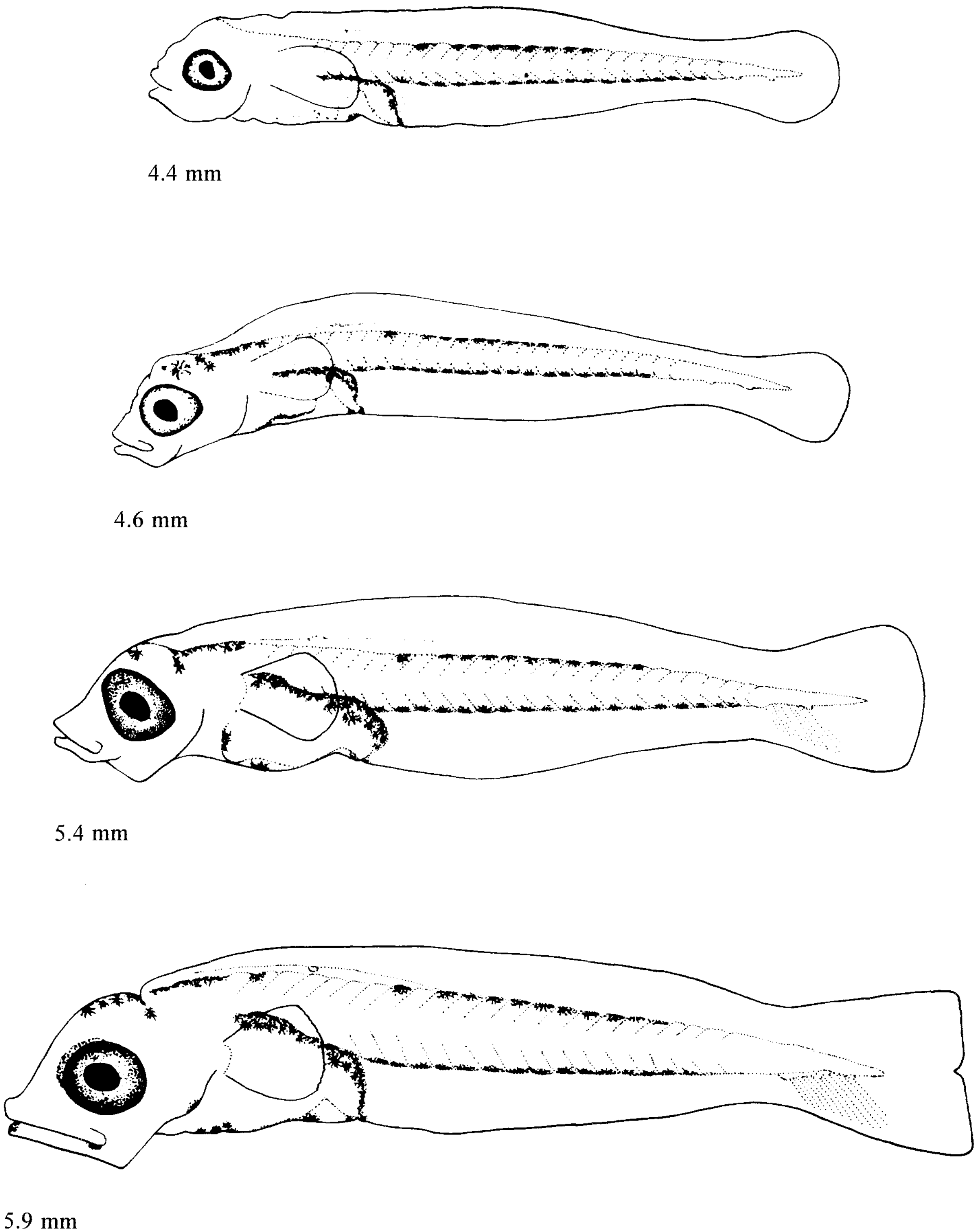


Figure Scorpaenidae 3. Preflexion larvae, 4.4 mm, 4.6 mm, 5.4 mm, 5.9 mm (Moreno 1993).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	26
Precaudal	11	11
Caudal	15–16	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	12–15	13
Anal spines	III	III
Anal rays	5–8	7
Pelvic	I,5	I,5
Pectoral	15–19	18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–11	11
Lower	9–12	11
Gill rakers:		
Upper	8–10	8
Lower	18–21	20
Branchiostegals	7	7

LIFE HISTORY

Range: Southeast Alaska to central Baja California

Habitat: On bottom in shallow waters & bays to 128 m depth

Spawning season: Late winter to spring

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1989, 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser et al. 1977
Stahl-Johnson 1985

* Based on Stahl-Johnson (1985).
† Eggs develop in ovaries.
‡ From Stahl-Johnson (1985).

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 5.5 mm
Flexion length: ca. 6.5–8.5 mm
Transformation length:
Fin development sequence: C_1, P_1, C_2, D & A & P_2
Pigmentation: *Preflexion*—Initially, 3–10 above midbrain, 0–8 above hindbrain, 0–3 at otic region, at angular (some specimens), at lower jaw tip (most specimens), dorsally & ventrally on gut, 1 anterior to & 1 posterior to anus, at cleithral symphysis, 35–58 in series on ventral margin of tail (from postanal myomere 1 to 15), 9–22 in series on dorsal margin of tail (typically from postanal myomere 3 to 14), & 1 to several laterally on the tail; by end of stage, laterally on lower jaw, other head loci augmented, some laterally on gut, at tip of snout, 1 at hypural region, & few on P_1 base & blade. *Flexion*—Series on dorsal margin of trunk (beginning on 3rd–5th myomere), becoming continuous with series above tail; heavy on lower jaw & preopercular spines; a patch on cheek anterior to preopercular spines; 1 or more on opercule; more laterally on tail. *Postflexion*—More on head loci; on upper & lower opercular patch; on P_1 base (heavy) & blade (moderate); gut covered; diffuse bar on tail. *Juvenile*—Heavy on upper half of head; large patch on opercle; heavy on dorsum; concentrated on myomeres; pale on ventrum.
Diagnostic features: In preflexion larvae, extensive pigmentation on head & dorsal & ventral margins of tail (series on dorsum limited to tail region in contrast to *S. caurinus* where it extends forward to nape); preopercular spines become heavily pigmented (sparsely pigmented in *S. caurinus*); cheek becomes heavily pigmented in flexion & postflexion stages (not in *S. caurinus*); upper & lower patches on opercle vs. single central patch in *S. caurinus.*

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–51 45	45–51 48	47–53 50		
BD/BL		16–26 20	19–25 23	22–29 24		
HL/BL		19–32 26	28–34 31	30–38 34		
HW/HL						
SnL/HL		23–34 30	24–32 28	23–30 28		
ED/HL		32–47 38	34–44 37	34–40 36		
P_1L/BL		7–22 14	6–10 9	7–10 9		
P_2L/BL		1–4 2	3–6 4	5–9 6		

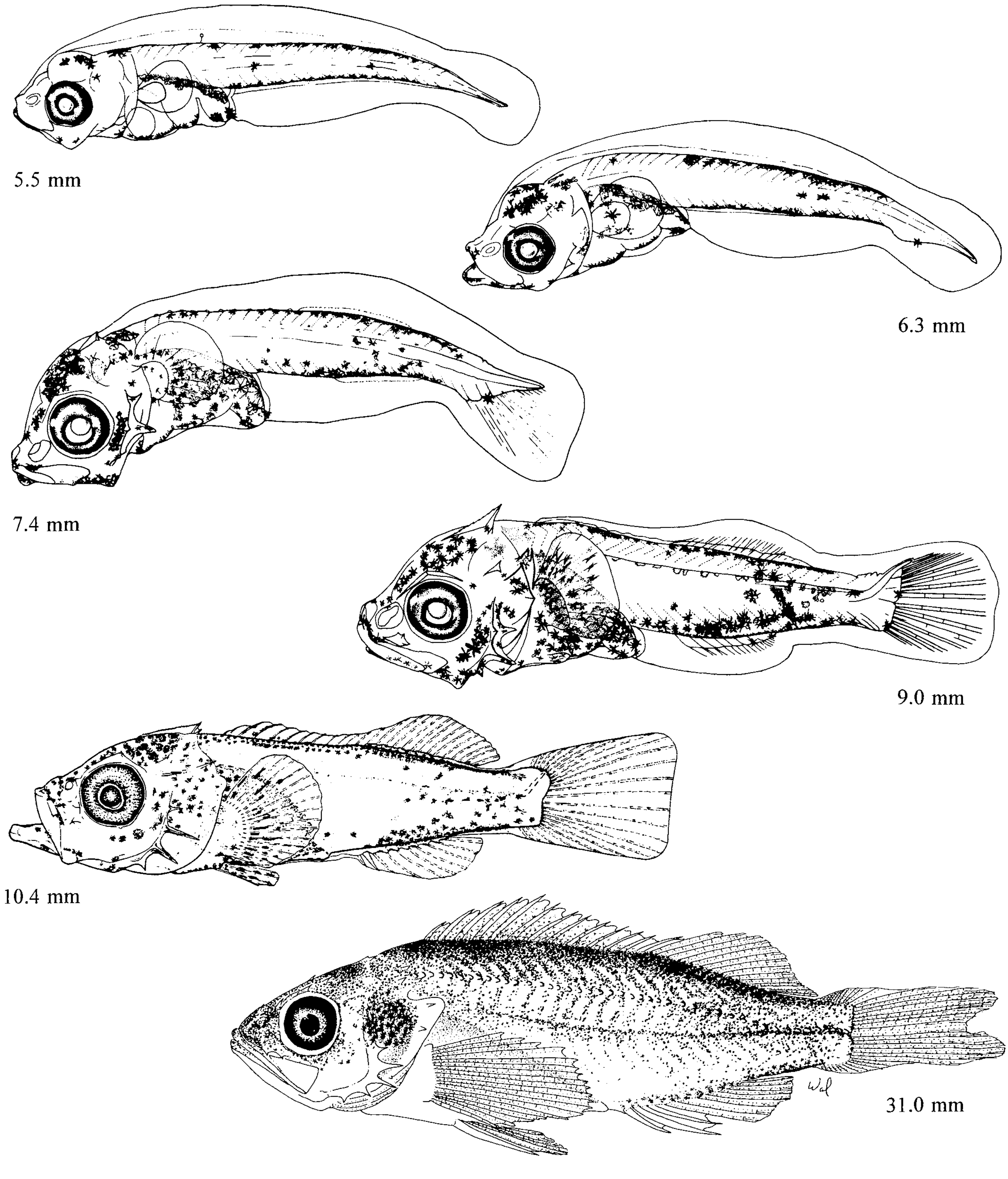


Figure Scorpaenidae 4. Preflexion larvae, 5.5 mm, 6.3 mm; flexion larva, 7.4 mm; postflexion larvae, 9.0 mm (Stahl-Johnson 1985), 10.4 mm (Kendall 1989); pelagic juvenile, 31.0 mm (Laroche, in prep., from Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	5–7	6
Pelvic	I,5	I,5
Pectoral	16–19	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–10	10
Lower	9–10	10
Gill rakers:		
Upper	7–8	8
Lower	18–20	19
Branchiostegals	7	7

LIFE HISTORY

Range: Southern British Columbia to central Baja California

Habitat: Demersal; adults to 768 m depth

Spawning season: March–July; in CalCOFI area, larvae collected November–August with peak abundance in May

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser et al. 1985

* Eggs develop in ovaries.
† Calculations from data in Moser et al. (1985).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 4.0 mm
Flexion length: 6.7–8.6 mm
Transformation length: ca. 13.0 mm
Fin development sequence: C_1, P_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Heavy bar develops from dorsal & ventral midline pigment (4th or 5th to 14th or 15th postanal myomere), up to 170 in bar; above brain; on nape, upper & lower jaw, isthmus, gular, otic & cleithral regions, preopercle, & opercle; dorsolaterally on gut; on both surfaces of P_1 base & proximally on blade. *Flexion–postflexion*—Proximal regions of P_2 & A. *Transformation–pelagic juvenile*—Postanal bar expands, second bar appears at midbody below D V–XI, & saddle forms below D I–III; entire head & body covered; 3 blotches form on membrane of 1D; large blotch forms on proximal region of 2D.
Diagnostic features: Heavy, distinctive pigmentation on head & body, especially the prominent postanal bar with numerous melanophores that form with augmentation of the dorsal & ventral midline pigment; heavy embedded snout pigment; preanal distance relatively large.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		38–49 44	51–60 56	56–66 62	61–67 64	59–62 61
BD/BL		15–27 20	26–29 27	26–34 31	29–34 32	30–30 30
HL/BL		21–30 25	33–37 35	33–40 38	35–42 38	35–36 35
HW/HL						
SnL/HL		23–37 30	35–39 37	34–38 36	28–36 33	23–26 25
ED/HL		29–39 34	28–33 31	28–33 29	26–30 28	30–31 31
P_1L/BL		5–9 8	10–12 11	11–18 15	19–25 23	22–26 24
P_2L/BL		0–0.5 0.1	1–4 2	3–11 7	11–18 15	16–18 17
P_1BD/BL		6–8 7	8–12 10	10–11 10	8–10 9	8–8 8

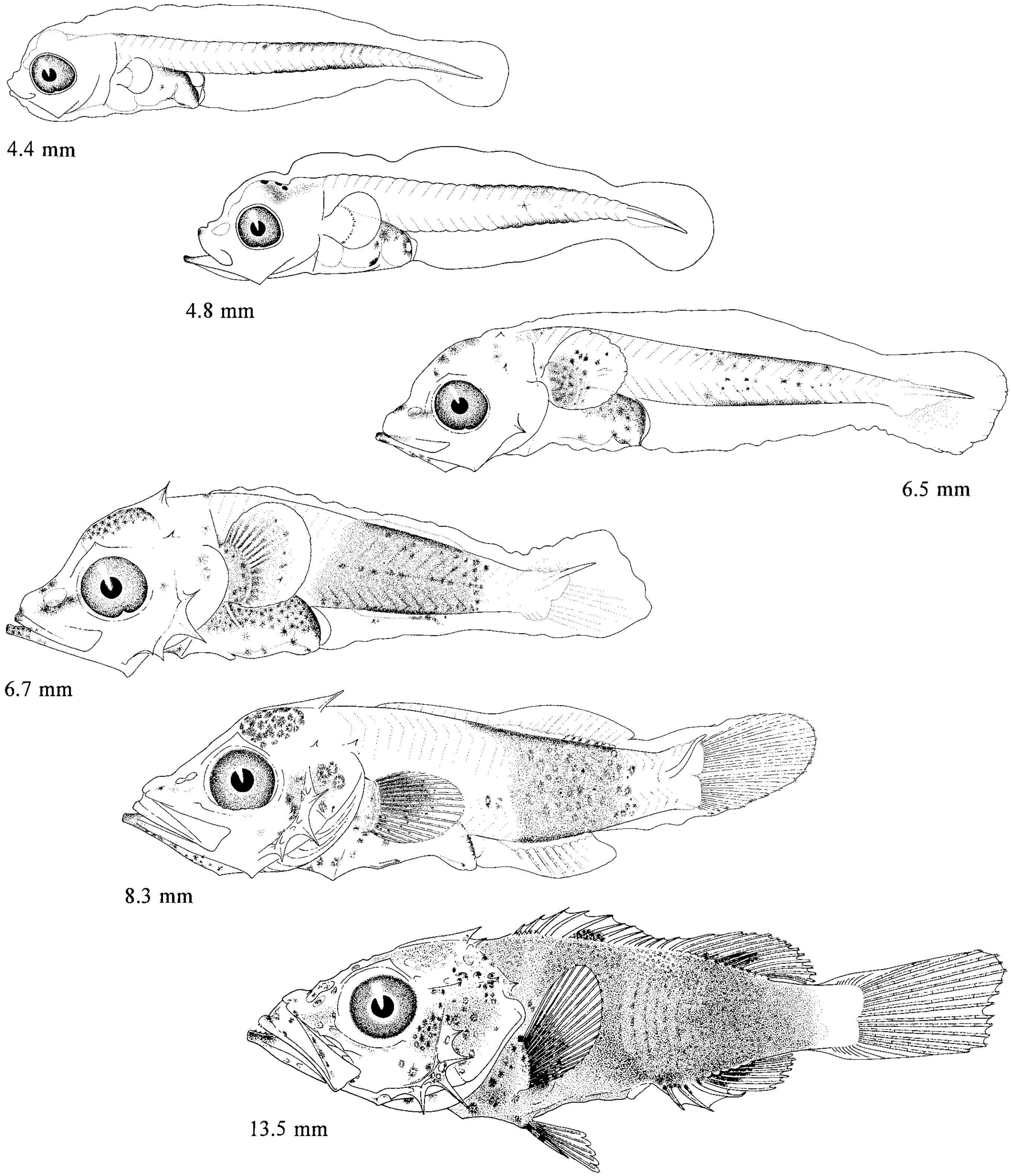


Figure Scorpaenidae 5. Preflexion larvae, 4.4 mm, 4.8 mm, 6.5 mm; flexion larva, 6.7 mm; postflexion larva, 8.3 mm; pelagic juvenile, 13.5 mm (Moser et al. 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	5–7	6
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper		
Lower		
Gill rakers:		
Total	23–30	29
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Northern California to central Baja California

Habitat: On bottom, often in crevices, to 55 m depth

Spawning season: Spring

ELH pattern: Viviparous; planktonic larvae

LITERATURE

Moreno 1993
Moser et al. 1977

* Based on Moreno (1993).
† Eggs develop in ovaries.
‡ From Moreno (1993); overall range is given above & range of means for size classes within the preflexion stage is given below.

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 4.3 mm
Flexion length:
Transformation length:
Fin development sequence:
Pigmentation: *Preflexion*—Initially, dorsally & ventrally on gut, ca. 10–25 in series on dorsal midline of tail (from postanal myomere 1–4 through 16–17), ca. 50–60 in series on ventral margin of tail (from postanal myomere 1 to 17); by 5.4 mm, at tip of lower jaw, laterally on upper & lower jaws (some specimens), above midbrain & nape, at otic region, laterally at cleithrum (some specimens), laterally on gut (some specimens), & 1 anterior to anus. *Flexion*—More above midbrain & nape & at otic region; at tip of snout; on P_1 base & dorsal & ventral margins of blade; 1 or more on lateral midline of tail (some specimens); internally above spinal column on tail.
Diagnostic features: Large numbers of melanophores in series on dorsal & ventral margins; typically, series on dorsal margin extends full length of tail; P_1 pigment pattern in flexion larvae.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–45 38–43				
BD/BL		2–23 10–21				
HL/BL		12–27 16–25				
HW/HL						
SnL/HL		17–50 25–34				
ED/HL		22–60 33–41				
P_1L/BL						
P_2L/BL						

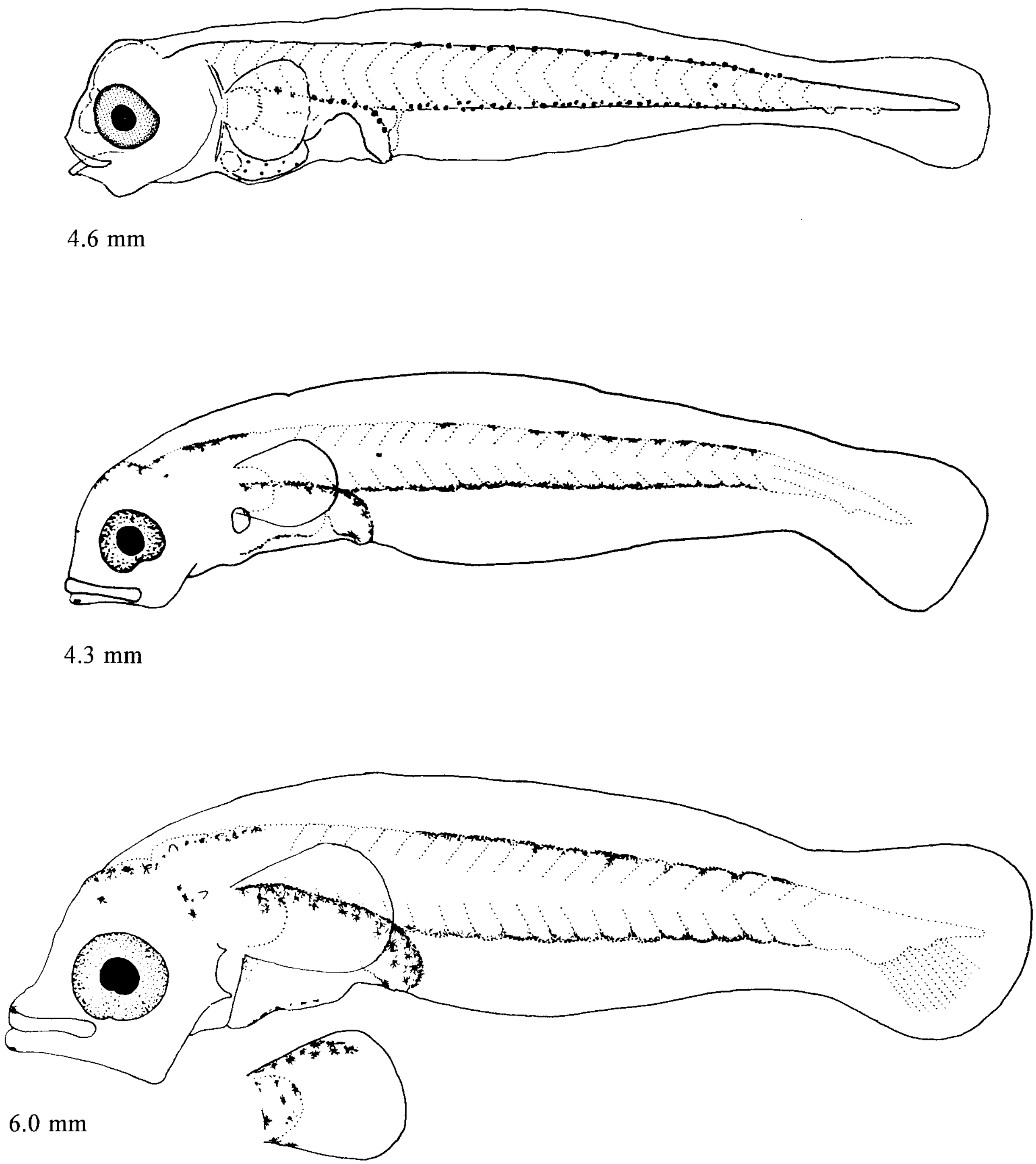


Figure Scorpaenidae 6. Preflexion larvae, 4.6 mm (late intraovarian specimen, Moser et al. 1977), 4.3 mm (Moreno 1993); late preflexion larva, 6.0 mm, with pectoral fin (below) showing pigmentation pattern (Moreno 1993).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25–26	26
Precaudal	11	11
Caudal	14–15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	11–14	13
Anal spines	III	III
Anal rays	5–7	6
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–11	10–11
Lower	9–11	11
Gill rakers:		
Total	26–32	28
Upper	8–10	
Lower	19–21	
Branchiostegals	7	7

LIFE HISTORY

Range: Gulf of Alaska to central Baja California

Habitat: On bottom in rocky reef areas; adults to ca. 180 m depth

Spawning season: Late winter; early spring

ELH pattern: Viviparous; planktonic larvae

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Stahl-Johnson 1985

* Based on Stahl-Johnson (1985).
† Eggs develop in ovaries.
‡ From Stahl-Johnson (1985).

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 5.3 mm
Flexion length: ca. 6.5–8.5 mm
Transformation length:
Fin development sequence: C_1, C_2 & D & A & P_1, P_2
Pigmentation: *Preflexion*—Initially, 0–4 above midbrain & 1–5 above hindbrain, 0–1 at otic region, at angular (rarely), at lower jaw tip (some specimens), dorsally & ventrally on gut, 1 anterior to & 1 posterior to anus, at cleithral symphysis (some specimens), 39–63 in series at ventral margin of tail (from postanal myomere 1 to 16), 15–32 in series on dorsum (nape to postanal myomere 16), & 1 laterally on tail (some specimens); by end of stage, laterally on lower jaw, other head loci augmented, some laterally on gut, & on snout. *Flexion*—Few on P_1 base & blade; more on jaws & dorsally on head; on midline posteriorly on tail. *Postflexion*—Postorbital patch; patch on opercle; sparse on preopercular spines; gut covered; laterally at cleithrum; more on P_1 base & blade; diffuse bar on tail; on margin of hypural. *Juvenile*—Heavy dorsally on head; 3 bars below 1D; broad bar below 2D; heavy on margin of 1D with 2 lighter areas proximally.
Diagnostic features: In preflexion larvae, extensive pigmentation on head & dorsal & ventral margins of tail (series extends entire length of dorsum in contrast to *S. auriculatus* where it is limited to tail); preopercular spines sparsely pigmented (heavily pigmented in *S. auriculatus*); postorbital pigment patch in postflexion larvae (none on cheek as in *S. auriculatus*); single opercular pigment patch in postflexion larvae (*S. auriculatus* larvae have upper & lower opercular patches).

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–47 41	43–52 47	42–54 49		
BD/BL		13–25 18	19–28 23	21–29 24		
HL/BL		19–31 23	26–36 30	29–36 32		
HW/HL						
SnL/HL		21–38 29	26–33 30	25–32 28		
ED/HL		30–45 36	33–43 37	30–42 37		
P_1L/BL		5–16 9	5–21 11	8–19 10		
P_2L/BL		3–4 3	1–5 4	4–11 5		

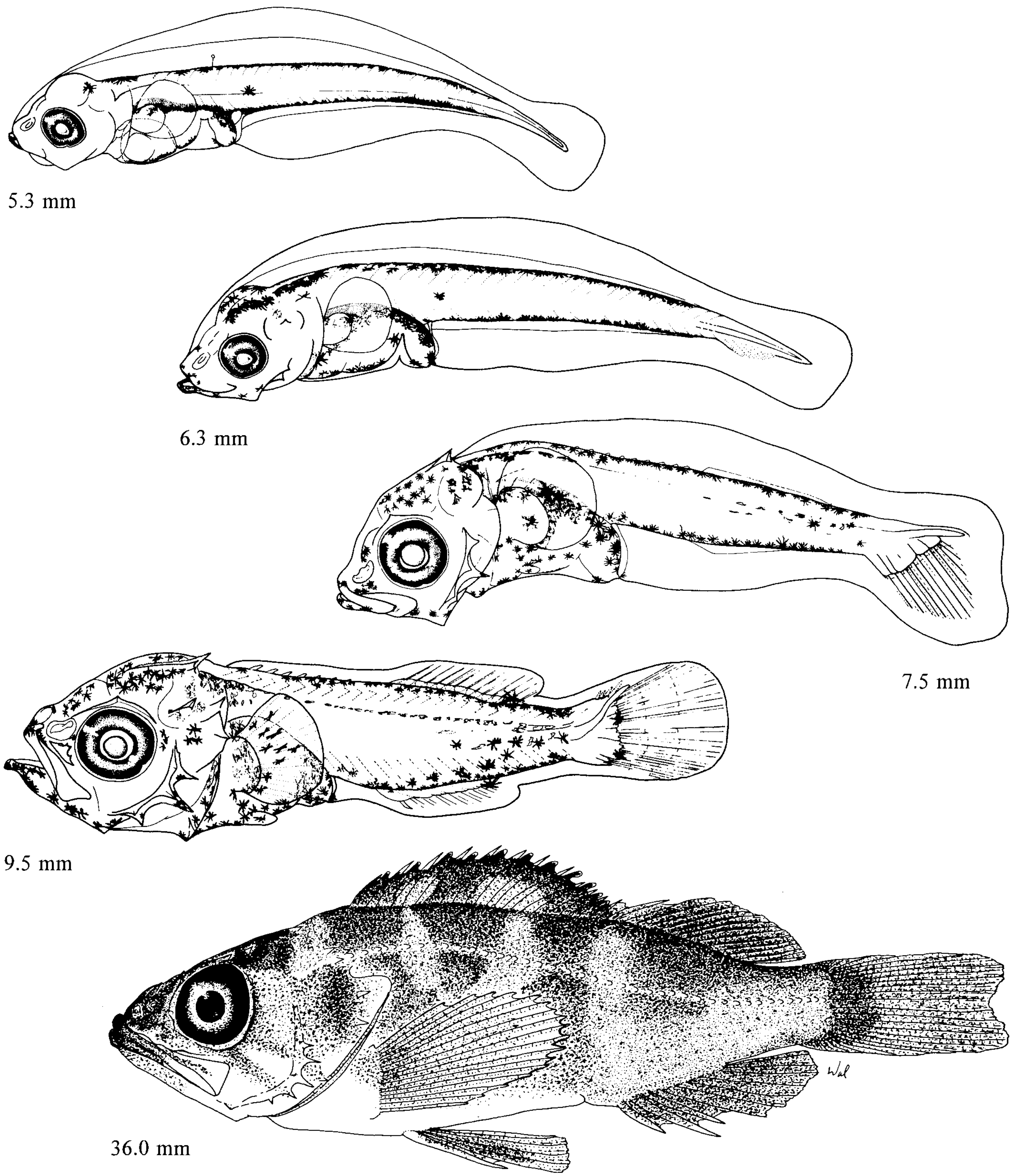


Figure Scorpaenidae 7. Preflexion larvae, 5.3 mm, 6.3 mm; flexion larva, 7.5 mm; early postflexion larva, 9.5 mm (Stahl-Johnson 1985); juvenile, 36.0 mm (Laroche, in prep., from Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25–26	26
Precaudal	11	11
Caudal	14–15	15
Fins:		
Dorsal spines	XIII–XIV	XIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	5–7	6
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–11	10
Lower	9–12	11
Gill rakers:		
Upper	7–9	
Lower	17–21	
Branchiostegals	7	7

LIFE HISTORY

Range: San Francisco, California to southern Baja California

Habitat: Demersal; adults to 274 m depth

Spawning season: March–May

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1989
Matarese et al. 1989
Moser 1967a
Moser & Butler 1987
Moser et al. 1977

* Eggs develop in ovaries.
† From Moser & Butler (1987); 5 preflexion specimens, 4.5–4.6 mm; 1 flexion specimen, 7.1 mm.

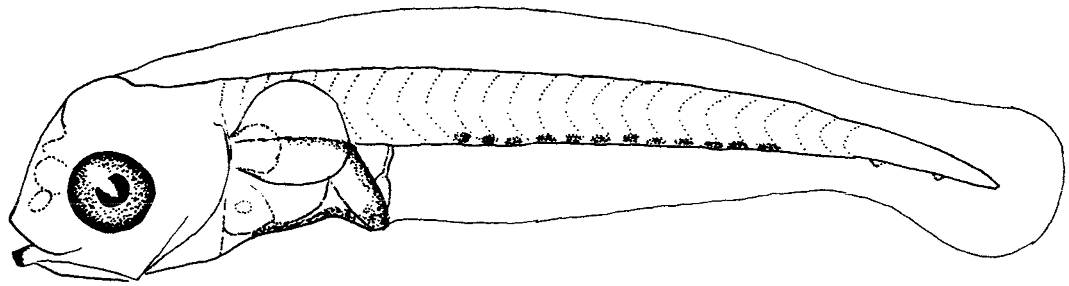
EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diaguostic features:

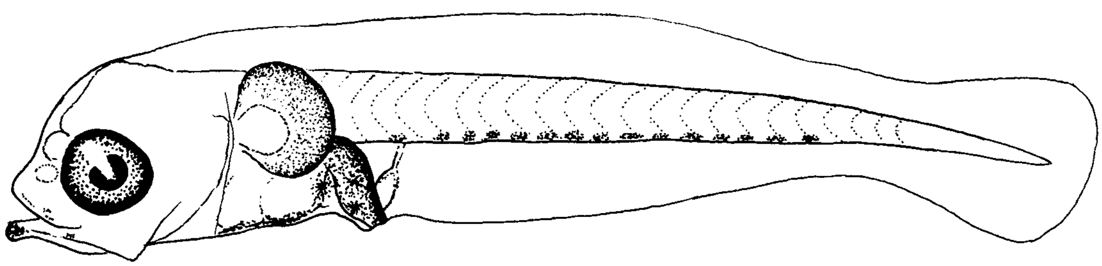
LARVAE
Length at birth: ca. 4.0 mm
Flexion length: ca. 7 mm
Transformation length:
Fin development sequence: C_1, P_1, D & A & P_2 & C_2
Pigmentation: *Preflexion*—Initially, dorsolaterally on gut, 11–17 in postanal ventral midline series (from 3rd to 15th postanal myomere), at lower jaw tip, ventral midline series below gut, & P_1 blade covered (darkest at distal margin). *Flexion*—At 7.1 mm, on snout, above brain, on nape, 1 at hypural margin, solid on P_1 base, on P_2, on isthmus, & 11 in embedded series on postanal ventral midline.
Diagnostic features: Heavy pigment on top of head, on jaws, in a ventral postanal series, & on paired fins; pigment on P_1 base & on blade, heaviest at distal margin; large, serrated parietal spines; larvae of other *Sebastomus* species share these features (see introduction to Scorpaenidae).

MORPHOMETRICS (range & mean in %)†

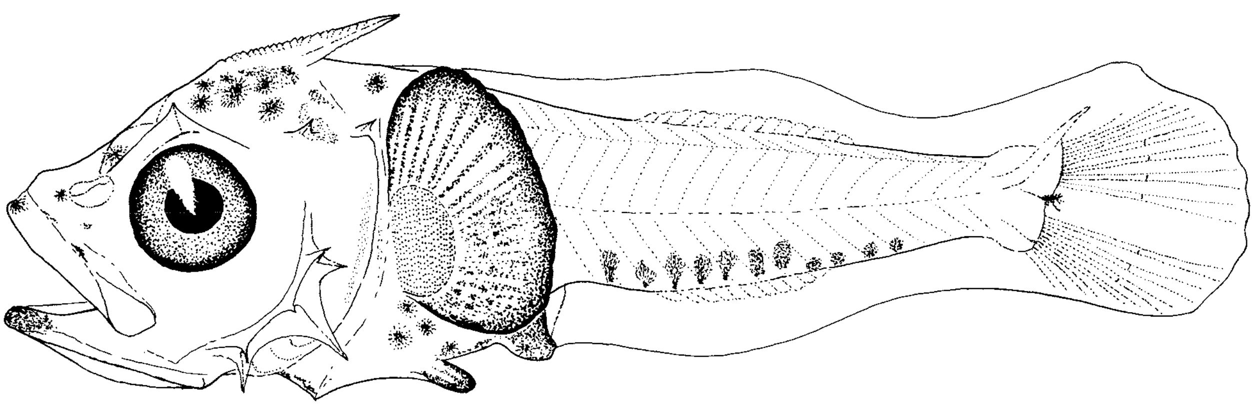
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–39 38	49			
BD/BL		15–17 16	28			
HL/BL		22–24 23	32			
HW/HL						
SnL/HL		26–30 28	34			
ED/HL		29–35 33	34			
P_1L/BL		5–6 6	14			
P_2L/BL		0–0 0	4			
P_1BD/BL		6–8 7	10			



4.5 mm



4.6 mm



7.1 mm

Figure Scorpaenidae 8. Preflexion larvae, 4.5 mm, 4.6 mm; late flexion larva, 7.1 mm (Moser and Butler 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	26
Precaudal	11	11
Caudal	15–16	15
Fins:		
Dorsal spines	XII–XIV	XIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	6–7	6
Pelvic	I,5	I,5
Pectoral	16–17	16–17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–13	12
Lower	10–13	12
Gill rakers:		
Upper	7–10	8
Lower	22–24	24
Branchiostegals	7	7

LIFE HISTORY

Range: San Francisco, California to central Baja California

Habitat: Demersal; adults to 256 m depth

Spawning season: Winter–spring

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser 1967a
Moser & Butler 1981
Moser et al. 1977

* Eggs develop in ovaries.
† Calculations from data in Moser & Butler (1981).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 5.0 mm
Flexion length: 6.5–8.0 mm
Transformation length: <22 mm
Fin development sequence: C_1, P_1, C_2, A & D & P_2
Pigmentation: *Preflexion*—Initially, postanal dorsal, ventral, & lateral series, 1 to several at nape, patch above brain, embedded in otic region, & dorsolaterally on gut; 29–49 in ventral midline series (from 1st to 16th postanal myomere), 7–19 in dorsal series (from 4th to 15th postanal myomere), 1–6 in lateral series; later in stage, on ventral gut, forebrain, lower jaw angle, hypural region (some specimens), lower jaw tip, & embedded above anterior region of spinal column. *Flexion*—Dorsal midline series becomes continuous from nape to caudal region as does series embedded above spinal column; nasal region; upper region of opercle; maxillary; posterior to eye; upper & lower regions of P_1 blade. *Postflexion*—On P_2, inner surface of P_1 base, & scattered on 1D.
Diagnostic features: Distinctive pigment pattern, particularly series at lateral midline, extended series at dorsal midline, & embedded series above spinal column; short head spines.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		42–43 42	43–48 46	48–56 51		56–58 57
BD/BL		15–20 18	19–23 21	22–28 24		25–25 25
HL/BL		21–24 23	25–29 27	28–33 30		29–30 30
HW/HL						
SnL/HL		19–29 25	27–32 28	29–31 30		33–33 33
ED/HL		35–41 38	36–46 40	34–39 37		33–34 34
P_1L/BL		5–6 6	8–9 8	8–14 11		23–24 24
P_2L/BL		0–0 0	0–2 1	2–9 4		15–16 16
P_1BD/BL		3–7 6	7–9 8	9–11 10		8–8 8

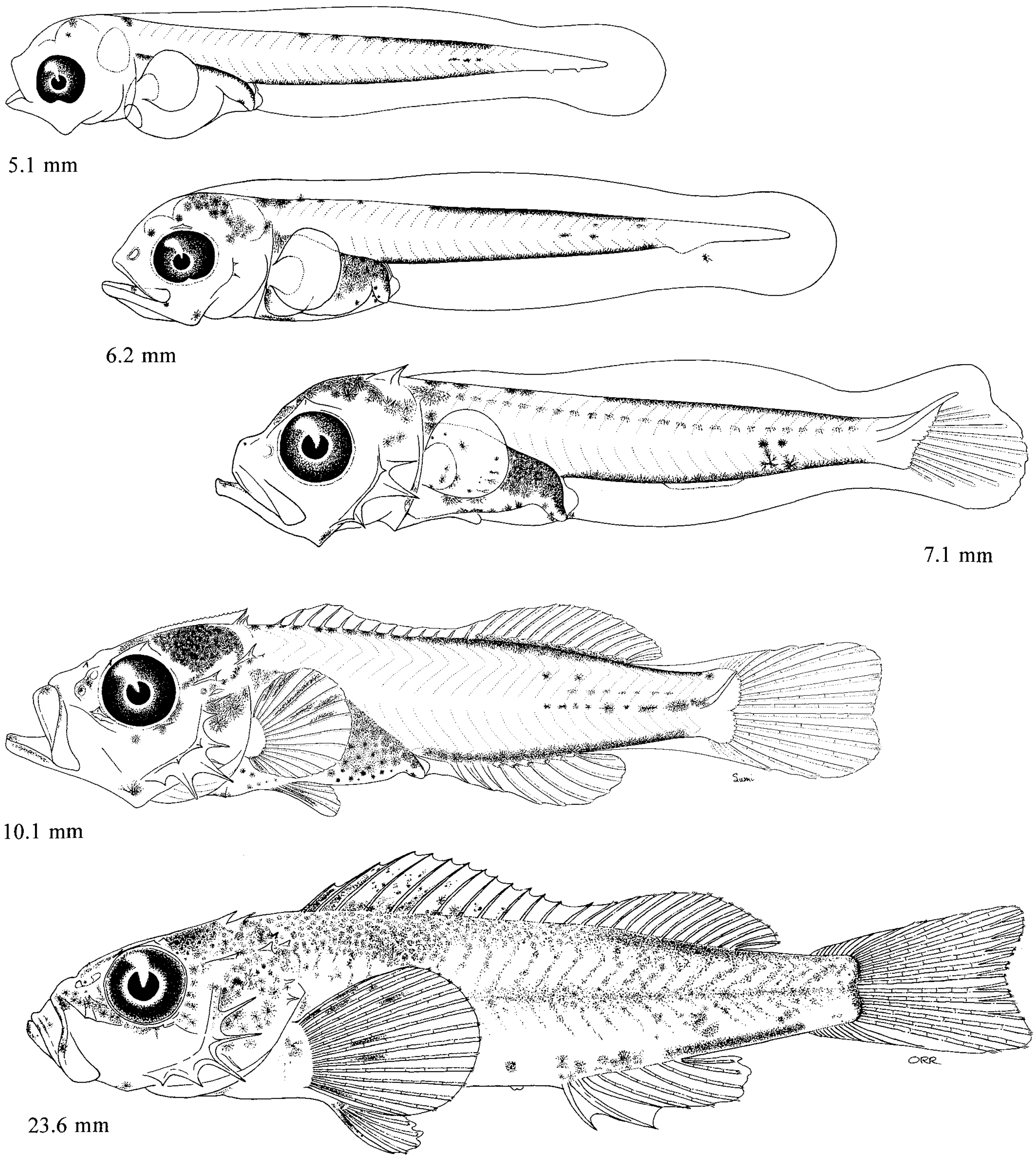


Figure Scorpaenidae 9. Preflexion larvae, 5.1 mm, 6.2 mm; flexion larva, 7.1 mm; postflexion larva, 10.1 mm; pelagic juvenile, 23.6 mm (Moser and Butler 1981).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	11–14	12
Anal spines	III	III
Anal rays	5–8	7
Pelvic	I,5	I,5
Pectoral	17–19	18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	10–12	11
Lower	11–13	12
Gill rakers:		
Upper	9–12	10
Lower	23–27	24
Branchiostegals	7	7

LIFE HISTORY

Range: Gulf of Alaska to central Baja California

Habitat: Demersal; adults to 579 m depth

Spawning season: January–September

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser et al. 1977

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 5.0, 5.9 mm (R. C. Walker)
Flexion larva, 7.7 mm (R. C. Walker)
Postflexion larva, 12.5 mm (R. C. Walker)
Pelagic juvenile, 21.2 mm (R. C. Walker)

* Eggs develop in ovaries.

EARLY LIFE HISTORY DESCRIPTION

EGGS*

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 4.4–5.2 mm
Flexion length: ca. 6.5–7.7 mm
Transformation length: PJuv, ca. 20 mm
Fin development sequence: P_1, C_1, D & A & C_2, P_2
Pigmentation: *Extrusion larvae*—Dorsolaterally on gut, 17–21 in postanal ventral midline series (from 4th or 5th to 16th–17th postanal myomere), & 1 or more at hypural. *Preflexion*—Initially, postanal ventral series reduced to 12–14, patch above midbrain, 1 to several at nape, anteriorly on lower jaw, scattered on P_1 blade (except distal margin), & on inner surface of P_1 base; by 5.0 mm, dorsolaterally on hindbrain, embedded anterior to gut, 1 to several on preanal ventral gut, & at posttemporal region. *Flexion*—1 to several in snout near jaw; above forebrain; on dorsal midline at caudal peduncle. *Postflexion*—Increasing dorsally on anterior trunk along entire dorsum, laterally at caudal peduncle, on snout, posteriorly on head, on opercle, & on P_2; head & body become solidly pigmented. *Transformation–pelagic juvenile*—2D & A with solid patch & 1D variegated.
Diagnostic features: No dorsal midline pigment in preflexion stage; hypural melanophore; distinctive sequence of pigment augmentation in larvae & pelagic juveniles; head spines relatively strong in flexion & postflexion stages.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		38–43 40	48–53 50	55–62 59	59–64 62	61–63 62
BD/BL		21–26 22	28–31 29	32–34 33	32–34 33	32–33 33
HL/BL		25–31 28	30–33 31	31–38 36	32–36 33	33–35 34
HW/HL						
SnL/HL		19–29 26	28–34 30	26–36 32	28–31 30	26–29 27
ED/HL		31–42 38	35–41 39	31–39 35	30–31 30	33–36 34
P_1L/BL		8–10 9	11–11 11	14–23 19	21–25 23	24–24 24
P_2L/BL		0–0 0	0.6–3 2	7–16 12	16–18 17	17–18 18
P_1BD/BL		8–10 9	11–12 11	9–13 11	9–10 9	8–9 9

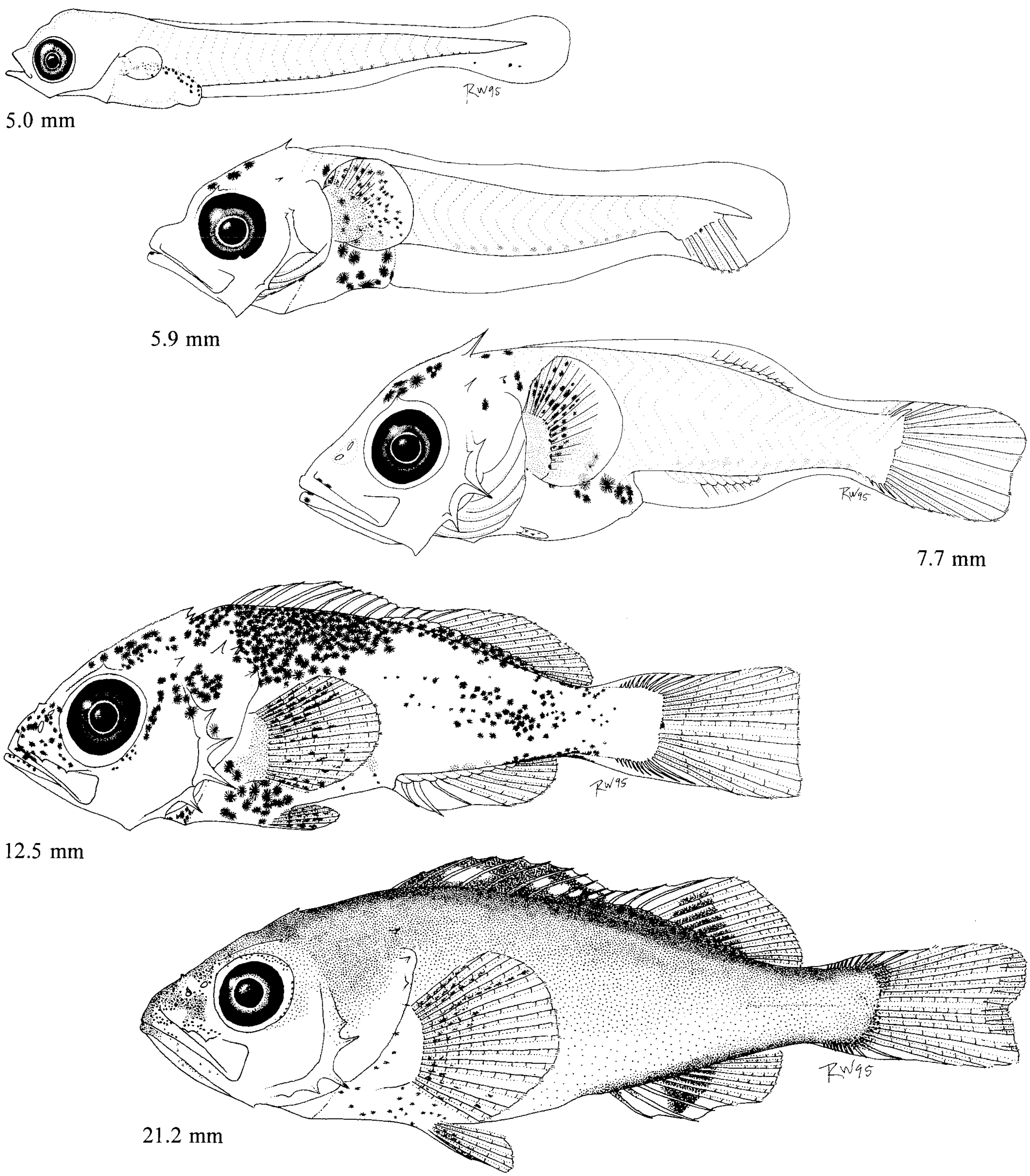


Figure Scorpaenidae 10. Preflexion larvae, 5.0 mm (extruded from 37 cm female, landed at Seattle, Washington, July 27, 1961, collected by R. L. Dryfoos), 5.9 mm (CalCOFI 8701, station 65.7.57.8); flexion larva, 7.7 mm (CalCOFI 8701, station 76.4.58.3); postflexion larva, 12.5 mm (CalCOFI 8701, station 72.9.55.1); pelagic juvenile, 21.2 mm (MEC I 28, station E–N).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	13–16	14
Anal spines	III	III
Anal rays	7–9	8
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	13–14	13–14
Lower	13–15	14–15
Gill rakers:		
Total	34–39	36
Upper		
Lower		
Branchiostegals		

LIFE HISTORY

Range: Vancouver Island to Bahía Magdalena, Baja California Sur

Habitat: Demersal to semi-pelagic at ca. 60 – >400 m depth; found over deep rocky reefs & also over soft bottom

Spawning season: October–June with a peak in December–January

ELH pattern: Viviparous; planktonic larvae, pelagic juveniles

LITERATURE

Kendall & Lenarz 1987
Matarese et al. 1989
Morris 1956
Moser et al. 1977
Sakuma & Laidig 1995

ORIGINAL ILLUSTRATIONS (Illustrator)

Newborn larva, 5.8 mm (G. Mattson)

* Based on Sakuma & Laidig (1995).
† Eggs develop in ovaries
‡ From Sakuma & Laidig (1995).

EARLY LIFE HISTORY DESCRIPTION*

EGGS†

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Length at birth: ca. 4.5–5.8 mm
Flexion length: ca. 6.5 mm through 8.1–8.8 mm
Transformation length: ca. 22 mm
Fin development sequence: P_1 & C_1, D & A & P_2, C_2
Pigmentation: *Preflexion*—Initially, dorsolaterally on gut, 6 – >12 in patch above midbrain, 2 – >5 on nape, 13–18 in series on ventral margin of tail (from ca. postanal myomere 4 through 17); by ca. 5.8 mm, on P_1 blade (becomes localized distally by end of stage). *Flexion*—Patch above forebrain. *Postflexion*—By ca. 9.0 mm, on P_2, row beginning to form posteriorly on each side of 2D fin base, & 8 or fewer in series on ventral margin of tail (row above posterior end of A base to caudal peduncle); by ca. 11.0 mm, linear patch along 1D base (extending onto fin membrane), & patch on opercle; by ca. 12.0 mm, on lower jaw tip, on hypural margin, short series on lateral midline in caudal peduncle region (some specimens), & saddle forming at nape; by ca. 14.0 mm, saddle forming below 4th–7th D spines; by ca. 16.0 mm, on snout, & continuous on dorsum at D base; by ca. 18 mm, on posteroventral margin of orbit. *Pelagic juvenile*—By ca. 26 mm, 3 more saddles forming (at 10th–13th D spines, at middle of 2D, & in caudal region), nape & 1D saddles directed anteroventrad, most of 1D membrane covered, becoming restricted to distal margins of P_1 & P_2, on lateral midline anteriad to A insertion, & lacking on ventral margin of tail; by ca. 34.0 mm, nearly lacking on P_1 & P_2, more on snout, & beginning to cover epaxial region of body.
Diagnostic features: In early larvae, pigment patch above midbrain, patch above nape, pigment series lacking on dorsal margin of tail, & pigment on P_1 (widespread on blade, becoming concentrated distally); pigment on 1D, patch on opercle, & distinctive saddles begin forming in postflexion; 5 saddles in pelagic juveniles (anterior 3 directed anteroventrad); preopercular, parietal, postocular, & other head spination moderately developed.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–34 33	37–50 40	51–60 54		
BD/BL		16–17 17	17–25 19	24–29 26		
HL/BL		18–20 19	21–32 24	32–39 36		
HW/HL						
SnL/HL		26–32 28	23–39 29	30–40 35		
ED/HL		37–45 42	31–40 37	30–38 35		
P_1L/BL		6–7 7	11–20 14	22–27 24		

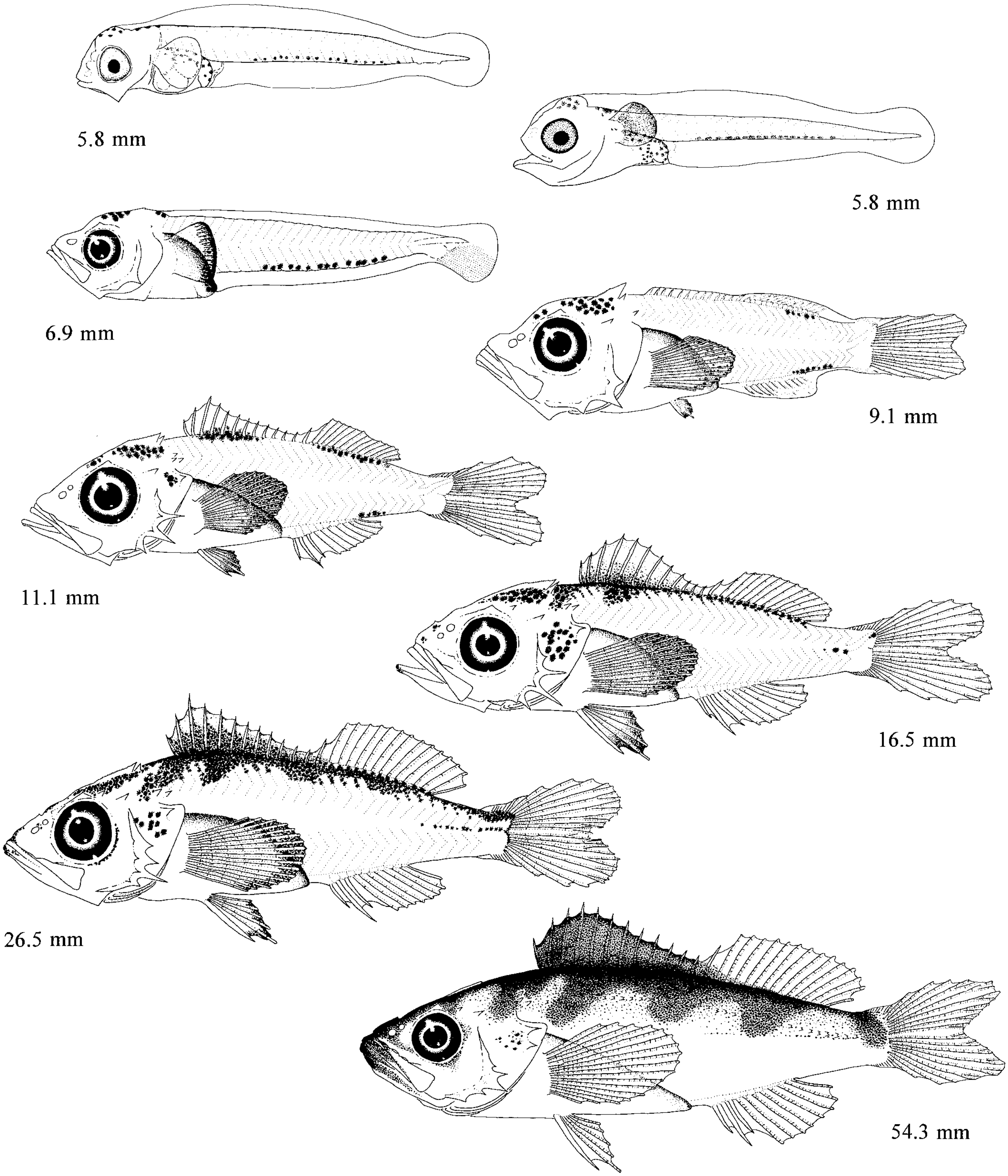


Figure Scorpaenidae 11. Newborn larva lacking pectoral fin pigment, 5.8 mm; preflexion larva with pectoral fin pigment, 5.8 mm (Moser et al. 1977); flexion larva, 6.9 mm; postflexion larvae, 9.1 mm, 11.1 mm, 16.5 mm; pelagic juveniles, 26.5 mm, 54.3 mm (Sakuma and Laidig 1995).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	13–16	14
Anal spines	III	III
Anal rays	8–11	9
Pelvic	I,5	I,5
Pectoral	19–22	20
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–16	13
Lower	13–16	14
Gill rakers:		
Upper	12	12
Lower	31	31
Branchiostegals	7	7

LIFE HISTORY

Range: British Columbia to Islas San Benito, Baja California

Habitat: Demersal & semi-pelagic; adults to 350 m depth

Spawning season: November–April; in CalCOFI area, larvae collected November–May with a peak in March

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Morris 1956
Moser et al. 1977
Washington et al. 1984b

* Eggs develop in ovaries.
† Calculations from data in Moser et al. (1977).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 5.4 mm
Flexion length: 8.0–10.0 mm
Transformation length: PJuv, ca. 27.0 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Initially, dorsolaterally on gut, patch over brain, 21–24 in postanal ventral series (from 3rd–5th to 14th–16th postanal myomere), 13–28 in dorsal midline series (from 7th–12th to 14th–16th postanal myomere); by end of stage, embedded above hindbrain & nape. *Flexion*—Above forebrain; dorsal midline series beginning to expand anteriad. *Postflexion*—By 13.0 mm, on snout near upper jaw & beginning of patch on upper opercular region; by 15.0 mm, on lateral hypural region; by 20.0 mm, continuous on dorsum, beginning to form on epaxial region of body; on lower jaw; more on snout; on posterior hypural margin. *Transformation*—Entire epaxial region covered, heavier at dorsum & at myosepta.
Diagnostic features: Most slender of known *Sebastes* larvae & relatively shortest preanal distance in the genus (wide space between anus & anal fin); position of dorsal midline series & number of constituent melanophores; relatively short P_1, usually lacking pigment; high P_1 ray count; relatively large size at hatching, flexion, & transformation stages; head spines inconspicuous after flexion stage.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	Juv
Sn-A/BL		36–38 37	41–45 42	46–54 51	52–55 53	
BD/BL		16–19 17	20–22 21	22–27 24	22–23 22	
HL/BL		21–25 23	26–30 28	31–36 33	28–34 31	
HW/HL						
SnL/HL		23–31 27	34–37 35	33–39 35	30–38 34	
ED/HL		36–38 38	29–36 33	27–34 30	24–28 27	
P_1L/BL		6–7 7	7–10 8	11–20 17	19–22 21	
P_2L/BL		0–0 0	0.9–2 1	3–13 9	12–15 13	
P_1BD/BL		6–7 7	7–8 8	7–10 8	7–7 7	

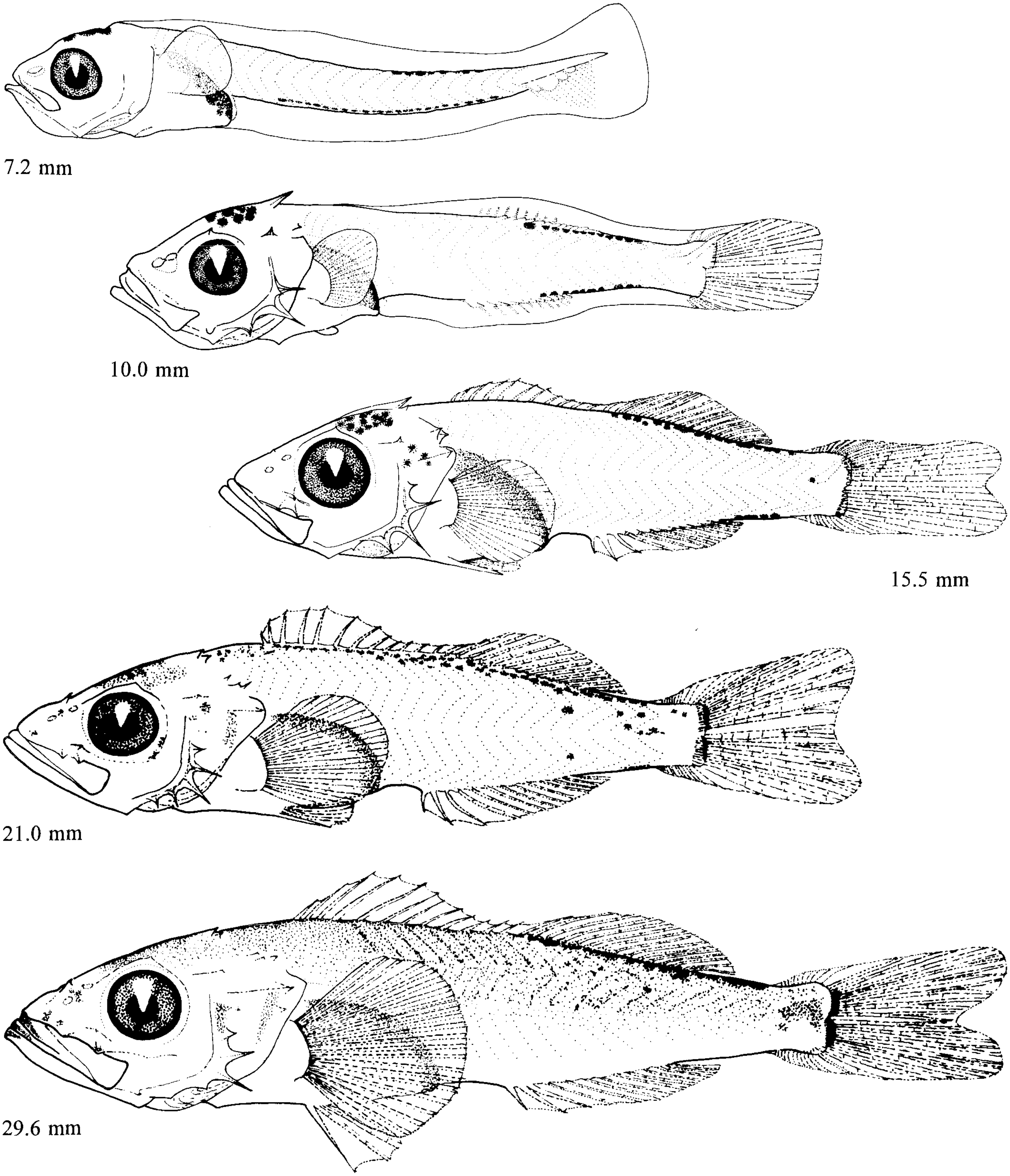


Figure Scorpaenidae 12. Preflexion larva, 7.2 mm; flexion larva, 10.0 mm; postflexion larvae, 15.5 mm, 21.0 mm; pelagic juvenile, 29.6 mm (Moser et al. 1977).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII–XIV	XIII
Dorsal rays	12–13	13
Anal spines	III	III
Anal rays	6–7	7
Pelvic	I,5	I,5
Pectoral	17–18	17–18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11	11
Lower	11–12	12
Gill rakers:		
Upper	7–9	8
Lower	21–23	22
Branchiostegals	7	7

LIFE HISTORY

Range: Mendocino County, California to Ranger Bank, Baja California

Habitat: Demersal; adults to 366 m depth

Spawning season: December–February; in CalCOFI area, larvae collected January–May with a peak in March

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser 1967a
Moser et al. 1977
Washington et al. 1984b

* Eggs develop in ovaries.
† Calculations from data in Moser et al. (1977); 6 additional preflexion larvae measured.

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 5.0 mm
Flexion length: ca. 7.6–10.4 mm
Transformation length: PJuv, ca. 20.0 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Initially, dorsolaterally on gut, patch over mid- & hindbrain, on anterior margin of lower jaw, covering P_1 blade (heaviest at margin), 13–22 in postanal ventral series (from 2nd to 14th–17th postanal myomere); later in stage, several ventrally on gut, on P_1 blade (concentrated at margin). *Flexion*—On nape, forebrain, snout near upper jaw, & P_2; on P_1 spreading from margin of blade toward base. *Postflexion*—On upper opercular region & posteriorly on upper head; on dorsum along 1D & 2D; late in stage, saddles begin to extend ventrad from dorsum, on 1D & 2D & A membranes. *Pelagic juvenile*—Saddle at D origin; 2 bars below 1D, 1 below 2D, & 1 at caudal peduncle.
Diagnostic features: P_1 elongate & fan-shaped with distinctive pigmentation; no dorsal midline pigment; distinct pattern of bars in pelagic juveniles.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		37–45 40	45–56 49	57–63 59	62–64 63	64
BD/BL		18–23 21	24–35 28	33–34 33	34–37 35	34
HL/BL		22–28 25	28–33 30	34–38 35	33–35 34	36
HW/HL						
SnL/HL		22–31 27	34–36 35	28–31 29	28–33 30	28
ED/HL		29–34 31	30–36 33	28–31 30	25–32 27	25
P_1L/BL		9–23 18	24–46 35	42–45 44	32–47 41	29
P_2L/BL		0–0 0	2–12 6	16–24 19	22–28 24	22
P_1BD/BL		8–12 10	12–14 13	11–12 12	9–11 10	10

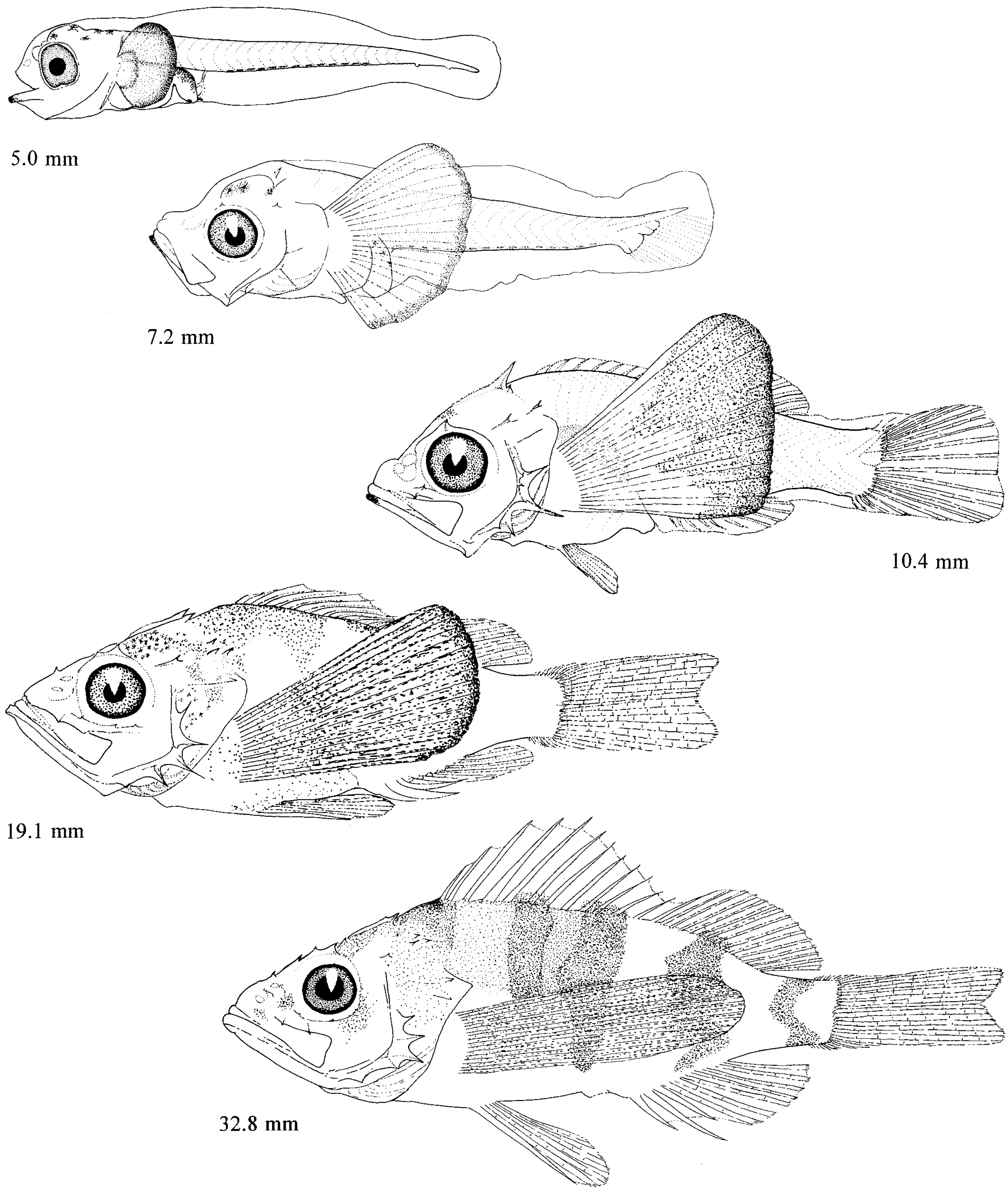


Figure Scorpaenidae 13. Preflexion larva, 5.0 mm; flexion larva, 7.2 mm; postflexion larvae, 10.4 mm, 19.1 mm; pelagic juvenile, 32.8 mm (Moser et al. 1977).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XII–XIV	XIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	7–8	7
Pelvic	I,5	I,5
Pectoral	18–20	19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	13–14	13
Lower	13–14	14
Gill rakers:		
Upper	9–12	11
Lower	26–28	27
Branchiostegals	7	7

LIFE HISTORY

Range: Point Sur, California to tip of Baja California & Gulf of California

Habitat: Demersal; adults to 238 m depth

Spawning season: In CalCOFI area, larvae collected January–May with peak abundance in April

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser 1972
Moser et al. 1977
Washington et al. 1984b

* Eggs develop in ovaries.
† Calculations from data in Moser (1972).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: 4.0–5.0 mm
Flexion length: 7.7–9.0 mm
Transformation length: PJuv, ca. 16.0 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Initially, dorsally & ventrally on gut, anteriorly on lower jaw, on nape, inner surfaces of P_1 & P_2 blades, & 6–14 in postanal ventral series (usually from 4th–5th to 14th–15th postanal myomere); by 5.0 mm, on optic & cerebellar lobes of brain in most specimens, 1 at hypurals in some; by 7.0 mm, on P_2, embedded anterior to cleithra, & solid between P_1 rays. *Flexion*—Continuous from nape to anterior gut; solid over entire brain; solid between P_2 rays. *Postflexion*—By 10.0 mm, at nasal & upper opercular regions, along upper jaw, on dorsum from nape to D insertion, & on 1D; by 12.0 mm, on D & A pterygiophores, a patch posteroventral to eye, & saddles developing on 1D & 2D. *Pelagic juveniles*—1D solid; P_1 solid except near base; P_2 solid; head covered; 3 saddles below 1D; bar between 2D & A, extending onto fins; bar on caudal peduncle.
Diagnostic features: Early larvae have few in postanal ventral pigment series, no dorsal series, & heavily pigmented P_1; P_1 relatively short until postflexion stage when it becomes somewhat fan-like; P_1, P_2 & 1D heavily pigmented; head spines relatively strong; pelagic juveniles with distinct pattern of saddles & bars.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	Juv
Sn-A/BL		36–47 42	48–56 52	55–64 60	61–68 65	
BD/BL		20–27 24	30–35 32	33–36 34	30–34 31	
HL/BL		24–31 28	34–38 36	34–41 37	32–38 35	
HW/HL						
SnL/HL		25–36 31	30–38 34	29–37 33	25–32 28	
ED/HL		31–38 34	31–35 32	31–35 33	26–34 31	
P_1L/BL		6–10 8	12–15 13	15–26 19	29–34 31	
P_2L/BL		0–3 0.6	3–9 6	10–21 14	21–22 22	

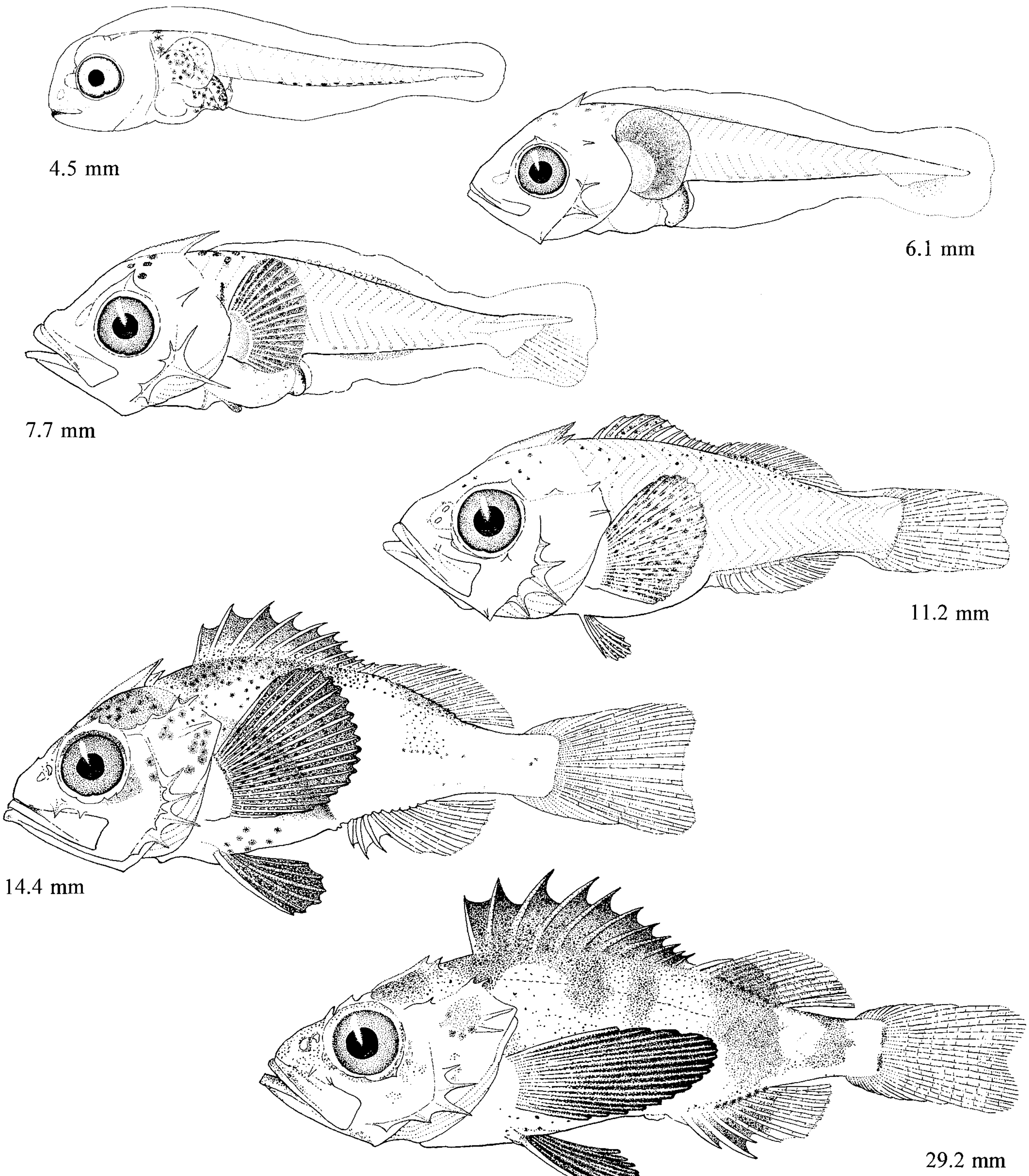


Figure Scorpaenidae 14. Preflexion larvae, 4.5 mm, 6.1 mm; flexion larva, 7.7 mm; postflexion larvae, 11.2 mm, 14.4 mm; pelagic juvenile, 29.2 mm (Moser 1972).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII–XIV	XIII
Dorsal rays	13–16	15
Anal spines	III	III
Anal rays	7–9	8
Pelvic	I,5	I,5
Pectoral	18–20	19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	12	12
Lower	12–13	
Gill rakers:		
Upper	9–13	11
Lower	23–28	26
Branchiostegals	7	7

LIFE HISTORY

Range: Aleutian Islands to southern California

Habitat: Demersal & pelagic, associated with reefs; at the surface to 366 m depth

Spawning season: Winter to spring (January–June)

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1989, 1991
Laroche & Richardson 1980
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.0 mm (H. G. Moser)

* Based on Kendall (1989) & Laroche & Richardson (1980).
† Eggs develop in ovaries.
‡ From data in Laroche & Richardson (1980).

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:

LARVAE
Length at birth: ca. 4.0 mm
Flexion length: ca. 5.7–7.7 mm
Transformation length: PJuv, ca. 24 mm
Fin development sequence: C_1, P_1, D & A & P_2 & C_2
Pigmentation: *Preflexion*—Initially, dorsally on gut, ca. 16 in series on ventral margin of tail (from ca. postanal myomere 4–6 through 18), & 1 or 2 ventral to notochord in caudal region; by 4.3 mm, gut covered, 1 or more on midbrain, nape, & lower jaw, some coalescence in series on ventral margin of tail (ca. 9 in series, closer together posteriorly), 1 on dorsum opposite posterior end of ventral tail series, heavy on inner surface of P_1 base & on P_1 blade; by 5.7 mm, ca. 8 on dorsum opposite posterior part of ventral tail series. *Flexion*–More on brain & nape; patches in otic & opercular regions & on trunk above P_1 base; heavy on P_1 & P_2; ventral tail series embedded; line on dorsum from middle of D base to caudal peduncle; 1 or more on lateral midline at caudal peduncle-hypural region. *Postflexion*—By 11.0 mm, on snout, upper jaw, postorbital region, more on top of head & on opercle, on dorsum from nape to C, on ventral margin of caudal peduncle, posteriorly on A base, & on posterior hypural margin; by 16.0 mm, more extensive on dorsal half of head, lateral midline streak extends from hypural region to trunk, increasing on epaxial region of trunk; by end of stage, head covered except lower cheek & ventral regions, heavy on dorsum, body covered above lateral midline (accentuated at myosepta), pale ventrally on body, & series on A base. *Pelagic juvenile*—Head covered, except on cheek; body covered, except on chest & ventral trunk region; heavy on dorsum; 1D covered with spot at 8th–12th spines; proximally on 2D.
Diagnostic features: Sequence of pigment development on head, dorsum, lateral midline, & fins; similar to *S. flavidus* larvae; in postflexion larvae, P_1 count usually 19 (18 in *S. flavidus*) & caudal peduncle shorter & deeper than in *S. flavidus*; pelagic juveniles have spot on 1D.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL				54–62 58	59–65 61	59–71 63
BD/BL				26–33 30	25–27 26	27–33 31
HL/BL				35–43 39	31–35 33	32–37 35
SnL/HL				25–31 28	24–30 27	20–27 23
ED/HL				27–34 31	24–29 26	23–29 26
P_1L/BL				19–25 22	22–25 24	23–27 25
P_2L/BL				13–17 15	17–19 18	18–23 21
P_1BD/SL				8–10 9	8–8 8	9–10 9

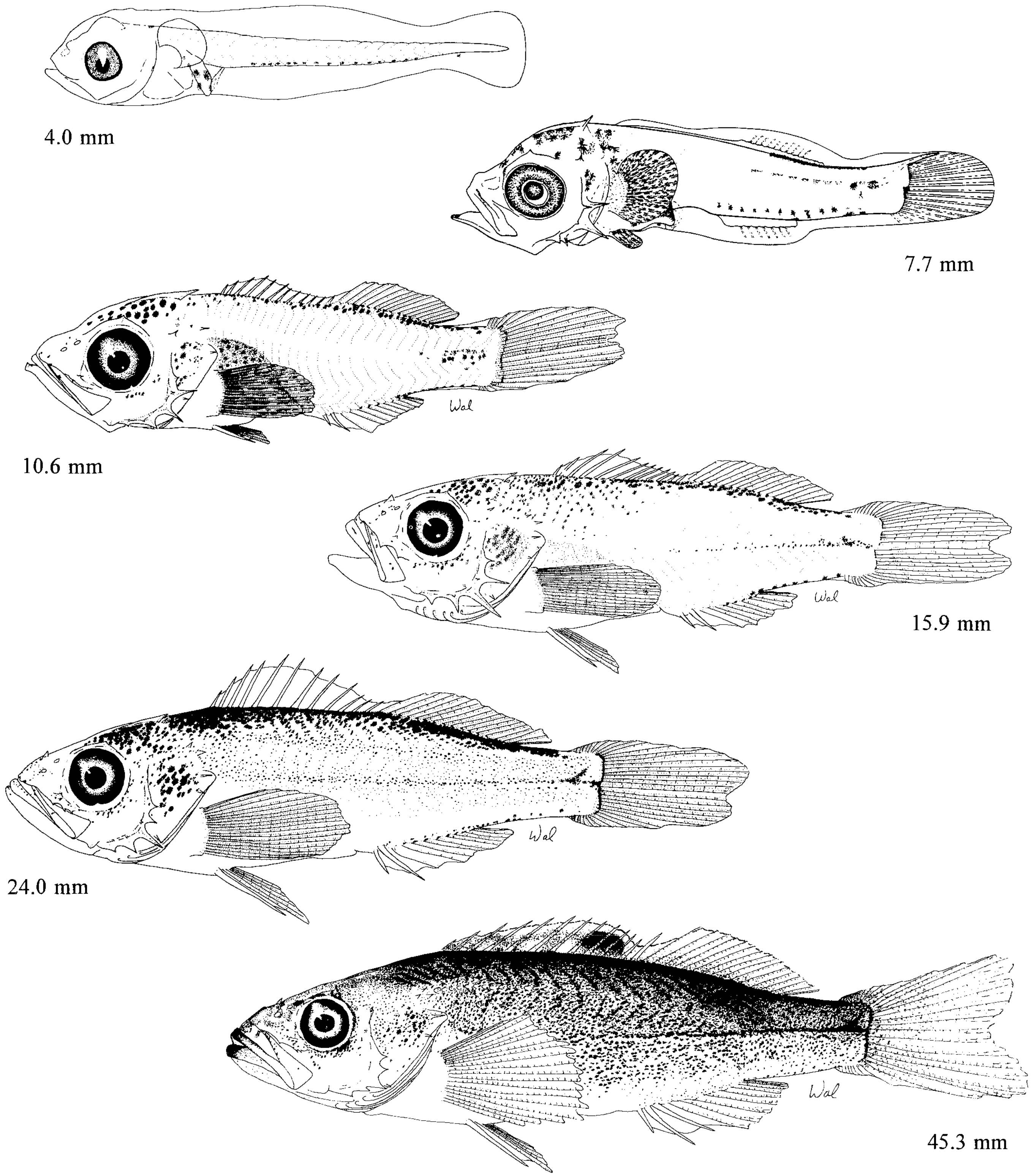


Figure Scorpaenidae 15. Preflexion larva, 4.0 mm (reared specimen provided by G. W. Boehlert); late flexion larva, 7.7 mm (Kendall 1989); postflexion larvae, 10.6 mm, 15.9 mm, 24.0 mm; pelagic juvenile, 45.3 mm (Laroche and Richardson 1980).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	12–15	13
Anal spines	III	III
Anal rays	6–8	7
Pelvic	I,5	I,5
Pectoral	17–20	19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–10	10
Lower	9–11	10
Gill rakers:		
Upper	8–10	9
Lower	21–23	22
Branchiostegals	7	7

LIFE HISTORY

Range: Washington (48° 30′ N) south to Punta Abreojos, Baja California Sur

Habitat: Demersal; adults to 768 m depth

Spawning season: February–April

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser & Ahlstrom 1978
Washington et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Late preflexion larva, 6.6 mm (R. C. Walker)

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* Eggs develop in ovaries.
† Calculations from data in Moser & Ahlstrom (1978); 2 additional preflexion larvae measured.

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 4.5 mm
Flexion length: 6.2–6.6 mm through 7.2 mm
Transformation length: PJuv, ca. 16.0 mm
Fin development sequence: P_1, C_1, D & A, P_2, C_2
Pigmentation: *Preflexion*—Initially, covering gut, above mid- & hindbrain, heavy anteriorly on lower jaw, most have 1 or more laterally on upper jaw, scattered on P_1 blade, 4–11 in postanal ventral series (usually from 3rd to 13th postanal myomere); by end of stage, embedded at nape, heavier at upper region of P_1; on oral valve of upper jaw. *Flexion*—Becoming restricted to margin of P_1, except for upper patch; on inner surface of P_1 base. *Postflexion*—By 8.0 mm, patch on upper opercular region; by ca. 12.0 mm, most have patch posteroventral to eye & a bar forming below 1D; at end of stage, a bar forms between 2D & A. *Pelagic juveniles*—Saddle at D origin; bar on caudal peduncle; proximally on P_1, P_2, 2D, & on 3 areas of 1D; streak in A.
Diagnostic features: In early larvae, few melanophores in postanal ventral series, no dorsal series, heavy lower jaw pigment, streak laterally on upper jaw, scattered on P_1 (not heavier at margin as in *Sebastomus* larvae); later larvae develop strong head spines; distinct saddles & bars in postflexion larvae & pelagic juveniles.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		38–52 45	53–60 56	55–63 59	61–70 64	63–65 63
BD/BL		22–31 27	35–36 35	37–42 39	34–40 37	35–38 36
HL/BL		21–33 28	44–50 48	39–45 41	34–42 38	36–37 36
HW/HL						
SnL/HL		29–35 32	29–33 31	29–35 32	25–34 29	21–31 25
ED/HL		33–38 35	29–31 30	32–38 34	25–36 30	27–34 31
P_1L/BL		6–11 9	18–19 19	20–24 22	22–29 26	27–28 28
P_2L/BL		0–2 0.5	10–11 11	13–20 16	19–21 20	20–21 20
P_1BD/BL		5–12 9	12–13 12	10–13 11	9–10 10	9–10 9

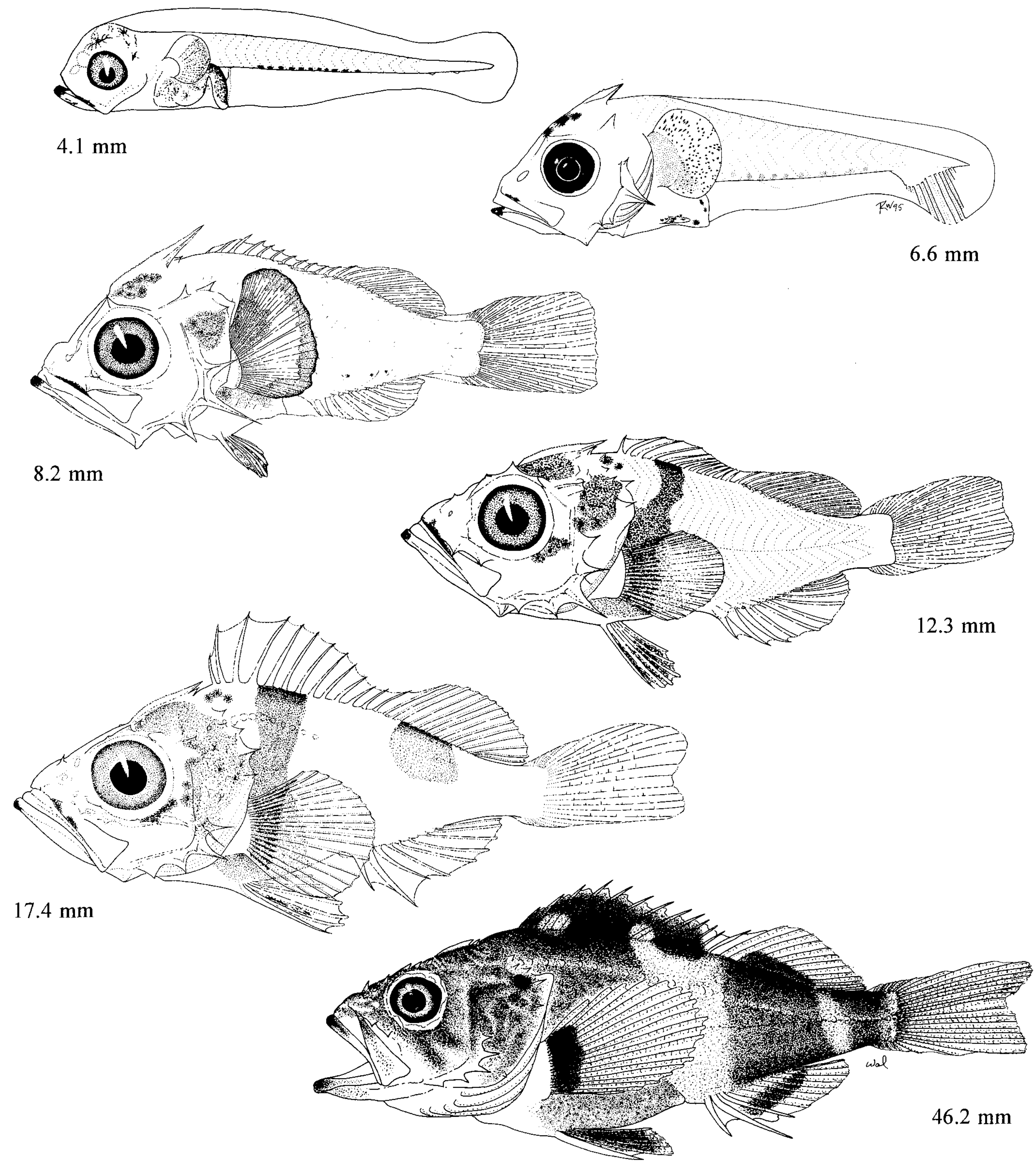


Figure Scorpaenidae 16. Preflexion larvae, 4.1 mm (Moser and Ahlstrom 1978), 6.6 mm (CalCOFI 7807, station 87.60); postflexion larvae, 8.2 mm, 12.3 mm (Moser and Ahlstrom 1978); pelagic juveniles, 17.4 mm (Moser and Ahlstrom 1978), 46.2 mm (Laroche, in prep., from Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	26
Precaudal	11–12	11
Caudal	15–16	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	15–17	16
Anal spines	III	III
Anal rays	8–10	9
Pelvic	I,5	I,5
Pectoral	16–19	18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–13	12
Lower	11–13	12
Gill rakers:		
Upper	9–12	10
Lower	23–29	25
Branchiostegals	7	7

LIFE HISTORY

Range: Vancouver Island to northern Baja California

Habitat: Schooling in midwater or at the surface near shallow & deep reefs & kelp forests; adults to >500 m depth

Spawning season: November to March with peak in January–February

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1989, 1991
Matarese et al. 1989
Moreno 1993

* Based on Matarese et al. (1989) & Moreno (1993).
† Eggs develop in ovaries.
‡ From Moreno (1993); overall range is given above & range of means for size classes within the preflexion stage is given below.

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 3.8 mm
Flexion length:
Transformation length: PJuv, >21 mm
Fin development sequence:
Pigmentation: *Preflexion*—Initially, dorsally & ventrally on gut, 1 anterior to anus, & ca. 15 in series on ventral margin of tail (from postanal myomere 5–6 through 16–18); at ca. 5.0 mm, on midbrain, nape, otic region, lower jaw, laterally on cliethrum, short series on dorsal margin of tail (from postanal myomere 9–10 through 18), & on P_1 blade (heavy on distal margin of blade). *Postflexion*—By 12.8 mm, heavy on brain & opercle, some on snout, upper jaw, on dorsum (heaviest at 2D), ventrally on caudal peduncle, posteriorly on A base, short series on lateral midline at caudal peduncle-hypural region, on posterior hypural margin, scattered on P_1 blade, & proximally on P_2; by end of stage, postorbital patch, heavy on top of head & entire dorsum, beginning to cover epaxial region of body, & streak at lateral midline extending forward to trunk. *Pelagic juvenile*—Heavy dorsally on head; 2 diagonal streaks on cheek; broad bars below 1D, 2D, & at caudal peduncle; 1D covered & black blotch between 7th–12th spines; patches proximally on 2D.
Diagnostic features: In preflexion larvae, relatively wide space (5–6 myomeres) separating anus & ventral pigment series, short pigment series dorsally on tail, & P_1 pigmentation; postflexion larvae similar to those of *S. melanops*, *S. flavidus*, & *S. entomelas* but differ from them in having a unique combination of 16 D soft rays, 9 A soft rays, & 18 P_1 rays; pelagic juveniles have broad bars & large blotch on 1D.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		28–41 35–39				
BD/BL		13–21 16–19				
HL/BL		15–26 19–24				
HW/HL						
SnL/HL		25–57 38–48				
ED/HL		25–50 31–38				
P_1L/BL						
P_2L/BL						

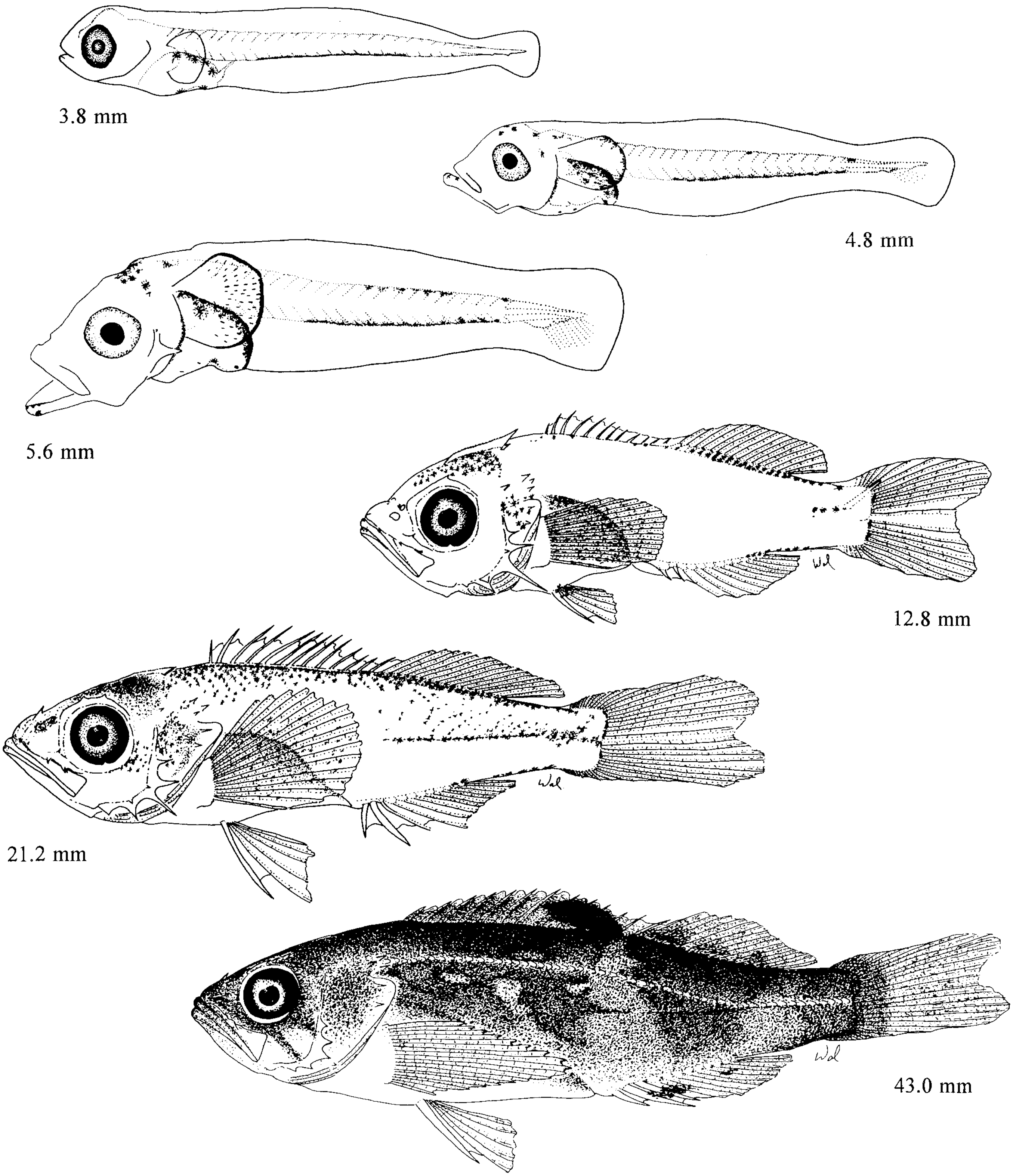


Figure Scorpaenidae 17. Preflexion larvae, 3.8 mm (Wold, unpubl., from Matarese et al. 1989), 4.8 mm, 5.6 mm (Moreno 1993); postflexion larvae, 12.8 mm, 21.2 mm; juvenile, 43.0 mm (Laroche, in prep., from Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27	27
Precaudal	11	11
Caudal	16	16
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	13–16	
Anal spines	III	III
Anal rays	7–8	
Pelvic	I,5	I,5
Pectoral	17–19	
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–13	
Lower	12	12
Gill rakers:		
Upper	8–9	
Lower	22–24	
Branchiostegals	7	7

LIFE HISTORY

Range: Central Oregon to northern Baja California; rare north of Santa Barbara, California

Habitat: Over deep rocky reefs to a maximum of ca. 365 m depth (usually at 75–150 m)

Spawning season: Fall to spring with peak in January–February

ELH pattern: Viviparous; planktonic larvae

LITERATURE

Moser 1967a
Moser & Butler 1987
Moser et al. 1977

* Eggs develop in ovaries.
† From Moser & Butler 1987.

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: ca. 5.0 mm
Flexion length: Begins at ca. 6.8 mm
Transformation length:
Fin development sequence:
Pigmentation: *Preflexion*—Initially, 5–8 on midbrain, 1–several on nape, dorsolaterally on gut, 1–2 on inner surface of P_1 base, scattered on P_1 blade, 13–17 in series on ventral margin of tail (from postanal myomere 5–6 through 18–19), & 11–12 in irregular double row on dorsal margin of tail (from postanal myomere 8–9 through 17–19); by end of stage, at tip of lower jaw, more on P_1 base & blade, & 19–21 in series on dorsal margin of tail.
Diagnostic features: Heavy pigmentation on brain & nape; lower jaw pigment; P_1 pigment; composition & location of dorsal & ventral postanal pigment series.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–41 38				
BD/BL		15–18 16				
HL/BL		22–26 24				
HW/HL						
SnL/HL		20–24 22				
ED/HL		36–40 38				
P_1L/BL		5–8 6				
P_2L/BL		0–0 0				
P_1BD/HL		7–9 8				

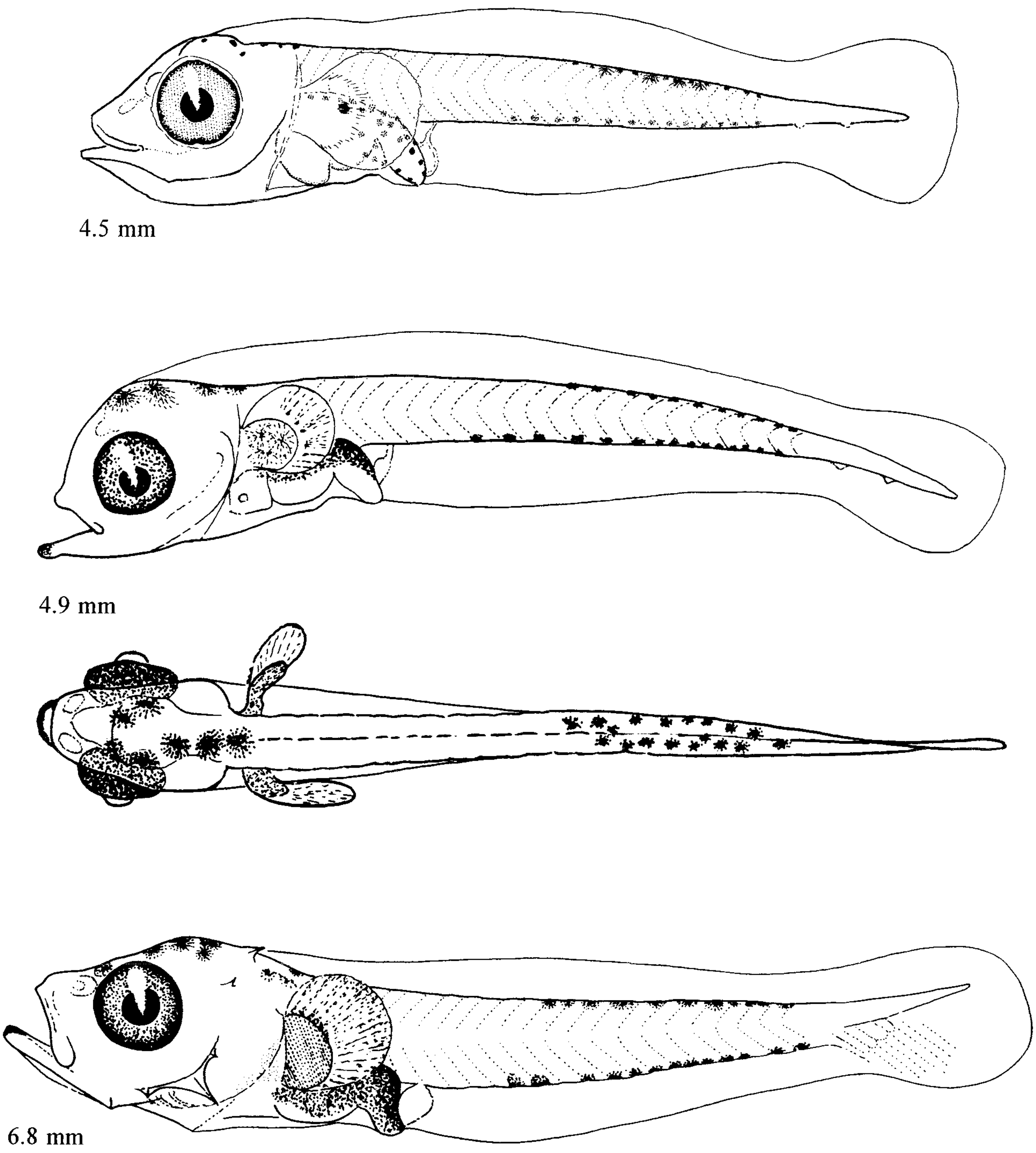


Figure Scorpaenidae 18. Preflexion larvae, 4.5 mm (Moser et al. 1977), 4.9 mm (lateral and dorsal views); early flexion larva, 6.8 mm (Moser and Butler 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII–XV	XIII
Dorsal rays	13–16	14
Anal spines	III	III
Anal rays	8–10	9
Pelvic	I,5	I,5
Pectoral	14–16	15
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–14	13
Lower	12–14	13
Gill rakers:		
Upper	8–9	8
Lower	20–21	20
Branchiostegals	7	7

LIFE HISTORY

Range: Kodiak Island, Alaska to central Baja California

Habitat: Demersal & semi-pelagic; adults to 475 m depth

Spawning season: October–May; in CalCOFI area, larvae collected October–June with peak abundance in January

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles; juveniles settle in nearshore nursery areas, then move to deeper habitats

LITERATURE

Ahlstrom 1965
Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Morris 1956
Moser 1967a
Moser et al. 1977
Washington et al. 1984b

* Eggs develop in ovaries.
† Calculations from data in Moser (1967a) & Moser et al. (1977).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: 4.0–5.0 mm
Flexion length: 7.2–9.7 mm
Transformation length: PJuv, ca. 15–30.0 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Initially, a shield over gut, heavy distally on P_1 blade, 6–14 in postanal ventral midline (from 3rd–4th to 14th–17th postanal myomere); by 6.0 mm, above mid- & hindbrain & concentrated at distal margin of P_1 blade. *Flexion*—On nape; on distal margin of P_2; on lateral region of hypurals; 1 on upper opercular region at end of stage. *Postflexion*—By 10.0 mm, a blotch on upper opercular & lateral hypural regions; by 15.0 mm, on dorsum along each side of D, on membrane of 1D; larger larvae develop 3 saddles below 1D & 1 below 2D. *Pelagic juveniles*—Saddles form anterior & posterior to saddle at 2D & posteriorly on caudal peduncle; 3rd & 5th saddles extend ventral to form irregular bars (see Moser 1967a).
Diagnostic features: In early larvae, few melanophores in postanal ventral series, no dorsal series, P_1 heavily pigmented distally; P_1 becomes very elongate & aliform with heavily pigmented distal margin; P_2 elongate & heavily pigmented on distal margin; head spines strong in mid-larval period; pelagic juveniles with distinctive barring.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	Juv
Sn-A/BL		37–44 41	40–50 45	52–65 59	60–60 60	
BD/BL		17–21 20	21–24 23	28–31 29	27–28 27	
HL/BL		24–29 27	27–32 30	36–39 37	33–37 35	
HW/HL						
SnL/HL		24–32 27	29–33 31	26–33 31	29–33 31	
ED/HL		29–37 33	29–33 30	27–33 30	26–27 26	
P_1L/BL		11–21 16	25–31 27	25–37 34	26–26 26	
P_2L/BL		0–11 3	9–26 15	24–39 33	22–24 23	
P_1BD/BL		8–10 9	8–10 9	5–8 7	5–6 6	

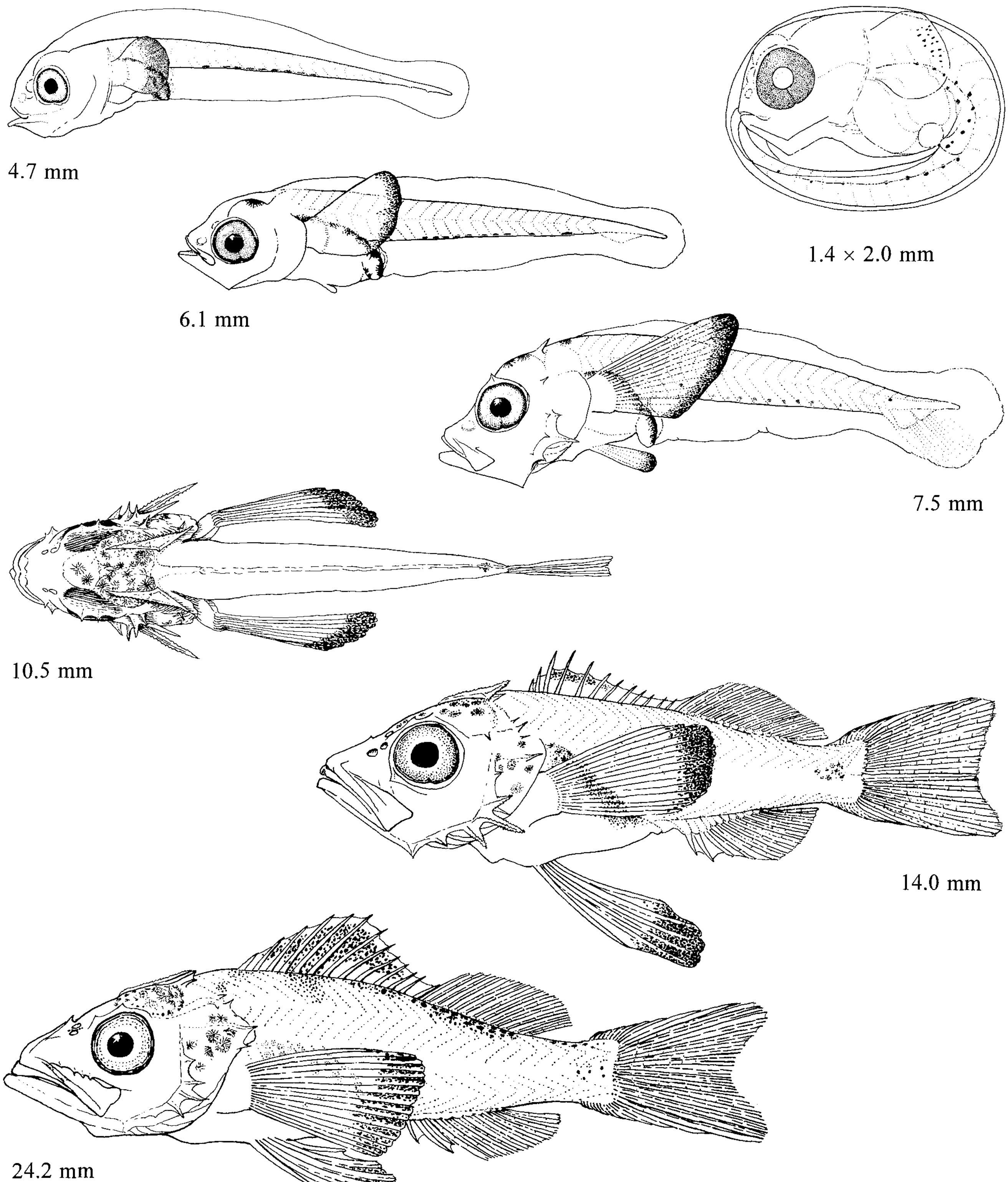


Figure Scorpaenidae 19. Late-stage intraovarian egg, ca. 1.4 × 2.0 mm; preflexion larvae, 4.7 mm, 6.1 mm; early flexion larva, 7.5 mm; postflexion larva, 10.5 mm, dorsal view; postflexion larva, 14.0 mm; pelagic juvenile, 24.2 mm (Moser 1967a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	13–15	14
Anal spines	III	III
Anal rays	7	7
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	12–15	14
Lower	26–31	28
Branchiostegals	7	7

LIFE HISTORY

Range: Southeast Alaska to northern Baja California

Habitat: Demersal in aggregations associated with reefs & pinnacles; adults to >400 m, but usually at ca. 90–270 m depth

Spawning season: December–March with a peak in midwinter

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser et al. 1977
Richardson & Laroche 1979
Waldron 1968

* Based on Waldron (1968) & Richarson & Laroche (1979).
† Eggs develop in ovaries.
‡ From data in Richardson & Laroche (1979).

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: 3.6–4.0 mm
Flexion length: <7.8 mm
Transformation length: PJuv, ca. 18–20 mm
Fin development sequence:
Pigmentation: *Preflexion*—Initially, dorsally & ventrally on gut, on tip of lower jaw, a short, irregular double row on ventral margin of tail (ca. postanal myomere 11 to 17); slightly larger larvae develop irregular double dorsal row (ca. postanal myomere 12 to 17) & some on P_1 blade. *Postflexion*—By 7.8 mm, over brain, several on lower jaw tip & on anteroventral margin of maxillary, at otic region, several at nape, a shield over gut, a few on ventral midline of gut, several on dorsal & ventral margins of caudal peduncle, on inner surface of P_1 base & light on blade, light on P_2; by end of stage, heavy over brain, 1 or 2 on snout, 6–10 in opercular patch, patch on dorsal margin of caudal peduncle (embedded & not visible on ventral margin), 1–4 on lateral midline of caudal peduncle, 3–4 internally above spinal column at caudal peduncle, & decreased on P_1 & P_2. *Pelagic juvenile*—More dorsally on head; on snout, premaxillary, & lower jaw; opercular patch larger; posteroventral margin of eye, eventually lining orbit; bar forming posteroventrally below orbit; 3 saddles below 1D (nape to 3rd spine, 4th–6th spines, & 8th–11th spines); broad saddle below 2D & saddle at caudal peduncle; all saddles eventually extend to fins as bars with large black spot at 7th–11th spines of D; P_1 & P_2 lack pigment in specimens >21 mm. *Benthic juvenile*—Strongly mottled.
Diagnostic features: Short, apposing pigment series posteriorly on tail (remnants of these visible in postflexion larvae); pigment on lower jaw, maxillary, opercular region, & top of head; moderately strong, serrated parietal spines; pelagic juveniles have 5 saddles & black spot on 1D.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL			58–60 59	52–63 60	56–67 61	61–67 64
BD/BL			40–41 40	34–42 38	30–37 33	33–37 35
HL/BL			42–44 43	38–48 42	33–42 38	36–37 37
SnL/HL			27–27 27	24–35 29	22–33 27	28–29 29
ED/HL			36–38 37	38–41 39	31–42 34	24–30 27
P_1L/BL			23–27 25	20–29 25	24–29 26	23–25 24
P_2L/BL			12–15 14	10–23 17	19–24 22	19–23 21
P_1BD/SL			14–15 15	11–14 13	8–10 9	9–9 9

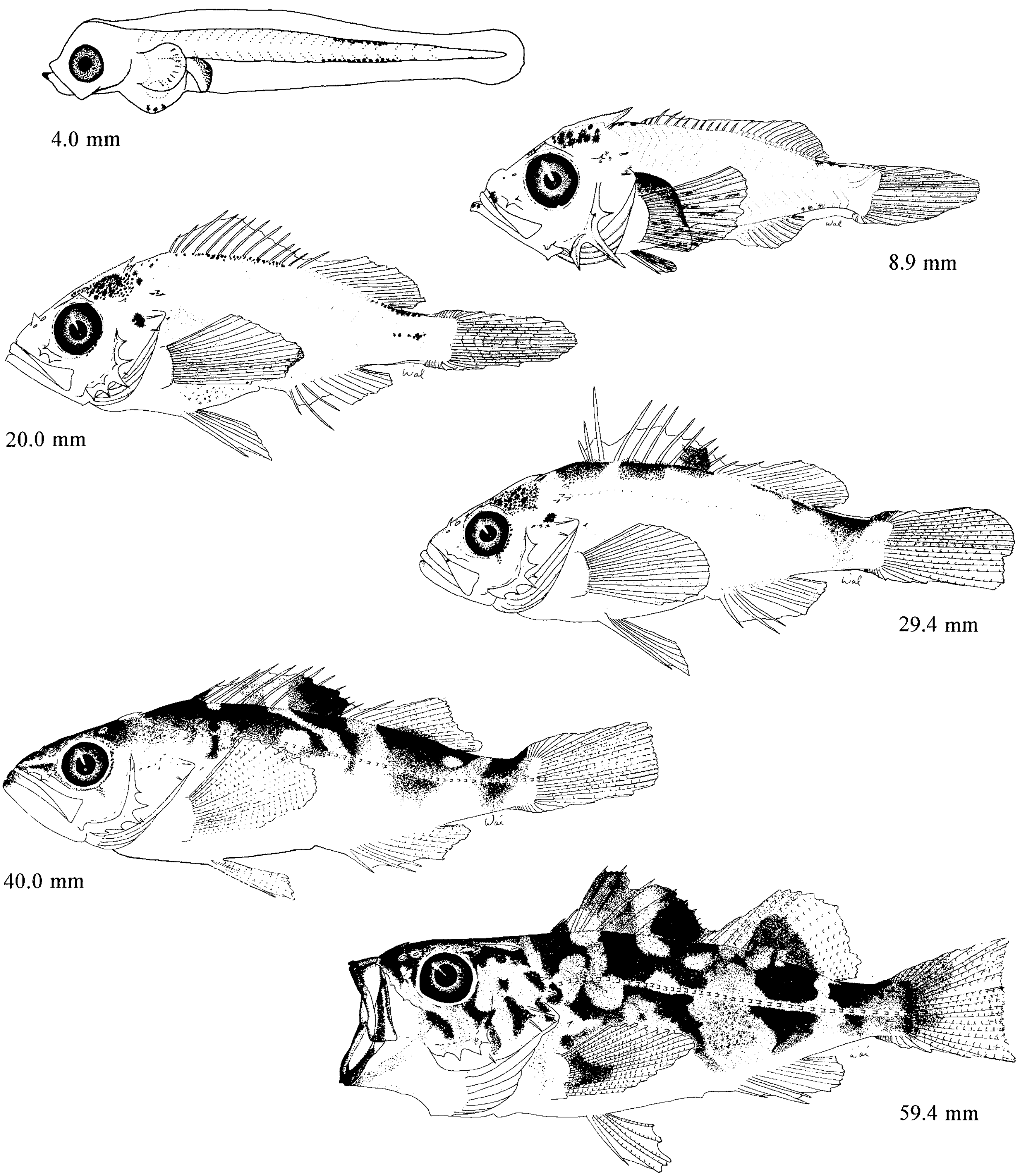


Figure Scorpaenidae 20. Preflexion larva, 4.0 mm (Moser et al. 1977); postflexion larvae, 8.9 mm, 20.0 mm; pelagic juveniles, 29.4 mm, 40.0 mm; benthic juvenile, 59.4 mm (Richardson and Laroche 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	6	6
Pelvic	I,5	I,5
Pectoral	18–20	19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper		
Lower		
Gill rakers:		
Total	17–25	23
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Yaquina Bay, Oregon to central Baja California

Habitat: On bottom in shallow waters, usually in rocky areas, kelp forests, or eelgrass beds; adults to 46 m depth but usually <15 m

Spawning season: Winter

ELH pattern: Viviparous; planktonic larvae

LITERATURE

Kendall 1991
Matarese et al. 1989
Moreno 1993

* Based on Matarese et al. (1989) & Moreno (1993).
† Eggs develop in ovaries.
‡ From Moreno (1993); overall range is given above & range of means for size classes within stages is given below.

EARLY LIFE HISTORY DESCRIPTION*

EGGS†
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: 4.3 mm
Flexion length: ca. 6.0–8.0 mm
Transformation length: <27 mm
Fin development sequence:
Pigmentation: *Preflexion*—Initially, on midbrain, on lower jaw tip (some specimens), laterally on upper & lower jaws (some specimens), on nape, dorsally & ventrally on gut, 1 anterior to anus, ca. 35–50 in series on dorsum (from nape to posteriormost myomere), heavy on entire ventral margin of tail, on lateral midline of tail (some specimens), laterally at cleithrum (some specimens), at angular (some specimens), & on forebrain (some specimens); by 5.0 mm, lower jaw tip & laterally on upper & lower jaws (most specimens), lateral midline of tail (most specimens), laterally on gut (most specimens), laterally on cleithrum (most specimens), otic region (most specimens), & at nares (some specimens). *Flexion*—More on head & nape; up to 90 in series on dorsum; series on ventral margin of tail becoming embedded; more in lateral midline series; internally above spinal column on tail; lacking on P_1. *Juvenile*—Heavy on head, except on cheek; heavy on body, except ventrally on gut; basally on 2D, A, & P_2; at mid-region of 1D.
Diagnostic features: In early preflexion larvae, heavy pigment on head, dorsum, ventral margin of tail, & jaws; in later preflexion larvae, pigment on nares & on lateral midline of tail (on surface & internally); P_1 lacks pigment; weakly developed parietal, postocular, pterotic, & preopercular spines.

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		30–41 34–38	37–44 40–43			
BD/BL		11–19 15–16	15–22 17–20			
HL/BL		16–26 19–20	21–28 24–26			
HW/HL						
SnL/HL		20–42 29–33	25–43 30–33			
ED/HL		27–46 36–39	27–50 35–44			
P_1L/BL						
P_2L/BL						

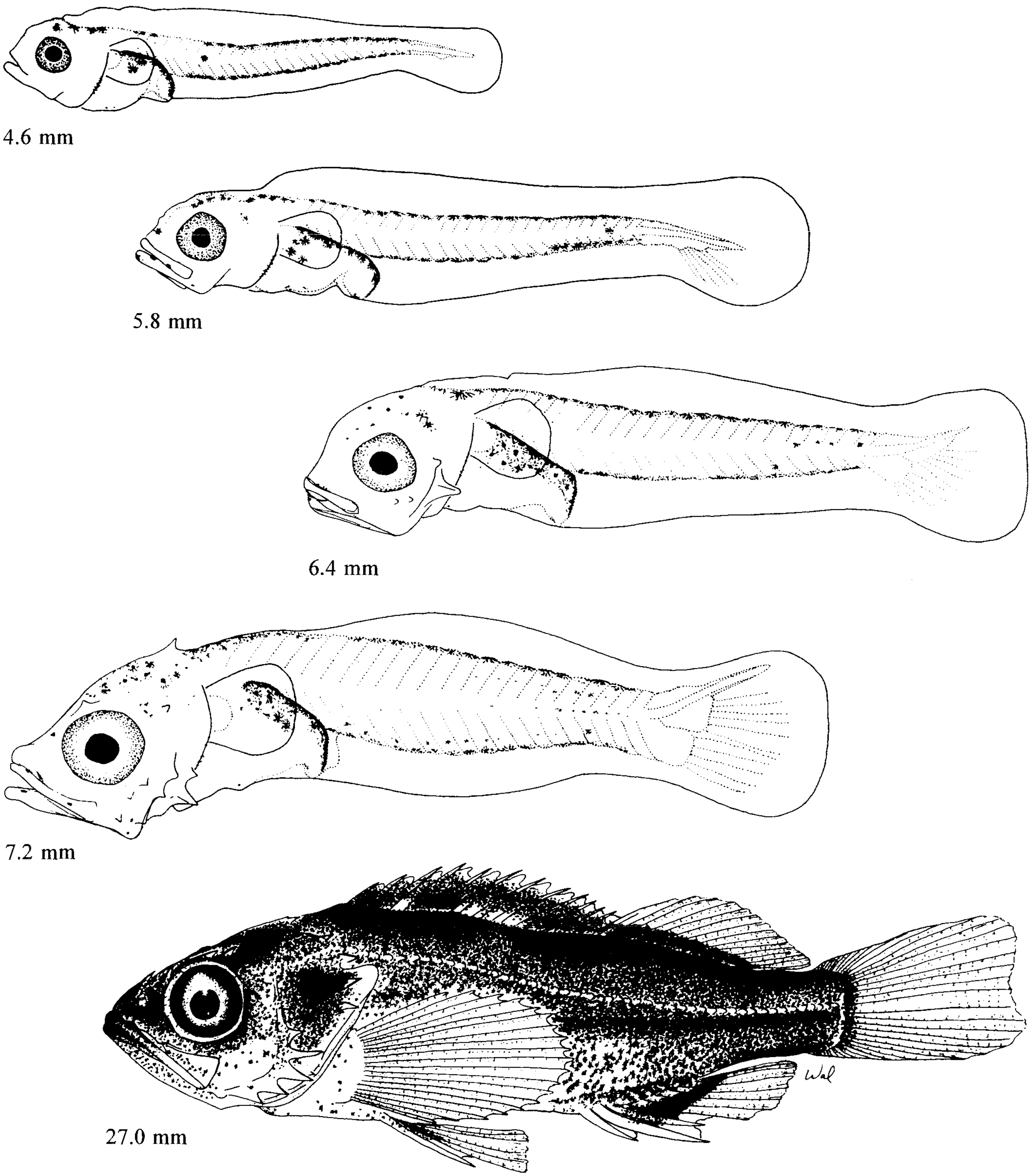


Figure Scorpaenidae 21. Preflexion larvae, 4.6 mm, 5.8 mm, 6.4 mm; flexion larva, 7.2 mm (Moreno 1993); juvenile, 27.0 mm (Laroche, in prep., from Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27–28	27
Precaudal	11	11
Caudal	16–17	16–17
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	13–16	15
Anal spines	III	III
Anal rays	8–9	8
Pelvic	I,5	I,5
Pectoral	17–19	18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	13–14	13
Lower	12–14	13
Gill rakers:		
Upper	8–10	10
Lower	23–26	23
Branchiostegals	7	7

LIFE HISTORY

Range: Fort Bragg, California to central Baja California & Isla de Guadalupe, Mexico

Habitat: Demersal & semi-pelagic; adults to at least 247 m depth

Spawning season: December–May

ELH pattern: Viviparous; planktonic larvae & pelagic juveniles

LITERATURE

Kendall 1991
Kendall & Lenarz 1987
Matarese et al. 1989
Moser & Butler 1987

* Eggs develop in ovaries.
† From Moser & Butler (1987).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Length at birth: 4.3–4.7 mm
Flexion length: ca. 6.2–7.6 mm
Transformation length:
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Initially, 1 or 2 above brain, 1 at nape, dorsolaterally on gut & some ventrally, 8–13 in postanal ventral series, (from 5th–6th to 14th–18th postanal myomere); before 5.0 mm, at tip of lower jaw, 1 or 2 on inner surface of P_1, streaks on P_1 blade, 1 or 2 more on nape, solid over midbrain, 2–4 in postanal dorsal midline series (from 13th–16th to 17th–18th postanal myomere), & 1 at hypural region (some specimens); by the end of stage, 9–13 in postanal dorsal series, solid on nape, solid above forebrain, solid on inner surface of P_1 base, most of P_1 blade covered (concentrated distally), embedded above spinal column at 17th–18th postanal myomeres. *Flexion*—11–19 in postanal dorsal series, 8 or more in series above spinal column, laterally on upper jaw, opercular region, between nape & P_1 base, & on dorsum extending posteriad from nape.
Diagnostic features: Early pigment pattern, particularly on P_1; composition, location, & sequence of formation of dorsal & ventral postanal pigment series; head spines not strongly developed.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–43 39	43–51 47			
BD/BL		14–21 17	22–24 23			
HL/BL		21–26 24	29–35 32			
HW/HL						
SnL/HL		20–31 26	26–26 26			
ED/HL		33–42 39	37–38 37			
P_1L/BL		5–10 7	12–14 13			
P_2L/BL		0–0 0	0.7–1 1			
P_1BD/BL		4–9 7	11–11 11			

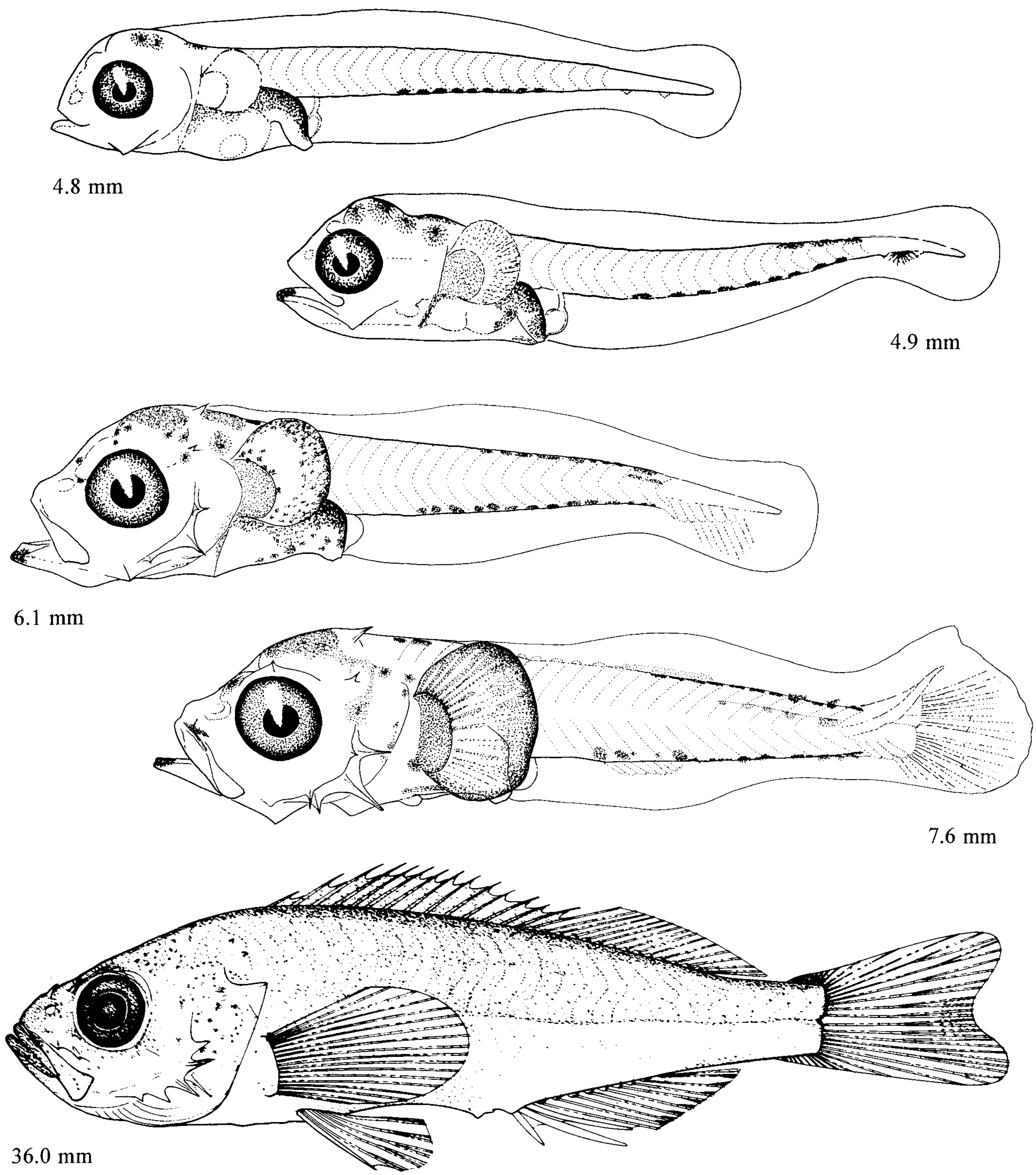


Figure Scorpaenidae 22. Preflexion larvae, 4.8 mm, 4.9 mm, 6.1 mm; flexion larva, 7.6 mm (Moser and Butler 1987); pelagic juvenile, 36.0 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XII–XIII	XIII
Dorsal rays	15–17	
Anal spines	8–10	
Anal rays	III	III
Pelvic	I,5	I,5
Pectoral	17–19	
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper		
Lower		
Gill rakers:		
Total	29–36	
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Northern California to central Baja California

Habitat: Over rocky reefs or other structures to ca. 150 m depth

Spawning season: January–March, with a peak in February

ELH pattern: Viviparous; planktonic larvae, & pelagic juveniles

LITERATURE

Moser & Butler 1987

* Eggs develop in ovaries.
† From Moser & Butler (1987).

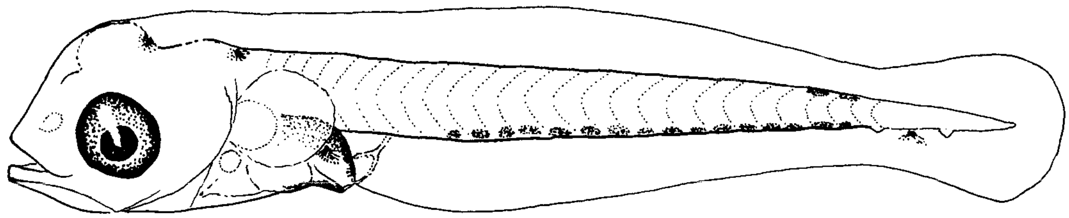
EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

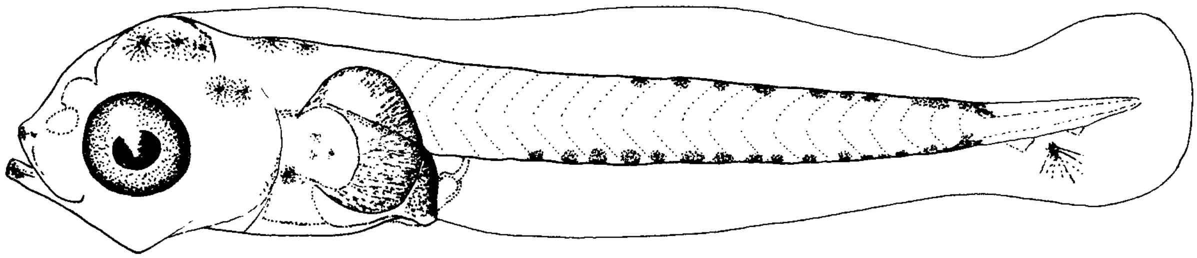
LARVAE
Length at birth: 4.8–5.4 mm
Flexion length:
Transformation length:
Fin development sequence:
Pigmentation: *Preflexion*—Initially, 0–4 (usually 1–2) on midbrain, 0–3 on nape, dorsolaterally on gut, 14–20 in series on ventral margin of tail (from postanal myomere 3–4 to 18–20), 0–2 on dorsal margin of tail, & 1 below notochord in caudal region; by 5.8 mm, midbrain & nape covered, on tips of upper & lower jaws, at otic region, ventrally & laterally on gut, on inner surface of P_1 base, on P_1 blade (heaviest at distal margin with clear zone dorsally in middle of blade), 7–16 on dorsal margin extending anteriad to ca. postanal myomere 7–8.
Diagnostic features: Heavy pigmentation on midbrain & nape & pigment on tips of jaws; composition & arrangement of pigment series on dorsal & ventral margins of tail (progressive enlargement of dorsal series); caudal melanophore.

MORPHOMETRICS (raage & mean in %)†

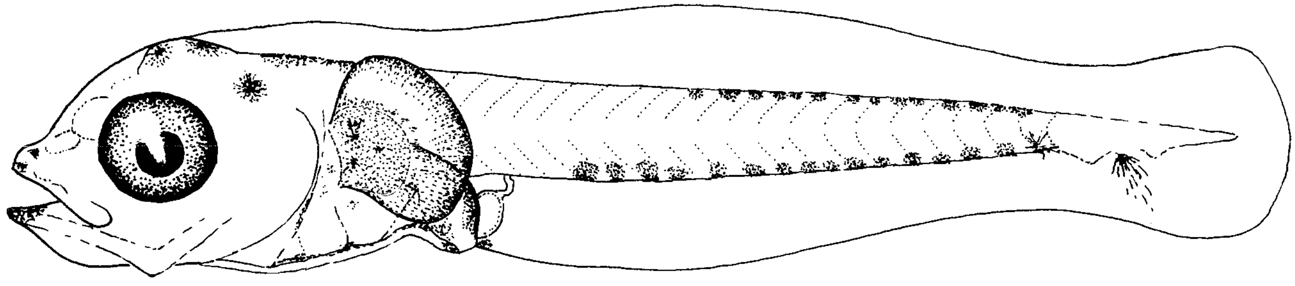
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–38 37				
BD/BL		14–18 16				
HL/BL		20–26 23				
HW/HL						
SnL/HL		25–32 28				
ED/HL		35–41 38				
P_1L/BL		4–6 5				
P_2L/BL		0–0 0				
P_1BD/BL		5–8 6				



5.0 mm



5.6 mm



5.8 mm

Figure Scorpaenidae 23. Preflexion larvae, 5.0 mm, 5.6 mm, 5.8 mm (Moser and Butler 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	XII	XII
Dorsal rays	8–9	9
Anal spines	III	III
Anal rays	5–6	5
Pelvic	I,5	I,5
Pectoral	16–19	18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	5–7	6
Lower	6–7	6
Gill rakers:		
Upper	1–3	2
Lower	7–8	8
Branchiostegals	7	7

LIFE HISTORY

Range: Southern Baja California & the Gulf of California to Peru

Habitat: Demersal; adults to at least 200 m depth

Spawning season: Possibly year-round

ELH pattern: Oviparous; eggs probably released in buoyant gelatinous mass; planktonic larvae & pelagic juveniles

LITERATURE

Moser et al. 1977
Washington et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Benthic juvenile, 21.6 mm (R. C. Walker)

* Calculations from data in Moser et al. (1977); 2 benthic juveniles measured in this study.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5.0–5.5 mm
Transformation length: Pjuv, ca. 10.5 mm; Bjuv, ca. 21–23 mm
Fin development sequence:
Pigmentation: *Flexion*—A few remaining from postanal ventral series present in preflexion stage; embedded shield above gas bladder; on P_1, elongate blotch on upper distal region, blotch on lower proximal region, & blotch on inner surface of base; blotch on 1D from D III or D IV to D VI, VII, or VIII; beginning of saddles below 1D; blotch at P_2 base. *Postflexion*—Blotches on P_1 blade join to form an oblique bar, wider on upper region of fin; 2 broad saddles at 1D; saddle at 2D enlarges ventrad to form broad bar by end of stage; above & lateral to brain; basal region of branchiostegal membrane; on posterior region of opercle. *Pelagic juvenile*—1D almost solid with darker region from D VI to D X; blotch on 2D confluent with bar; lateral blotch at caudal peduncle expands to form bar; most of head covered. *Benthic juvenile*—Scattered laterally on head, except lower cheek region; broad bars under 1D & 2D, & bar forming on caudal peduncle; on 1D, with black blotch at 7th–10th spines; basally on 2D.
Diagnostic features: Relative preanal length, body depth, head length & eye diameter (after flexion stage) greater than in *Pontinus* sp.; notochord flexion & transition to pelagic juvenile occur at smaller size than in *Pontinus* sp.; pigment pattern somewhat different, especially oblique bar on P_1; head spines larger than in other species; spiny suborbital ridge strongly developed.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL			60–69 65	67–68 67	61–69 66	69–69 69
BD/BL			46–46 46	40–47 44	39–46 41	33–33 33
HL/BL			44–46 45	44–47 45	39–46 42	41–42 42
HW/HL						
SnL/HL			29–32 31	26–29 28	22–27 24	21–27 24
ED/HL			28–30 29	28–32 30	31–37 34	33–34 33
P_1L/BL			33–34 33	24–30 27	24–29 27	30–30 30
P_2L/BL			18–19 19	20–20 20	19–22 21	22–23 23
P_1BD/BL			17–18 18	14–18 16	13–15 14	11–13 12

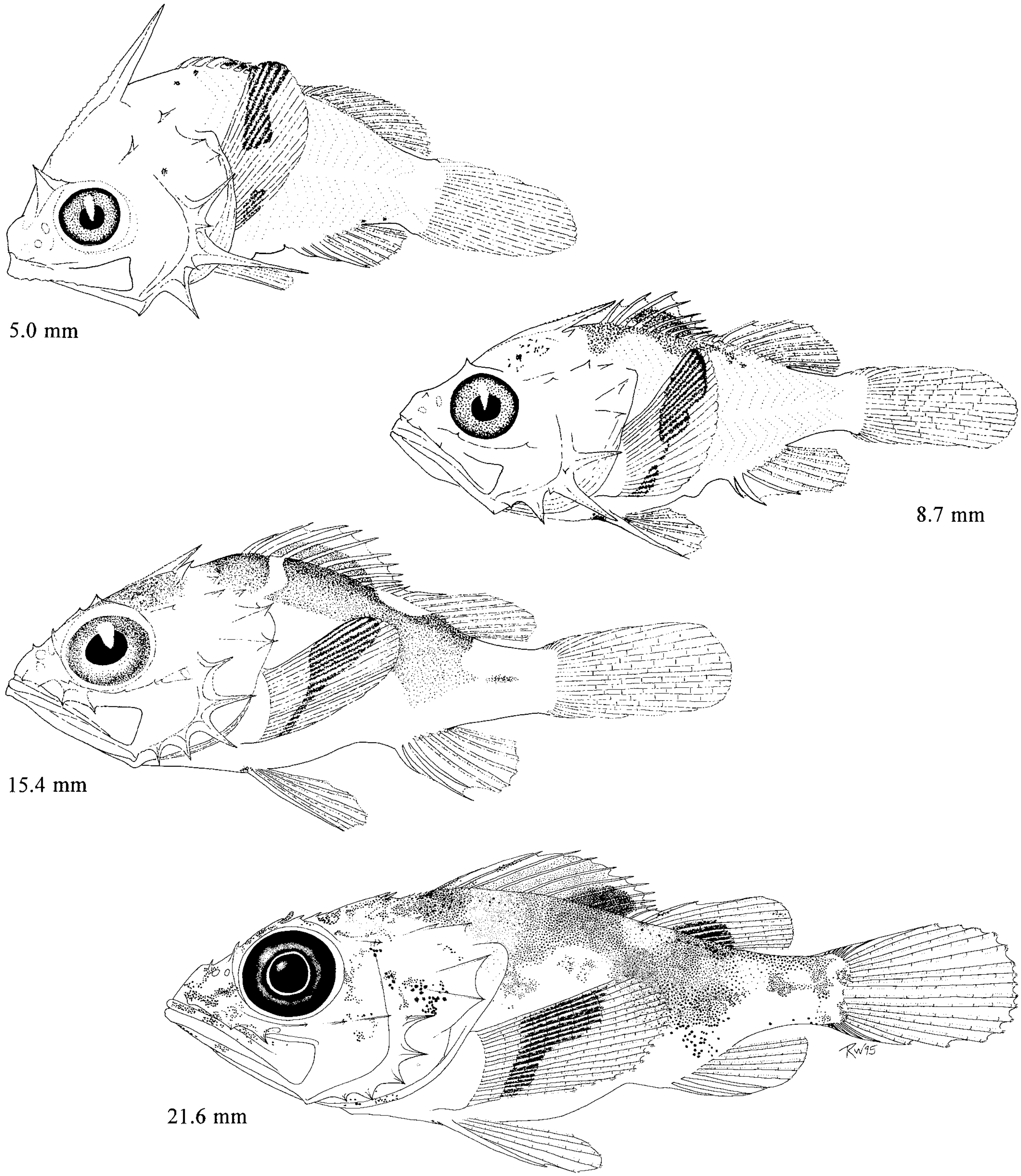


Figure Scorpaenidae 24. Late flexion larva, 5.0 mm; postflexion larva, 8.7 mm; pelagic juvenile, 15.4 mm (Moser et al. 1977); benthic juvenile, 21.6 mm (SIO 73–281).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	XII	XII
Dorsal rays	8–9	9
Anal spines	III	III
Anal rays	5–6	5
Pelvic	I,5	I,5
Pectoral	18–19	19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	5–6	6
Lower	6–7	6
Gill rakers:		
Upper	2–3	2
Lower	7–8	8
Branchiostegals	7	7

LIFE HISTORY

Range: Central Baja California & Gulf of California to northern Peru

Habitat: Demersal

Spawning season: Possibly year-round

ELH pattern: Oviparous; eggs probably released in buoyant gelatinous mass; planktonic larvae & pelagic juveniles

LITERATURE

Moser et al. 1977
Washington et al. 1984b

* Calculations from data in Moser et al. (1977).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.3 mm
Flexion length: ca. 4.1–4.6 mm
Transformation length: Pjuv, ca. 15.0 mm; Bjuv, 17–27 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—11–16 in postanal median ventral series, extending from anus to hypural region; beginning of blotch above developing gas bladder; a few dorsally on terminal gut & streak on ventral midline of gut; on edge of finfold at anus; peppering on the entire P_1 blade & some medially at the margin of the P_1 base. *Flexion*—Lost at P_1 base & beginning to recede from basal region of blade. *Postflexion*—By 6.5 mm, blotch between D III & D IV; larvae >7.0 mm have series of blotches on 1D; by 10.0 mm, above midbrain & restricted to distal margin of P_1; by ca. 13.0 mm, distal bar on P_1 spreading toward base, saddles forming below D I–III & D V–X. *Pelagic juvenile*—Saddle below 2D & at caudal peduncle; solid on P_2.
Diagnostic features: Head spines large in mid-larval period, especially parietal, supraocular ridge, & preopercular but not at subocular ridge; initially, large aliform P_1 covered with pigment (pigment recedes to margin & later covers fin in postflexion stage); pigment above gas bladder; pelagic juvenile with distinct pigment saddles & fin pigment.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		44–53 48	54–54 54	58–65 61	61–65 64	62–65 64
BD/BL		25–32 28	33–34 33	36–42 39	36–41 38	36–36 36
HL/BL		26–33 30	32–33 32	38–44 40	38–43 41	39–40 40
HW/HL						
SnL/HL		27–33 30	40–42 41	29–40 33	27–32 29	26–30 28
ED/HL		30–36 33	31–31 31	22–31 27	22–30 27	28–29 28
P_1L/BL		18–19 18	26–27 27	27–36 31	31–35 33	30–34 32
P_2L/BL		0–0 0	2–5 4	13–25 20	19–24 21	21–24 22
P_1BD/BL		15–16 15	15–16 16	12–16 14	12–14 13	12–13 13

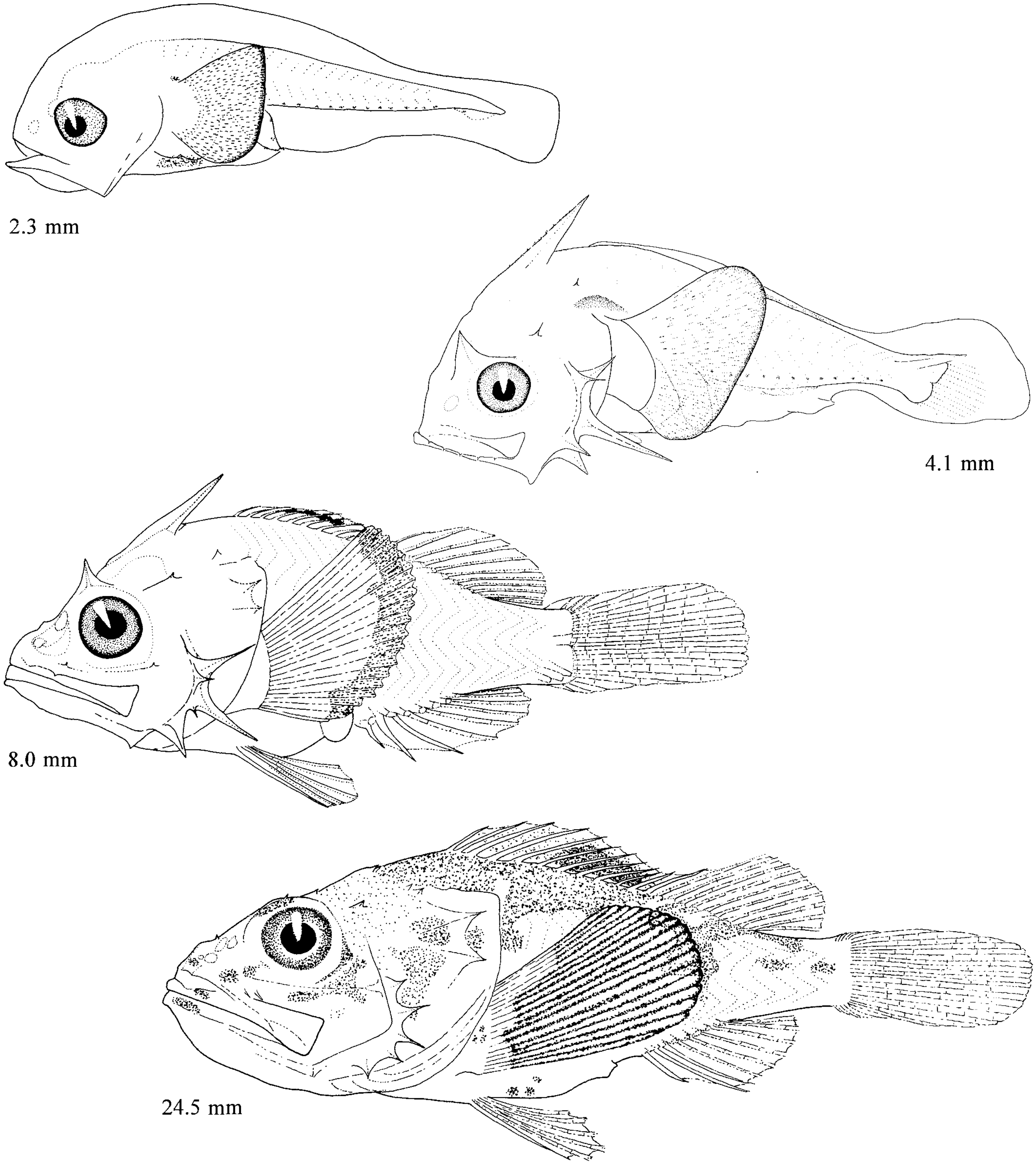


Figure Scorpaenidae 25. Preflexion larva, 2.3 mm; flexion larva, 4.1 mm; postflexion larva, 8.0 mm; pelagic juvenile, 24.5 mm (Moser et al. 1977).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	XII	XII
Dorsal rays	8–10	9
Anal spines	III	III
Anal rays	5–6	5
Pelvic	I,5	I,5
Pectoral	17–19	18
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	6–8	7
Lower	7–9	8
Gill rakers:		
Upper	4–6	5
Lower	10–12	11
Branchiostegals	7	7

LIFE HISTORY

Range: Santa Cruz, California to Gulf of California

Habitat: Demersal; adults usually shallower than 30 m but some as deep as 183 m

Spawning season: June–November with a peak in August

ELH pattern: Oviparous; eggs released in bilobed gelatinous masses that float to the surface; planktonic larvae

LITERATURE

Barnhart 1932
David 1939
Moser et al. 1977
Orton 1955
Washington et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Benthic juvenile, 20.5 mm (R. C. Walker)

* Calculations from data in Moser et al. (1977); 2 benthic juveniles measured in this study.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.16–1.19 mm × 1.22–1.29 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: smooth
Pigment:
Diagnostic features: Slightly elliptical eggs in bilobed gelatinous mass; homogeneous yolk; no OG

LARVAE

Hatching length: 1.9–2.0 mm
Flexion length: 4.5–5.7 mm
Transformation length: BJuv <20.5 mm
Fin development sequence: P_1, C_1, D & A, C_2, P_2
Pigmentation: *Yolk-sac*—A patch above gut. *Preflexion*—Initially, 2–7 in series along posterior half of postanal ventral midline & distally on P_1 blade; by 4.0 mm, entire blade & inner surface of P_1 base covered, gut completely covered, & blotch on ventral midline anterior to cleithral symphysis. *Flexion*—Fewer in postanal ventral series; on nape; above midbrain. *Postflexion*—Clear zone at distal margin of P_1; above forebrain; at base of P_2; in epaxial myosepta above P_1; on cheek & below eye. *Benthic juvenile*—Strongly mottled on head, body, & fins; pale zone posteriorly on head; on foliose skin flap above eye & on small flaps laterally on trunk.
Diagnostic features: Relatively large preanal distance; pigment above gut (not restricted to region above gas bladder); P_1 somewhat fan-shaped with pigment initially at margin, then over entire fin, & later a clear zone on distal margin; inner surface of P_1 base & P_2 heavily pigmented; initial postanal series on posterior half of tail; epaxial myosepta pigment on trunk in late larvae; head spines well developed.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	BJuv
Sn-A/BL		44–55 49	49–56 51	55–64 60		60–62 61
BD/BL		29–45 36	28–32 29	36–44 40		34–36 35
HL/BL		19–33 29	32–36 34	35–41 38		34–37 35
HW/HL						
SnL/HL		28–37 31	31–35 33	28–35 32		27–29 28
ED/HL		27–47 35	28–34 31	26–36 32		34–36 35
P_1L/BL		7–22 16	19–22 21	18–29 23		28–31 30
P_2L/BL		0–2 0.4	2–6 3	9–20 15		22–24 23
P_1BD/BL		8–16 14	15–17 16	14–17 16		13–14 13

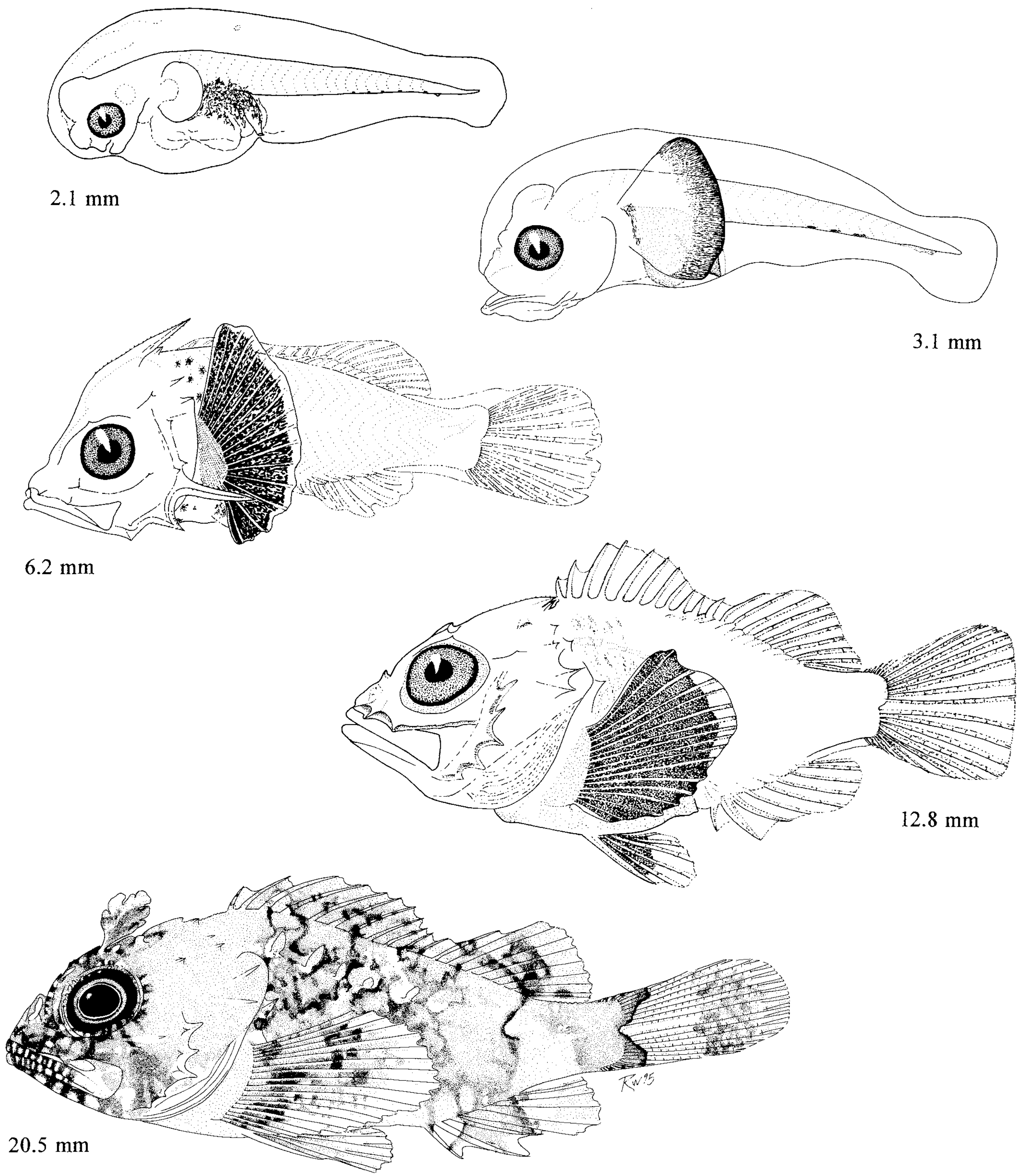


Figure Scorpaenidae 26. Yolk-sac larva, 2.1 mm; preflexion larva, 3.1 mm; postflexion larvae, 6.2 mm, 12.8 mm (Moser et al. 1977); benthic juvenile, 20.5 mm (SIO 57–190).

MERISTICS

	Range	Mode
Vertebrae:		
Total	23–25	24
Precaudal	10	10
Caudal	13–15	14
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	9–10	9
Anal spines	III	III
Anal rays	4–6	5
Pelvic	I,5	I,5
Pectoral	16–19	17
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	4–5	4
Lower	3–5	5
Gill rakers:		
Upper	5–7	6
Lower	11–12	11
Branchiostegals	7	7

LIFE HISTORY

Range: Santa Catalina Island, California to Peru, including the Galapagos Islands

Habitat: Demersal in rocky areas; adults to 26 m depth

Spawning season: Apparently year-round

ELH pattern: Oviparous; eggs released in buoyant, bilobed gelatinous egg mass; planktonic larvae.

LITERATURE

Moser et al. 1977
Washington et al. 1984b

* Calculations from data in Moser et al. (1977).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.74–0.78 × 0.78–0.82 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: smooth
Pigment:
Diagnostic features: Slightly elliptical eggs in bilobed gelatinous egg mass; homogeneous yolk; no OG

LARVAE

Hatching length: ca. 1.8 mm
Flexion length: 4.0–5.4 mm
Transformation length: BJuv, 11.0–13.0 mm
Fin development sequence: P_1 & C_1 & P_2, C_2 & D & A
Pigmentation: *Preflexion*—Initially, 12–18 in postanal ventral series (from point of deflection of terminal gut section to hypural region), several above terminal gut & patch on ventral midline of gut, some embedded dorsal to axilla, & peppering on distal margin of P_1; by 3.0 mm, distal half of P_1 peppered, heaviest at margin; postanal series lost by end of stage. *Flexion*—Increases in axillary region to form shield over gas bladder; ventral gut series lost. *Postflexion*—By 9.0 mm, limited to distal margin of P_1; some on preopercle & opercle by end of stage. *Transformation*—Head mottled; irregular bars on body extending into fins. *Benthic juvenile*—Vague bars on body with pale caudal peduncle; fins barred; black spot on 1D (from D VII to D XII).
Diagnostic features: Prominent crestlike parietal ridges that terminate in double spines, with the posterior (nuchal) spine larger than the anterior (parietal) spine; strong head spination appears early in preflexion stage; large fan-shaped P_1 with distinctive distal pigmentation; embedded shield over gas bladder; XIII dorsal spines.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	BJuv
Sn-A/BL		44–47 46	48–59 53	56–66 61	62–65 64	66
BD/BL		26–31 28	29–37 34	36–41 39	35–37 36	35
HL/BL		29–31 30	29–41 35	33–41 37	36–39 38	38
HW/HL						
SnL/HL		25–40 31	32–42 36	28–35 32	25–26 26	23
ED/HL		29–35 32	23–34 28	27–37 32	30–35 33	38
P_1L/BL		10–26 22	29–41 34	36–45 39	35–39 37	34
P_2L/BL		0–0 0	0–13 6	11–22 18	19–20 19	22
P_1BD/BL		8–18 15	17–20 19	16–21 18	17–18 7	17

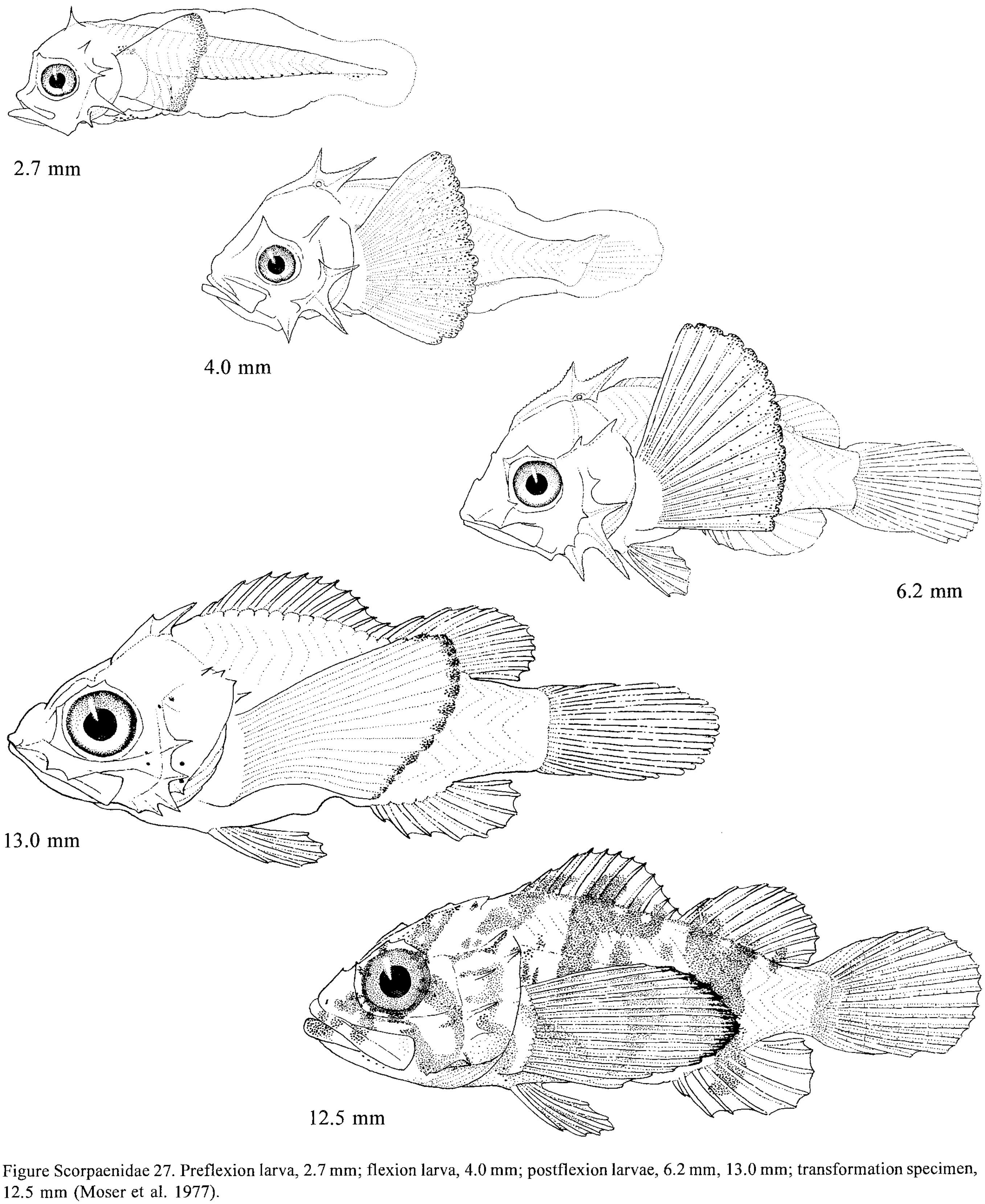


Figure Scorpaenidae 27. Preflexion larva, 2.7 mm; flexion larva, 4.0 mm; postflexion larvae, 6.2 mm, 13.0 mm; transformation specimen, 12.5 mm (Moser et al. 1977).

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–31	30
Precaudal	12–13	12
Caudal	17–21	18
Fins:		
Dorsal spines	XIV–XVII	XVI
Dorsal rays	8–10	9
Anal spines	III	III
Anal rays	3–5	5
Pelvic	I,5	I,5
Pectoral	20–23	21
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	8–10	9
Lower	8–9	9
Gill rakers:		
Upper	5–8	6
Lower	12–17	14
Branchiostegals	7	7

LIFE HISTORY

Range: Bering Sea & northern Japan to northern Baja California

Habitat: Demersal on soft bottom; adults to >1500 m depth on continental slope

Spawning season: January–June

ELH pattern: Oviparous; eggs released in bilobed gelatinous masses that float to the surface; planktonic larvae; relatively short pelagic juvenile stage

LITERATURE

Matarese et al. 1989
Moser 1974
Moser et al. 1977
Pearcy 1962
Washington et al. 1984b

* Descriptions of eggs & of larvae smaller than 10.0 mm refer to *Sebastolobus* spp. since they can not be identified to species.
† Calculations from data in Moser (1974).

EARLY LIFE HISTORY DESCRIPTION*

EGGS

Shell diam.: 1.1 × 1.2 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.10 mm
Shell surface: smooth
Pigment: In late stage embryos, above gut, blotch on ventral midline at ca. 13th postanal myomere
Diagnostic features: In a bilobed gelatinous mass; elliptical shape; 1 small OG; postanal pigment & vesiculate finfold in late-stage eggs

LARVAE

Hatching length: ca. 2.6 mm
Flexion length: 6.0–7.3 mm
Transformation length: PJuv, ca. 20 mm; BJuv, ca. 22–27 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—(See illustrations for *S. altivelis*) Initially, median dorsal blotch forms above ventral postanal blotch & when expanded forms bar; on dorsal, lateral, & ventral gut; begin losing postanal blotches in larvae as small as 4.2 mm; postanal blotches lacking in larvae >6.4 mm; peppering on distal margin of P_1 & on inner surface of P_1 base in 4.0–5.0 mm larvae; on mid- & hindbrain & nape in some larvae >5.2 mm. *Flexion–postflexion*—Above forebrain in 7.0–9.0 mm larvae; in larvae 14.0–20.0 mm, blotch posteriorly on opercle, scattered posteroventral to eye, on lateral P_1 base, over lateral gut region, on P_2 base, & on P_1 rays (some specimens). *Pelagic juvenile*—Entire head becomes speckled; irregular mottled sheath over entire trunk & onto 1D. *Benthic juvenile*—Entire body, 1D, 2D, & A mottled; P_2 covered; 4 bars on P_1.
Diagnostic features: Early larvae of *Sebastolobus* spp. have ventral or apposing dorsal & ventral postanal blotches; 28–31 myomeres; later preflexion larvae have fan-shaped P_1, pigmented distally; flexion larvae have prominent parietal ridges with double spines, the posterior one (nuchal) larger than the anterior spine (parietal); postflexion *S. alascanus* >10.0 mm have 29–31 myomeres & relative P_1 base depth & P_1 length slightly smaller than in *S. altivelis*; pelagic juveniles mottled on trunk & 1D & reach a maximum length of ca. 27 mm before settlement.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		40–44 42	42–52 47	53–68 60	59–68 63	58–67 61
BD/BL		15–27 20	23–34 29	31–39 35	31–36 34	22–32 25
HL/BL		17–31 26	28–35 31	35–45 39	39–43 41	34–41 36
SnL/HL		16–34 26	31–43 36	22–41 32	22–30 27	23–34 27
ED/HL		22–40 27	25–30 28	26–38 32	29–37 34	31–42 38
P_1L/BL		7–17 12	19–25 22	24–32 29	28–32 30	23–28 25
P_2L/BL		0–0 0	2–12 5	11–21 18	18–22 21	20–22 21
P_1BD/BL		5–15 10	13–19 16	13–20 15	12–15 14	9–13 11

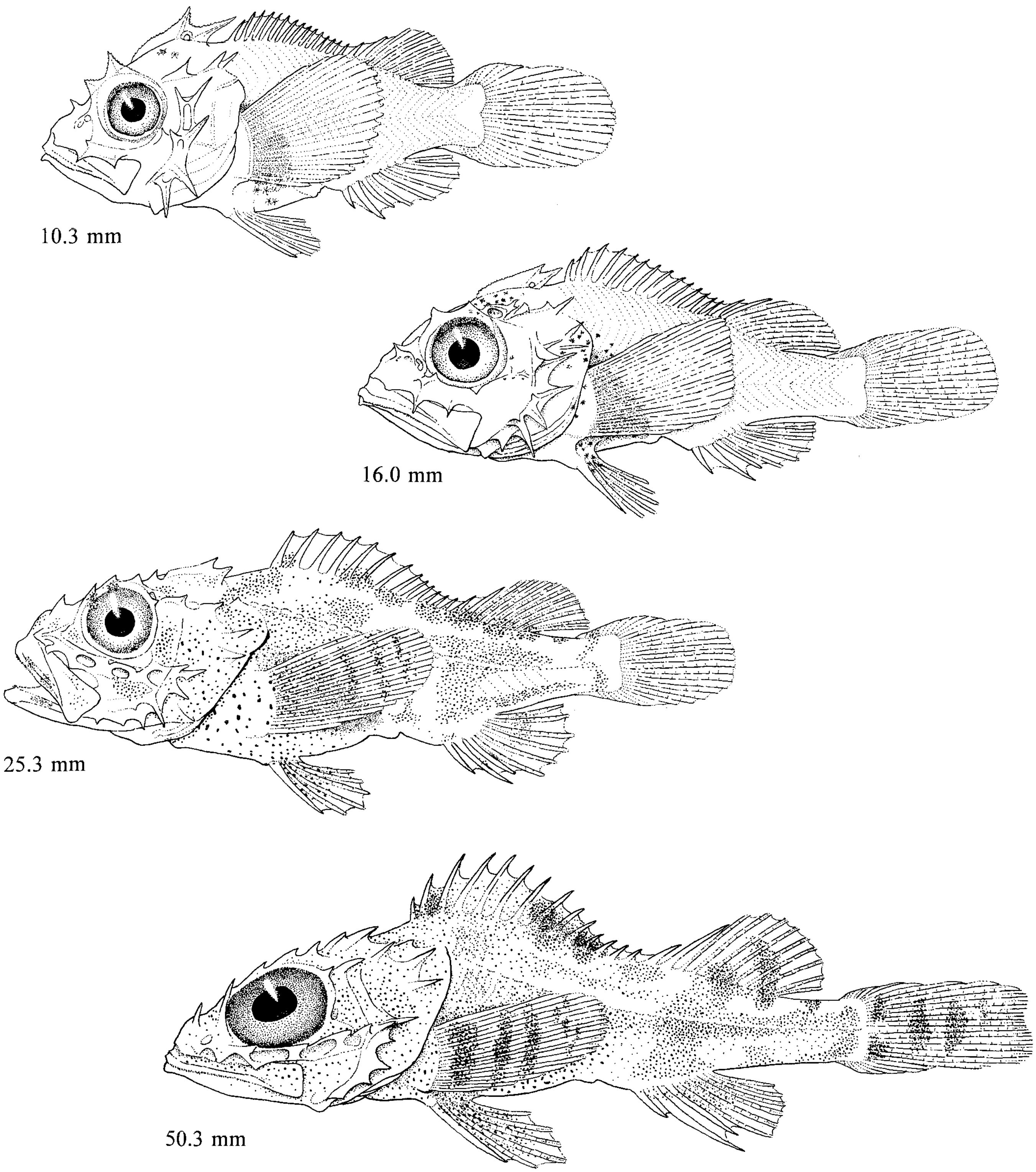


Figure Scorpaenidae 28. Postflexion larvae, 10.3 mm, 16.0 mm; pelagic juvenile, 25.3 mm; benthic juvenile, 50.3 mm (Moser 1974); see Figure Scorpaenidae 29 for preflexion and flexion stages.

MERISTICS

	Range	Mode
Vertebrae:		
Total	28–29	29
Precaudal	12–13	12
Caudal	16–17	17
Fins:		
Dorsal spines	XV–XVI	XV
Dorsal rays	8–10	9
Anal spines	III	III
Anal rays	4–6	5
Pelvic	I,5	I,5
Pectoral	22–24	23
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	6–8	7
Lower	7–8	7
Gill rakers:		
Upper	7–9	7
Lower	14–17	15
Branchiostegals	7	7

LIFE HISTORY

Range: Aleutian Islands to Cabo San Lucas, Baja California Sur

Habitat: Demersal on soft bottom; adults to >1500 m depth on continental slope

Spawning season: January–June

ELH pattern: Oviparous; eggs released in bilobed gelatinous egg masses that float to the surface; larvae planktonic; extended midwater pelagic juvenile stage

LITERATURE

Matarese et al. 1989
Moser 1974
Moser et al. 1977
Washington et al. 1984b

* Descriptions of eggs & of larvae smaller than 10.0 mm refer to *Sebastolobus* spp. since they cannot be identified to species.
† Calculations from data in Moser (1974).

EARLY LIFE HISTORY DESCRIPTION*

EGGS

Shell diam.: 1.1 × 1.2 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.10 mm
Shell surface: Smooth
Pigment: In late-stage embryos, above gut, blotch on ventral midline at ca. 13th postanal myomere
Diagnostic features: In a bilobed gelatinous mass; elliptical shape; 1 small OG; postanal pigment & vesiculate finfold in late-stage eggs.

LARVAE

Hatching length: ca. 2.6 mm
Flexion length: 6.0–7.3 mm
Transformation length: PJuv, 22 mm; BJuv, 42–56 mm
Fin development sequence: P_1, C_1, C_2 & D & A & P_2
Pigmentation: *Preflexion*—Initially, median dorsal blotch forms above ventral postanal blotch &, when expanded, they form bar; on dorsal, lateral, & ventral gut; begin losing postanal blotches in larvae as small as 4.2 mm; postanal blotches lacking in larvae >6.4 mm; peppering on distal margin of P_1 & on inner surface of P_1 base in 4.0–5.0 mm larvae; on mid-, & hindbrain & on nape in some larvae >5.2 mm. *Flexion–postflexion*—Above forebrain in 7.0–9.0 mm larvae; in larvae 14.0–20.0 mm, patches on opercle, cheek, snout, & lateral to gut, some develop solid shield over gut, anteriorly on 1D, on base of P_1, & proximally on rays (some specimens). *Pelagic juvenile*—Head becomes dusky, darker on opercle & jaws; increases on 1D & eventually on 2D; increases on P_1 & eventually covers all but distal margin; sheath over gut enlarges to cover trunk & expands posteriad to 2D & A; increases on P_2 & eventually covers entire fin. *Benthic juvenile*—Solid with darker fins.
Diagnostic features: Larvae <10.0 mm indistinguishable from *S. alascanus* (see *S. alascanus* description); *S. altivelis* postflexion larvae >10.0 mm have 28–29 myomeres & relative P_1 base depth & P_1 length slightly greater than in *S. alascanus*; pelagic juveniles deeper & more robust than those of *S. alascanus* & have black shield on body & on P_1 that expands posteriad with growth; pelagic juveniles attain larger size (>40 mm) compared with those of *S. alascanus*.

MORPHOMETRICS (range & mean in %)†

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL		40–44 42	42–52 47	53–70 63	65–73 69	63–66 64
BD/BL		15–27 20	23–34 29	31–45 39	34–44 40	27–30 28
HL/BL		17–31 26	28–35 31	35–43 40	38–43 40	37–40 38
SnL/HL		16–34 26	31–43 36	26–41 30	25–33 28	26–30 27
ED/HL		22–40 27	25–30 28	26–34 31	27–36 30	34–42 38
P_1L/BL		7–17 12	19–25 22	24–39 32	32–40 37	25–33 29
P_2L/BL		0–0 0	2–12 5	11–24 19	21–27 23	21–24 22
P_1BD/BL		5–15 10	13–19 16	15–20 18	15–20 17	13–15 14

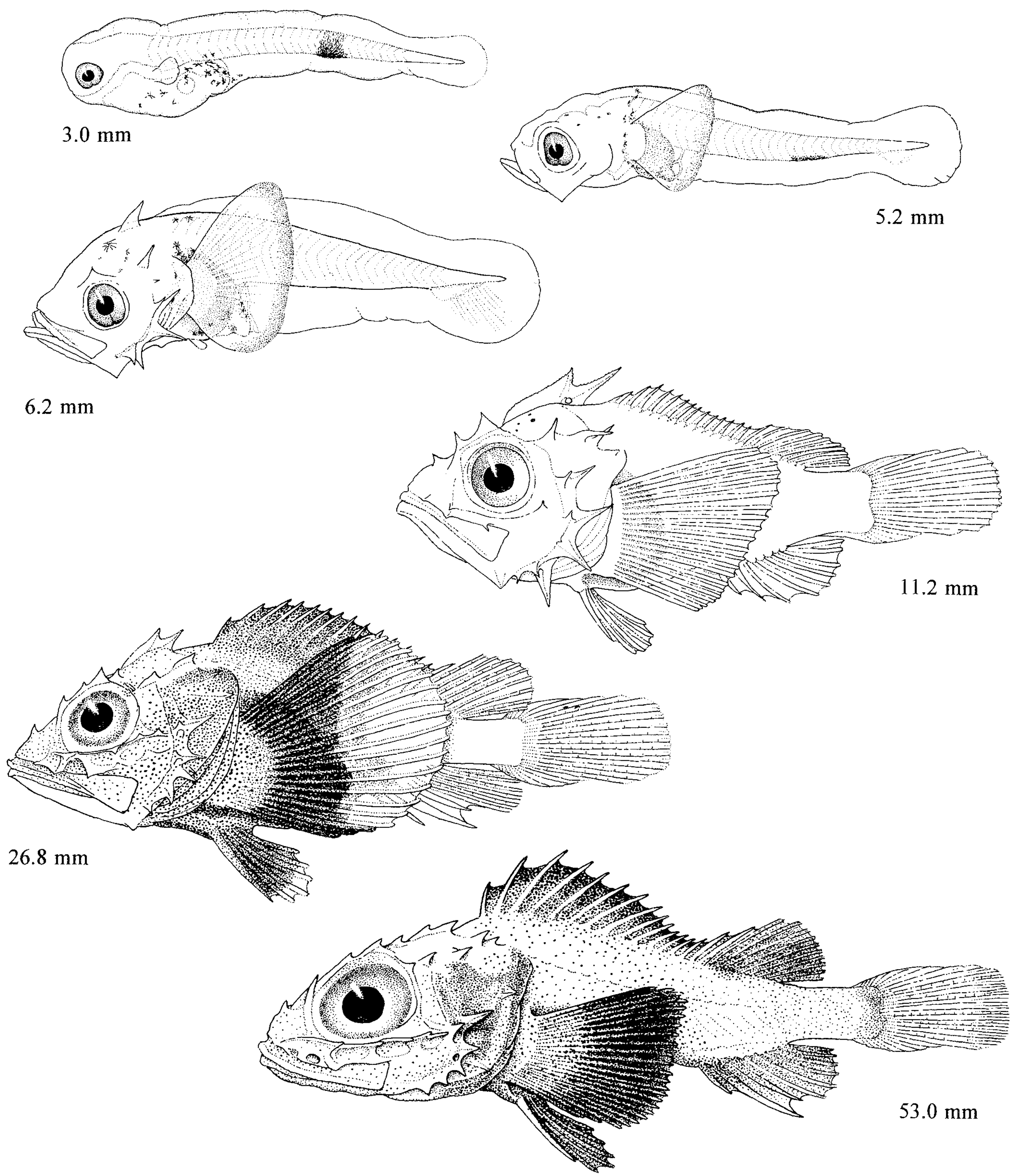


Figure Scorpaenidae 29. Yolk-sac larva, 3.0 mm; preflexion larva, 5.2 mm; early flexion larva, 6.2 mm; postflexion larva, 11.2 mm; pelagic juvenile, 26.8 mm; benthic juvenile, 53.0 mm (Moser 1974); the 3.0 mm, 5.2 mm, and 6.2 mm larvae are not identifiable to species and could be either *S. altivelis* or *S. alascanus*.

TRIGLIDAE: Searobins

W. J. RICHARDS[1]

The fishes of the family Triglidae are distributed worldwide primarily in tropical waters, with some inhabiting temperate waters, typically on continental and insular shelves and slopes. There are two subfamilies: the armored searobins or armored gurnards (Peristediinae) and the searobins or gurnards (Triglinae). The two subfamilies are very different and have been put in different families by some workers (e.g., Heemstra 1982; Miller and Richards 1991a). Both subfamilies occur in the eastern tropical Pacific. The peristediines are represented by two species in the genus *Peristedion*, which live on the deep shelves and continental slopes in depths greater than 100 m (Table Triglidae 1). Larvae were not found for these species, but larvae are known for the genus (Richards 1990). Triglinae is represented by two genera, *Bellator* and *Prionotus*, that occur on continental and insular shelves (Table Triglidae 1). In the CalCOFI survey area, larvae of *Prionotus stephanophrys* are common in nearshore waters of Baja California from Bahía Sebastian Viscaino south to Cabo San Lucas. Larvae of *P. ruscarius* are rare in CalCOFI collections and have been identified only in samples taken south of Punta Abreojos, Baja California Sur. Larvae of *Bellator xenisma* were not found in the CalCOFI collections although an adult of this species was reported as far north as Santa Barbara, California (Miller and Lea 1972). Larvae of *B. loxias* were identified in samples from Panama and they are described along with those of *P. stephanophrys* and *P. ruscarius*.

Triglids are moderate-sized fishes (up to ca. 1 m) that have an elongate body and head encased in bony plates with prominent spines and ridges. The snout is steep in triglines; peristediines have an elongate, flat snout with a projecting bilobed rostrum (much more pronounced than in triglines) and a subterminal mouth with mandibular barbels. The body is covered with scales (triglines) or spinous scutes (peristediines). The dorsal fins are separate; the first has 7–11 spines and the second has 11–23 soft rays (Nelson 1994). Pectoral fins are large and the lowermost 3 (triglines) or 2 (peristediines) rays are separate and used in creeping over and sensing the substrate. The anal fin is long-based with one or no spines and 11–23 soft rays. The pelvic fins, located between the bases of the pectoral fins, are large and have one spine and five rays. Triglids can produce sounds with their swim bladders. Some species have commercial importance. Some critical adult features of eastern Pacific triglids are summarized in Tables Triglidae 1 and 2. Additional information on adults is available in Garman (1899), Meek and Hildebrand (1928), Teague (1951), Miller and Richards (1991a,b), Allen and Robertson (1994), and Bussing (1995).

Triglids are oviparous and produce relatively large, planktonic eggs (ca. 1.0–1.7 mm) with a smooth chorion that has an orange tint in preservation. The eggs of most species have a single oil globule; *Prionotus carolinus* and *P. stephanophrys* have multiple oil globules (Washington et al. 1984b). Peristediine larvae are long and slender with an extremely long first dorsal spine and greatly elongated fin rays and do not resemble trigline larvae. Trigline larvae, with their large spine-bearing head, deeply concave snout profile, short triangular gut, and large pectoral fins most closely resemble scorpaenid larvae. The snout is especially concave in small larvae, distinguishing them from scorpaenid larvae which have moderately concave snouts. Pigmentation is light except for heavy pectoral fin pigmentation in some species. All species have a row of pigment spots along the ventral margin of the tail by the bases of the anal rays (Washington et al. 1984b). Pigment is present over the gut and may occur on the gular membranes, and on various locations on the head and trunk depending on the species. With growth, pigmentation increases and juveniles are generally heavily pigmented. The lower pectoral fin rays are stout but not completely free from the upper group of rays as in juveniles and adults. Myomeres separate the peristediines (>30) from *Prionotus* and *Bellator* (both 26). Separation of early larvae of *Prionotus* and *Bellator* is difficult; once fin rays can be counted, the separation is simple since *Bellator* usually has 11 dorsal spines and 10-11 dorsal soft rays whereas *Prionotus* usually has 10 dorsal spines and 12-13 dorsal soft rays. These counts can be made in larvae larger than 6 mm SL, but in smaller larvae the counts are difficult to make with confidence. The soft dorsal

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and anal fins develop simultaneously before the first dorsal fin, thus, second dorsal counts can be made at the smaller sizes. Morphometrics are of little value in separating species since most measurements overlap and large differences are not apparent with growth. Larvae for all species were not available in the material studied, thus, specific identifications are tentative for the species described.

The following descriptions are based on the literature (Washington et al. 1984b) and on detailed examinations of 17–29 specimens of each taxon (Table Triglidae 3). Meristic data were obtained from Miller and Lea (1972) and from counts made during this study. Primary sources for ecological information were Fitch and Lavenberg (1971) and Eschmeyer et al. (1983).

Table Triglidae 1. Meristic characters and distribution for the triglid species from the eastern tropical Pacific Ocean; infrequent counts in parentheses. Data from Garman (1899), Teague (1951), Miller & Richards (1991a).

Species	Fin rays				Lat. line scales	Gill rakers	Opercle flap	Distribution
	1D	2D	A	P_1				
Peristediinae								
Peristedion barbiger	VIII	18–19	18–19	12+2	33	5+16		Off Colombia, 100–232 m depth
P. crustosum	VIII	17	17–18	12+2	32–33	3–5+24		Off Colombia, 182–332 m depth
Triglinae								
Bellator gymnostethus	XI (X)	11 (10)	11 (12)	12+3	48–52	14–18	Unscaled	Baja CA to Peru
B. loxias	XI (X, XII)	11	11 (10)	12 (13)+3	49–55	1–3+9–11	Unscaled	Gulf of CA to Peru, & Galápagos Is.
B. xenisma	XI (X)	11 (10)	10 (9,11)	12 (11,13)+3	35–39	11–16	Unscaled	Santa Barbara, CA to Colombia
Prionotus albirostris	X	12	11	13+3	51	9–10	Scaled	Gulf of CA to Panama
P. birostratus	X	12	11	13+3	51	8	Unscaled	Honduras (Gulf of Fonseca)
P. horrens	X	11	9	13+3	51–52	7	Scaled	Honduras to Panama
P. miles	X	12	11	13+3	52	11–13	Unscaled	Galápagos
P. ruscarius	X (IX)	11–13	11–12	13+3	49–52	0–1+5–7	Scaled	Gulf of CA to Panama
P. stephanophrys	X	12–13	11–12	13+3	48–52	1–3+11–12	Scaled/ Unscaled	Oregon to Panama, & Galápagos Is.

Table Triglidae 2. Morphological characters of *Prionotus* from the eastern tropical Pacific Ocean.

Characters for *Prionotus*	*P. horrens*	*P. ruscarius*	*P. birostratus*	*P. miles*	*P. albirostris*	*P. stephanophrys*
1st infraorbital bone projecting	no	no	yes	no	no	no
Spine on 1st infraorbital bone	yes	yes	yes	no	no	no, recurved in juveniles
Spine on 2nd infraorbital bone	yes	yes	yes	no	no	no, recurved in juveniles
Spine on 3rd infraorbital bone	yes	yes	yes	no	no	no
Supplementary preopercular spine	yes	yes	yes	no	yes	no, recurved in juveniles
Preocular spine	large	large	large	small	large	small
Shape of free pectoral rays	broad basally	broad basally	broad	broad distally	slender	slender
Length of free pectoral fin rays	short	short	moderate	moderate	very long	long
Shape of pectoral fin	emarginate	emarginate	elongate	rounded	rounded	rounded
Length of pectoral fin	short	short	moderate	moderate	long	long
Color pattern of pectoral fin	banded	banded	banded	uniform	uniform	uniform, very dark
Trunk scales	smooth	very rough	rough	rough	rough	rough
1st dorsal spine condition	smooth	serrate	serrate	serrate	serrate	weakly serrate
Anal fin rays	9	11–12	11	11	11	11–12

Table Triglidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the triglid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Bellator loxias	0	0	0	1 5.5	5 6.1–9.0	3 10.3–17.1	8 27.1–47.0
Prionotus ruscarius	0	0	4 3.2–4.7	2 5.5–5.9	5 6.4–8.9	7 9.5–15.3	1 22.4
P. stephanophrys	L[a],7 1.0–1.2	3 1.8–2.0	8 1.9–4.8	5 5.3–5.6	2 6.7–7.3	1 9.2	3 74.4–77.6

[a] Washington et al. 1984b

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	9	9
Caudal	17	17
Fins:		
Dorsal spines	X–XII	XI
Dorsal rays	11	11
Anal spines	0	0
Anal rays	10–11	11
Pelvic	I,5	I,5
Pectoral	12–13+3	12+3
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	7	7
Lower	6	6
Gill rakers:		
Upper	1–3	2
Lower	9–11	10
Branchiostegals	7	7

LIFE HISTORY

Range: Northern Gulf of California south to Isla San Lorenzo, Callao Peru, offshore to Galápagos Islands

Habitat: Shelf & upper slope; sand-rubble bottom

Spawning season: Larvae collected in summer & in fall (Panama)

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Miller & Richards 1991a

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 5.5 mm (R. C. Walker)
Postflexion larva, 7.6 mm (R. C. Walker)
Transformation specimen, 10.3 mm (R. C. Walker)
Pelagic juvenile, 11.0 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3 mm
Flexion length: <5 mm through ca. 7 mm
Transformation length: 10 mm
Fin development sequence: C_1 & P_1, A & 2D, 1D, P_2, C_2
Pigmentation: *Flexion–postflexion*—Light in small larvae with few on jaws, top of head, & nape; ventrally on gut; dorsal gut shield; few across base of gular membrane, extending posteriad as series on base of branchiostegal membrane; postanal ventral midline series, double anteriorly; scattered on distal half of P_1, increasing & spreading proximally. *Late postflexion–transformation*—Trunk covered; above A; P_1 covered, heaviest distally; on 1D; increasing on jaws, gular membrane, breast, & belly; eventually entire head & body becoming heavily mottled.
Diagnostic features: Pigment sparse initially, increasing in characteristic pattern; on base of gular region extending posteriad on base of branchiostegal membrane; XI spines in 1D compared with X in *Prionotus*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				51–59	61–63	54–61
			55	57	62	58
BD/BL				32–36	29–38	26–30
			29	33	34	28
HL/BL				39–41	40–43	40–42
			36	40	41	41
HW/HL				70–92	50–81	60–71
			70	79	69	64
SnL/HL				32–38	31–57	35–42
			35	35	41	39
ED/HL				22–24	25–29	24–29
			25	23	27	26
P_1L/BL				21–34	26–31	27–32
			20	28	28	30
P_2L/BL				11–24	22–35	31–35
			18	18	26	33

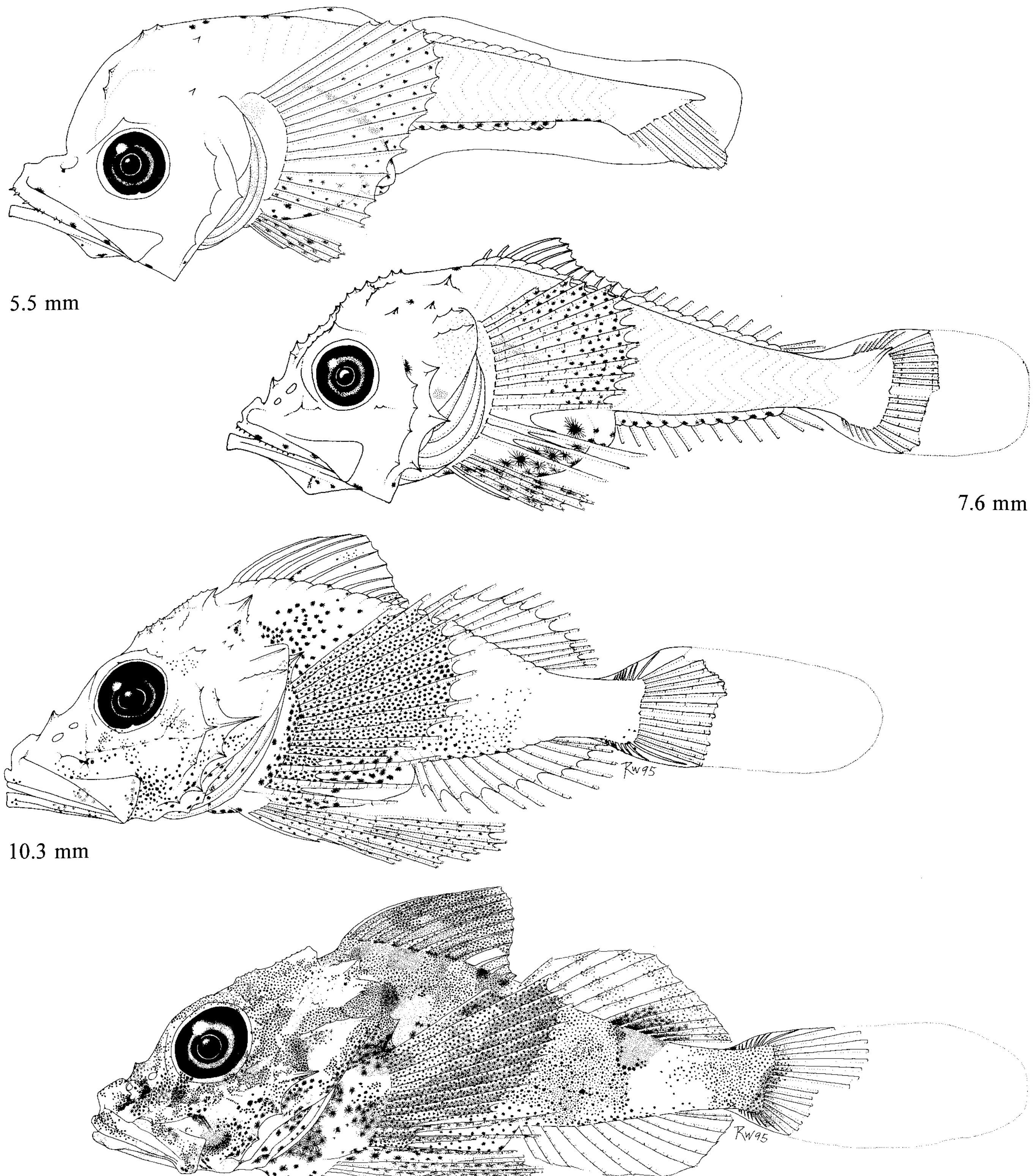


Figure Triglidae 1. Flexion larva, 5.5 mm; postflexion larva, 7.6 mm; transformation specimen, 10.3 mm (IATTC 90011, station ASB#1 Red); pelagic juvenile, 11.0 mm (IATTC 90006, station ASC#1 Red).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	9–10	10
Caudal	16–17	16
Fins:		
Dorsal spines	IX–X	X
Dorsal rays	11–13	12
Anal spines	0	0
Anal rays	11–12	11
Pelvic	I,5	I,5
Pectoral	13+3	13+3
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	7–9	8
Lower	7–8	8
Gill rakers:		
Upper	0–1	0
Lower	5–7	7
Branchiostegals	7	7

LIFE HISTORY

Range: Outer coast of southern Baja California; Gulf of California to Panama

Habitat: Shelf & bays; sand-rubble bottom

Spawning season: Larvae collected August, September, November & February

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.2 mm, 4.7 mm (R. C. Walker)
Flexion larva, 5.5 mm (R. C. Walker)
Postflexion larva, 6.4 mm (R. C. Walker)
Postflexion larva, 9.1 mm (B. Sumida MacCall)
Juvenile, 23.5 mm, with dorsal view of head (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.2 mm
Flexion length: 5.5–6.3 mm
Transformation length: 11–13 mm
Fin development sequence: C_1 & P_1, A & 2D, 1D, C_2 & P_2
Pigmentation: *Preflexion*—Postanal ventral midline series, double anteriorly; patch above gut; ventrally on gut & embedded anteriorly; series laterally on upper jaw, sparse or absent on lower jaw; usually 2 series on each side of midline in gular region; lateral to hindbrain; at nape; elongate patch or series on dorsum, anteriorly on trunk. *Flexion–postflexion*—Increasing on head with growth, eventually covering it; in late postflexion stage, patch on 1D & at hypural region, & saddles below 1D & 2D; P_1 covered, heaviest distally.
Diagnostic features: Moderate pigmentation in preflexion larvae, increasing with growth; P_1 covered with fine melanophores; paired series on gular membrane; short P_1 in transformation specimens & larvae & juveniles; X spines in 1D compared with XI in *Bellator*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–55 51	53–62 58	58–65 60	57–63 60	66
BD/BL		30–34 32	29–34 31	31–34 33	29–38 34	33
HL/BL		30–34 32	36–41 39	41–46 43	41–49 44	45
HW/HL		70–85 78	60–67 63	59–73 68	64–84 72	76
SnL/HL		10–30 22	33–35 34	31–35 33	29–33 31	38
ED/HL		23–35 29	24–25 25	22–24 23	19–23 21	25
P_1L/BL		15–26 20	22–36 29	19–38 27	26–41 30	30
P_2L/BL		0–4 1	18–19 18	11–34 27	31–38 34	37

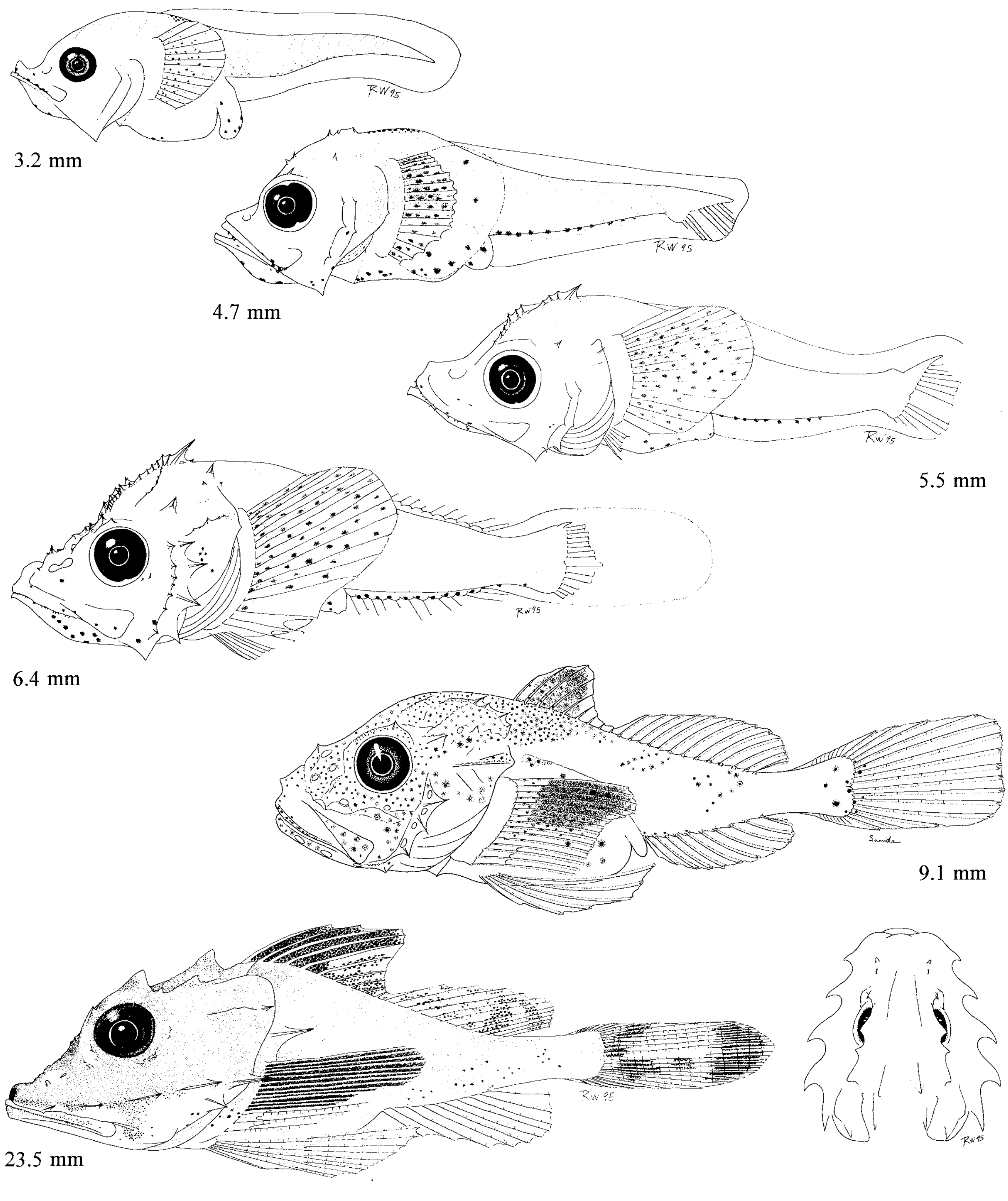


Figure Triglidae 2. Preflexion larvae, 3.2 mm (CalCOFI 6509, station 133.30), 4.7 mm; flexion larva, 5.5 mm; postflexion larvae, 6.4 mm (IATTC 90011, station ASB#2 Red), 9.1 mm (CalCOFI 5708, station 133.25); juvenile, 23.5 mm, with dorsal view of head (SIO 62–71).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	X	X
Dorsal rays	12–13	13
Anal spines	0	0
Anal rays	11–12	12
Pelvic	I,5	I,5
Pectoral	13+3	13+3
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	8	8
Lower	8	8
Gill rakers:		
Upper	1-3	2
Lower	11-12	11
Branchiostegals	7	7

LIFE HISTORY

Range: Oregon to Panama, offshore to Galápagos Islands

Habitat: Shelf & bays; sand-rubble bottom

Spawning season: Larvae taken September, October & February off Baja California

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Washington et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac, larva, 1.9 mm (R. C. Walker)
Preflexion larva, 3.8 mm (B. Sumida MacCall)
Flexion larva, 5.5 mm (B. Sumida MacCall)
Postflexion larva, 5.8 mm (B. Sumida MacCall)

* Eye initially elliptical, becoming round by preflexion stage; horizontal axis is given first, vertical axis second for yolk-sac stage.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.0–1.2 mm **Yolk:** Homogeneous
No. of OG: 16–28 **Diam. of OG:** 0.02–0.20 mm
Shell surface: Smooth
Pigment: Evenly dispersed melanophores on top of brain; irregular double row on dorsal midline of body; on caudal finfold
Diagnostic features: Size; orangish chorion in preserved eggs; multiple oil globules distributed at surface of yolk

LARVAE

Hatching length: ca. 1.9 mm
Flexion length: ca. 5 mm through 8 mm
Transformation length: 9 mm
Fin development sequence: C_1 & P_1, A & 2D, 1D, P_2 & C_2
Pigmentation: *Yolk-sac*—Migrating ventrad from top of head & dorsum; scattered on yolk sac. *Preflexion*—Postanal ventral midline series, double anteriorly; heavy patch above gut; a patch embedded anterior to gut; sparse ventrally on gut; sparse or absent on upper & lower jaws; sparse or absent in gular region (if present, a few scattered or in median series); sparse or absent on P_1, limited to distal margin. *Flexion-postflexion*—On nape & dorsally on brain; heavier on P_1; in late postflexion stage, at mid-lateral hypural region & below 1D. *Juvenile*—P_1 very dark.
Diagnostic features: Pigmentation sparse; P_1 pigment limited to distal margin of fin until late postflexion stage; pigmentation on gular membrane limited to medial areas; P_1 heavily pigmented in juveniles; X spines in 1D compared with XI in *Bellator*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	53–56	44–67	51–58	55–56		59–63
	54	54	55	55	53	61
BD/BL	23–41	21–33	24–46	27–32		22–24
	33	28	33	29	31	23
HL/BL	28–30	24–38	32–41	36–41		39–40
	29	32	36	38	38	40
HW/HL	57–64	48–133	60–92	60–77		49–55
	60	81	69	69	60	53
SnL/HL	15–17	17–38	32–38	33–38		38–40
	16	30	36	35	34	39
ED/HL*	36–37× 28–30	23–50	23–27	23–24		22–23
	37×29	37	25	24	23	23
P_1L/BL	3–10	10–26	18–26	29–30		44–46
	6	19	23	30	38	45
P_2L/BL	0–0	0–10	9–12	18–27		26–28
	0	6	11	23	30	27

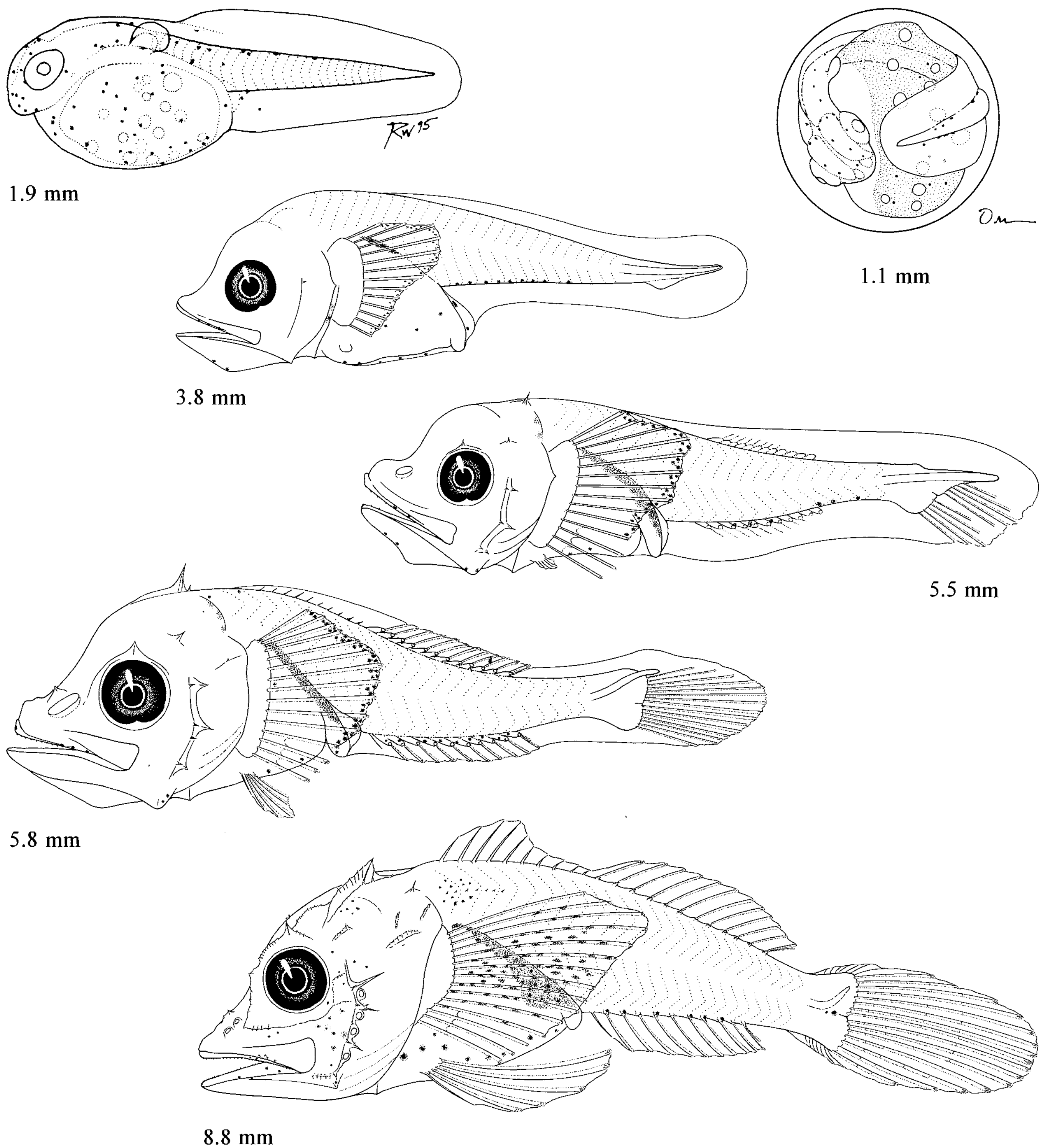


Figure Triglidae 3. Late-stage egg, 1.1 mm (Matarese and Sandknop 1984); yolk-sac larva, 1.9 mm (CalCOFI 5210, station 137.25); preflexion larva, 3.8 mm (CalCOFI 7510, station 117.70); flexion larva, 5.5 mm (CalCOFI 5710, station 133.25); postflexion larvae, 5.8 mm (CalCOFI 5710, station 133.25), 8.8 mm (Washington et al. 1984b).

ANOPLOPOMATIDAE: Sablefish and skilfish

H. G. Moser

The family Anoplopomatidae consists of two species: the sablefish, *Anoplopoma fimbria*, and the skilfish, *Erilepis zonifer*. The family is included in Scorpaeniformes based on the presence of a suborbital stay; however, the affinities of anoplopomatids within the order are unclear and the suborbital stay may have evolved independently in this family (Quast 1965; Nelson 1994). Sablefish larvae are neustonic and only a few have been taken by oblique plankton tows on CalCOFI surveys. Use of surface nets on CalCOFI and CFRD cruises since 1975 has produced increased numbers of sablefish larvae (Ahlstrom and Stevens 1976; Moser et al. 1994b); however, these catches are small in comparison to those to the north of the CalCOFI survey area (Kendall and Matarese 1987). The eggs and larvae of *E. zonifer* are unknown.

Anoplopomatids are relatively large (sablefish to 119 cm, skilfish to 183 cm) semi-demersal fishes of the north Pacific shelf and slope, ranging from Japan to the Bering Sea and Gulf of Alaska, and south to Monterey Bay, California (skilfish) and to central Baja California (sablefish). Sablefish are elongate and roundish in cross section while skilfish are deep-bodied and basslike. The head is smooth, without spines or ridges, and the body is covered with ctenoid scales (small in sablefish). In sablefish, a wide space separates the spinous and soft-rayed dorsal fins; the two are close together in skilfish. The species differ in the number of dorsal spines (17–30 in sablefish and 12–16 in skilfish). The anal fin has 2 or 3 weak spines and either 15–23 rays (sablefish) or 11–14 rays (skilfish). Pelvic fins are thoracic with 1 spine and 5 rays. The species have markedly different vertebral counts: 61–66 in sablefish and 45–46 in skilfish. Adult sablefish are black to greenish gray with pale markings on the dorsum and a pale ventrum; juveniles are bluish black with a whitish ventrum. Adult skilfish are black with whitish scale edges and a pale ventrum; juveniles and young adults are grayish blue or green with whitish blotches on the head and body. Sablefish larvae are neustonic and pre-settlement juveniles are epipelagic, often associating with floating kelp mats (Michell and Hunter 1970; Kendall and Matarese 1987; Moser et al. 1994b). Young sablefish may remain offshore and epipelagic to at least 25 cm but usually settle in shallow coastal waters at smaller sizes (Brodeur and Pearcy 1986). With growth, they occupy deeper habitats and the largest fish are found at mid- to deep-slope depths (MacFarlane and Beamish 1983; Cailliet et al. 1988). Sablefish has a high oil content and is a valuable commercial species fished by trawl, trap, and longline throughout its range. Declining catches have necessitated careful and innovative management of the fishery (Henry 1992). Skilfish are relatively rare and have limited commercial value.

Sablefish are oviparous, annual fecundity is determinate, and the eggs are released in three or four batches during a relatively short winter–spring spawning season (Hunter et al. 1989; Macewicz and Hunter 1994). Eggs are relatively large (1.8–2.2 mm), have yellowish, homogeneous yolk (vesiculate after initial epiboly), a smooth chorion, and no oil globules. Eggs rise to a depth of ca. 200–500 m where they develop and hatch as relatively undeveloped yolk-sac larvae. MacFarlane and Beamish (1992) hypothesized that newly hatched yolk-sac larvae sink to ca. 1000 m and begin a gradual ascent to ca. 200 m depth, utilizing all their yolk reserves within about 40 days after hatching. After a rapid ascent to the surface, they become neustonic and experience high growth rates; Boehlert and Yoklavich (1985) estimated a maximum rate of ca. 2 mm/day. The slender neustonic larvae are unmistakable with their heavy pigmentation and elongate pectoral fins with heavy distal pigment. Development is gradual with no sharp transformation to the juvenile stage (Kobayashi 1957; Ahlstrom and Stevens 1976; Mason et al. 1983; Kendall and Matarese 1987; Matarese et al. 1989; Moser et al. 1994b).

Kendall and Matarese (1987) and Matarese et al. (1989) described the early stages of sablefish and this description complements their work. Morphometrics were calculated from Kendall and Matarese's (1987) data combined with measurements taken during this study. A total of 23 specimens were measured: 5 yolk-sac larvae (4.0–7.8 mm), 5 preflexion larvae (8.0–10.0 mm), 5 flexion larvae (10.5–15.4 mm), and 8 postflexion larvae (16.4–33.9 mm). Meristic data were obtained from Matarese et al. (1989) and from counts made during this study. Ecological and fisheries information were obtained mainly from Eschmeyer et al. (1983), Kendall and Matarese (1987), Henry (1992), and Moser et al. (1994b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	61–66	63
Precaudal	29–33	31
Caudal	31–34	33
Fins:		
Dorsal spines	XVII–XXX	XXII
Dorsal rays	16–21	18
Anal spines	II–III	II–III
Anal rays	15–23	19
Pelvic	I,5	I,5
Pectoral	14–17	16
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	12–14	13
Lower	12–14	13
Gill rakers:		
Upper		
Lower		
Branchiostegals	6–6	6

LIFE HISTORY

Range: North Pacific from northern Honshu, Japan to Bering Sea, the Gulf of Alaska, south to Isla Cedros, Baja California

Habitat: Demersal on shelf & slope to 2740 m depth; habitat depth increases with age/size

Spawning season: Seasonal northward progression from December–April off California to summer–fall in Bering Sea

ELH pattern: Oviparous; pelagic eggs are deep in water column (ca. 200–500 m depth); larvae & early juveniles are neustonic

LITERATURE

Ahlstrom & Stevens 1976
Brock 1941
Kendall & Matarese 1987
Matarese et al. 1989
Moser et al. 1994b

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 2.1 mm (B. Sumida MacCall)
Yolk-sac larva, 4.0 mm (B. Sumida MacCall)

* Eye slightly elliptical in yolk-sac to flexion larvae; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.80–2.22 mm **Yolk:** Initially homogeneous; vesiculate after epiboly
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth
Pigment: Yolk yellow to light orange
Diagnostic features: Large size; narrow perivitelline space; lack of OG; vesiculate yolk (after epiboly); depth of capture >200 m

LARVAE

Hatching length: 4.4–6.0 mm
Flexion length: 10.3–16.1 mm
Transformation length: ca. 35 mm
Fin development sequence: C_1 & P_1, 2D & A, C_2, 1D
Pigmentation: *Yolk-sac*—At ca. 6.5 mm, a double series above gut; by ca. 7.0 mm, short, dense, apposing dorsal & ventral series at caudal peduncle region, widely spaced series in ventral midline posterior to anus, & a series in dorsal midline from nape to caudal peduncle region (double posterior to midgut); several above brain by end of stage. *Preflexion*—Beginning to form laterally on myosepta. *Flexion*—Body almost covered, concentrated in myosepta; on isthmus, P_1 base, cleithrum, upper jaw (anteriorly), lower jaw, subocular region, preopercular & opercular regions, & entire brain; none laterally or ventrally on gut; on distal half of P_1 by end of stage. *Postflexion*—Becoming denser, especially dorsally; lightly on gut; on posterior hypural margin; none on lower P_1 rays.
Diagnostic features: Slender body; gut slender, elongate (preanal length 49–63% BL), with sharp ventral curvature in anal region; pigment heavy & distinct, especially on elongate P_1; 61–66 total vertebrae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	49–59 55	49–53 51	50–56 53	54–63 58		
BD/BL	11–43 20	10–11 10	10–14 12	15–18 16		
HL/BL	14–23 17	14–16 15	16–23 20	22–27 25		
HW/HL	48–70 55	46–56 49	49–57 55	48–57 51		
SnL/HL	10–25 15	13–17 15	19–27 23	26–30 28		
ED/HL*	35–60× 20–34 43×28	35–43× 28–34 38×30	34–40× 31–34 37×33	28-34 31		
P_1L/BL	0–5 3	5–6 5	7–23 14	25–33 30		
P_2L/BL	0–0 0	0–0 0	0–0 0	0.2–11 5		

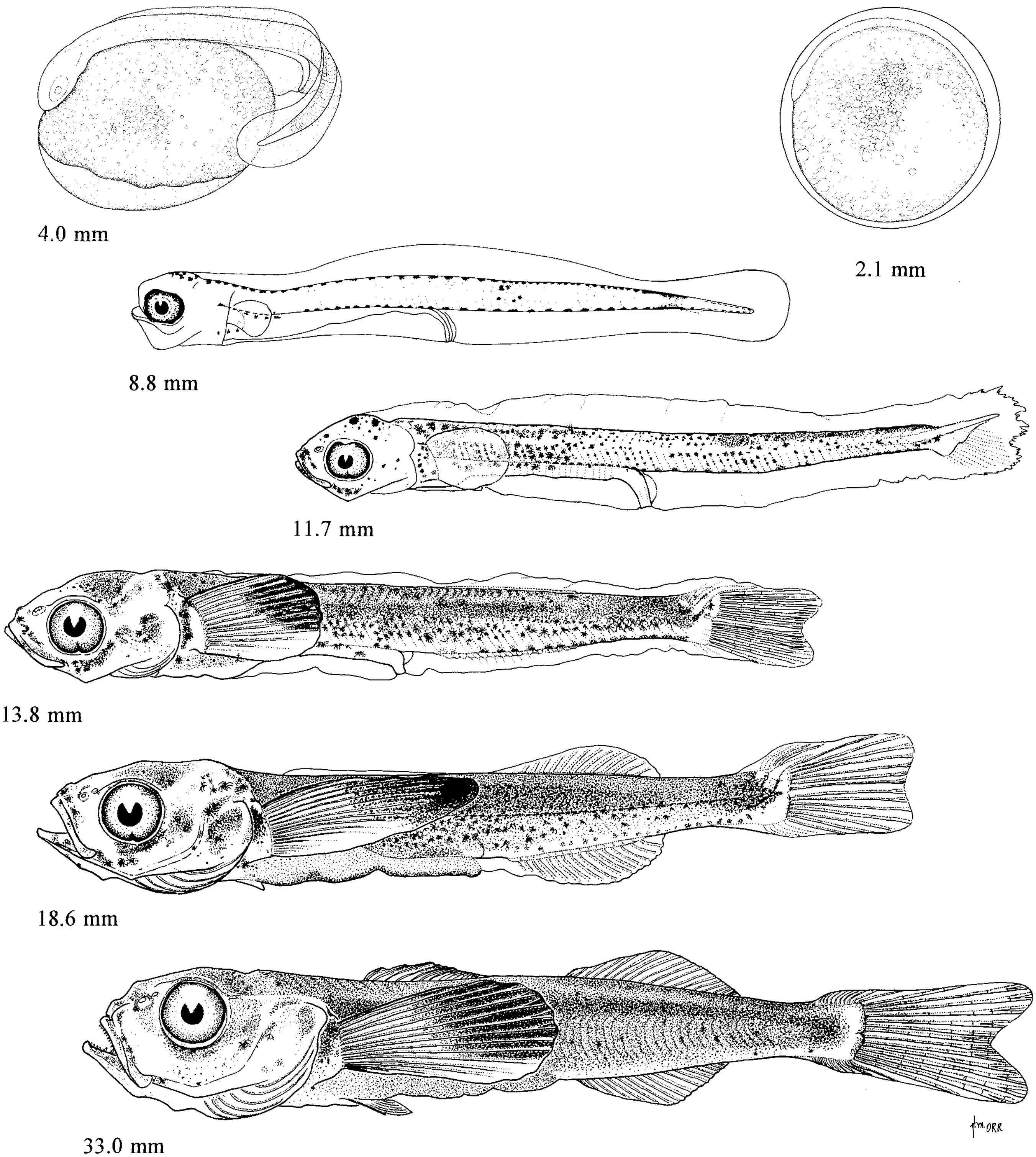


Figure Anoplopomatidae 1. Mid-stage egg, 2.1 mm; yolk-sac larva, 4.0 mm (CFRD 8701, station 62.2 57.2, MOCNESS); preflexion larva, 8.8 mm (Kendall and Matarese 1987); flexion larva, 11.7 mm; postflexion larvae, 13.8 mm, 18.6 mm; juvenile, 33.0 mm (Ahlstrom and Stevens 1976).

HEXAGRAMMIDAE: Greenlings

D. A. AMBROSE

Hexagrammidae consists of five genera and 11 species (Nelson 1994). There is a lack of consensus in classification at the family level. Quast (1965) treated *Zaniolepis* as a separate family, while Shinohara (1994) gave familial status to both *Zaniolepis* and *Oxylebius*. Some researchers place *Ophiodon* in the Ophiodontidae (Eschmeyer et al. 1983). Eschmeyer (1990) included each genus in its own hexagrammid subfamily. Larvae of the following four genera have been collected in the CalCOFI area, and are listed in order of decreasing abundance: *Zaniolepis*, *Oxylebius*, *Hexagrammos*, and *Ophiodon*. *Pleurogrammus* adults range into the study area but their larvae have not been collected (Table Hexagrammidae 1).

Greenlings are endemic to the coastal North Pacific. *Ophiodon elongatus* reach ca. 150 cm but other species are less than 61 cm. The head has cirri but no ridges or spines. One to five lateral lines are present along the somewhat elongate body. Scales are usually ctenoid (cycloid in *Ophiodon*). The single notched dorsal fin (unnotched in *Pleurogrammus*) is composed of 16–28 spines and 11–30 soft rays. Pelvic fins are thoracic with 1 spine and 5 rays. The anal fin is long-based with 0–4 spines and 12–28 soft rays. A swim bladder is absent and vertebrae number 36–63. Color varies and some species are sexually dimorphic. *Ophiodon elongatus* and *Pleurogrammus monoterygius* are the only commercially important species.

Early life history stages of most hexagrammids are well known (Kendall and Vinter 1984; Washington et al. 1984b). Eggs are demersal and usually guarded in nests. A *Zaniolepis latipinnis* egg mass collected off Point Loma, California at a depth of 97 m in February 1994 consisted of clear 1.4–1.5 mm diameter eggs, each with a 0.3–0.4 mm oil globule and attached by three to six disks to adjacent eggs. *Hexagrammos decagrammus* eggs are pale blue (Clemens and Wilby 1946). *Ophiodon elongatus* eggs are 2.2–3.2 mm, opaque, thick, and have a single oil globule (Matarese et al. 1989). Larvae hatch at ca. 2.5–10 mm with pigmented eyes and a well developed mouth. Pigment is heavy and development is direct to an epipelagic juvenile stage. The pectoral fin forms first in *Oxylebius* and *Zaniolepis* species, but it forms second after the caudal fin in the other member of the family followed by the dorsal and anal rays, dorsal spines, and the pelvic fin. Larvae of the five genera may be differentiated by body shape, pigment pattern, meristic characters, and geographic distribution. *Oxylebius* and *Zaniolepis* are similar to each other and more similar to presumed primitive cottids than the other hexagrammid genera (Kendall and Vinter 1984). *Oxylebius* and *Zaniolepis* larvae have lower vertebral counts, larger pectoral fins with heavier pigment, larger heads, longer preanal length, and deeper bodies than the other genera. *Zaniolepis* larvae have pigment on the snout and isthmus while this is lacking on *Oxylebius*. *Zaniolepis* have distinctive prickles on the body by ca. 7 mm. *Ophiodon* larvae have a pointed snout and large mouth, unlike the other genera. Larvae of *Hexagrammos* and *Pleurogrammus* are similar; however, snout pigment is present in *Hexagrammos* and absent in *Pleurogrammus*. *Hexagrammos* have been identified only to genus in CalCOFI samples. Kendall and Vinter (1984) observed considerable variation in number, position, and degree of contraction of melanophores in *Hexagrammos*; however, postanal ventral midline pigment is absent until ca 13 mm in *H. decagrammus* and present throughout development in *H. lagocephalus*. In juveniles, at the completion of caudal fin formation, the number of inferior principal rays is 9 in *H. decagrammus* and 10 in *H. lagocephalus*.

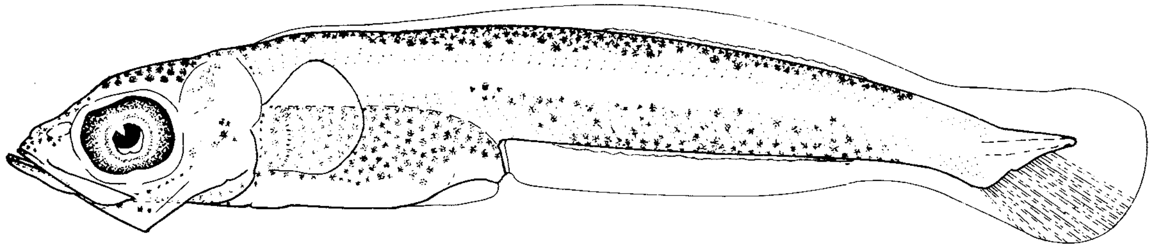
Representative larvae of *Ophiodion, Hexagrammos*, and *Pleurogrammus* are illustrated (Figure Hexagrammidae 1) but separate descriptions are given only for *Oxylebius* and the two species of *Zaniolepis*. Refer to Kendall and Vinter (1984) and Matarese et al. (1989) for descriptions and additional illustrations. Meristic data were obtained from literature (Kendall and Vinter 1984) and from counts made during this study. Ecological information was obtained primarily from Eschmeyer et al. (1983).

Table Hexagrammidae 1. Meristic characters for the hexagrammid species in the CalCOFI area. All species normally have 6 branchiostegal rays and a I, 5 pelvic fin count. Abbreviations: AK, Alaska; BCA, Baja California; BRT, British Columbia; C, central; CA, California; G, Gulf; N, northern; OR, Oregon; S, southern; WA, Washington.

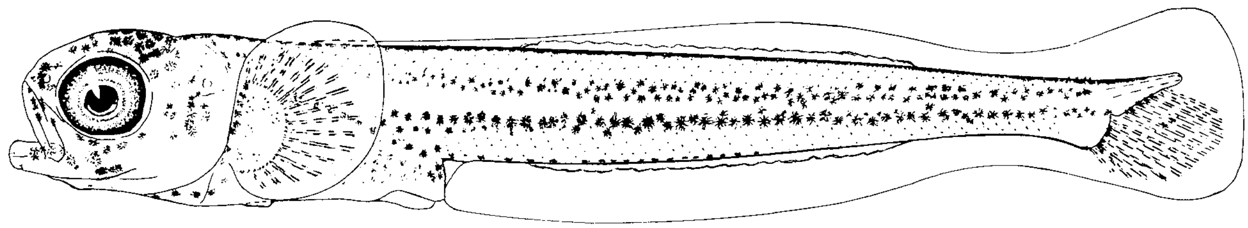
		Vertebrae			Fin rays					
Species	Distribution	PrCV	CV	Total	D	A	P_1	C_1	C_2	GR Total
Oxylebius pictus	G of Alaska to N C BCA (rare N of WA)	13–15	23–25	36–40	XV–XVII, 13–16	III–IV, 12–14	14–17	7+6	9+9	9–13
Zaniolepis frenata	OR to C BCA	13–15	26–28	40–43	XX–XXI, 11–13	III,15–17	14–15	7+6	6–9+ 5–8	13–16
Z. latipinnis	BRT to C BCA	14	28	42	XXI–XXII, 11–12	III,15–17	13–15	7+6	6–8+ 7–9	11–12
Ophiodon elongatus	G of AK to N BCA	23–24	33–35	56–59	XXV–XXVIII, 19–21	III,21–25	16–18	7+7	13–15+ 12–14	19–28
Hexagrammos decagrammus	Bering Sea to S CA	20–22	33–35	52–57	XXI–XXIII, 22–26	23–26	18–20	7+9	12–16+ 12–14	15–20
H. lagocephalus	Bering Sea to S CA	20–23	32–34	52–57	XX–XXIII, 20–25	21–24	18–21	7+10	17–22+ 15–19	14–18
Pleurogrammus monopterygius	Bering Sea to S CA (rare S of AK)	26–28	32–35	58–63	XXI–XXIV, 24–30	23–28	23–28	8+11	16–19+ 16–20	22–27

Table Hexagrammidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the hexagrammid descriptions.

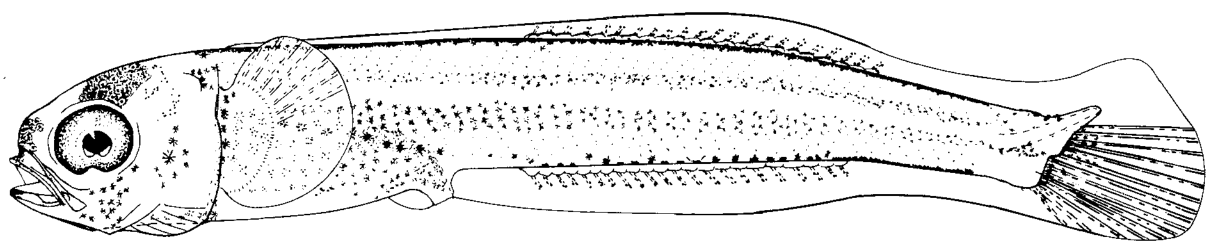
Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
O. pictus	0	1 3.6	10 3.8–6.7	4 7.2–9.1	5 9.5–12.4	0	5 20.2–74.5
Z. frenata	0	4 3.6–3.8	9 3.9–5.8	7 6.1–9.3	5 10.1–16.2	6 24.1–44.3	3 51.0–64.5
Z. latipinnis	11 1.4–1.5	5 4.0–4.5	10 4.3–6.3	9 6.7–8.1	2 9.2–12.2	0	5 44.6–80.7



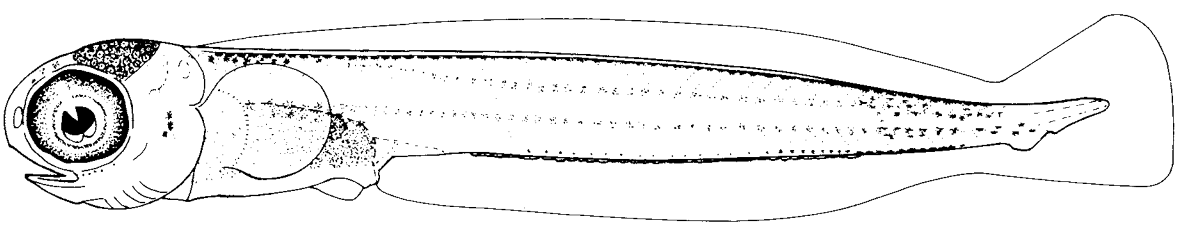
12.2 mm



15.0 mm



14.5 mm



14.1 mm

Figure Hexagrammidae 1. Flexion larvae of four hexagrammid species: *Ophiodon elongatus*, 12.2 mm; *Hexagrammos decagrammus*, 15.0 mm; *H. lagocephalus*, 14.5 mm; *Pleurogrammus monopterygius*, 14.1 mm (Kendall and Vinter 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–40	37
Precaudal	13–15	13
Caudal	23–25	24
Fins:		
Dorsal spines	XV–XVII	
Dorsal rays	13–16	
Anal spines	III–IV	
Anal rays	12–14	
Pelvic	I,5	I,5
Pectoral	14–17	
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	9	9
Lower	9	9
Gill rakers:		
Upper	2–5	
Lower	7–8	
Branchiostegals	6	6

LIFE HISTORY

Range: Gulf of Alaska to north central Baja California

Habitat: Intertidal to 49 m depth

Spawning season: October–July

ELH pattern: Oviparous; demersal, adhesive eggs; planktonic larvae

LITERATURE

Kendall and Vinter 1984
Matarese et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatchiug length: <3.5 mm
Flexion length: 7–9 mm
Transformation length: 16–20 mm
Fin development sequence: P_1, C, D_2 & A, D_1, P_2
Pigmentation: *Yolk-sac*—On eyes, forebrain; dorsally on head extending along dorsum above trunk; under otic capsule; inner surface of P_1 base; peppering on P_1 blade; dashes along ventral midline of tail; dorsolaterally on gut. *Preflexion*—On preopercle; by 6 mm, on isthmus. *Flexion–postflexion*—On both sides of P_1 base; patch anterolaterally on tail enlarges to join head patch; a few on C. *Juvenile*—By 20 mm, 4 bars forming laterally on body; 4 patches on D.
Diagnostic features: Pigment absent from snout, lateral body beneath P_1 & caudal peduncle; by 7 mm, pigment on outer surface of P_1 base; no spiny scales on body; myomeres 36–40 (usually 37).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		41–50	48–54	59–68		54–62
	48	46	50	62		57
BD/BL		19–24	21–28	30–37		26–34
		22	25	32		28
HL/BL		24–26	24–29	36–43		31–37
	24	25	27	39		34
HW/HL		67–80	66–77	55–58		39–56
	77	74	73	57		44
SnL/HL		16–22	16–25	18–22		24–28
	19	19	20	20		26
ED/HL		39–48	40–44	35–38		23–29
	42	41	42	37		25
P_1L/BL		16–21	21–24	33–43		27–47
	14	18	22	37		33
P_2L/BL		0–0	0–5	8–12		18–22
	0	0	2	10		20

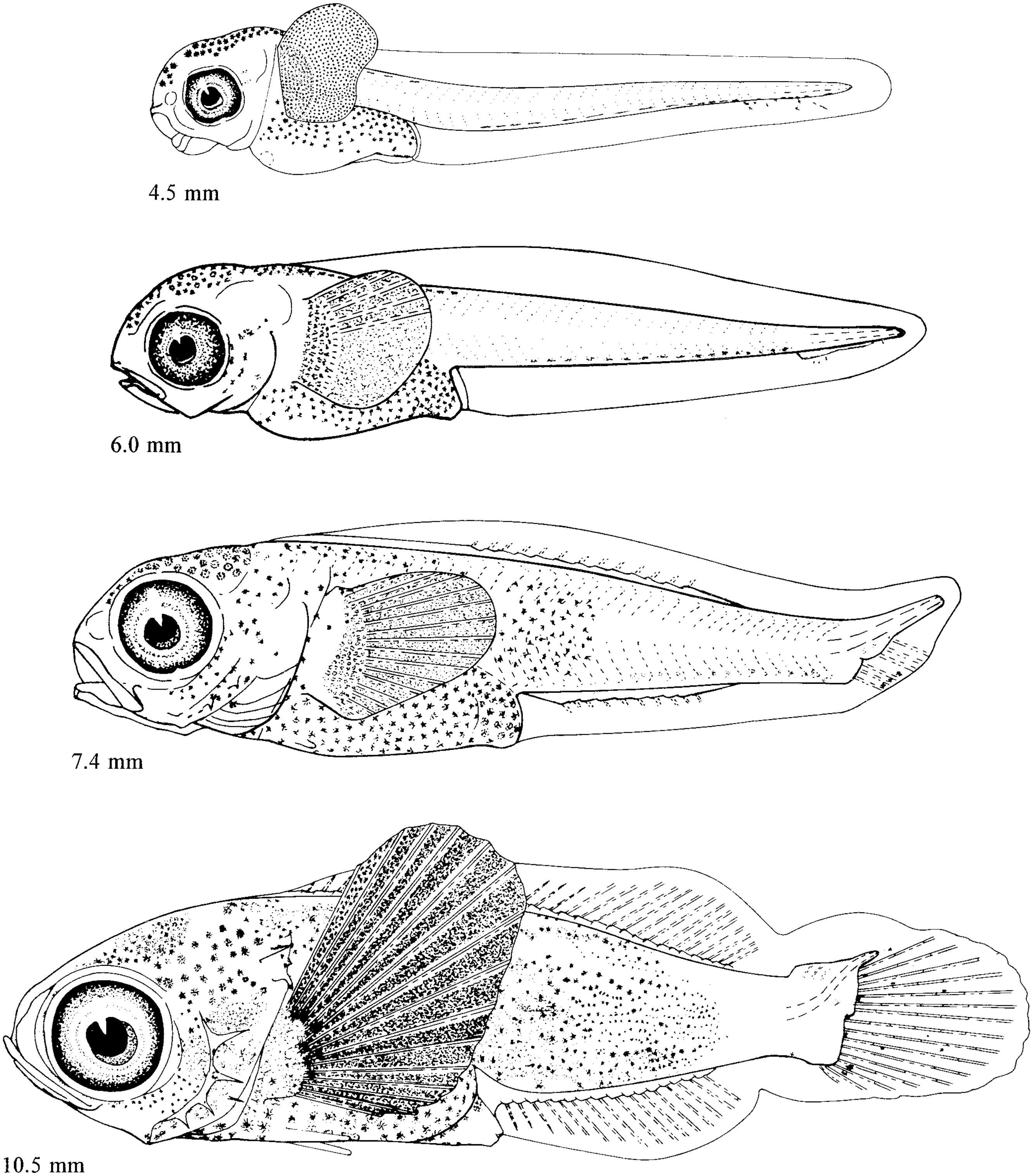


Figure Hexagrammidae 2. Yolk-sac larva, 4.5 mm; preflexion larva, 6.0 mm; flexion larva, 7.4 mm; postflexion larva, 10.5 mm (Kendall and Vinter 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	40–43	42
Precaudal	13–15	14
Caudal	26–28	28
Fins:		
Dorsal spines	XX–XXI	XXI
Dorsal rays	11–13	12
Anal spines	III	III
Anal rays	15–17	
Pelvic	I,5	I,5
Pectoral	14–15	15
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–9	
Lower	5–8	
Gill rakers:		
Total	13–16	14–15
Upper	4	4
Lower	9–12	10–11
Branchiostegals	6–7	6

LIFE HISTORY

Range: Southern Oregon to central Baja California

Habitat: On mud bottom, 55–244 m depth

Spawning season: Winter to spring

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Kendall and Vinter 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.6 mm (R. C. Walker)
Flexion larva, 6.3 mm (R. C. Walker)

* Unfertilized hydrated eggs.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.4–1.6 mm* **Yolk:** Opaque
No. of OG: 30–50 **Diam. of OG:** 0.04–0.12 mm
Shell surface: Finely striated
Pigment: Oil globules red-orange
Diagnostic features:

LARVAE

Hatching length: 2.5 mm
Flexion length: ca. 6–9 mm
Transformation length:
Fin development sequence: P_1, C, D_2 & A, D_1, P_2
Pigmentation: *Yolk-sac–preflexion*—On eyes, snout, isthmus, & branchiostegal region; dorsally on head; on inner surface of P_1 base; heavy on P_1 blade; on gut; dorsally on trunk; series along ventral midline extending to anterior third of tail. *Flexion–postflexion*—Absent laterally on body above gut; anterior tail patch increasing ventrolaterally; some of ventral midline series migrate internally in anterior half of tail. *Transformation*—Body uniformly light brown; patch at A insertion; heavy on P_1 blade. *Juvenile*—By 51 mm, 3 patches in D_1; at A insertion; mottled on body.
Diagnostic features: In yolk-sac through preflexion stages, pigment absent laterally on body above gut & ventral midline series present in anterior third of tail by preflexion stage; in flexion–postflexion larvae, pigment absent laterally on body above gut & series along ventral midline of tail extending anteriorly more than for similar size *Z. latipinnis* (until ca. 10 mm); in transformation–juvenile stages, distinct pigmentation; by 51 mm, cirri over eyes; P_1 14–15 (usually 15); by ca 7 mm, spiny scales on body.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	48–57 52	49–55 52	51–57 54	52–57 55	47–53 49	44–48 46
BD/BL		20–25 22	19–23 21	21–24 22	19–22 20	19–19 19
HL/BL	23–27 26	26–32 28	28–33 31	33–34 34	28–31 29	26–29 28
HW/HL	67–83 73	61–75 68	55–67 63	48–52 51	42–55 46	40–49 43
SnL/HL	15–21 18	16–26 21	20–25 23	19–25 23	21–28 25	18–28 24
ED/HL	39–57 46	33–42 39	31–38 35	30–35 32	23–32 27	23–27 25
P_1L/BL	6–8 7	9–14 11	13–36 22	29–42 36	38–42 40	30–35 33
P_2L/BL	0–0 0	0–0 0	0–4 1	4–15 10	19–23 22	21–22 21

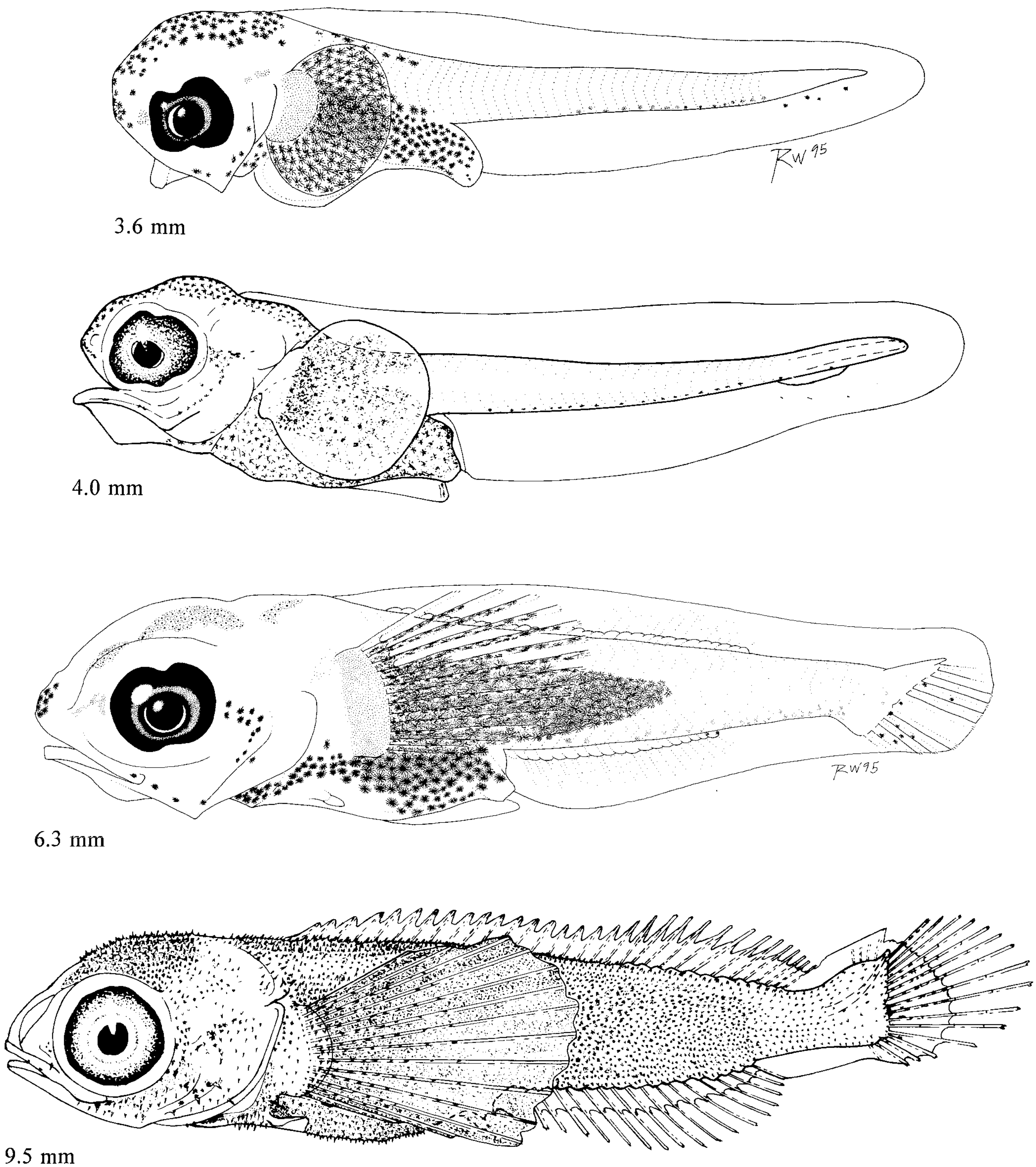


Figure Hexagrammidae 3. Yolk-sac larva, 3.6 mm (CalCOFI 6610, station 60.50); preflexion larva, 4.0 mm (Kendall and Vinter 1984); flexion larva, 6.3 mm (CalCOFI 7808, station 63.52); postflexion larva, 9.5 mm (Kendall and Vinter 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	42	42
Precaudal	14	14
Caudal	28	28
Fins:		
Dorsal spines	XXI–XXII	
Dorsal rays	11–12	
Anal spines	III	III
Anal rays	15–17	
Pelvic	I,5	I,5
Pectoral	13–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–8	
Lower	7–9	
Gill rakers:		
Total	11–12	
Upper	3	3
Lower	8–9	
Branchiostegals	6–7	6

LIFE HISTORY

Range: British Columbia to Central Baja California

Habitat: On soft bottom, 37–201 m depth

Spawning season: Winter to spring

ELH pattern: Oviparous, benthic egg mass; planktonic larvae

LITERATURE

Kendall and Vinter 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.4 mm (R. C. Walker)
Yolk-sac larva, 4.3 mm (R. C. Walker)
Flexion larva, 7.7 mm (R. C. Walker)
Postflexion larva, 9.2 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.4–1.5 mm **Yolk:**
No. of OG: 1 **Diam. of OG:** 0.28–0.40 mm
Shell surface: Smooth with circular attachments to adjacent eggs
Pigment: Late-stage embryo similar to yolk-sac larva
Diagnostic features: Size; single OG & size; eggs in benthic mass

LARVAE

Hatching length: ca. 3 mm
Flexion length: ca. 6.5–9 mm
Transformation length:
Fin development sequence: P_1, C, D_2 & A, D_1, P_2
Pigmentation: *Yolk-sac*—On eyes, snout; dorsally on head; on isthmus & branchiostegal region; on inner surface of P_1 base; heavy on P_1 blade; on yolk; dorsolaterally on body above gut; series midway on ventral margin of tail. *Preflexion*—Increasing laterally on trunk and posteriorly along ventral midline of tail. *Flexion–postflexion*—Spreading midlaterally along tail; ventral midline pigment restricted to posterior third of tail. *Juvenile*—By 45 mm, line from snout to eye; 6 dorsolateral patches alternate with 7 ventrolateral patches on body; medial line along D_1; along mid P_1; 3 patches at C base.
Diagnostic features: In yolk-sac through preflexion, pigment present laterally on body above gut & ventral midline melanophores, absent from anterior third of tail; in flexion–postflexion, pigment laterally above gut, but decreasing; number and extent of spots along ventral midline of tail less than for similar size *Z. frenata* (until ca. 10 mm); in juvenile, by 45 mm, pigment pattern; P_1 13–15 (usually 14); by ca. 7 mm, spiny scales on body.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	46–50 47	47–54 50	49–58 54	54–57 56		44–50 46
BD/BL		19–24 22	21–26 23	22–23 22		17–21 19
HL/BL	23–26 25	25–31 27	27–33 30	31–35 33		24–26 25
HW/HL	52–71 61	65–83 72	60–71 65	47–63 55		41–47 44
SnL/HL	10–20 13	17–23 20	18–24 21	20–25 23		19–26 23
ED/HL	38–44 41	37–45 39	31–40 37	27–37 32		28–33 31
P_1L/BL	6–10 8	9–24 16	22–30 24	30–31 30		24–31 27
P_2L/BL	0–0 0	0–0 0	0–3 2	4–13 9		22–27 25

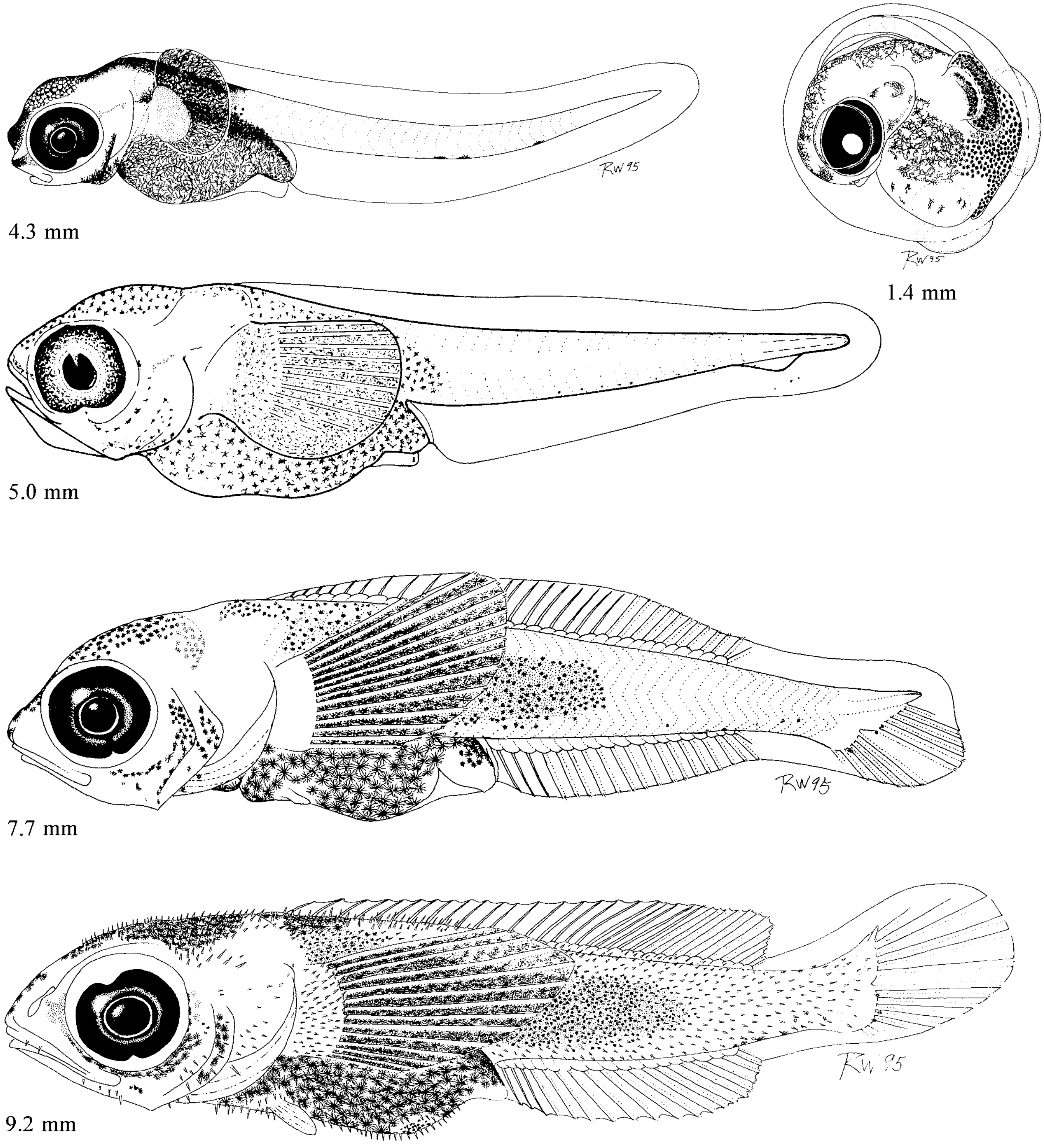


Figure Hexagrammidae 4. Egg, 1.4 mm; yolk-sac larva, 4.3 mm (CFRD Ref. Coll., collected near Pt. Loma, California); preflexion larva, 5.0 mm (Kendall and Vinter 1984); flexion larva, 7.7 mm (CalCOFI 7501, station 113.22); postflexion larva, 9.2 mm (CalCOFI 5304, station 97.30).

COTTIDAE: Sculpins

D. A. AMBROSE

The family Cottidae includes about 70 genera with about 300 species (Nelson 1994). We follow Eschmeyer (1990) by including *Rhamphocottus* and *Blepsias* in the Cottidae; Yabe (1985) and Nelson (1994) placed them in two separate families. In the CalCOFI study area, there are 45 species in 21 genera (Table Cottidae 1; Howe and Richardson 1978). Larvae of 30 of these species have been described. Cottid larvae occur throughout the year in CalCOFI collections, with a strong peak from January to July, at stations inshore and near islands.

Cottids occur in all oceans except the Indian Ocean. Most are benthic in circumboreal marine, brackish, and freshwater habitats. There are a wide variety of body shapes, but most sculpins have a small to medium-sized (5–99 cm SL) stout, rounded body. The large head usually has spines or knobs and cirri. Large eyes are located high on the head. The large pectoral fins are fan-like, often with the lower rays free. The body often is only partially scaled and almost all species have embedded scales along the lateral line. The anal fin is usually long and without spines. The dorsal fin is usually deeply notched or divided into separate spinous and soft-rayed portions. The pelvic fins (absent in *Ascelichthys*) have one spine, covered by skin and closely attached to the first soft ray, and five or fewer rays (usually 2–3). A swim bladder is absent. Males of some genera have a well-developed penis-like appendage that is used for internal fertilization of the female. Most sculpins are cryptically colored brown and green which matches the algae among which they live. Many species inhabit the intertidal and subtidal on hard substrates; however, several genera including *Icelinus*, prefer deeper water and soft bottom. Only *Scorpaenichthys marmoratus*, the cabezon, is fished commercially in our area. Cottids are considered closely related to agonids; however, the composition and taxonomic status of the Cottidae have not yet been clearly defined (Washington et al. 1984a).

Cottids spawn demersal eggs (ca. 0.8–4.0 mm diameter) that usually adhere to each other, and in some species, to the substrate. Most cottid eggs contain at least one oil globule and may be quite colorful. Larvae hatch at 3–12 mm with pigmented eyes and a relatively short gut that lengthens with development. They are usually pelagic and some are primarily neustonic (*S. marmoratus* and *Hemilepidotus spinosus*). Development is fairly direct and larvae transform to benthic juveniles at ca. 9–23 mm SL. There is a wide variety of larval forms within the family. Richardson (1981a) arranged the cottid larvae into phenetic groups based on the general shape of the body and snout, melanistic pigment patterns, unusual diverticula of the gut, head spination, and meristics. The updated arrangement of phenetic groups of Washington et al. (1984b) is followed in this chapter.

The following descriptions of cottid early life histories are based on the literature. A single larval illustration (usually flexion stage) and associated early life history notes are presented for each species. For additional larval illustrations of most of these species, and others with more northern distributions, refer to Materese et al. (1989). Meristic data were obtained primarily from Miller and Lea (1972), Howe and Richardson (1978), Washington (1986), and Matarese et al. (1989). Principal sources of ecological information were Miller and Lea (1972) and Eschmeyer et al. (1983).

Table Cottidae 1. Meristic characters for the cottid species in the CalCOFI study area. Branchiostegals usually number six, except seven in *Artedius harringtoni*. Abundance: Common (C); Uncommon (U); Rare (R). Geographic abbreviations: AK, Alaska; BCA, Baja California; BRT, British Columbia; C, central; CA, California; N, northern; OR, Oregon; S, southern; SE, southeast; SW, southwest; WA, Washington. Species with larval descriptions marked with an asterisk.

Species	Distribution	Abundance	Total vertebrae	Fin rays			
				D	A	P_1	P_2
*Artedius corallinus**	WA to N BCA	C	31–33	VIII–IX+14–16	12–13	14–16	I,3
*A. creaseri**[a]	C CA to C BCA	U	30–31	IX–XI+12–14	9–11	15–17	I,3
*A. fenestralis**	SW AK to C CA	U	32–35	VIII–X+16–18	12–14	14–16	I,3
*A. harringtoni**	S AK to S CA	U	32–34	VIII–X+16–18	10–14	13–15	I,3
*A. lateralis**[a]	Aleutians to N BCA	C	32–34	VII–X+15–17	12–14	14–16	I,3
*A. meanyi**	SE AK to N CA	R	33–35	IX–X+14–17	10–12	14–16	I,2–3
*A. notospilotus**	WA to N BCA	U	32–34	IX–X+14–16	11–13	14–17	I,2–3
*Ascelichthys rhodorus**	SE AK to C CA	U	33–36	VII–X,17–20	13–16	16–18	0
*Blepsias cirrhosus**	Bering Sea to C CA	U	37–39	VI–IX+20–25	18–21	11–13	I,3
*Chitonotus pugetensis**	SE AK to S BCA	U	35–36	VIII–XI+14–17	14–17	16–18	I,2–3
*Clinocottus acuticeps**	Bering Sea to C CA	U	31–33	VII–IX+13–17	9–13	13–15	I,3
*C. analis**	N CA to C BCA	C	31–35	VIII–X+14–18	11–15	14–17	I,3
*C. embryum**	Bering Sea to N BCA	C	33–35	VIII–X+14–17	9–12	12–15	I,3
*C. globiceps**	S AK to S CA	C	32–34	VIII–X+13–17	10–12	13–15	I,3
*C. recalvus**	S OR to C BCA	C	32–33	VIII–IX+14–17	9–13	13–15	I,3
Cottus aleuticus	Bering Sea to C CA	U	34–39	VIII–X+16–20	12–16	13–16	I,4
*C. asper**	S AK to S CA	U	34–39	VIII–XI+18–21	14–18	14–17	I,4
*Enophrys bison**	S AK to C CA	C	29–31	VII–IX,9–13	8–10	15–18	I,2–3
E. taurina	C CA to S CA	U	27–29	VI–VIII,8–10	6–7	15–18	I,3
*Hemilepidotus hemilepidotus**	Bering Sea to C CA	C	35–37	X–XIII,17–20	13–16	15–17	I,3–4
*H. spinosus**	SE AK to S CA	U	35–37	X–XI,18–20	14–16	14–16	I,4
Icelinus burchami	SE AK to S CA	R	33–37	VIII–XI+15–18	10–14	16–19	I,2
I. cavifrons	C CA to S BCA	U	35–37	IX–XII+12–15	11–13	14–16	I,2
I. filamentosus	S AK to S CA	U	34–37	IX–XII+15–18	13–16	16–18	I,2
I. fimbriatus	BRT to S CA	R	35–37	X–XI+12–14	12–14	16–18	I,2
I. oculatus	BRT to S CA	R	37	X–XI+15–17	13–14	17	I,2
*I. quadriseriatus**	C CA to S BCA	C	33–35	VII–X+12–16	10–15	15–17	I,2
Icelinus sp.	S CA	R	31–34	IX–X+13–15	11–12	15–17	I,2
I. tenuis	BRT to C BCA	U	37–39	IX–XI+16–19	14–17	15–17	I,2
Jordania zonope	SE AK to C CA	U	46–48	XVII–XVIII,15–18	22–24	13–15	I,4–5
Leiocottus hirundo	S CA to N BCA	U	35–36	IX–X+16–17	14–16	17–18	I,3
*Leptocottus armatus**	Bering Sea to N C BCA	C	35–39	VI–VIII,15–20	15–20	17–20	I,4

Table Cottidae 1. Continued.

Species	Distribution	Abundance	Total vertebrae	Fin rays D	A	P_1	P_2
*Nautichthys oculofasciatus**	Bering Sea to S CA	U	40–41	VIII–IX,27–30	16–21	13–14	I,3
*Oligocottus maculosus**	Bering Sea to S CA	C	33–34	VIII–IX+15–18	12–14	12–15	I,3
O. rimensis	SE AK to N BCA	C	34–37	VIII–X+16–19	13–15	13–15	I,3
O. rubellio	N CA to N BCA	C	32–35	VII–IX+13–17	10–14	13–15	I,3
*O. snyderi**	SE AK to N BCA	C	34–37	VII–IX+17–20	12–15	12–15	I,3
*Orthonopias triacis**	C CA to N BCA	C	33–35	VIII–IX+16–18	11–13	13–15	I,3
*Paricelinus hopliticus**	BRT to S CA	R	42–43	XII–XIII,19–20	23–24	14–15	I,5
*Radulinus asprellus**	S AK to N BCA	U	38–40	VIII–XI+20–23	21–25	17–20	I,3
*R. boleoides**	BRT to S CA	R	39–40	VIII–XI+20–22	21–23	18–20	I,3
R. vinculus	C CA to S CA	R		X+17	18	17	I,3
*Rhamphocottus richardoni**	Bering Sea to S CA	U	26–28	VII–IX+12–14	6–9	14–18	I,3–4
*Scorpaenichthys marmoratus**	SE AK to C BCA	C	35–37	VIII–XII,15–19	11–14	14–16	I,4–5
*Synchirus gilli**	SE AK to S CA	U	38–39	VIII–X,19–21	18–21	21–24	I,3
Zesticelus profundorum	Bering Sea to N BCA	R	25–26	V–VII+10–13	8–11	19–21	I,2–3

[a] *Artedius creaseri* and *A. meanyi* were assigned to the genus *Ruscarius* by Begle (1989). *Artedius* is retained here for these two species to avoid confusion with other field guides from this region.

***RHAMPHOCOTTUS* Phenetic Group (*Rhamphocottus*):** Larvae deep-bodied (ca. 29–40% BL), with long preanal length (ca. 66–73% BL), pigment uniformly heavy over body except absent from caudal peduncle, prickles on body by 9–10 mm; 1 preopercular spine develops by ca. 10 mm.

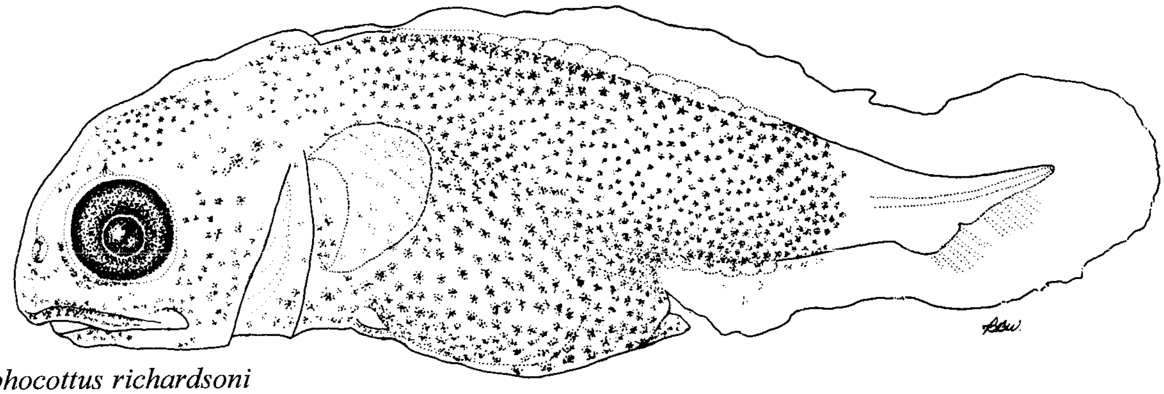
Rhamphocottus richardsoni (Grunt sculpin)—Eggs yellow to orange, guarded by female, 2.5–2.8 mm; hatching length ca. 6–7 mm; notochord flexion length ca. 8.4 mm; transformation length ca. 14–15 mm; pigmented preanal finfold distinct. Literature: Blackburn 1973; Garrison and Miller 1982; Kojima 1988d; Marliave 1975; Matarese et al. 1989; Richardson and Washington 1980; Washington et al. 1984b.

***HEMILEPIDOTUS-SCORPAENICHTHYS* Phenetic Group (*Hemilepidotus, Scorpaenichthys*):** Larvae relatively long and slender at hatching becoming deeper-bodied with development; snout rounded; pigment relatively heavy, especially dorsally and ventrally on tail; 4 prominent preopercular spines develop.

Hemilepidotus hemilepidotus (Red Irish lord) — Eggs pink, guarded, 1.5–1.6 mm, with single oil globule (0.31–0.56 mm); hatching length ca. 5–6 mm; notochord flexion length <9 mm; transformation length ca. >19–23 mm; preanal length increases from 35–58% BL during development; postanal ventral midline melanophore series begins at ca. 9th or 10th postanal myomere and usually consists of <15 melanophores. Literature: Garrison and Miller 1982; Gorbunova 1964; Matarese et al. 1989; Richardson and Washington 1980; Washington et al. 1984b.

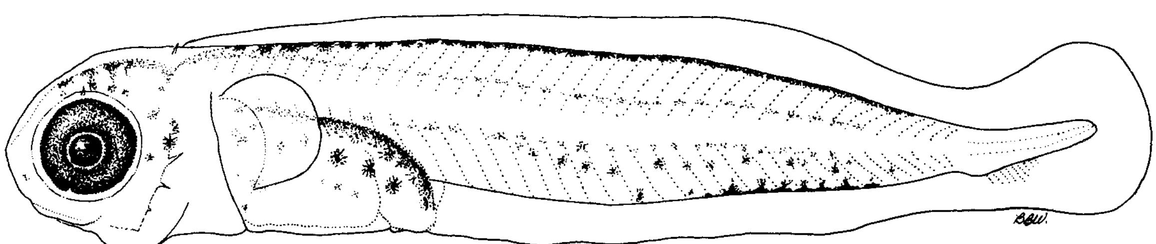
H. spinosus (Brown Irish lord) — Hatching length ca. 5 mm; notochord flexion length 7.6–10 mm; transformation length ca. 19 mm; pelagic juvenile until ca. 27 mm; preanal length increases from 38 to 61% BL; postanal ventral midline melanophore series begins immediately behind anus and usually consists of >15 melanophores in all but largest specimens. Literature: Follette 1952; Matarese et al. 1989; Peden 1964; Richardson and Washington 1980; Washington et al. 1984b.

Scorpaenichthys marmoratus (Cabezon) — Eggs adhesive, attached to substrate, green to amber, 1.4–1.9 mm, 1 large oil globule (0.2–0.3 mm) and 1–4 smaller ones; hatching length ca. 3–6 mm; notochord flexion length ca. 7.6–10.0 mm; transformation length ca. 14 mm; pelagic juvenile until ca. 35 mm; preanal length relatively long increasing from 49–53% SL in preflexion larvae to 57–66% SL in postflexion larvae; pigment heavy; no ventral midline melanophores posterior to lateral pigment. Literature: Matarese et al. 1989; O'Connell 1953; Richardson and Washington 1980; Wang 1981; Washington et al. 1984b.

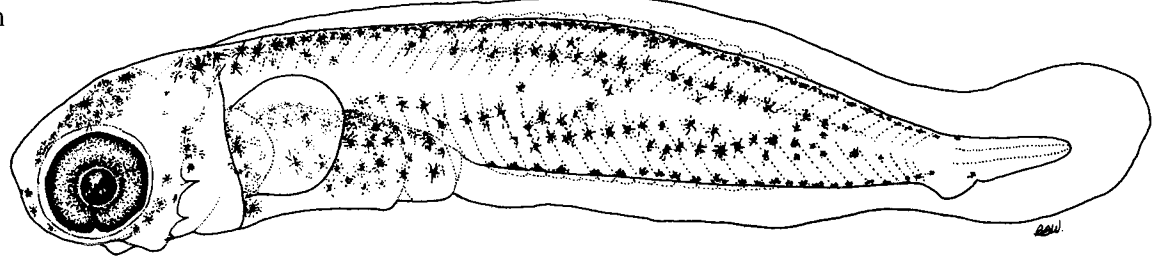


Rhamphocottus richardsoni
8.4 mm

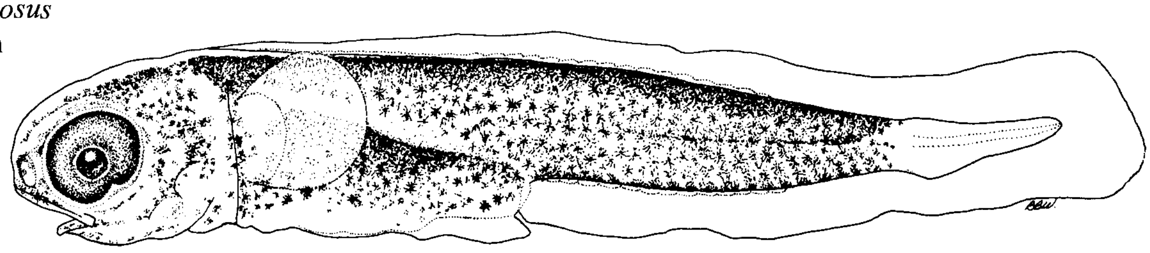
HEMILEPIDOTUS-SCORPAENICHTHYS Phenetic Group



Hemilepidotus hemilepidotus
9.1 mm



H. spinosus
8.9 mm



Scorpaenichthys marmoratus
8.6 mm

Figure Cottidae 1. *Rhamphocottus richardsoni*, 8.4 mm; *Hemilepidotus hemilepidotus*, 9.1 mm; *H. spinosus*, 8.9 mm; *Scorpaenichthys marmoratus*, 8.6 mm (Richardson and Washington 1980).

***LEPTOCOTTUS* Phenetic Group (*Cottus, Leptocottus*):** Larvae relatively slender (body depth usually <20% BL) with rounded snout, preanal length usually between 40% and 46% BL; postanal pigment light, widely spaced melanophores along postanal ventral midline; by ca. 8 mm, 4 weak preopercular spines develop, other head spines absent.

Cottus asper (Prickly sculpin) — Eggs adhesive, orange, guarded, 1.4–1.6 mm, 1 large (0.2–0.3 mm) and some smaller oil globules; hatching length 4.5–6.3 mm; notochord flexion length ca. 7 mm; transformation length ca. 10 mm; postanal ventral melanophore series decreases in number, more evenly spaced with development; pigment ventrally on gut; gut shape unique, forked posteriorly. Both *C. asper* and *C. aleuticus* are found in brackish water but only *C. asper* is known to spawn in estuaries. Literature: Morrow 1980; Matarese et al. 1989; Richardson and Washington 1980; Stein 1972; Wang 1981; Washington et al. 1984b.

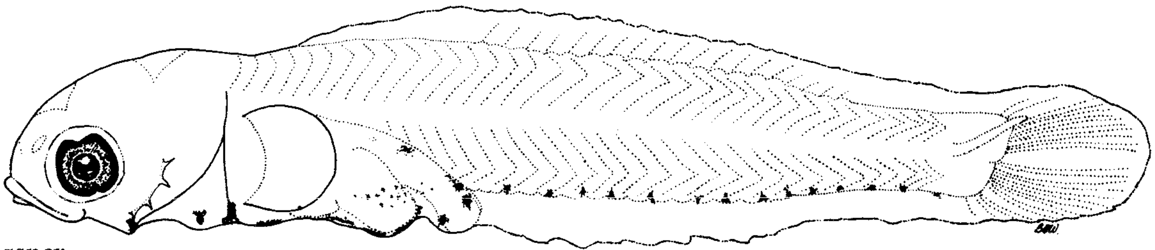
Leptocottus armatus (Pacific staghorn sculpin) — Eggs adhesive, bumpy, creamy white to pale yellow orange to deep orange, 1.4–1.5 mm, 1 large (0.3 mm) and some smaller oil globules; hatching length 3.8–5.0 mm; notochord flexion length ca. 8 mm; transformation length 15–20 mm; pigment internally on snout and otic capsule, unique 6–8 bars dorsolaterally on gut. Literature: Jones 1962; Matarese et al. 1989; Richardson and Washington 1980; Wang 1981; Washington et al. 1984b.

***HEMITRIPTERUS* Phenetic Group (*Blepsias, Nautichthys*):** Larvae with elongate, slender body which deepens with development, and rounded snout; pigment heavy extending onto dorsal and anal finfolds; hatching size large (>7 mm); 4 rounded, unpronounced preopercular spines.

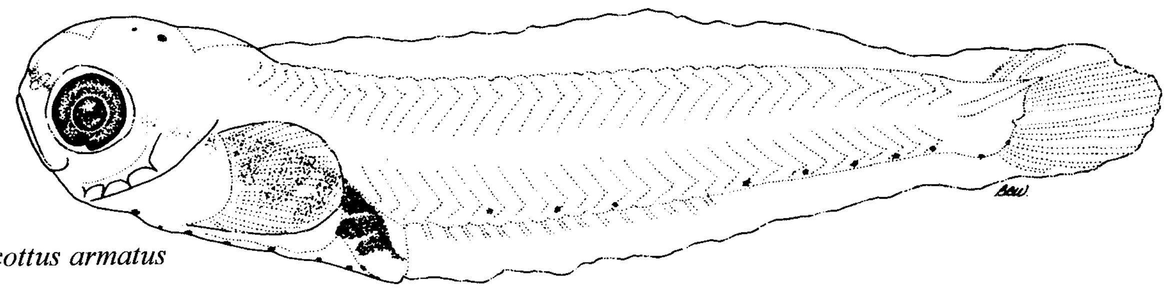
Blepsias cirrhosus (Silverspotted sculpin) — Eggs light brown; notochord flexion length <10 mm; pigment heavy on entire body except for caudal peduncle, opercle region, and ventrolaterally on gut; pigment on chin; strong frontoparietal ridge. Literature: Blackburn 1973; Marliave 1975; Matarese et al. 1989; Richardson 1981a; Shiogaki 1988; Washington et al. 1984b.

Nautichthys oculofasciatus (Sailfin sculpin) — Eggs adhesive, attached, in mussel beds, orange 2.0–2.5 mm, with 1 oil globule; notochord flexion length ca. 9–11 mm; transformation length >17 – <26 mm; distinctive pigment laterally on body; band on distal margin of elongate pectoral fin. Literature: Blackburn 1973; Marliave 1975; Matarese et al. 1989; Richardson and Washington 1980; Washington et al. 1984b.

LEPTOCOTTUS Phenetic Group

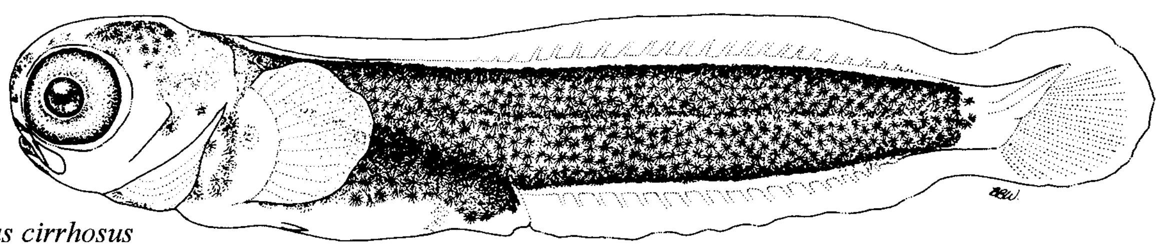


Cottus asper
8.2 mm

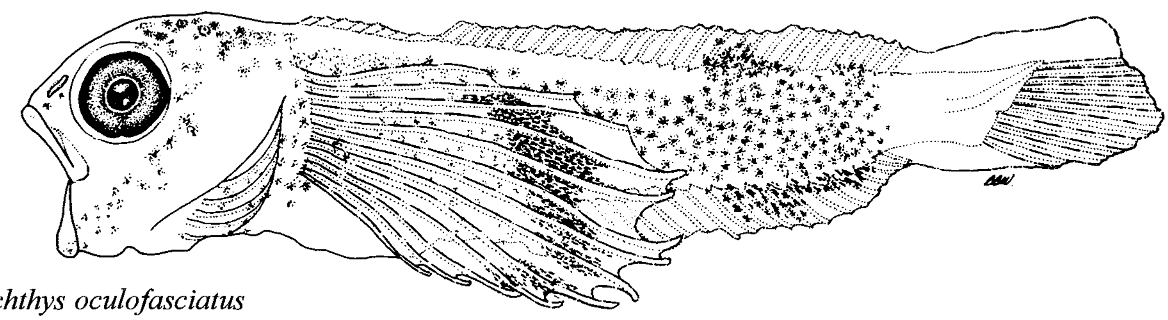


Leptocottus armatus
8.1 mm

HEMITRIPTERUS Phenetic Group



Blepsias cirrhosus
11.0 mm



Nautichthys oculofasciatus
11.7 mm

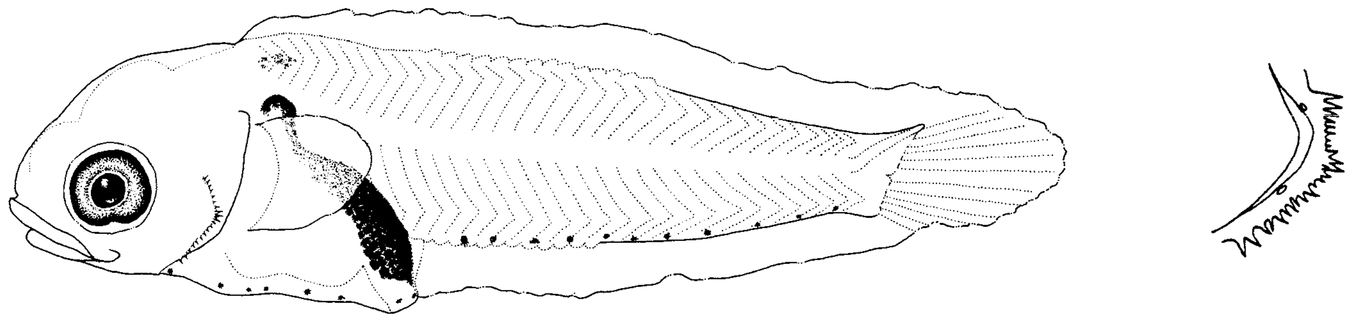
Figure Cottidae 2. *Cottus asper*, 8.2 mm; *Leptocottus armatus*, 8.1 mm (Richardson and Washington 1980); *Blepsias cirrhosus*, 11.0 mm (Richardson 1981a); *Nautichthys oculofasciatus*, 11.7 mm (Richardson and Washington 1980).

***ARTEDIUS* Phenetic Group (*Artedius* other than *A. creaseri* and *A. meanyi*; *Clinocottus*, *Oligocottus*):** Larvae are distinguished by stubby body often with a slight hump in nape region; rounded snout; gut trailing below ventral body midline; some species with gut diverticula; pigment light, occurring on head (some species), nape, dorsolaterally on gut, and along postanal ventral midline; unique preopercular spine pattern with 4–26 spines (enlargements shown in illustrations); hatching length 3–5 mm and transformation to benthic juvenile by 10–13 mm.

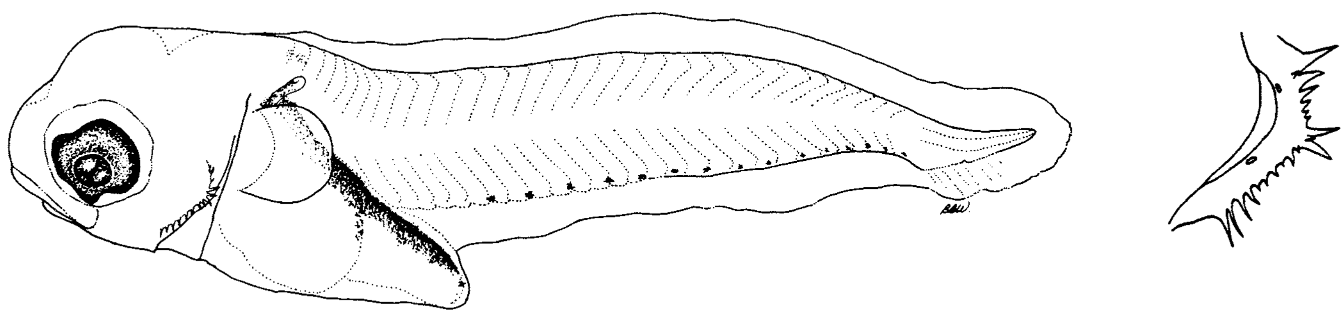
Artedius corallinus (Coralline sculpin) or *A. notospilotus* (Bonyhead sculpin) — Larvae probably *A. corallinus* based on collection location and adult abundance (see Washington 1986: Artedius type III). Hatching length <3 mm; notochord flexion length 5.6–6.9 mm; pigment absent on head, present on nape; only 9–13 postanal ventral midline melanophores, originating at 3rd or 4th postanal myomere; dorsolateral gut diverticula posterior to pectoral fin base; 21–24 preopercular spines form early. Literature: Matarese et al. 1989; Washington 1986.

A. fenestralis (Padded sculpin) — Hatching length 3.5–3.8 mm; notochord flexion length 5.9–6.8 mm; transformation length 12–14 mm; pigment absent on head, usually light on nape; 13–19 postanal ventral midline melanophores originating at 3rd or 4th postanal myomere; dorsolateral gut diverticula posterior to pectoral fin base; by late flexion stage, 18–22 preopercular spines. Literature: Blackburn 1973; Marliave 1975; Matarese et al. 1989; Richardson and Washington 1980 (as *Artedius* Type 2); Washington 1981, 1986.

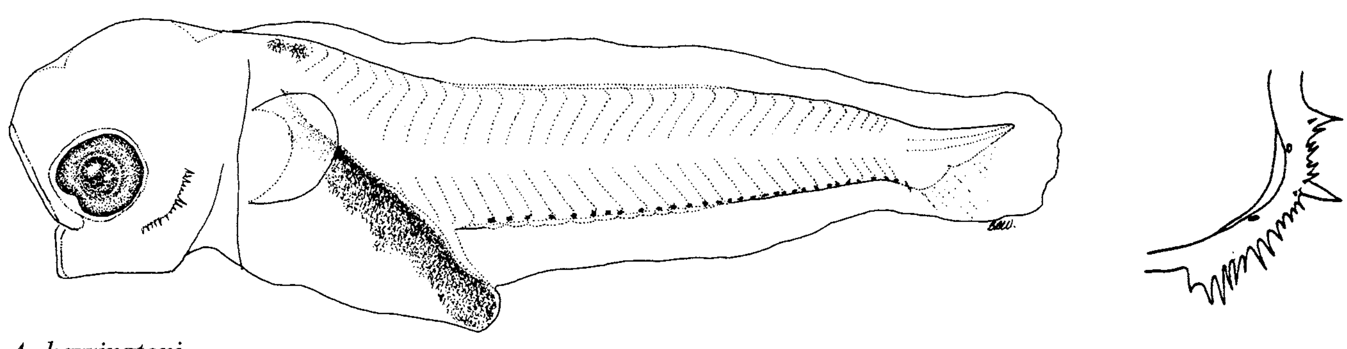
A. harringtoni (Scalyhead sculpin) — Hatching length <3 mm; notochord flexion length 5.2–6.4 mm; transformation length 12–14 mm; pigment absent on head, present on nape; 21–23 pigment slashes along ventral midline of tail; humped nape region; gut diverticula absent; by postflexion stage, 18–22 preopercular spines; branchiostegals 7. Literature: Blackburn 1973; Matarese et al. 1989; Richardson and Washington 1980; Washington 1981, 1986.



Artedius corallinus or *A. notospilotus*
6.8 mm



A. fenestralis
6.0 mm



A. harringtoni
6.9 mm

Figure Cottidae 3. *Artedius corallinus* or *A. notospilotus*, 6.8 mm (Washington 1986); *A. fenestralis*, 6.0 mm; *A. harringtoni*, 6.9 mm (Richardson and Washington 1980). Preopercle enlargements from Washington (1986).

***ARTEDIUS* Phenetic Group (Continued)**

Artedius lateralis (Smoothhead sculpin) — Eggs adhesive, red, 0.98–1.16 mm; 1 oil globule (0.22 mm); hatching length 3.9–4.5 mm; notochord flexion length 5.0–6.3 mm; transformation length 9–10 mm; preflexion larvae lack head and nape pigment; head pigment present by notochord flexion and increases with development; 22–32 postanal ventral midline melanophores; dorsolateral gut diverticula present; by postflexion stage, 14–16 preopercular spines present. Literature: Budd 1940; Marliave 1975; Matarese et al. 1989; Richardson and Washington 1980; Washington 1981, 1986; Washington 1984b.

Clinocottus acuticeps (Sharpnose sculpin) — Eggs brown, 1.0–1.2 mm; hatching length 3–4 mm; notochord flexion length 5.5–7.3 mm; transformation length 12.6–14.5 mm; pigment on head, snout, and nape; 4–10 postanal ventral midline melanophores originating beneath 7th–10th postanal melanophore; unique long diverticulum extending posteriorly from gut on either side of anus; preanal length long (ca. 63% SL); an outer bubble of skin surrounds body anteriorly; in transitional and juvenile specimens, a membrane attaches inner pelvic ray to belly. Literature: Blackburn 1973; Matarese et al. 1989; Richardson and Washington 1980; Washington 1981, 1986; Washington et al. 1984b.

C. analis (Wooly sculpin) — Eggs greenish or brownish yellow to red to light lavender, 1.2–1.3 mm, several oil globules <ca. 18 mm; hatching length 3.1–4.5 mm; notochord flexion length ca. 5.2–<8.4 mm; transformation length 10–12 mm; pigment on head and nape; 18–33 (usually ca. 25) postanal ventral melanophores originating beneath ca. 6th postanal myomere; gut diverticula absent; slight hump at nape; by late flexion stage, 9–12 preopercular spines; by postflexion stage, several post-temporal/supracleithral spines; by ca. 10 mm, W-shape pigment patch on body under second dorsal fin. Literature: Budd 1940; Eigenmann 1892; Feeney 1992; Hubbs 1966; Washington 1986.

C. embryum (Calico sculpin) — Hatching length ca. 4 mm; notochord flexion length 6.4–9.6 mm; transformation length 13–14 mm; pigment variable on head (usually absent), light on long trailing gut; preanal length ca. 50% SL; gut diverticula absent; 11–14 preopercular spines; by ca. 7.4 mm, tiny parietal spine present. Literature: Matarese et al. 1989; Richardson and Washington 1980 (as cottid Type 2); Washington 1981, 1986.

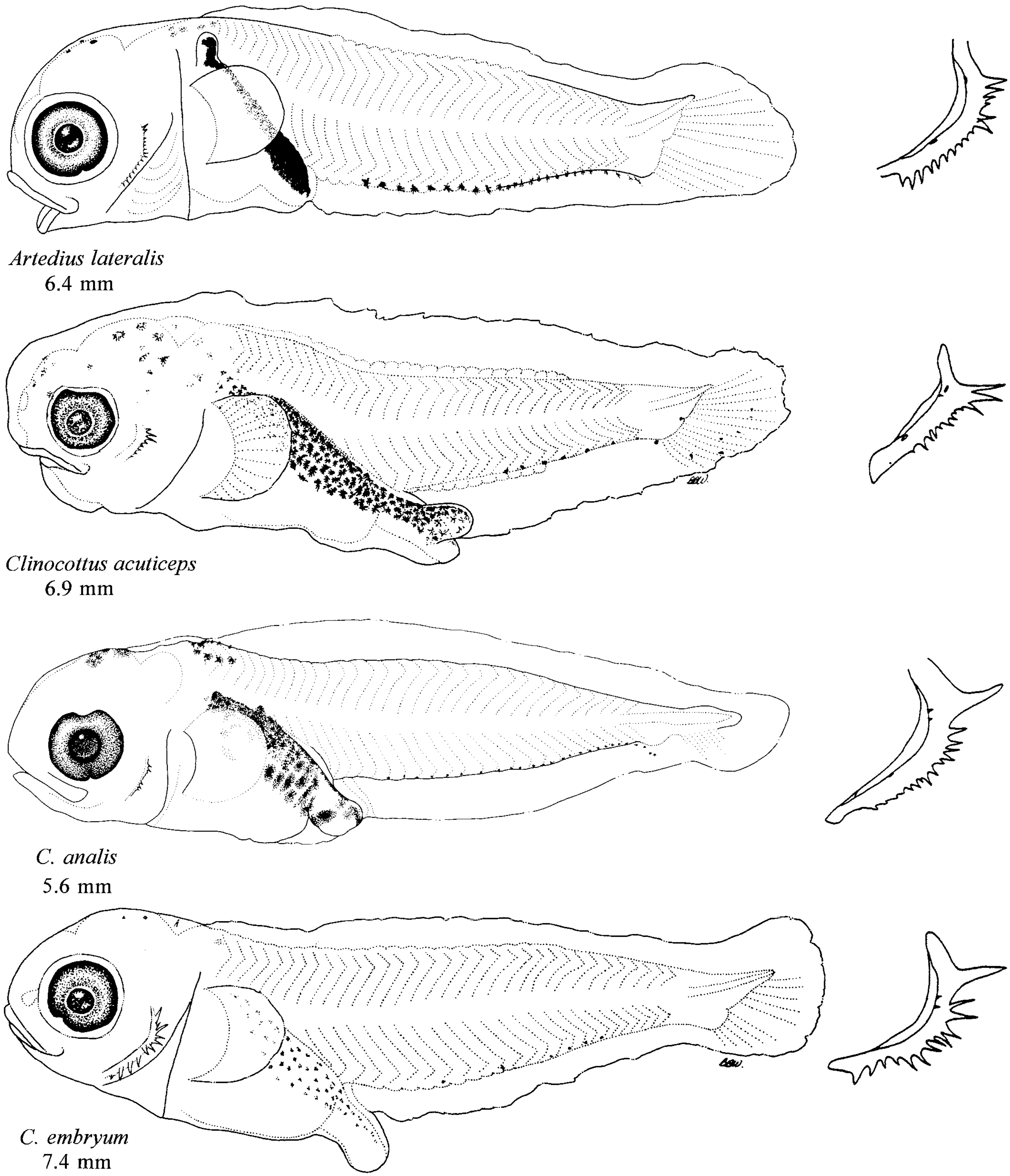


Figure Cottidae 4. *Artedius lateralis*, 6.4 mm (Washington 1986); *Clinocottus acuticeps*, 6.9 mm (Richardson and Washington 1980); *C. analis*, 5.6 mm (Feeney 1992); *C. embryum*, 7.4 mm (Richardson and Washington 1980). Preopercle enlargements from Washington (1986).

***ARTEDIUS* Phenetic Group (Continued)**

Clinocottus globiceps (Mosshead sculpin) — Eggs 1.5–2.0 mm; hatching length 5.1–5.4 mm; notochord flexion length 6.2–8.5 mm; transformation length 12.9–13.5 mm; pigment heavy on head, otic capsule, nape, and dorsolaterally on gut; 4–8 ventral midline melanophores on posterior half of tail; gut diverticula absent; by late flexion stage, 15–20 preopercular spines and a cluster of parietal spines present. Literature: Matarese et al. 1989; Richardson and Washington 1980 (as Type 3); Washington 1981, 1986; Washington et al. 1984b.

C. recalvus (Bald sculpin) — Eggs pale cream colored, 1.25–1.35 mm, guarded by males; hatching length ca. 4.6 mm; notochord flexion length ca. 6.5–9.0 mm; transformation length 9–11 mm; pigment heavy on head, snout, otic capsule, nape, anteriorly and dorsolaterally on gut; ventral midline melanophore series extends onto finfold; relatively short trailing gut; diverticula absent; by flexion stage, multiple preopercular spines present. Literature: Matarese et al. 1989; Morris 1951.

Oligocottus maculosus (Tidepool sculpin) — Eggs pale apple green, adhesive, 1.3–1.5 mm, 1 large oil globule, many small oil globules; hatching length 4.2–4.5 mm; notochord flexion length 7.2–7.6 mm; transformation length ca. 8–10 mm; pigment on head, nape, dorsolaterally on gut; >15 postanal ventral midline melanophores, becoming more closely spaced posteriorly with development; until ca. 7.5 mm, pigmented skin bubble anterior to dorsal finfold; 1–2 melanophores on gut below pectoral fin base; true diverticula absent, dorsolateral bump on gut behind pectoral fin disappears after yolk absorption; by notochord flexion, ca. 8–10 preopercular spines and 3 tiny parietal spines present. Literature: Kojima 1988e; Matarese et al. 1989; Stein 1972, 1973; Washington 1981, 1986; Washington et al. 1984b.

O. snyderi (Fluffy sculpin) — Eggs 1.2–1.3 mm; hatching length 4.5 mm; notochord flexion length 6.2–8.4 mm; transformation length 11–13 mm; pigment very light on head and nape, heavier dorsolaterally on gut; <10 evenly spaced ventral midline melanophores; until ca. 7 mm, unpigmented skin bubble present anterior to dorsal finfold; by flexion stage, 10–20 prickles in parietal region, 10–12 spines on preopercular margin, and 8–10 smaller spines anterior to base of larger preopercular spines. Literature: Matarese et al. 1989; Richardson and Washington 1980 (as Cottid Type I); Stein 1973; Washington 1981, 1986; Washington et al. 1984b.

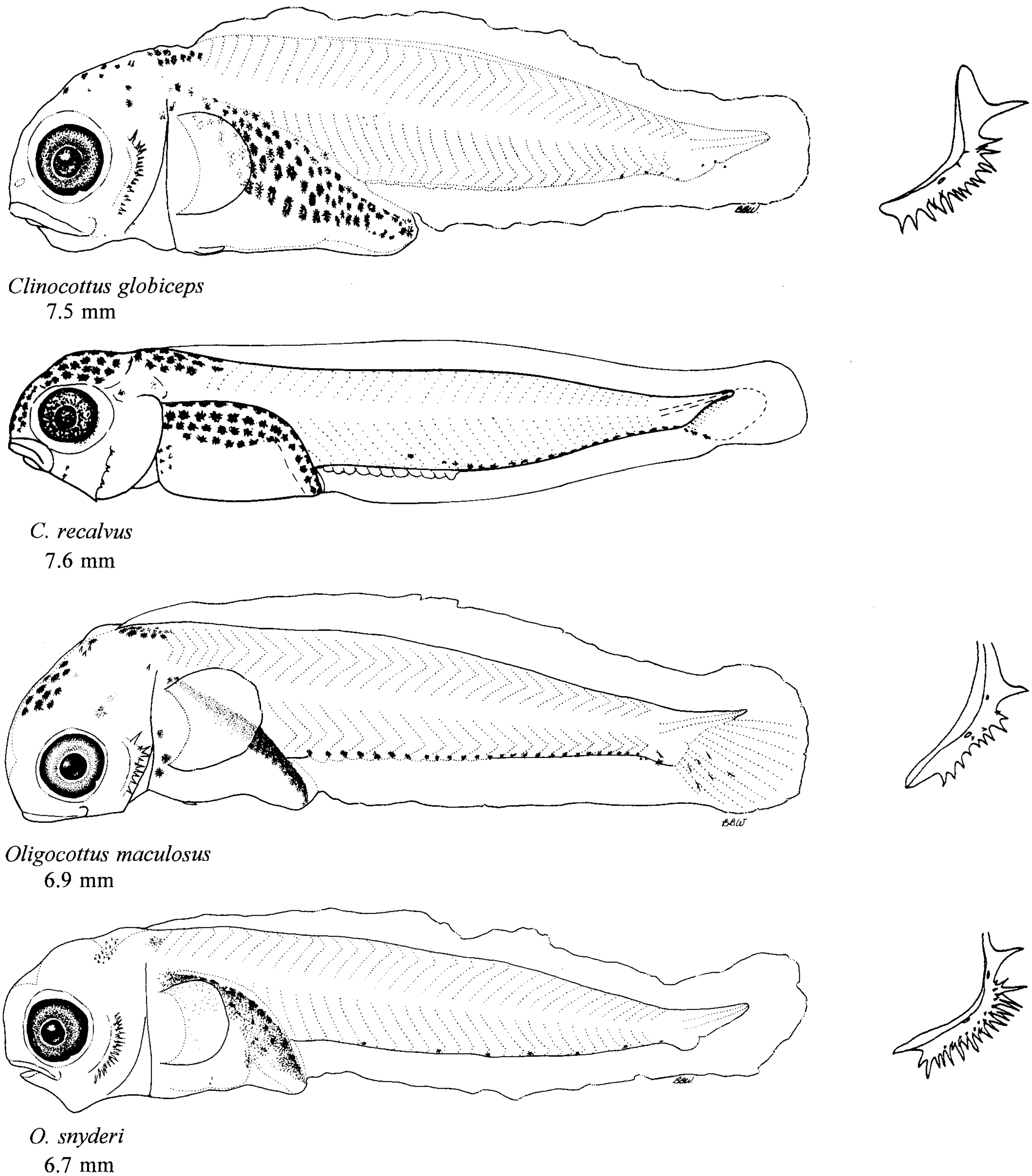


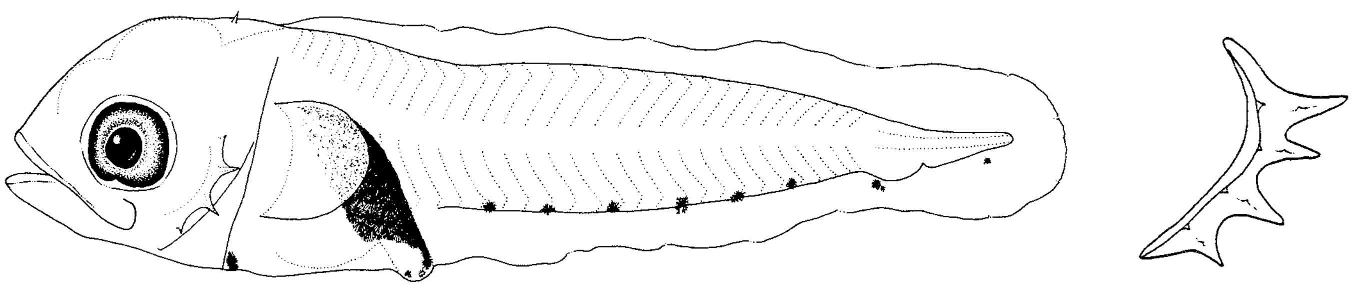
Figure Cottidae 5. *Clinocottus globiceps*, 7.5 mm (Richardson and Washington 1980); *C. recalvus*, 7.6 mm (Matarese et al. 1989); *Oligocottus maculosus*, 6.9 mm (Washington 1986); *O. snyderi*, 6.7 mm (Richardson and Washington 1980). Preopercle enlargements from Washington (1986).

***MYOXOCEPHALUS* Phenetic Group (Artedius creaseri, *A. meanyi*, *Ascelichthys*, *Chitonotus*, *Enophrys*, *Icelinus*, *Orthonopias*, *Paricelinus*, *Radulinus*, *Synchirus*):** Least well defined and most diverse group. Larvae generally slender-bodied with pointed snout (*Enophrys*—stout-bodied; *Orthonopias*—blunt rounded snout); most with heavy pigment dorsolaterally on gut (light in *Icelinus*) and numerous melanophores along the postanal ventral midline (*Radulinus* with heavy lateral body pigment); 4 preopercular spines and a distinct preopercular shelf develop (*Synchirus* with multiple accessory preopercular spines); parietal, nuchal, and supracleithral spines develop.

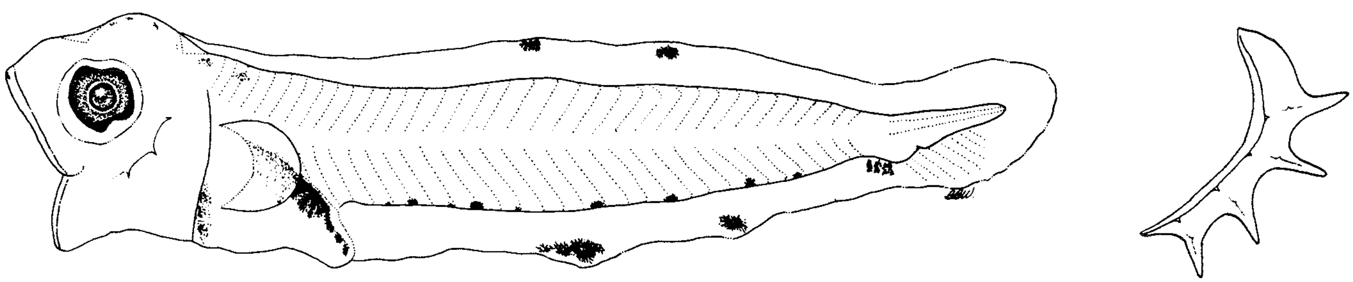
Artedius creaseri (Roughcheek sculpin) — Hatching length ca. 3.5 mm; notochord flexion length 5.7–7.9 mm; transformation length ca. 13.5 mm; pigment absent from head until flexion stage; large, round melanophores dorsolaterally on gut; 1–3 melanophores anteroventrally on gut; 7–11 large, evenly spaced melanophores along postanal ventral midline; 2 large melanophores ventrally in caudal finfold; by ca. 7 mm, 4 large, evenly-spaced preopercular spines, and a prominent parietal and nuchal spine present. Literature: Washington 1986.

A. meanyi (Puget Sound sculpin) — Hatching length ca. 3 mm; notochord flexion length 6.2–9.4 mm; transformation length 15–19 mm; pigment absent from head until flexion stage; pigment anteriorly and dorsolaterally on gut; 2 pigment blotches on dorsal and anal finfolds; <15 postanal ventral midline melanophores; by ca. 7 mm, a single parietal spine present; by ca. 9 mm, 4 large, evenly-spaced preopercular spines present; by 11.5 mm, pelvic fin ray count usually I,2. Literature: Blackburn 1973 (as cottid 3); Matarese et al. 1989; Richardson and Washington 1980 (as *Icelinus* spp.); Washington 1986; Washington et al. 1984b.

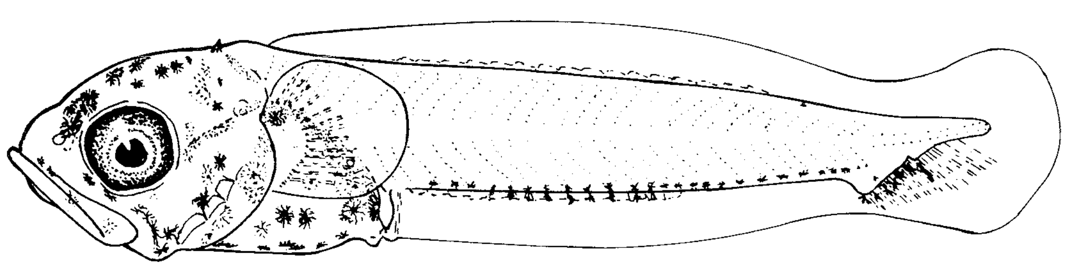
Ascelichthys rhodorus (Rosylip sculpin) — Eggs adhesive, blue to purple, 1.7–2.0 mm, no oil globule; hatching length ca. 6 mm; notochord flexion length 8.8–11.0 mm; transformation length 12–13 mm; pigment heavy on head and gut; pigment ventrally on gut; 20–30 postanal ventral midline melanophores prior to flexion stage, 15–20 in postflexion larvae; by ca. 9 mm, 4 preopercular spines and a single small parietal spine present; pelvic fins absent. Literature: Matarese et al. 1989; Matarese and Marliave 1982.



Artedius creaseri
6.6 mm



A. meanyi
8.6 mm



Ascelichthys rhodorus
9.0 mm

Figure Cottidae 6. *Artedius creaseri*, 6.6 mm (Washington 1986); *A. meanyi*, 8.6 mm (Richardson and Washington 1980); *Ascelichthys rhodorus*, 9.0 mm (Matarese and Marliave 1982). Preopercle enlargements from Washington (1986).

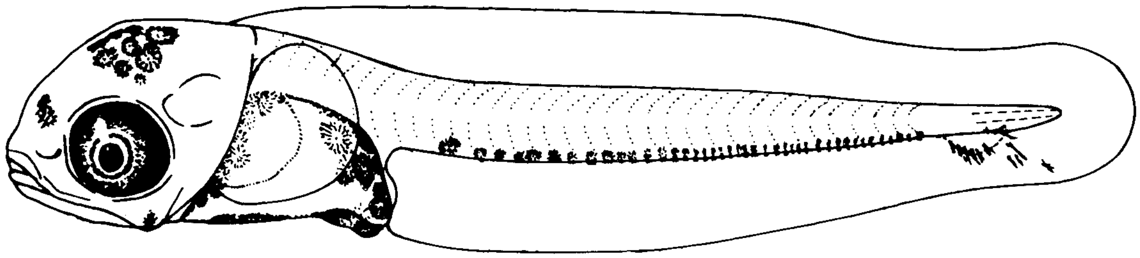
MYOXOCEPHALUS Phenetic Group (Continued)

Chitonotus pugetensis (Roughback sculpin) — Eggs adhesive, salmon-colored, 1.02–1.05 mm, 1 large oil globule (0.3 mm) and 5–8 smaller ones; hatching length 2.9–3.0 mm; transformation begins ca. 16 mm; pigment on head by 4.8 mm; pigment on anterior, dorsal and ventral margins of gut; jaw and nape pigment usually absent; >40 postanal ventral midline melanophores in preflexion larvae; >20 of these melanophores in larvae >6 mm; by 11.5 mm, diagnostic deep emargination evident between 3rd and 4th dorsal fin spines. Literature: Matarese et al. 1989; Misitano 1980; Richardson and Washington 1980; Washington et al. 1984b.

Enophrys bison (Buffalo sculpin) — Eggs adhesive, brownish orange (but variable), guarded by male, 1.7–2.0 mm, 1 oil globule (0.36 mm); hatching length ca. 5 mm; notochord flexion length 5.2–7.0 mm; transformation length 7.6–ca. 9.5 mm; pigment on nape and heavy dorsolaterally on gut; by ca. 5.4 mm in reared larvae, pigment heavy on head, isthmus, and pectoral fin base; 4–16 postanal ventral midline melanophores present; by 7 mm, supraocular, nuchal, parietal and 4 preopercular spines present; body depth increases from ca. 19% BL at hatching to ca. 31% by transformation; 29–31 myomeres, 8–10 anal fin rays. Literature: Blackburn 1973; Marliave 1975; Matarese et al. 1989; Misitano 1978; Richardson and Washington 1980; Washington et al. 1984b.

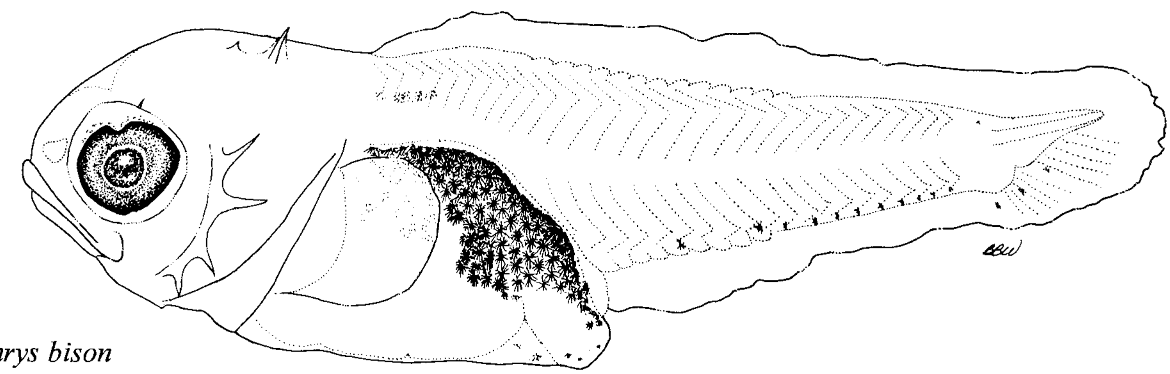
Icelinus quadriseriatus (Yellowchin sculpin) — Eggs adhesive, pale green, 1.08–1.17 mm, multiple oil globules coalesce into 1 (0.14–0.19 mm); hatching length 2.6–3.4 mm; notochord flexion length 5.0–7.4 mm; transformation length >10.5 – <16.3 mm; larvae ca. >4 mm may have chin and pectoral insertion pigment; 1–6 rows of ventral gut melanophores; 25–63 postanal ventral midline melanophores; angular pigment; by 9.3 mm, nasal, parietal and 4 preopercular spines present; by 10.3 mm, 3 pigment patches dorsolaterally on body. Literature: Feeney 1987.

Orthonopias triacis (Snubnose sculpin) — Eggs adhesive, colorless to pale straw yellow or pinkish brown, 0.86–1.0 mm, oil globule ca. 0.18–0.20 mm; hatching length 2.6–3.8 mm; notochord flexion length 4.2–4.7 mm; transformation length >9.2 – <13.2 mm; pigment heavy dorsoposteriorly on gut; occasionally 1 melanophore at nape and 1–2 on head; 26–55 postanal ventral midline melanophores; gut short (preanal length ca. 32–45% SL in preflexion larvae); by late flexion stage, 4 equal-sized, evenly spaced preopercular spines present; in postflexion larvae and juveniles, a space separates anus from anal fin; juveniles have row of spiny scales between dorsal fin and lateral line. Literature: Bolin 1941; Feeney 1992; Washington et al. 1984b.



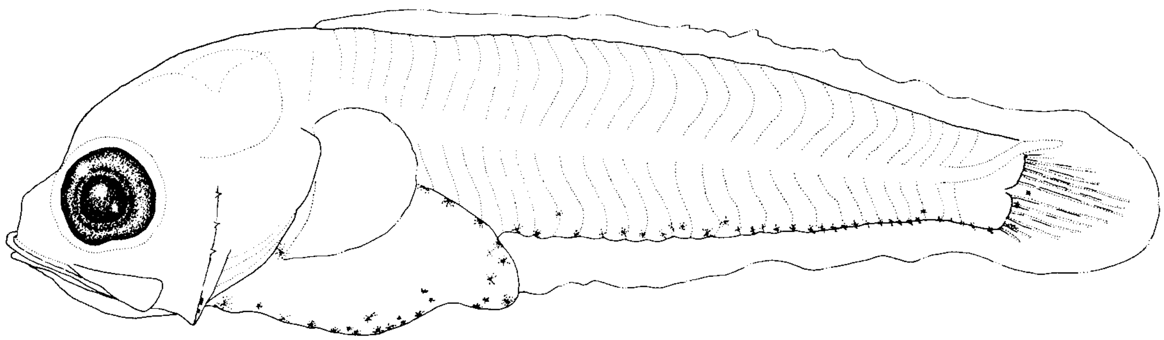
Chitonotus pugetensis

4.9 mm



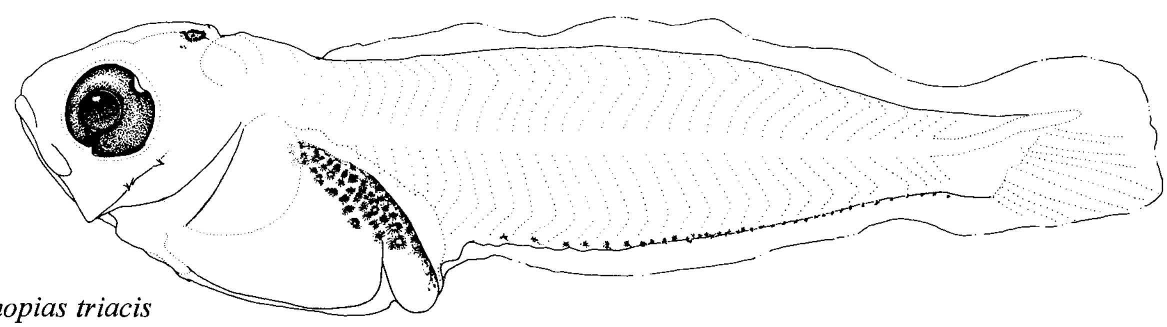
Enophrys bison

7.0 mm



Icelinus quadriseriatus

6.6 mm



Orthonopias triacis

5.5 mm

Figure Cottidae 7. *Chitonotus pugetensis*, 4.9 mm (Matarese et al. 1989); *Enophrys bison*, 7.0 mm (Richardson and Washington 1980); *Icelinus quadriseriatus*, 6.6 mm (Feeney 1987); *Orthonopias triacis*, 5.5 mm (Feeney 1992).

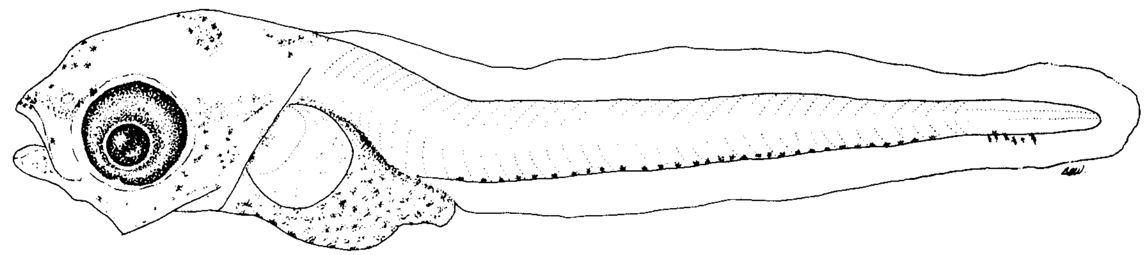
***MYOXOCEPHALUS* Phenetic Group (Continued)**

Paricelinus hopliticus (Thornback sculpin) — Hatching length <5.6 mm; notochord flexion length >6.2 – <13.8 mm, transformation length 18.6 – <25.6 mm; pigment covering entire gut, scattered over snout, lower jaw, head, and pectoral fin base; >30 postanal ventral midline melanophores in preflexion larvae decreasing to 15–20 by postflexion stage; distinctive group of melanophores in finfold near tail tip persisting at base of caudal fin through transformation; by postflexion stage, 4 preopercular spines present; by transformation, spiny scales on body; 42–43 myomeres. Literature: Matarese et al. 1989; Richardson and Washington 1980; Washington et al. 1984b.

Radulinus asprellus (Slim sculpin) — Hatching length ca. 4.5 mm; notochord flexion length 7.2–10.9 mm; transformation length ca. 15 mm; body slender (BD <25% SL); snout sharply pointed; gut distinctly coiled; preanal length ca. 44–54% SL; pigment heavy over body except dorsolaterally above body midline over gut and dorsolaterally on tail tip; distinctive series of elongate melanophores along lateral line; by ca. 10 mm, 4 small preopercular spines visible. Literature: Matarese et al. 1989; Richardson and Washington 1980; Washington et al. 1984b.

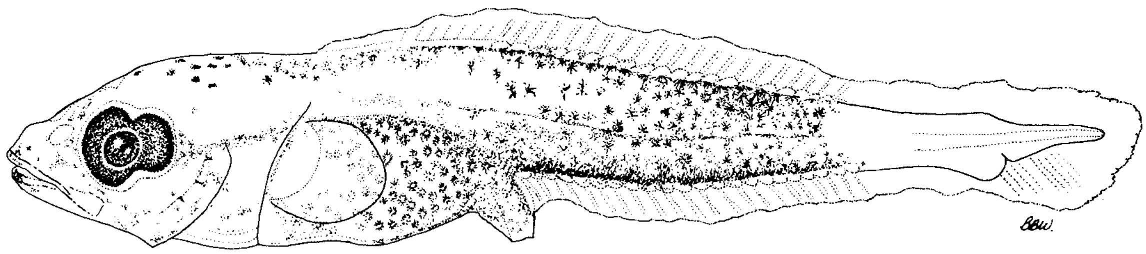
R. boleoides (Darter sculpin) — Notochord flexion length ca. 7.5 mm; snout sharply pointed; body deeper (ca. 22 vs. 18% SL) and fins more developed than in similar size *R. asprellus* flexion stage larvae; preanal length longer (58% SL) and pectoral fin length longer than in *R. asprellus*; gut coiling and pigmentation similar in these two species. Literature: Matarese et al. 1989; Richardson and Washington 1980.

Synchirus gilli (Manacled sculpin) — Eggs adhesive, pink, attached to *Laminaria* holdfasts; hatching length <5.2 mm; notochord flexion length 6.5–8.5 mm; transformation length ca. 16.8 mm; pigmentation absent from head until flexion stage; unique pigment on gut—fine specks dorsolaterally, banding posteriorly, and series ventrally; ca. 50 postanal ventral melanophores, larger anteriorly; unlike other members of *Myoxocephalus* phenetic group, anterior accessory spines associated with 4–9 preopercular spines in preflexion larvae; by 12–14 mm, pectoral fins united ventrally. Literature: Marliave et al. 1985; Matarese et al. 1989.



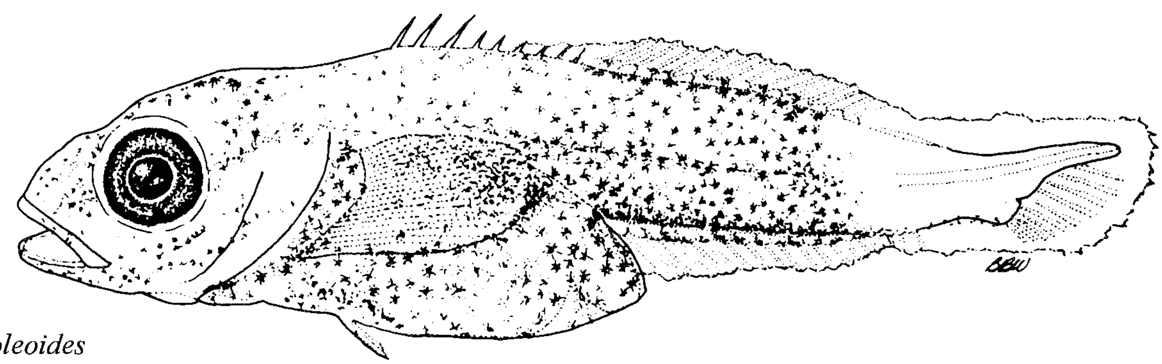
Paricelinus hopliticus

6.2 mm



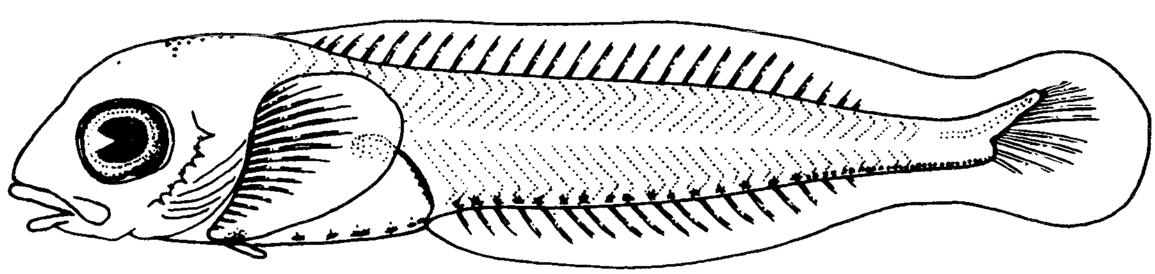
Radulinus asprellus

9.6 mm



R. boleoides

8.7 mm



Synchirus gilli

8.3 mm

Figure Cottidae 8. *Paricelinus hopliticus*, 6.2 mm; *Radulinus asprellus*, 9.6 mm; *R. boleoides*, 8.7 mm (Richardson and Washington 1980); *Synchirus gilli*, 8.3 mm (Marliave et al. 1985).

PSYCHROLUTIDAE: Fathead sculpins

D. A. AMBROSE

Psychrolutids were formerly included in Cottidae (e.g., Jordan and Gilbert 1882; Stein and Bond 1978; Matarese et al. 1989). We follow Washington et al. (1984a), Yabe (1985), and Eschmeyer (1990) by placing them in a separate family. Nelson (1982) recognized three subfamilies with seven genera and about 29 species. *Psychrolutes phrictus*, the largest (65 cm) and deepest living (839–2800 m) psychrolutid, is the only representative of the family in our study area. Three larvae tentatively identified as this species were collected off central California.

Adult psychrolutids have naked bodies or are covered with plates bearing prickles. The interorbital width usually is greater than the exposed eye diameter. Prevomerine teeth are present or absent, palatine teeth are always absent. The dorsal fin usually is continuous, with the spinous dorsal often partially hidden by skin (Nelson 1994). Meristics for the family are: V 28–38; D VI–XII, 12–23; A 9–17; P_1 15–26; P_2 I,2–3 (usually 3); and Br 7 (Washington 1984a)

Larval psychrolutids hatch at a relatively large size (6–7 mm) and settle from the plankton at about 18–20 mm (Washington et al. 1984b). Larvae are generally tadpole-shaped with a large, rounded head tapering toward the tail, with an outer layer of loose flabby skin, and without head or preopercular spines. Pigment occurs on the head, nape, gut, and pectoral fins. Postanal ventral midline melanophores are absent; however, pigment is added posteriad over the body with development. Richardson and Washington (1980) described three larval specimens (9.8, 12.8, 13.4 mm) collected off Oregon as an unidentified cottoid primarily because a 26.4 mm juvenile was deeper bodied (51 vs. 31% SL) and had a longer preanal length (61 vs. 51% SL) than a 35 mm *P. phrictus* juvenile. Our specimens (7.2, 7.9, 8.3 and 8.7 mm), tentatively identified as *P. phrictus*, are similar to those larvae. The larvae described by Richardson and Washington (1980) may represent an undescribed psychrolutid species, although it seems unlikely there is more than one species in the northeast Pacific with such an array of unusual characters (e.g., bizarre form, meristics, pattern of belly prickles, and pelvic fin development within skin depressions).

Meristic data are from Stein and Bond (1978). Ecological information is primarily from Eschmeyer et al. (1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	33
Precaudal	12	
Caudal	23	
Fins:		
Dorsal spines	VII–IX	VIII
Dorsal rays	19–20	20
Anal spines	0	0
Anal rays	12–14	13
Pelvic	I,3	I,3
Pectoral	22–26	24
Caudal:		
Principal	6+7	6+7
Procurrent:		
Upper		
Lower		
Gill rakers:		
Total	9–13	11
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Bering Sea to San Diego, California

Habitat: Benthic, 839–2800 m depth

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Matarese et al. 1989
Richardson & Washington 1980

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 7.9 mm (M. T. Vona)

* Identification as *P. phrictus* is tentative until additional material is available (see discussion of Cottoid type A in Richardson & Washington 1980).

† Measurements taken from 7.9 mm & 8.3 mm preflexion larvae (CFRD 9104, stations 68.3.57.3 & 76.7.52.5), 8.7 mm flexion larva (CalCOFI 7205, station 60.52), & literature (Richardson & Washington 1980).

‡ HW of 8.7 mm flexion larva.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 8 mm
Transformation length: >13.4, <26.4 mm
Fin development sequence: P_1, 2D & A, C, 1D, P_2
Pigmentation: *Preflexion*—Covering head, trunk, & anterior 25% of tail. *Flexion*—Spreading posteriad on tail. *Postflexion*—On entire body except at end of tail, C & distally on P_1, D & A.
Diagnostic features: P_1 22–26; Br 7; 1D appears embedded in skin; 2D & A partially covered by skin; loose outer skin; globose, deep body; prickles on skin from 7.2 mm to 50 mm; P_2 appears inserted in skin pocket; P_2 skin pockets present by at least 7.2 mm, but P_2 not visibly out of pocket until >9 mm; head spines lacking.

MORPHOMETRICS† (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		51–55 53	54–58 56	79		
BD/BL		30–37 33	36–42 39	56		
HL/BL		29–33 30	34–37 35	48		
HW/HL‡		83–93 88	81			
SnL/HL		21–27 22	18–19 19	25		
ED/HL		37–39 38	34–36 35	28		
P_1L/BL		8–10 9	11–17 14	29		

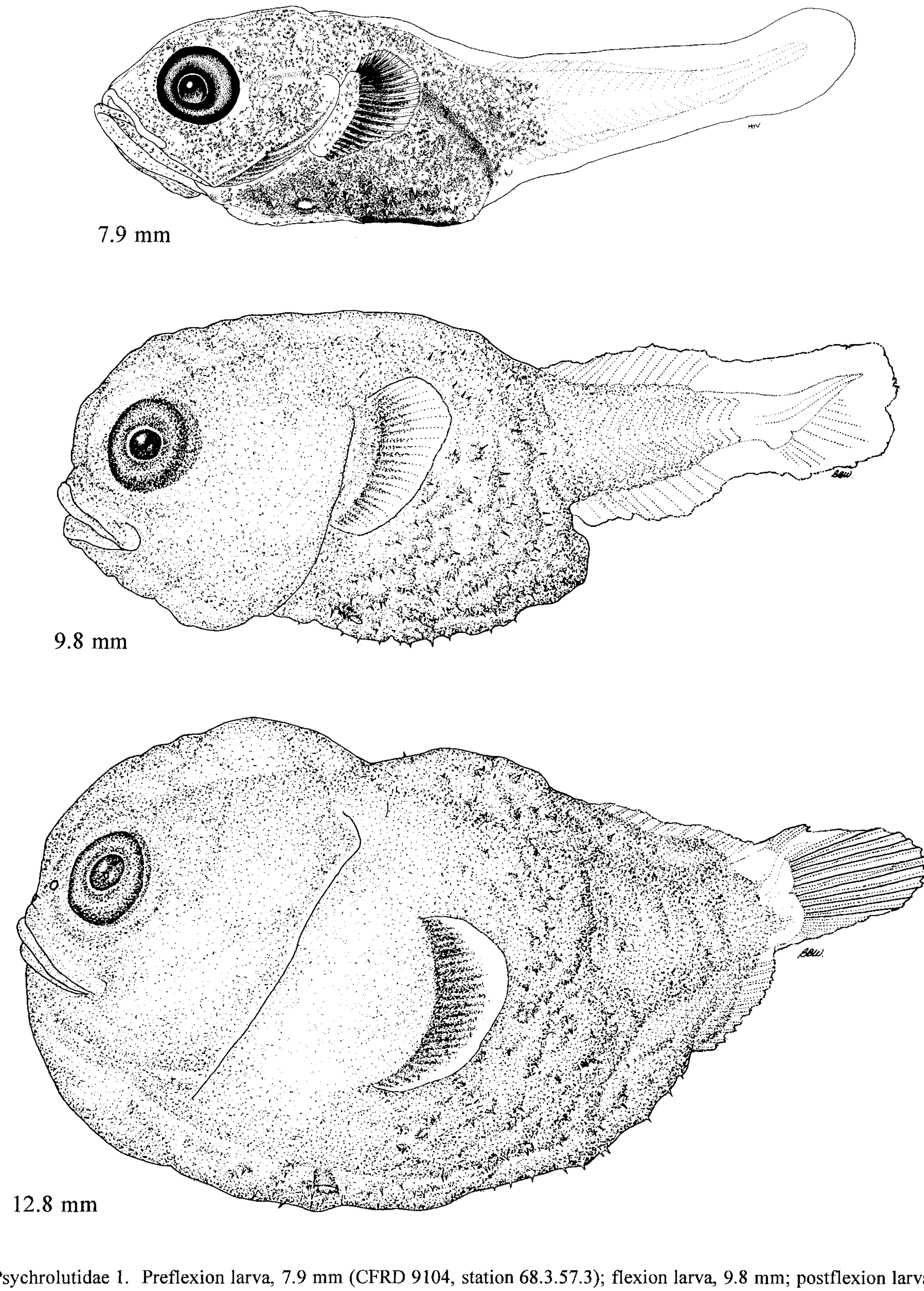


Figure Psychrolutidae 1. Preflexion larva, 7.9 mm (CFRD 9104, station 68.3.57.3); flexion larva, 9.8 mm; postflexion larva, 12.8 mm (Richardson and Washington 1980).

AGONIDAE: Poachers

D. A. Ambrose

At least 18 agonid species occur in the CalCOFI area (Table Agonidae 1), but larvae of only six have been identified in CalCOFI ichthyoplankton samples. These are, in decreasing order of abundance: *Odontopyxis trispinosa*, *Xeneretmus latifrons*, *Bathyagonus pentacanthus*, *X. leiops*, *Agonopsis sterletus*, and *Bothragonus swanii*. Larvae are known for all 18 species except *X. ritteri* and *X. triacanthus* (Busby and Ambrose 1993; Busby, in prep.). Most species range northward to at least British Columbia, except *A. sterletus* and *X. ritteri* do not occur north of central and southern California, respectively. Only five species range as far south as central Baja California (*A. sterletus, O. trispinosa, Stellerina xyosterna, X. ritteri* and *X. triacanthus*). Most poachers are elongate, 15 cm or less (some reach 30 cm), and are covered by large fused bony plates that are modified scales. The plates are arranged in rows and usually bear spines. All fin rays are unbranched. Pectoral fins are fan-like, with lower rays elongate in some species. Usually there are two dorsal fins, the first one spinous (absent in *Anoplagonus inermis*) and the second one soft-rayed. Pelvic fins are thoracic and reduced to one spine and two soft rays. In several species, pelvic fins, and sometimes the anal fin, are longer in males than in females. Vertebrae number 29–52. Most are countershaded brownish above and paler below. Poachers occur primarily in the North Pacific, three species inhabit the North Atlantic, and one species occurs off the tip of South America (Maeda and Amaoka 1988). Agonids are usually found on soft bottoms at moderate depths; a few species are intertidal and some range to depths of more than 1200 m (Eschmeyer et al. 1983). There are about 20 genera and 44 species (Kanayama 1991). Cottids are thought to be the closest living relatives of agonids; in particular, hemitripterids have been hypothesized as a sister group (Yabe 1985, Nelson 1994).

Agonid eggs are spherical, 1–2 mm in diameter with a single oil globule, spawned demersally in adhesive clusters often under rocks (Washington et al. 1984b). Larvae are characteristically long and slender, with a relatively long gut, large fan-shaped pectoral fins, and a spiny head with large frontoparietal ridges and usually with four large preopercular spines. Rows of body spines form early in larval development; these correspond to the plates of adults and are useful for identification. Melanistic pigment may be present on the head (especially giving a "bearded" appearance in some early-stage larvae), on the nape, scattered over the gut, frequently extending onto the dorsal and anal finfolds, and also in bands on the postanal lateral surface of the body in postflexion and later larval stages. Transformation to juvenile is gradual and direct with no striking changes. The transformation stage for the purpose of this study was considered to begin at 15 mm SL, based primarily on the development of body pigment similar to the juvenile pattern for all species examined, even though at this size the finfold still persisted in the caudal peduncle region of these specimens (Table Agonidae 2). Terminology of bony plates follows Grunchy (1969) and Maeda and Amaoka (1988). In larvae and early juveniles, the exact separation of the dorsolateral plates (DLR) and the mid-dorsal plates (MDR) is difficult; consequently, these bony plates should be counted together. This is also the case for the ventrolateral plates, VLR, and mid-ventral plates, MVR (Maeda and Amaoka 1988).

The following species accounts are based primarily on detailed examinations of between 3 and 37 specimens of each taxon (Table Agonidae 2) and on literature (Washington et al. 1984b). Larval *A. sterletus* and *X. leiops* are described for the first time. Adults of *Agonomalus mozinoi, Occella verrucosa,* and *Stellerina xyosterna* occur in the study area but their larvae were not found in CalCOFI collections (Figure Agonidae 1). Meristic data were obtained from counts made during this study and from literature (Miller and Lea 1972; Matarese et al. 1989; Kanayama 1991; Busby, in prep.). Ecological information was obtained primarily from Eschmeyer et al. (1983).

Table Agonidae 1. Meristic characters for the agonid species in the California Current vicinity. All have I,2 pelvic fin elements. Principal caudal rays are usually 6+5 but range to 7+6 for *Bothragonus swanii* and 5+4 for *Pallasina barbata* (Kanayama 1991). *Pallasina barbata* occasionally have five branchiostegal rays, all other species have six. Abbreviations for rows of bony plates: DLR, dorsolateral; MDR, middorsal caudal peduncle; VLR, ventrolateral; MVR, midventral caudal peduncle. Geographic abbreviations: AK, Alaska; BCA, Baja California; BRT, British Columbia; C, central; CA, California; N, northern; OR, Oregon; S, southern; SE, southeast; SW, southwest; WA, Washington.

		Vertebrae	Fin Rays			Gill	Body plates	
Species	Distribution	Total	D	A	P_1	Rakers	DLR+ MDR	VLR + MVR
Agonomalus mozinoi[a]	BRT to C CA	34	VII–IX+6–8	10–12	11–12		30–36+	20–23+
Agonopsis sterletus	C CA to C BCA	38–39	VI–VIII+7–8	8–9	12–13	0–1+7–8	28+8–9	27–28+8–9
A. vulsa	Gulf of AK to S CA	38–42	VIII–XI+7–9	10–12	13–15		29–32+7–9	29–30+7–9
Anoplagonus inermis	Bering Sea to N CA	41–45	4–6	4–5	8–11		25–27+13	22–25+14–16
Bathyagonus alascanus	Bering Sea to N CA	39–41	V–VIII+5–8	6–8	14–16	1–2+9–11	23–24+12–14	20–22+13–15
B. infraspinatus	Bering Sea to N CA	38–41	V–VIII+5–8	5–8	15–16	1+10	21–23+14–15	18–19+16
B. nigripinnis	Bering Sea to N CA	43–46	V–VIII+6–7	6–9	14–17	0–2+11–18	25–28+15–17	21–27+16–19
B. pentacanthus	Gulf of AK to S CA	40–46	V–VIII+5–8	6–9	14–16	1+8	26–28+15–16	22–25+16–18
Bothragonus swanii	Kodiak Island to C CA	29–32	II–V+4–6	4–5	10–12		21+5–6	22–23+2–3
Occella verrucosa[b]	Bering Sea to C CA	34–38	VII–X+6–9	7–13	13–15	1–2+8–12	29–31+5–7	25–28+3–5
Odontopyxis trispinosa	SE AK to C BCA	37–42	III–VI+5–7	5–7	13–15	0–1+7	21+14	20+15
Pallasina barbata	Bering Sea & Japan to C CA	42–52	V–IX+6–9	8–14	10–13	1+10–12	30–46+3–12	28–42+3–10
Podothecus acipenserinus	Bering Sea to N CA	39–42	VII–X+6–9	6–9	16–19		21–24+13–16	20–22+14–16
Stellerina xyosterna	BRT to C BCA	34–37	VI–VIII+5–7	8–9	17–19	1–3+8–16	22–23+11–12	18–20+11–13
Xeneretmus latifrons	BRT to N BCA	39–43	VI–VIII+6–8	6–9	13–15	1–2+10–16	22–24+14–16	20–23+14–16
X. leiops	SE AK to S CA	39–45	VI–VII+6–8	5–8	13–15	1+10	24–25+17–19	22–24+17–19
X. ritteri	S CA to C BCA	40–41	V–VII+6–7	6–7	16–17		22–23+14–15	22–23+14–16
X. triacanthus	BRT to C BCA	41–42	V–VII+6–7	5–7	12–14	1+8–13	23–24+15–16	21–22+16–17

[a] Placed in the genus *Hypsagonus* by Kanayama (1991).
[b] Placed in the genus *Chesnonia* by Kanayama (1991).

Table Agonidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the agonid species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Agonopsis sterletus	0	0	6 4.8–6.7	5 7.3–10.2	2 10.5–14.5	0	5 36.8–49.8
Bathyagonus pentacanthus	0	0	6 4.9–7.7	4 8.5–9.4	4 10.2–13.7	1 16.5	0
Bothragonus swanii	0	0	0	1 6.1	2 7.5–8.4	0	0
Odontopyxis trispinosa	0	0	11 4.3–7.2	6 7.1–11.7	10 11.8–14.8	5 15.0–17.7	5 28.0–41.6
Xeneretmus latifrons	0	3 4.9–5.3	10 5.1–7.8	6 8.9–10.8	11 10.8–14.7	1 16.8	5 30.0–42.0
X. leiops	0	0	7 4.5–9.0	3 10.8–11.8	2 12.2–13.3	5 18.6–22.5	0

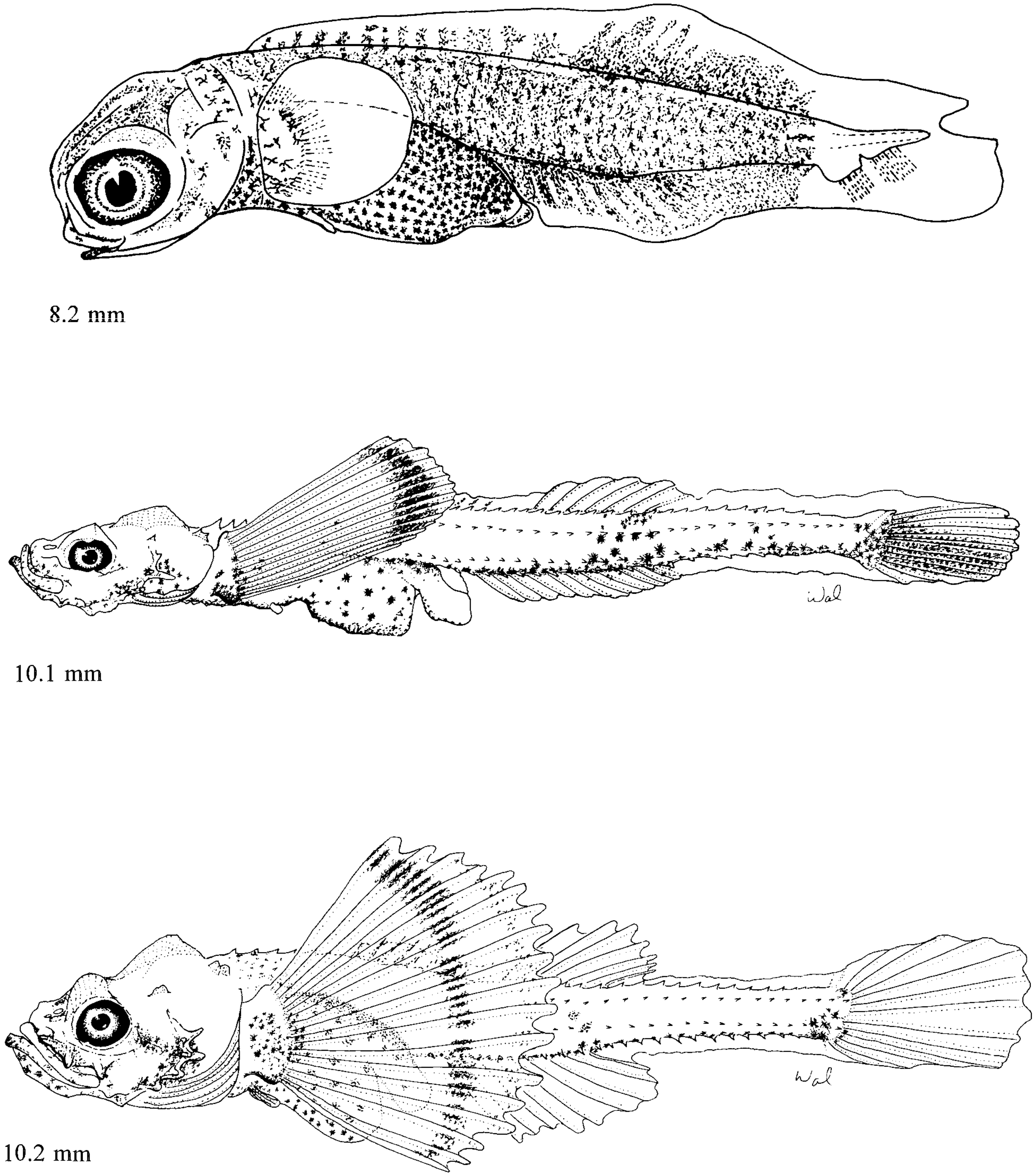


Figure Agonidae 1. *Agonomalus mozinoi*—flexion larva, 8.2 mm (Matarese et al. 1989); *Occella verrucosa*—late flexion larva, 10.1 mm; *Stellerina xyosterna*—late flexion larva, 10.2 mm (Washington et al. 1984b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–39	
Precaudal		
Caudal		
Fins:		
Dorsal spines	VI–VIII	
Dorsal rays	7–8	
Anal spines	0	0
Anal rays	8–9	
Pelvic	I,2	I,2
Pectoral	12–13	
Caudal:		
Principal	6+5	6+5
Procurrent:		
Upper	3	3
Lower	3	3
Gill rakers:		
Upper	0–1	
Lower	7–8	
Branchiostegals	6	6

LIFE HISTORY

Range: San Simeon Pt., California to Punta San Hipolito, Baja California Sur (ca. 27° N)

Habitat: Soft bottom at about 42–92 m depth

Spawning season: Preflexion larvae in CalCOFI tows in all seasons

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.2 mm (B. Sumida MacCall)
Flexion larva, 8.1 mm (B. Sumida MacCall)
Postflexion larva, 14.5 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

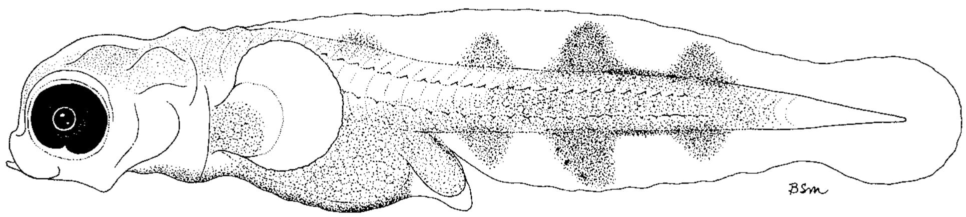
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

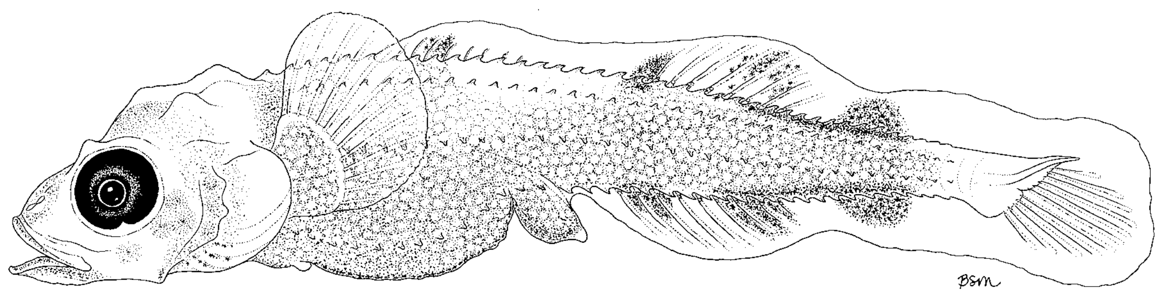
Hatching length: <4.8 mm
Flexion length: ca. 7.3–10 mm
Transformation length: ca. 15 mm, gradual
Fin development sequence: P_1, 2D & A & C, 1D, P_2
Pigmentation: *Preflexion*—Dorsolaterally on head, isthmus, gut, & most of trunk; absent above gut & at end of tail; 4 triangular-shaped patches on the dorsal finfold & 3 similar patches on anal finfold. *Flexion*—On upper & lower jaws, hyoid, opercular & branchiostegal regions; spreading into region above gut. *Postflexion*—Uniformly covering most of body except posterior opercular region; absent from C; patch at mid 1D, anteriorly & posteriorly on 2D & A & a patch dorsally & ventrally on the finfold in the caudal peduncle region. *Juvenile*—On C, 2 bars on P_2, ca. 7 lateral bars on body.
Diagnostic features: Total vertebrae 38–39; P_1 12–13; A 8–9; pigment pattern on dorsal & anal finfolds; pigment absent near end of C; pigment present dorsally on head & on P_1 base; parietals rounded; notochord flexion by ca. 7 mm.

MORPHOMETRICS (range & mean in %)

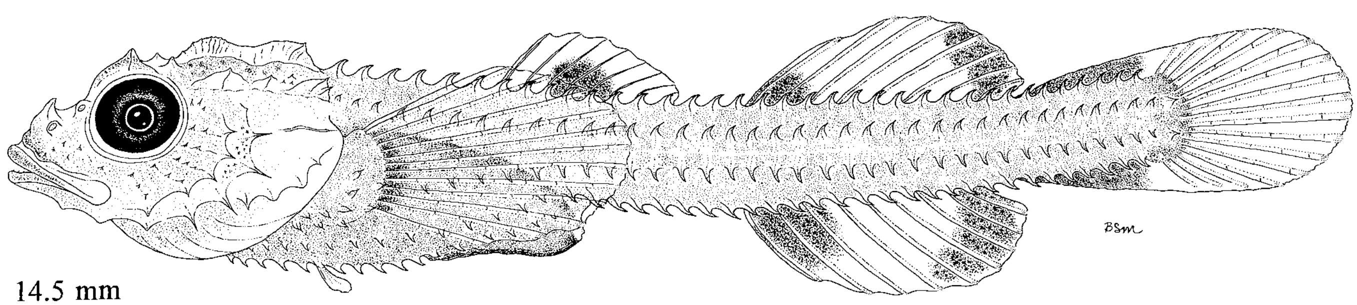
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–56 52	49–57 54	49–54 52		34–38 36
BD/BL		14–16 16	14–20 16	15–16 15		13–16 14
HL/BL		19–26 22	25–29 26	26–29 28		26–30 27
HW/HL		48–82 64	43–58 50	49–53 51		44–53 48
SnL/HL		8–26 13	21–26 24	25–27 26		22–30 25
ED/HL		28–47 40	27–33 30	26–29 28		20–23 21
P_1L/BL		4–10 7	11–15 13	17–19 18		17–20 18
P_2L/BL		0–0.6 0.1	1–3 3	4–5 5		10–13 12



5.2 mm



8.1 mm



14.5 mm

Figure Agonidae 2. Preflexion larva, 5.2 mm (CalCOFI 6501, station 103.28.5); flexion larva, 8.1 mm (CalCOFI 7510, station 127.34); postflexion larva, 14.5 mm (CalCOFI 6601, station 100.30).

MERISTICS

	Range	Mode
Vertebrae:		
Total	40–46	
Precauda	12	12
Caudal	28–34	
Fins:		
Dorsal spines	V–VIII	
Dorsal rays	5–8	
Anal spines	0	0
Anal rays	6–9	
Pelvic	I,2	I,2
Pectoral	14–16	
Caudal:		
Principal	6+5–6	6+6
Procurrent:		
Upper	2	2
Lower	1	1
Gill rakers:		
Upper	1	1
Lower	8	8
Branchiostegals	6	6

LIFE HISTORY

Rauge: Bering Sea to Cortez Bank (off southern California)

Habitat: Soft bottom, 110–375 m depth

Spawning season: Preflexion larvae collected in CalCOFI surveys from January–May, with a peak in January–February.

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Busby, in prep.

* Eye slightly oval; horizontal axis given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.9 mm
Flexion length: ca. <8.5–10 mm
Transformation length: ca. 15 mm
Fin development sequence: P_1, C, 2D & A, 1D, P_2
Pigmentation: *Preflexion*—Absent dorsally on head & C finfold, otherwise, completely covering gut & body; small patch anteriorly in dorsal finfold; dorsal finfold posterior to anus & anal finfold completely covered; by ca. 7 mm, "bearded" appearance. *Flexion*—Small patch persists in 1D region; medium-sized patch in 2D region; large patch dorsally in caudal peduncle region. *Postflexion–transformation*—Patches anteriorly & posteriorly on A; increasing dorsolaterally on head; light or absent on P_2; rounded patch extending on to <33% of C; ca. 6 blotches forming laterally on body.
Diagnostic features: Total vertebrae 40–46; P_1 14–16; A 6–9; MDR 15–16; MVR 16–18; by ca. 13 mm, 2 pairs of plates on breast anterior to P_2; anal finfold completely pigmented; large patch over most of dorsal finfold preceded by a small patch; pigment extends onto <33% of C; parietals rounded; notochord flexion by ca. 8 mm; spines present on eye by 16.5 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–52 49	49–60 53	48–56 53	 49	
BD/BL		12–16 13	12–13 13	12–16 14	 19	
HL/BL		16–23 20	20–24 22	28–29 28	 29	
HW/HL		43–63 51	43–53 48	43–52 48	 51	
SnL/HL		14–19 16	14–23 18	21–26 24	 27	
ED/HL*		28–41× 24–35 34×30	25–31× 24–25 28×24	20–25× 16–23 22×20	 23×21	
P_1L/BL		6–8 7	7–10 9	22–23 22	 29	
P_2L/BL		0–0 0	0–1 0.3	6–11 8	 10	

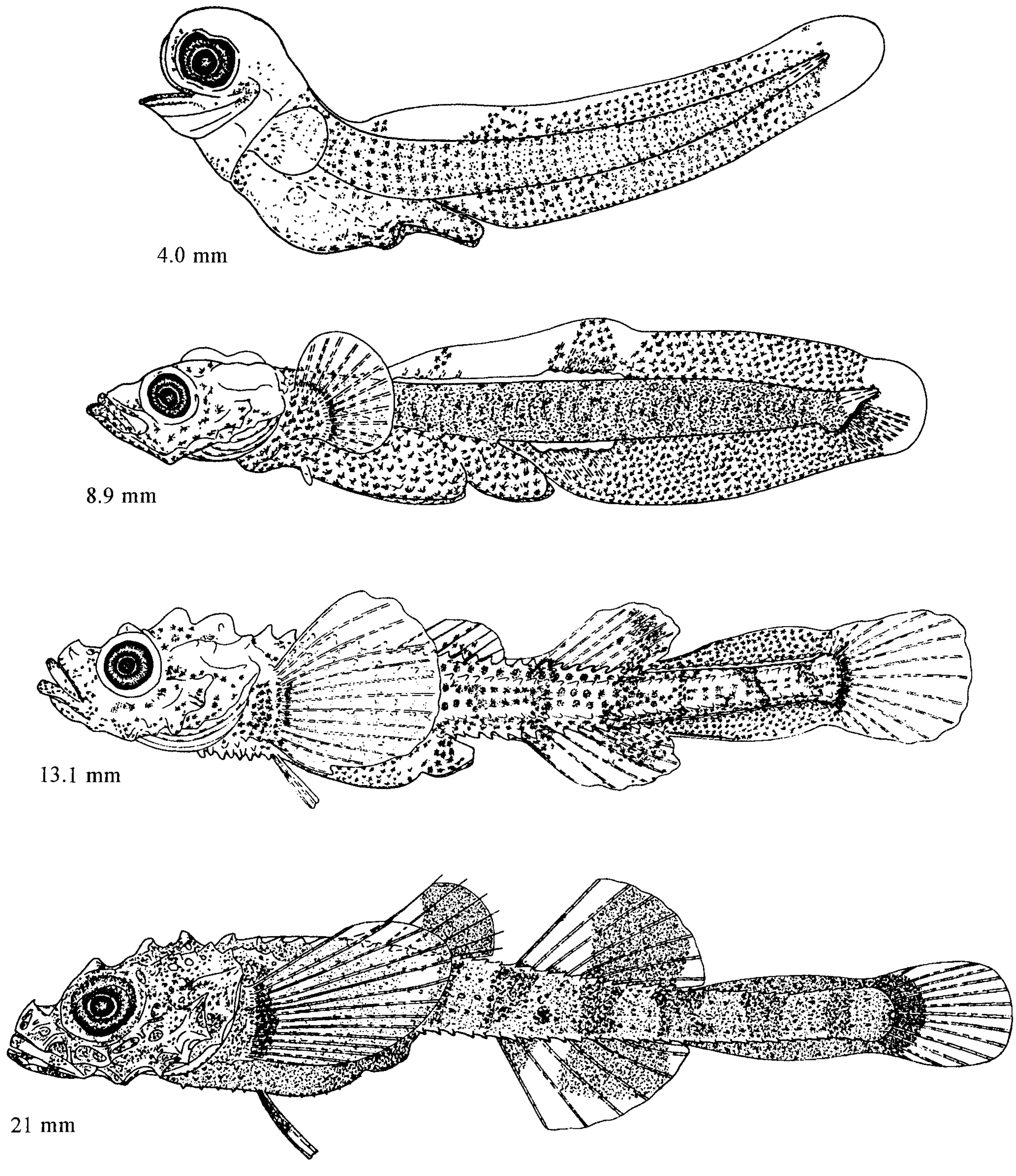


Figure Agonidae 3. Preflexion larva, 4.0 mm; flexion larva, 8.9 mm; postflexion larva, 13.1 mm; transformation specimen, 21 mm (Busby in prep.).

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–32	
Precaudal	10–11	
Caudal	18–21	
Fins:		
Dorsal spines	II–V	
Dorsal rays	4–6	0
Anal spines	0	
Anal rays	4–5	
Pelvic	I,2	I,2
Pectoral	10–12	
Caudal:		
Principal	6–7+6	7+6
Procurrent:		
Upper	2	2
Lower	1	1
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Kodiak Island, Alaska to southern California (ca. 34° N)

Habitat: Intertidal, to 18 m depth

Spawning season: Winter–spring on kelp holdfasts

ELH pattern: Oviparous; demersal attached eggs; planktonic larvae

LITERATURE

Busby, in prep
Marliave 1975
Matarese et al. 1989
Washington et al. 1984b

EARLY LIFE HISTORY DESCRIPTION*

EGGS

Shell diam.: 2 mm (Marliave 1975) **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <6 mm in California; >10 mm in British Columbia
Transformation length:
Fin development sequence: P_1, C, 2D & A, 1D, P_2
Pigmentation: *Flexion*—Along lower jaw; on branchiostegals, breast, & isthmus; distally on P_1; heavy row along ventral margin of gut; scattered laterally on gut; patch on finfold in 2D & A region; a few scattered along lateral midline in anterior 50% of body; bar forming laterally posterior to 2D & A; scattered ventrolaterally on tail anterior to bar. *Postflexion*—"Bearded" appearance; patch at mid 1D, & distally on 2D & A; scattered on finfold posterior to A; 2 ventrally on hypural.
Diagnostic features: Total vertebrae 29–32; P_1 10–12; A 4–5; pigment on P_1 & a bar laterally on body posterior to 2D & A; short, stout body; Sn-A 60% BL; flexion occurs at <6 mm in specimens from California & at >10 mm in British Columbia specimens; ends of P_1 rays lobed by postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				57–61		
			61	59		
BD/BL				19–23		
			16	21		
HL/BL				31–33		
			29	32		
HW/HL				57–65		
			64	61		
SnL/HL				24–28		
			21	26		
ED/HL†				19–21× 20–22		
			25×23	20×21		
P_1L/BL				25–28		
			12	27		
P_2L/BL				6–6		
			2	6		

* Descriptions of pigmentation and morphometrics were taken from CalCOFI specimens, which were similar to the 6.3 mm larva identified as *B. swanii* by Washington et al. (1984b). The larval series identified as *B. swanii* by Marliave (1975) differs in pigment pattern and size at notochord flexion.
† Eye slightly off-round; horizontal axis given first, vertical axis second.

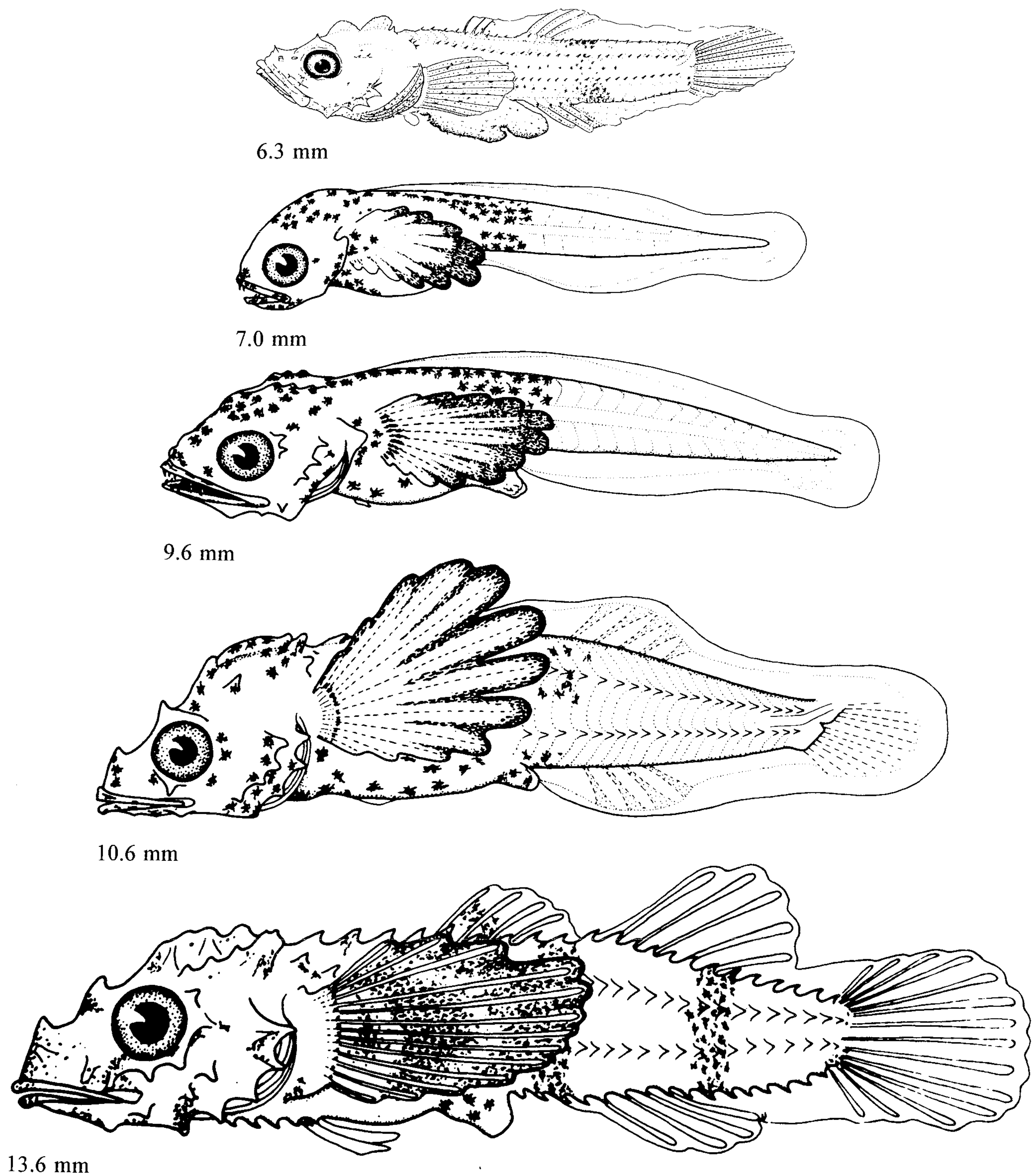


Figure Agonidae 4. Postflexion larva, 6.3 mm (Washington et al. 1984b); preflexion larvae, 7.0 and 9.6 mm; flexion larva, 10.6 mm; postflexion larva, 13.6 mm (Marliave 1975; lengths converted to standard length).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–42	
Precaudal	10–12	
Caudal	27–30	
Fins:		
Dorsal spines	III–VI	
Dorsal rays	5–7	
Anal spines	0	0
Anal rays	5–7	
Pelvic	I,2	I,2
Pectoral	13–15	
Caudal:		
Principal	6+5–6	6+6
Procurrent:		
Upper	3	3
Lower	0	0
Gill rakers:		
Upper	0–1	
Lower	7	7
Branchiostegals	6	6

LIFE HISTORY

Rauge: Southeast Alaska to central Baja California

Habitat: On sandy & rocky bottoms at 9–373 m depth

Spawning season: Preflexion larvae in CalCOFI tows in all seasons, with peak occurrences in January & July

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Busby, in prep.
Busby and Ambrose 1993

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.3 mm
Flexion length: ca. 7.1–11.7 mm
Transformation length: ca. 15 mm, gradual
Fin development sequence: P_1, C, 2D & A, 1D, P_2
Pigmentation: *Preflexion*—On upper & lower jaws, snout, isthmus, opercular & hyoid regions (bearded appearance); on P_1 base; over gut & most of body, except absent from dorsal midline above P_1 & occasionally at notochord tip; usually 5 triangular-shaped patches in dorsal finfold & 3 in anal finfold; caudal finfold nearly covered by semicircular patch that connects with dorsal & anal finfold patches. *Flexion*—Dorsolateral body pigment recedes ventrally. *Postflexion–juvenile*—7 vertical bars on body; first & second bars connected ventrally by a stripe; bars extending onto posterior halves of 1D, 2D & A; rounded patch covering most of C; in juveniles, stripe from snout tip to eye.
Diagnostic features: Total vertebrae 37–42; 1D III–VI; P_1 13–15; A 5–7; dorsal & anal finfold pigment pattern, in particular, the small patch just posterior to the anus, which by postflexion stage forms a stripe connecting the 1st & 2nd lateral body bars ventrally; rounded patch covers most of C; body elongate (BD ca. 11% BL); parietals somewhat pointed; notochord flexion by ca. 7 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–50 48	43–51 47	40–47 44	39–43 40	32–35 33
BD/BL		10–13 12	8–12 11	9–12 11	10–12 11	10–12 11
HL/BL		16–21 18	17–22 20	19–24 21	24–25 25	23–26 24
HW/HL		39–72 49	44–51 47	44–55 48	43–48 45	34–39 37
SnL/HL		17–24 21	22–29 24	24–33 27	25–29 27	21–26 24
ED/HL		26–42 33	23–29 26	21–25 24	19–24 22	22–25 23
P_1L/BL		7–8 7	7–14 12	18–21 19	21–22 21	17–17 17
P_2L/BL		0–0 0	0–4 2	5–8 6	8–9 9	7–9 8

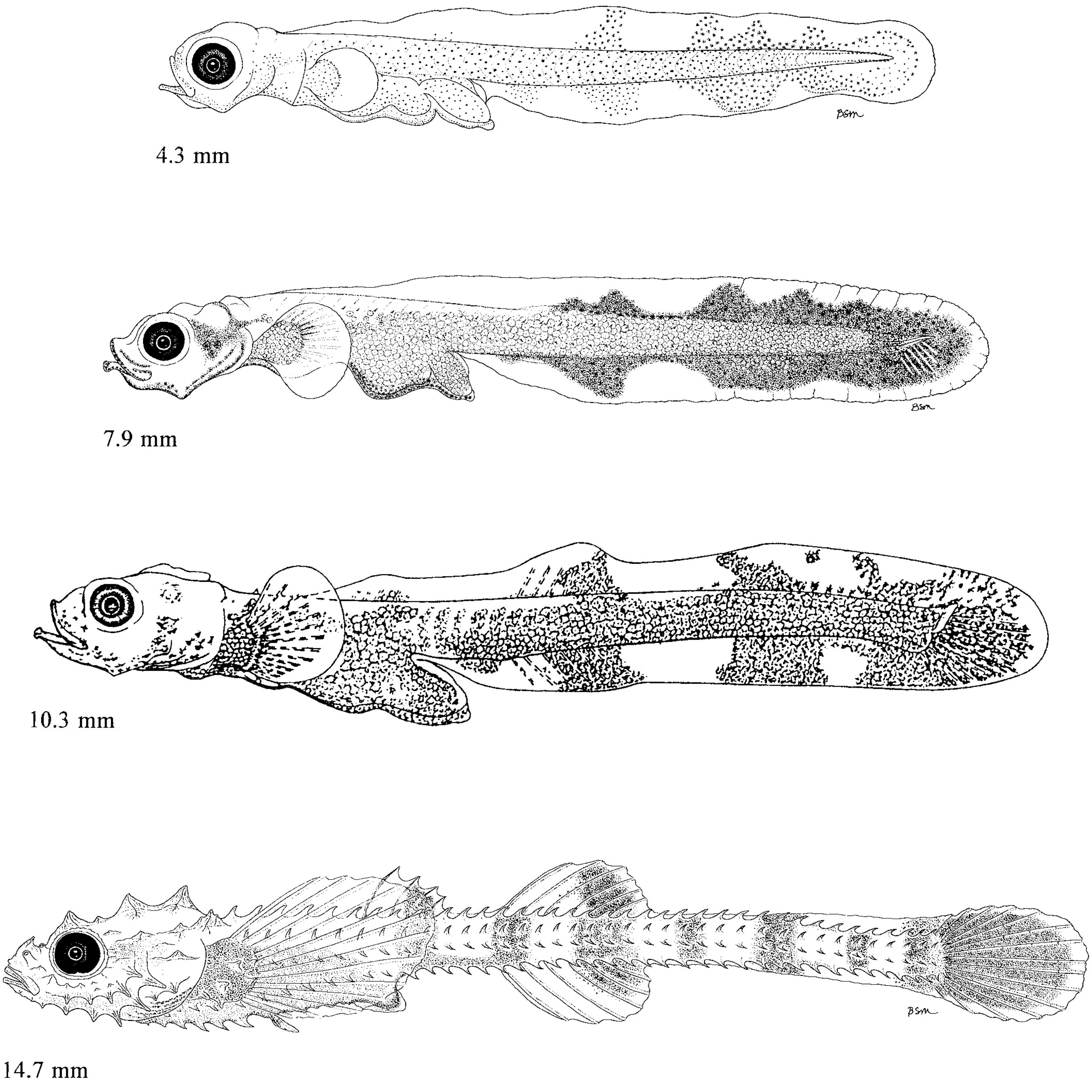


Figure Agonidae 5. Preflexion larva, 4.3 mm; flexion larvae, 7.9 mm, 10.3 mm; postflexion larva, 14.7 mm (Busby and Ambrose 1993).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–43	
Precaudal	11–13	
Caudal	28–30	
Fins:		
Dorsal spines	VI–VIII	
Dorsal rays	6–8	
Anal spines	0	0
Anal rays	6–9	
Pelvic	I,2	I,2
Pectoral	13–15	
Caudal:		
Principal	6+5–6	6+6
Procurrent:		
Upper	2	2
Lower	1	1
Gill rakers:		
Upper	1–2	
Lower	10–16	
Branchiostegals	6	6

LIFE HISTORY

Range: Burrard Inlet, British Columbia to Punta Colnett, Baja California (ca. 31° N)

Habitat: On soft bottom at 18–400 m depth

Spawning season: Preflexion larvae in CalCOFI tows in all seasons with peak occurrence in March

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Busby, in prep.
Busby and Ambrose 1993
Marliave 1975
Matarese et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.9 mm
Flexion length: ca. 8.5–10.8 mm
Transformation length: ca. 15 mm, gradual
Fin development sequence: P_1, 2D & C, 1D & A, P_2
Pigmentation: *Yolk-sac–preflexion*—On upper & lower jaws, hyoid & opercular regions (bearded appearance); on gut & P_1 base; over most of body except near notochord tip until 6 mm; absent from dorsal midline above P_1; large patch with serrated edge on dorsal finfold beginning ca. 33% of distance from anus to notochord tip; by ca. 6 mm, small patch on dorsal finfold above constriction in gut; large patch with rounded edge on anal finfold beginning ca. 25% of distance from anus to notochord tip; dorsal & anal finfold patches constrict toward body at ca. 80% of anus to notochord tip distance. *Flexion*—Receding from finfold, forming 4–5 bars on body. *Postflexion*—Body bars increase to 8; patch on mid 1D, posteriorly on 2D, anteriorly & posteriorly on A & a patch (usually bilobed) proximally on C. *Juvenile*—Extending distally on 1D, 2D & C.
Diagnostic features: Total vertebrae 39–43; P_1 13–15; A 6–9; pigment pattern on dorsal & anal finfolds, in particular, the unpigmented area of the anal finfold just posterior to the anus; a usually bilobed patch extends onto ca. 25% of C; parietals rounded; notochord flexion by >8 mm & <9 mm; 1 barbel at tip of mandible; by juvenile stage, spines present on eye.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	45–50	49–62	55–61	50–58		32–38
	47	53	57	53	47	36
BD/BL	13–15	12–16	12–16	14–16		11–13
	13	13	14	15	15	12
HL/BL	17–19	18–27	22–29	24–29		27–30
	18	21	25	26	27	28
HW/HL	49–57	48–56	51–57	52–66		41–50
	53	52	54	59	52	46
SnL/HL	7–18	17–27	19–25	20–27		21–26
	14	20	23	24	25	23
ED/HL	40–45	28–40	29–32	25–31		26–34
	43	34	30	28	27	31
P_1L/BL	6–7	6–15	10–20	19–26		17–18
	7	8	17	23	23	18
P_2L/BL	0–0	0–0.6	0.2–6	4–12		10–12
	0	0.1	3	8	11	11

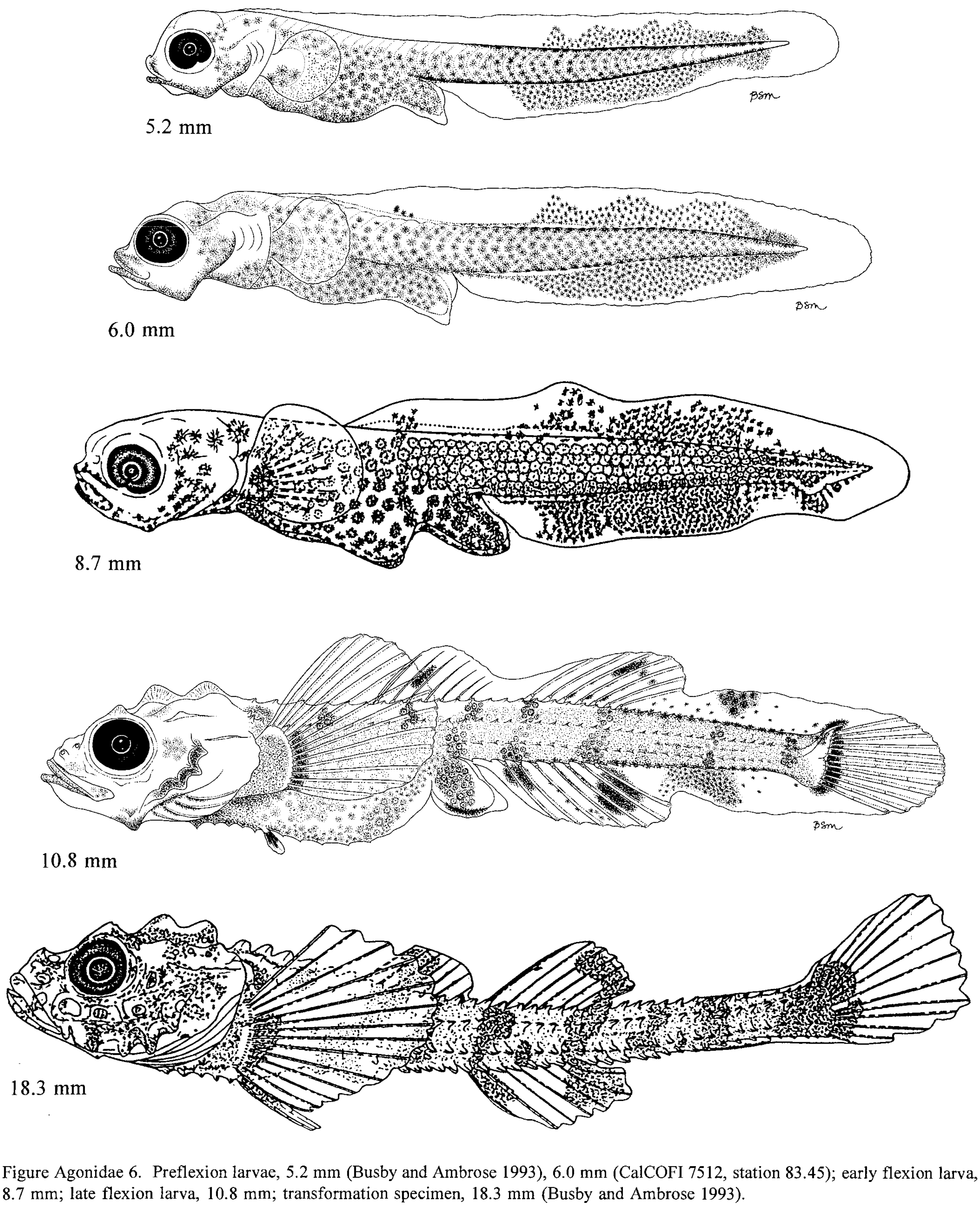


Figure Agonidae 6. Preflexion larvae, 5.2 mm (Busby and Ambrose 1993), 6.0 mm (CalCOFI 7512, station 83.45); early flexion larva, 8.7 mm; late flexion larva, 10.8 mm; transformation specimen, 18.3 mm (Busby and Ambrose 1993).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–45	
Precaudal		
Caudal		
Fins:		
Dorsal spines	VI–VII	
Dorsal rays	6–8	
Anal spines	0	0
Anal rays	5–8	
Pelvic	I,2	I,2
Pectoral	13–15	
Caudal:		
Principal	6+5	6+5
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	1	1
Lower	10	10
Branchiostegals	6	6

LIFE HISTORY

Range: Southern British Columbia to at least Santa Catalina Island (off southern California)

Habitat: Benthic at 37–399 m depth

Spawning season: Larvae occur in CalCOFI collections from February–May

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.5 mm (R. C. Walker)
Flexion larva, 10.8 mm (R. C. Walker)
Transformation specimen, 19.0 mm (R. C. Walker)

* Eye oval until about transformation stage; horizontal axis given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

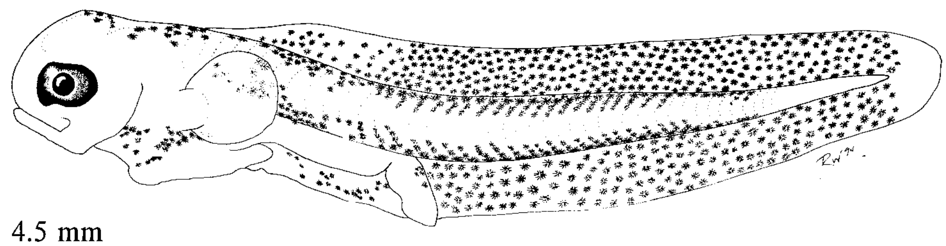
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

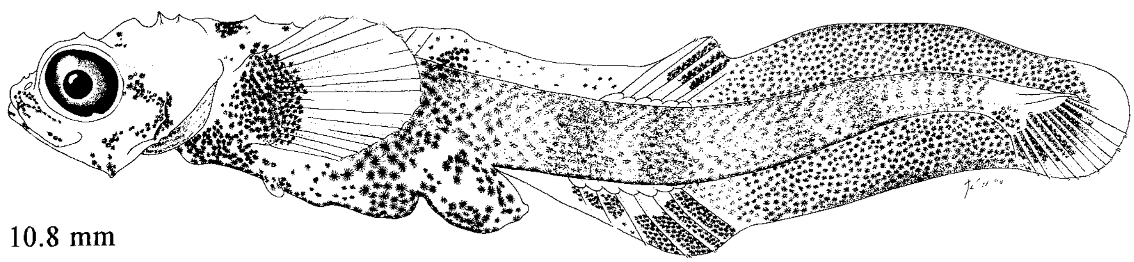
Hatching length: <4.5 mm
Flexion length: >9 mm, <12 mm
Transformation length: ca. 15 mm
Fin development sequence: P_1, C, 2D & A, 1D, P_2
Pigmentation: *Preflexion*—Initially absent dorsally on head & at end of caudal finfold, otherwise completely covered including P_1 base, dorsal & anal finfolds; by ca. 7.5 mm, "bearded" appearance & laterally on mid- & hindbrain. *Flexion*—Patches forming on mid 1D, posteriorly on 2D, anteriorly & posteriorly on A; on P_2; fan-shaped patch extending over proximal half of C; "windows" forming posteriorly on finfolds in caudal peduncle region. *Postflexion–transformation*—8–10 blotches forming laterally on body.
Diagnostic features: Total vertebrae 39–45; P_1 13–15; A 5–8; MDR 17–19; MVR 17–19; pigment completely covering dorsal & anal finfolds; by notochord flexion, fan-shaped patch covers ca. half of C; by postflexion stage, 8–10 blotches laterally on body; parietal pointed; notochord flexion by >9 & <12 mm; by transformation, 1 barbel at tip of mandible & no spines on eye.

MORPHOMETRICS (range & mean in %)

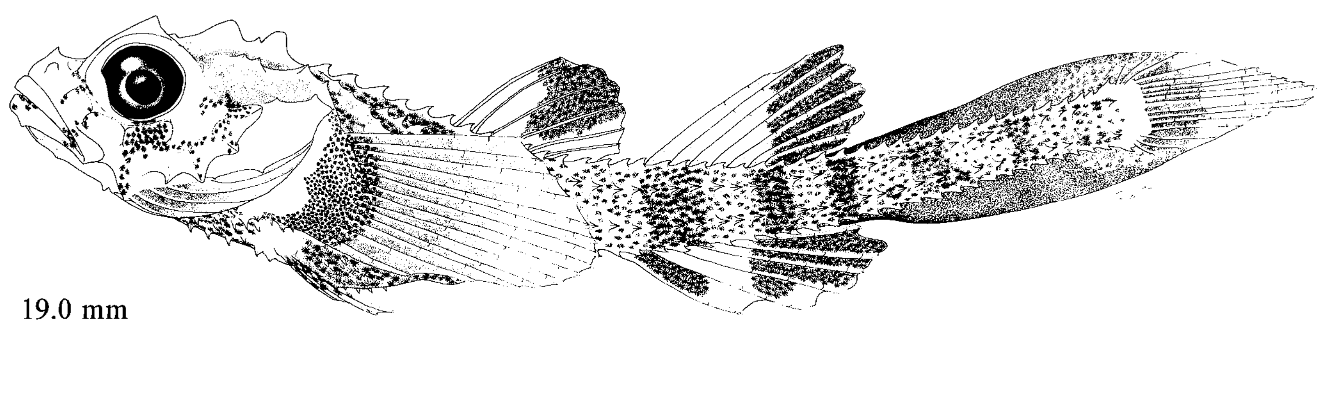
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		44–50 47	49–51 50	47–51 49	42–47 44	
BD/BL		12–19 14	14–16 14	16–16 16	15–17 16	
HL/BL		18–22 20	22–24 23	24–25 24	24–28 26	
HW/HL		47–61 55	57–61 59	64–65 65	54–64 59	
SnL/HL		13–24 18	17–23 21	22–25 24	23–28 25	
ED/HL*		29–38× 21–32 33×27	30–33× 27–30 31×28	33–33× 25–27 33×26	26–31× 25–29 29×28	
P_1L/BL		5–8 7	13–20 17	21–22 22	21–24 22	
P_2L/BL		0–0 0	2–3 3	4–5 4	10–11 11	



4.5 mm



10.8 mm



19.0 mm

Figure Agonidae 7. Preflexion larva, 4.5 mm (CalCOFI 5302, station 83.51); flexion larva, 10.8 mm (CalCOFI 8405, station 80.60); transformation specimen, 19.0 mm (CalCOFI 5403, station 85.45).

CYCLOPTERIDAE: Snailfishes and lumpsuckers

D. A. AMBROSE

Snailfishes and lumpsuckers have been classified variously as separate families (Liparidae and Cyclopteridae) or as cyclopterid subfamilies (Liparinae and Cyclopterinae) (Nelson 1994). We follow Eschmeyer (1990) and include both in the same family. However, since Puget Sound is about the southernmost range of lumpsuckers only snailfishes are included in this identification guide. See Able et al. (1984) and Matarese et al. (1989) for information about lumpsuckers.

There are about 19 snailfish genera with about 195 species distributed predominantly in the North Pacific, North Atlantic and Southern Oceans (Nelson 1994). At least 26 species occur in the CalCOFI area (Table Cyclopteridae 1), but larvae of only *Liparis mucosus* and larvae tentatively identified as *Liparis fucensis* are common in CalCOFI ichthyoplankton samples. Larval *Liparis pulchellus* are rare in CalCOFI samples. Larval *Careproctus melanurus* have not been taken in CalCOFI ichthyoplankton samples but were reared from eggs found inside the peribranchial cavity of a lithodid crab. Young *Nectoliparis pelagicus* have been taken occasionally in deep plankton tows off central California. Young *Paraliparis cephalus*, *Rhinoliparis attenuata*, and *R. barbulifer* have been collected in a plankton net attached to a bottom trawl headrope towed at about 800–1100 m depth off central California.

Most adult snailfishes have elongate, jellylike bodies (most species <15 cm long; one reaches about 61 cm) with a preanal length that is less than half the body length. Pelvic rays (if present) are modified into a ventral sucking disk. Dorsal and anal fins are long and confluent, or nearly so, with the caudal fin. Pectoral fins are often deeply divided by shorter rays at midfin; in these species, the lower lobe may be easily mistaken for the pelvic fin. There are no fin spines and all rays are unbranched. Nostrils are single or double (usually double in *Liparis*). Teeth are usually present and the shape varies from trilobed to simple. There are no scales or plates, but body prickles are present in a few species. Meristic ranges for snailfishes (excluding lumpsuckers) are V 34–86, D 28–82, A 21–76, P_1 12–43, C_1 1–14, BrR 5–6 (Eschmeyer et al. 1983; Able et al. 1984; Stein and Andriashev 1990; Nelson 1994).

Snailfishes are known from the estuarine and intertidal zones to over 7000 m depth. Most species are benthic or epibenthic; a few are pelagic. Taxonomic reviews have been done by Burke (1930), Stein (1978), Able and McAllister (1980), Andriashev (1986), Kido (1988), and Stein et al.(1991). Many undescribed species are known to exist.

Able et al. (1984) summarized the small amount of early life history information available on snailfishes. Eggs are demersal and range in size from ca. 0.8–8.0 mm. Some parental protection of the eggs, either hiding, guarding, or both may be characteristic. For example, male *Liparis fucensis* are known to guard eggs laid in a mussel shell (DeMartini 1978), while eggs and larvae of *Careproctus* spp. have been found in the gill cavities of lithodid crabs (Anderson and Cailliet 1974). Most *Liparis* eggs are <2 mm and larvae of these relatively shallow-living species hatch at an early developmental state. Hatching at an advanced state of development apparently is characteristic for deep-water snailfishes (Andriashev et al. 1977; Stein 1980a).

Snailfish larvae typically have loose flabby skin surrounding the entire body, a bulbous head, and rather large eyes. The preanal length is short and the gut coiled. The gill opening decreases in size with development. Meristic counts, body proportions and pigmentation patterns are useful in differentiating the various snailfish larvae. Pigment in *Liparis* is usually heavy on the inner surface of the pectoral fin base. Reared preflexion larvae of *Liparis fucensis* have a hexagonal pattern of melanin on the pectoral fins, a postanal midventral row of numerous melanophores, a second row of melanophores which develops on the ventral finfold margin, and melanophores on the lower jaw (Marliave 1975; Marliave and Peden 1989). Yolk-sac and early preflexion larvae in our series, tentatively identified as *L. fucensis*, lack the hexagonal pigment pattern on the pectoral fins and the pigment on the margin of ventral finfold described by Marliave and Peden (1989). Also, our specimens have ca. 33

melanophores on the postanal ventral margin compared to ca. 20 in those of Marliave and Peden (1989). Specimens >6 mm in our series are similar in pigmentation and morphology to those of Marliave and Peden (1989). Pectoral fin-ray counts in our specimens >10 mm were 34–38 compared with the published range of 37–43 for *L. fucensis* (Table Cyclopteridae 1). Our specimens were collected as far south as CalCOFI line 107 (north central Baja California), whereas, the southernmost record for adult *L. fucensis* is near San Simeon Pt. in central California (Miller and Lea 1972). *Careproctus* are heavily pigmented at hatching, in contrast to *Rhinoliparis* which is unpigmented until ca. 12.5 mm. The smallest *Paraliparis* examined (12.5 mm) has heavy pigment on the peritoneum. *Liparis* have a double nostril; other snailfishes known from this region have a single nostril opening on each side of the head. In *Liparis* larvae, disk formation occurs during the preflexion stage and nostrils split during the flexion stage. During transformation in *Liparis*, the skin bubble is lost and shrinkage occurs giving the juvenile a slender distinctly liparine appearance. The pelvic disk is absent in *Acantholiparis*, *Lipariscus*, *Nectoliparis*, *Paraliparis*, and *Rhinoliparis*.

The following descriptions of early life history stages of *C. melanurus*, *L. fucensis*, *L. mucosus*, and *L. pulchellus* are based on detailed examination of between 7 and 41 specimens of each species (Table Cyclopteridae 2). Early life history descriptions of *N. pelagicus*, *P. cephalus*, *R. attenuatus*, and *R. barbulifer* are not given; however, a single specimen of each is illustrated in Figure Cyclopteridae 1 and specimens examined in this study are listed in Table Cyclopteridae 2. Larvae described as *L. fucensis* may be those of another species. Meristic data were obtained from counts made during this study and from literature (Gilbert 1915; Townsend and Nichols 1925; Burke 1930; Miller and Lea 1972; Hart 1973; Stein 1978; Kido 1988; Matarese et al. 1989). Ecological information was obtained principally from Stein (1978) and Eschmeyer et al. (1983).

Table Cyclopteridae 1. Meristic characters for the cyclopterid species in the CalCOFI study area. *Lipariscus nanus* and *Nectoliparis pelagicus* have five branchiostegal rays, all other species have six. Abbreviations: AK, Alaska; BCA, Baja California; C, central; CA, California; N, northern; OR, Oregon; S, southern; SE, southeast; WA, Washington.

Species	Distribution	Total Vertebrae	Fin rays D	A	P_1	P_2	C_1	Pyloric caeca
Acantholiparis opercularis	Bering Sea to CA	50	42–52	38–47	20–24	Absent	8	Absent
Careproctus gilberti	Bering Sea to C CA		45–55	41–48	30–33	Disk	8–9	10–12
C. longifilis	OR to Panama	55–58	50–54	44–48	17–23	Disk	8–9	10–13
C. melanurus	Bering Sea to S CA	57–63	53–58	47–51	27–33	Disk	9–11	20–31
C. microstomus	OR to C CA	67–69	61–67	54–60	22–27	Disk	8	5–7
C. osborni	C CA (35°N)		44	39		Disk		
Elassodiscus caudatus	SE AK to C CA	55–62	49–55	41–50	27–29	Disk	9	14
Liparis florae	Bering Sea to S CA	34–40	30–35	21–27	29–33	Disk	11	
L. fucensis	SE AK to S CA	38–43	33–35	27–29	37–43	Disk	13	26?–55
L. fucensis—southern	N CA to N BCA	39–41	30–35	26–28	34–38	Disk	12	
L. mucosus	SE AK to C BCA	36–38	28–32	22–25	27–32	Disk	11	48?–70
L. pulchellus	Bering Sea to C CA	51–55	47–53	39–42	36–37	Disk	10	25–35
L. rutteri	Bering Sea to C CA	34–38	30–32	23–27	30–33	Disk	13	23–31
Lipariscus nanus[a]	SE AK to C CA	60–62	40–56	37–52	12–15	Absent	4	4–8
Nectoliparis pelagicus	Bering Sea to C CA	61–66	44–58	40–53	19–25	Absent	4–6	6–9

Table Cyclopteridae 1. Continued.

Species	Distribution	Total Vertebrae	Fin rays D	A	P_1	P_2	C_1	Pyloric caeca
Paraliparis albescens	C CA		49	44	18	Absent	4	
P. cephalus	Bering Sea to S CA	57–63	50–57	44–51	14–16	Absent	4–5	6–10
P. dactylosus	Bering Sea to C CA	59–61	54–56	49–51	26–30	Absent	8	17–23
P. deani	SE AK to N CA	56–57	56–59	44–49	18–22	Absent	6	9
P. latifrons	OR to Panama	61	54–57	48–50	21–24	Absent	5–6	Small
P. megalopus	OR to C CA	76	66–71	63–65	16–19	Absent	4	6–8
P. mento	WA to C CA	61	55–59	49–51	16–18	Absent	5	6–8
P. pectoralis	Bering Sea to C CA	63–64	55–58	49–52	28–32	Absent	7–8	9–10
P. rosaceus	Bering Sea to Gulf of CA	67–74	57–69	53–60	18–22	Absent	6–8	6–9
P. ulochir	Bering Sea to Gulf of CA	72–74	65–69	60–64	21–24	Absent	4	8
Rhinoliparis attenuatus	Bering Sea to C CA	80–83	68–78	60–73	21–25	Absent	2	9–10
R. barbulifer[a]	Bering Sea to S CA	68	63–68	57–59	18–21	Absent	3	7–9

[a] Placed in the genus *Paraliparis* by Kido (1988).

Table Cyclopteridae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the cyclopterid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Careproctus melanurus	3 3.3–3.7	1 8.5	0	0	3 9.6–11.2	0	0
Liparis fucensis(?)	0	5 2.8–3.1	10 3.2–7.3	6 7.3–9.7	10 10.0–17.4	2 19.7–22.8	3 24.5–43.6
L. mucosus	0	4 2.2–2.7	10 3.2–5.9	6 5.9–8.3	13 8.8–10.2	5 10.5–15.3	3 31.5–50.0
L. pulchellus	0	0	4 3.4–4.8	1 15.0	1 22.0	0	1 53.0
Nectoliparis pelagicus	0	0	L[a]	0	L[a], 1 18.0	0	L[b], 5 26.5–42.0
Paraliparis cephalus	0	0	0	0	1 12.5	0	2 25.0–41.0
Rhinoliparis attenuatus	0	1 ca. 11.5	0	0	2 14.7–15.8	0	1 40.0
R. barbulifer	0	L[c]	0	0	L[c], 2 15.5–18.0	0	L[c]

[a] Matarese et al. 1989
[b] Gilbert and Burke 1912
[c] Kido and Kitagawa 1986

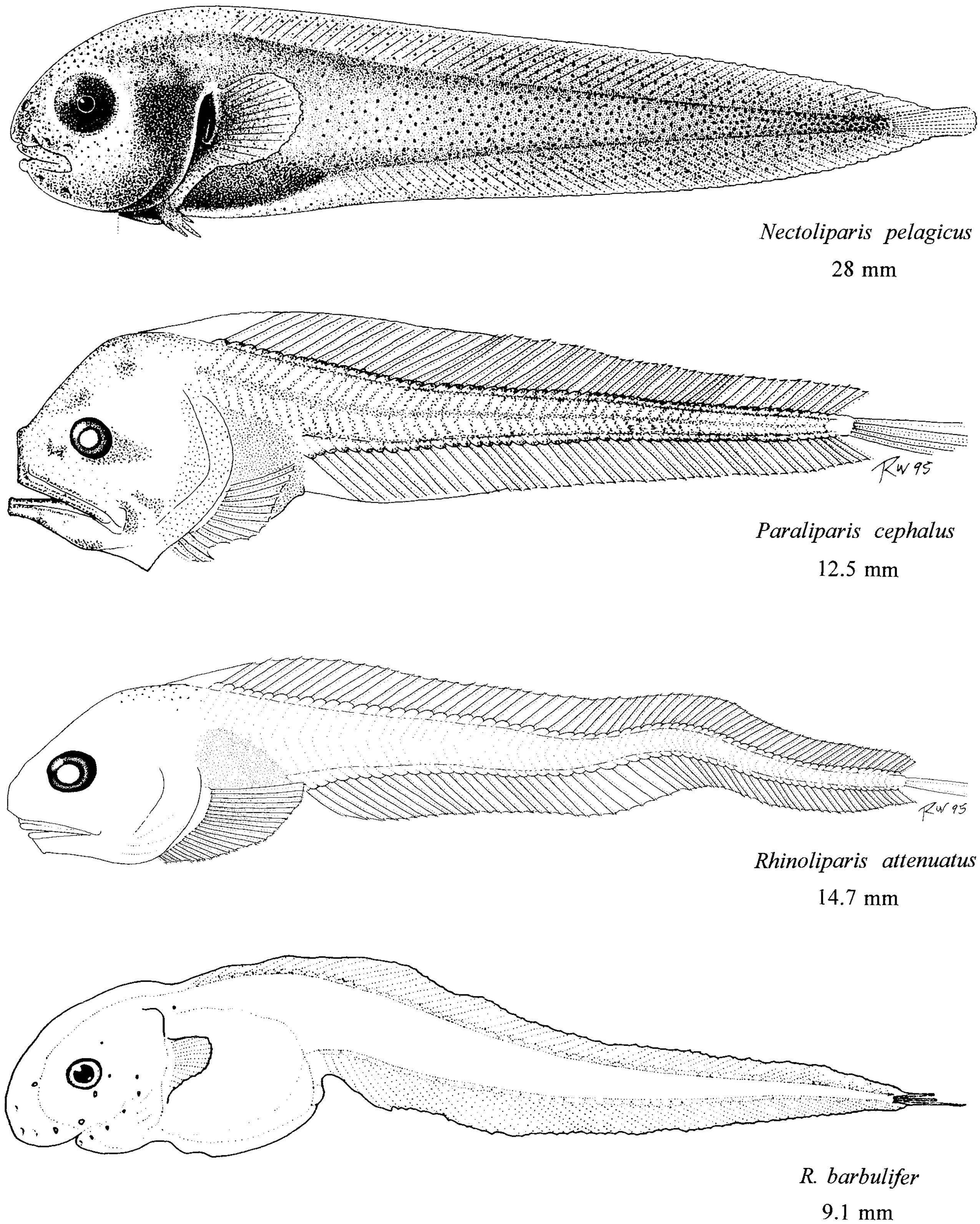


Figure Cyclopteridae 1. *Nectoliparis pelagicus* juvenile, 28 mm (Gilbert and Burke 1912); *Paraliparis cephalus* postflexion larva, 12.5 mm (CFRD 8701, station 74.6.57.9); *Rhinoliparis attenuatus* postflexion larva, 14.7 mm (CFRD 8701, station 61.6.57.2); *R. barbulifer* yolk-sac larva, 9.1 mm (Kido and Kitagawa 1986). Original illustrations of *P. cephalus* and *R. attenuatus* by R. C. Walker.

MERISTICS

	Range	Mode
Vertebrae:		
Total	57–63	60
Precaudal		
Candal		
Fins:		
Dorsal spines		
Dorsal rays	53–58	56
Anal spines		
Anal rays	47–51	51
Pelvic		
Pectoral	27–33	31
Caudal:		
Principal	4–5+5–6	5+5
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Bering Sea to San Diego, California

Habitat: 91–1600 m depth on mud bottom

Spawning season:

ELH pattern: Oviparous, eggs incubate in lithoid crab peribranchial chamber

LITERATURE

Parrish 1972

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 8.5 mm (R. C. Walker)

* Embryo completes notochord flexion while still in the egg.

EARLY LIFE HISTORY DESCRIPTION

EGGS

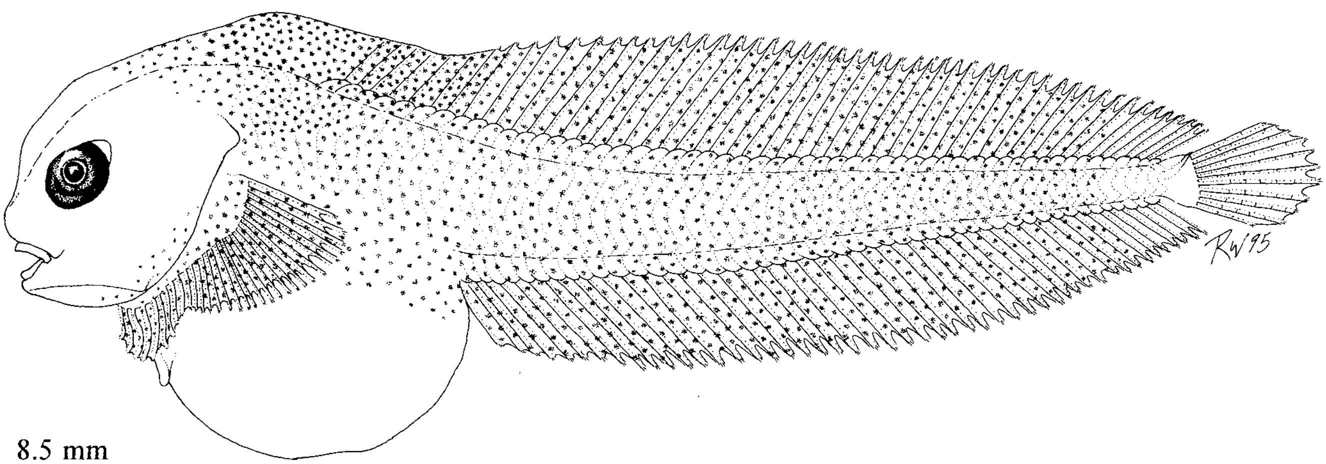
Shell diam.: 3.3–3.7 mm (with late-stage embryo)
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 8.5 mm
Flexion length:
Transformation length:
Fin development sequence:
Pigmentation: *Yolk-sac–postflexion*—"Bearded" appearance, fine specks cover skin bubble, body, & fins; sparse on C, anteriorly on head, & ventrally on gut.
Diagnostic features: Total vertebrae 57–63; D 53–58; A 47–51; P_1 27–33; P_2 disk <35% HL; C_1 9–11; single nostril.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF*	Tr	Juv
Sn-A/BL	38			36–40 37		
BD/BL	24			21–25 23		
HL/BL	21			24–27 26		
HW/HL	84			69–79 73		
SnL/HL	21			21–31 25		
ED/HL	25			21–25 23		
P_1L/BL	10			9–13 11		
P_2DL/BL	27			30–34 32		



8.5 mm

Figure Cyclopteridae 2. Yolk-sac larva, 8.5 mm (SIO 74–171).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–41	39
Precaudal	9–11	10
Caudal	28–30	29
Fins:		
Dorsal spines	0	0
Dorsal rays	30–35	
Anal spines	0	0
Anal rays	26–28	
Pelvic	disk	disk
Pectoral	34–38	
Caudal:		
Principal	6+7	6+7
Procurrent:		
Upper	3–4	3
Lower	3–4	4
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Aleutian Islands to central California (near San Simeon Pt.); larvae collected from CalCOFI lines 40 to 107, most commonly from central California (lines 60–70)

Habitat: Intertidal to 388 m depth

Spawning season: Preflexion larvae collected mainly January through August with a June peak

ELH pattern: Oviparous, adhesive eggs guarded by male; planktonic larvae

LITERATURE

DeMartini 1978
Marliave and Peden 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.8 mm (R. C. Walker)
Flexion larva, 7.3 mm (R. C. Walker)
Postflexion larva, 15.2 mm (R. C. Walker)

* Tentatively identified as *L. fucensis*.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: ca. 0.98 mm **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 7.3–9.7 mm
Transformation length: ca. 20 – >23 mm
Fin development sequence: P_1, D, A, P_2 disk, C
Pigmentation: *Yolk-sac*—P_1 blade covered; heavy on inner P_1 base; on gular & opercular regions, "bearded appearance"; on gut; 2 dorsally on air bladder; patch dorsolaterally on body above gut; ca. 33 along postanal ventral midline of tail; 2 on caudal finfold; occasionally a few (minute) laterally on tail. *Preflexion*—"Bearded" appearance increases; postanal ventral midline series decreases to ca. 14; by ca. 6 mm, some along A finfold margin. *Flexion*—Internally on top of head; scattered over skin envelope on trunk region; heavy internally in trunk region. *Postflexion*—Patch anterior to eye; dorsally, ventrally, & midlaterally on tail forming a bar; on D & A. *Transformation*—Patch posterior to eye.
Diagnostic features: Total vertebrae 39–41; D 30–35; A 26–28; P_1 34–38; P_2 disk <12% HL by postflexion stage; C_1 13; nostrils double; large head; robust body; very loose skin bubble; pigment pattern.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	36–39 37	38–48 44	48–52 50	47–55 51	45–47 46	42–48 45
BD/BL	27–32 30	27–36 32	33–37 35	31–39 36	31–36 34	21–25 23
HL/BL	20–22 21	21–33 27	28–37 31	28–37 32	30–31 30	29–33 31
HW/HL	75–95 84	76–100 88	70–97 82	81–100 81	81–89 85	53–63 58
SnL/HL	17–21 19	17–23 20	15–20 19	18–25 22	27–29 28	25–31 27
ED/HL	44–50 47	30–46 36	27–35 30	27–32 30	26–31 28	17–26 20
P_1L/BL	6–8 7	5–14 12	11–15 13	13–18 16	14–16 15	18–19 19
P_2DL/BL	0–0 0	0–4 1	5–8 6	6–11 9	10–11 11	13–13 13

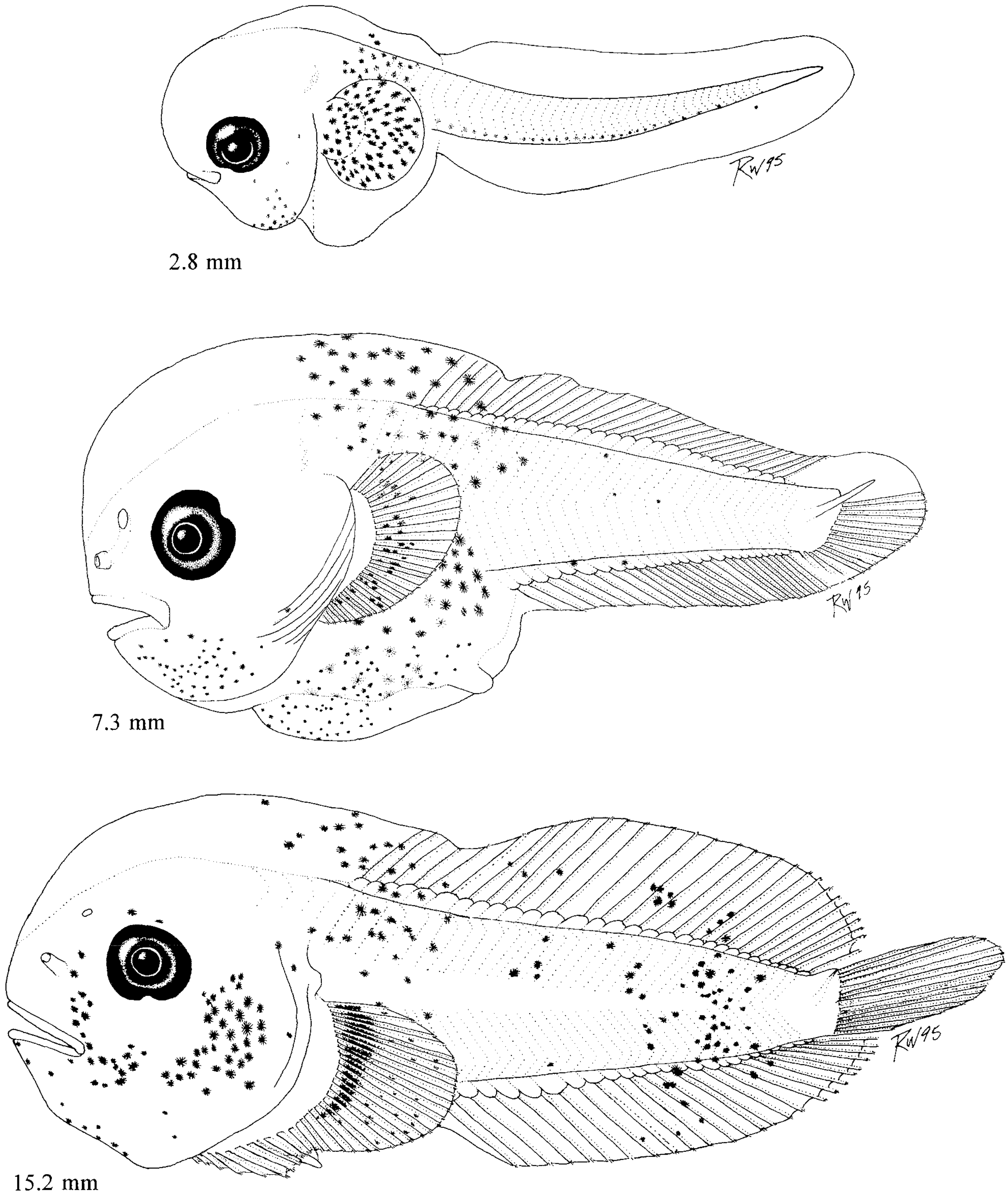


Figure Cyclopteridae 3. Yolk-sac larva, 2.8 mm (CalCOFI 7801, station 63.52); flexion larva, 7.3 mm (CalCOFI 8102, station 60.80); postflexion larva, 15.2 mm (CFRD 9107, station 69.7.77.9).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	36
Precaudal	10	10
Caudal	26	26
Fins:		
Dorsal spines		
Dorsal rays	28–32	30
Anal spines		
Anal rays	22–25	24
Pelvic	disk	disk
Pectoral	27–32	30
Caudal:		
Principal	5+6	5+6
Procurrent:		
Upper	4–5	4
Lower	3–3	3
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Southeast Alaska to central Baja California

Habitat: Intertidal to 15 m depth; usually not in tidepools

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.2 mm (R. C. Walker)
Flexion larva, 7.0 mm (R. C. Walker)
Postflexion larva, 9.2 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.2 mm
Flexion length: ca. 5.9–8.5 mm
Transformation length: ca. 10.5– <31.5 mm, gradual
Fin development sequence: P_1, C_1, D_1, A, D_2, P_2 disk
Pigmentation: *Yolk-sac*—On eyes; heavy on P_1 blade & inner base; dorsolaterally on gut; scattered over anterior half of tail; scattered on anal finfold; row along postanal ventral midline extending almost to tail tip; 3 on caudal finfold. *Preflexion–flexion*—On gular region; on lower jaw spreading to upper jaw; ventrally on gut; spreading posteriad over tail; along base of C. *Postflexion*—Fading on P_1, A, & tail. *Transformation*—Uniformly scattered over tail & dorsolaterally on head; absent on P_1, gut, & ventrolaterally on head. *Juvenile*—Varies from uniform, to stripes, to reticulate patterns.
Diagnostic features: Total vertebrae 36; D 28–32; A 22–25; P_1 27–32; P_2 disk >35% HL by postflexion stage; C_1 11; nostrils double; pigmentation pattern.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	41–47 44	41–48 45	45–55 49	50–55 47	49–52 50	37–40 39
BD/BL	23–26 25	25–33 28	27–32 29	27–32 29	25–29 26	21–22 22
HL/BL	20–24 22	20–28 23	22–32 26	27–33 29	31–33 33	25–27 26
HW/HL	82–89 85	73–89 79	66–85 74	67–82 75	56–60 58	58–65 61
SnL/HL	18–29 24	20–32 26	24–28 26	25–32 28	28–30 29	25–31 27
ED/HL	44–48 46	30–45 36	21–31 27	20–23 21	17–20 18	16–20 18
P_1L/BL	7–9 8	6–9 8	9–14 12	12–16 14	15–16 15	15–18 17
P_2DL/BL	0–0 0	0–26 14	24–38 31	37–43 40	42–47 45	53–55 54

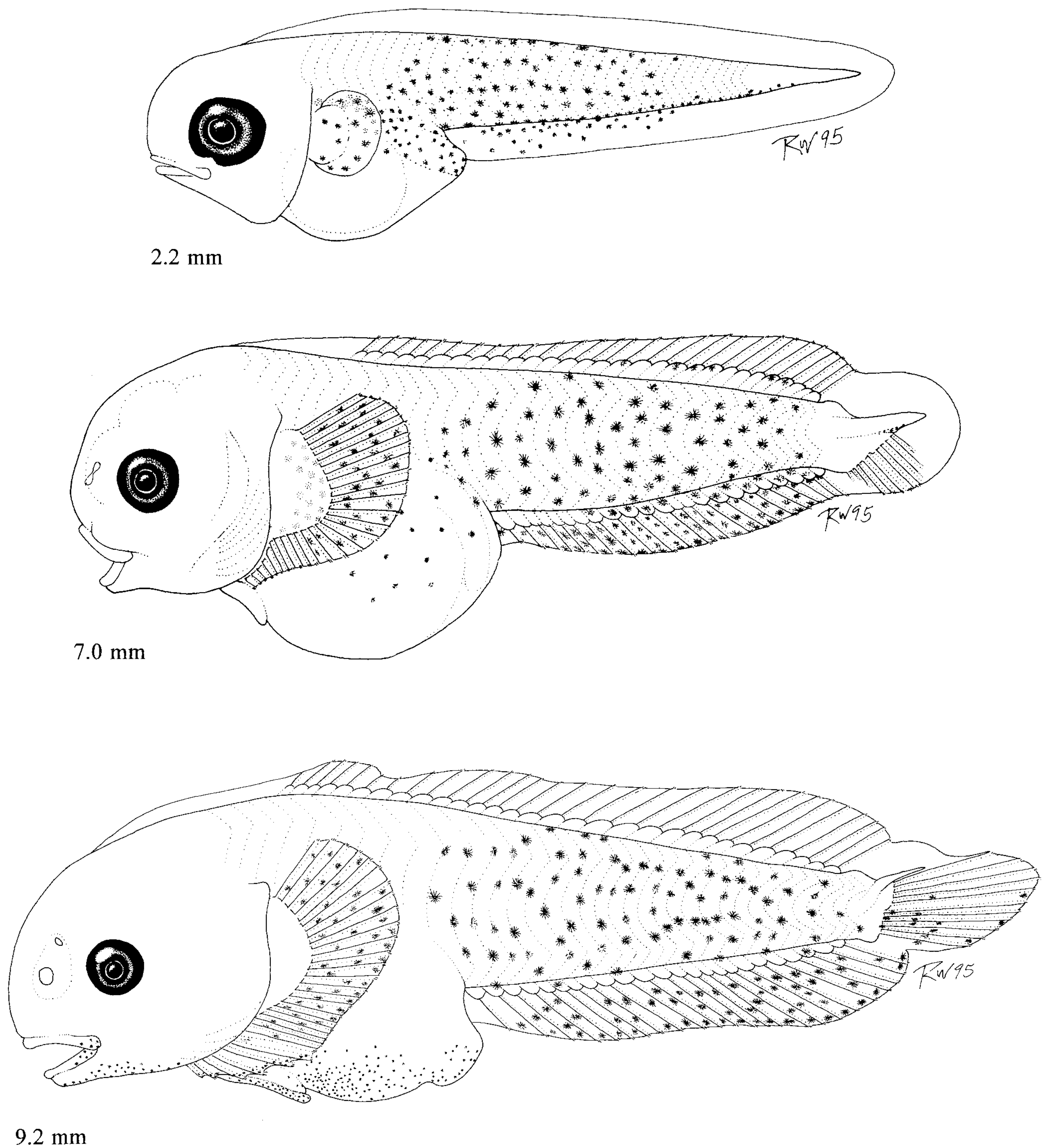


Figure Cyclopteridae 4. Yolk-sac larva, 2.2 mm (CalCOFI 6904, station 110.32); flexion larva, 7.0 mm (CalCOFI 6104, station 110.33); postflexion larva, 9.2 mm (CalCOFI 7203, station 103.30).

MERISTICS

	Range	Mode
Vertebrae:		
Total	51–55	52
Precaudal	11–12	12
Caudal	40–42	40
Fins:		
Dorsal spines	0	0
Dorsal rays	47–53	
Anal spines	0	0
Anal rays	39–42	
Pelvic	disk	disk
Pectoral	36–37	
Caudal:		
Principal	5+5	
Procurrent:		
Upper	2	
Lower	2	
Gill rakers:		
Upper	0	
Lower	6–9	
Branchiostegals	6	6

LIFE HISTORY

Range: Bering Sea to Monterey Bay, California

Habitat: 9–183 m depth on soft bottom

Spawning season: Preflexion larvae occur in CalCOFI collections in January–May; gravid females collected in northern California from December to July

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Johnson 1969

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.8 mm (R. C. Walker)
Postflexion larva, 22.0 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

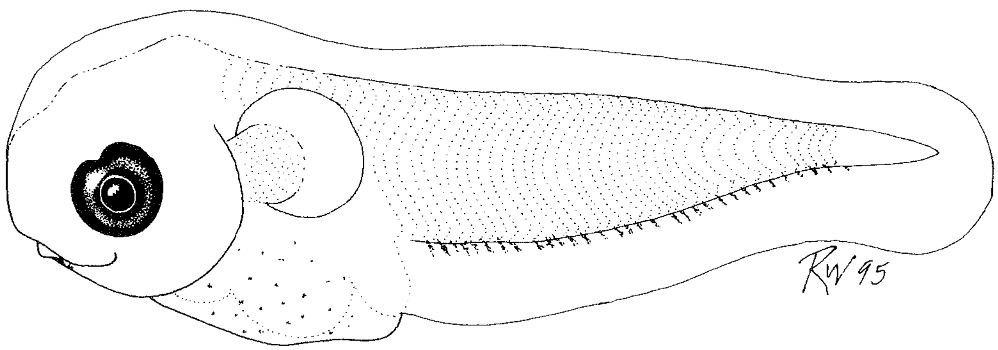
Shell diam.: Ovarian, $\bar{x}$ = 0.95 mm, maximum 1.48 mm
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

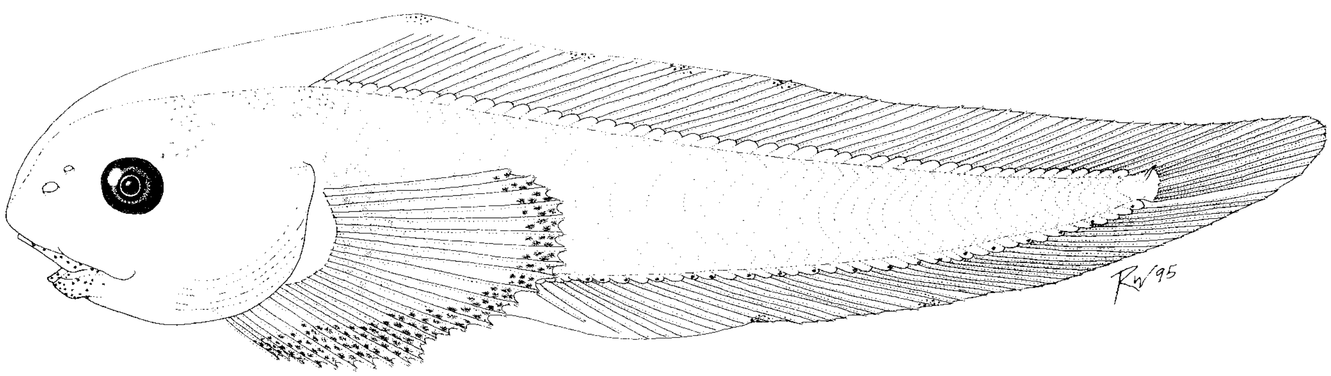
Hatching length: <3.4 mm
Flexion length: >5 mm, <22 mm
Transformation length: >22 mm, <53 mm
Fin development sequence:
Pigmentation: *Preflexion*—On inner P_1 base; row of >30 along postanal ventral midline extending onto A; fine specks appear gradually in gular region & ventrally on gut. *Flexion*—Scattered on brain; scattered on gut; closer together posteriorly on gut, heavy around anus. *Postflexion*—On lower jaw; on trailing edge of P_1; dorsally on body above gut; patch dorsally on skin bubble & in trunk region; 3 patches each on the skin bubble at the margins of D & A; series midlaterally on tail. *Juvenile*—Variable (usually with wavy lines, sometimes spotted, or plain colored); D & A darker at edge.
Diagnostic features: Total vertebrae 51–55; D 47–53; A 39–42; P_1 36–37; P_2 disk ≥40% HL by postflexion stage; C_1 10; nostrils double; pigment pattern.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		37–43 40	37	39		38
BD/BL		24–27 26	20	21		16
HL/BL		20–22 21	26	26		21
HW/HL		71–83 79	75	69		65
SnL/HL		22–29 26	21	28		25
ED/HL		38–50 45	24	20		21
P_1L/BL		6–10 8	23	22		19
P_2DL/BL		0–20 5	27	40		44



4.8 mm



22.0 mm

Figure Cyclopteridae 5. Preflexion larva, 4.8 mm (CalCOFI 7505, station 77.48); postflexion larva, 22.0 mm (CalCOFI 6806, station 60.52).

PERCIFORMES

W. WATSON

Perciforms range from the smallest to among the largest of fishes and occupy all depths of fresh and marine waters throughout the world. The perciforms are predominantly marine shorefishes; they constitute the dominant component of the marine fish fauna in many tropical areas. Perciforms include some of the most valuable commercial species and most highly prized sport species, as well as numerous species that are of great importance in smaller scale commercial, subsistence, and sport fisheries.

This largest and most diverse order of fishes contains more than 9000 species in 148 families and 18 suborders (Nelson 1994). Characters shared among most of these fishes include the presence of spines in the dorsal and anal fins, the lack of an adipose fin, pelvic fins with one spine and five or fewer soft rays, 17 or fewer principal caudal rays supported by the parhypural and five or fewer hypural bones, seven or fewer branchiostegal rays, and four gill arches. However, there are no shared specialized characters that unite the perciform fishes and it is generally accepted that the order is polyphyletic (e.g., Greenwood et al. 1966; Johnson 1993; Nelson 1994). Although the composition and limits of the component families and suborders are gradually being worked out, interrelationships among the suborders remain poorly known and the status of the order is far from resolution. In this volume we follow, with few exceptions, Eschmeyer's (1990) classification, which differs little from most other present classifications.

Suborders and families included:

- Percoidei
  - Polyprionidae
  - Serranidae
  - Priacanthidae
  - Apogonidae
  - Echeneidae
  - Carangidae
  - Nematistiidae
  - Coryphaenidae
  - Bramidae
  - Caristiidae
  - Lutjanidae
  - Malacanthidae
  - Lobotidae
  - Gerreidae
  - Haemulidae
  - Sparidae
  - Sciaenidae
  - Mullidae
  - Kyphosidae
  - Ephippidae
  - Chaetodontidae
  - Pomacentridae
  - Cirrhitidae
  - Opistognathidae
  - Howellidae
- Mugiloidei
  - Mugilidae
- Polynemoidei
  - Polynemidae
- Labroidei
  - Labridae
  - Scaridae
- Zoarcoidei
  - Bathymasteridae
  - Stichaeidae
  - Pholidae
  - Anarhichadidae
- Trachinoidei
  - Chiasmodontidae
  - Ammodytidae
  - Uranoscopidae
- Blennioidei
  - Tripterygiidae
  - Labrisomidae
  - Clinidae
  - Chaenopsidae
  - Dactyloscopidae
  - Blenniidae
- Icosteoidei
  - Icosteidae
- Callionymoidei
  - Callionymidae
- Gobioidei
  - Eleotridae
  - Gobiidae
  - Microdesmidae
- Sphyraenoidei
  - Spyraenidae
- Scombroidei
  - Gempylidae
  - Scombridae
  - Trichiuridae
- Stromateoidei
  - Centrolophidae
  - Nomeidae
  - Tetragonuridae
  - Stromateidae

POLYPRIONIDAE: Giant sea basses and wreckfishes

M. A. SHANE[1], W. WATSON, AND H. G. MOSER

The giant sea bass, *Stereolepis gigas*, ranges from northern California to Oaxaca, Mexico, including the Gulf of California, and is found in the coastal waters of northern Japan and the Sea of Japan. Until recently, it's relationships have been confused and it has been placed variously in the Serranidae (Jordan and Evermann 1896; Miller and Lea 1972), Percichthyidae (Hubbs et al. 1979; Eschmeyer et al. 1983; Mochizuki 1984), Acropomatidae (Nelson 1994), and Moronidae (Heemstra 1995a). Roberts (1986) suggested that it belongs in the Polyprionidae and some recent classifications (Eschmeyer 1990; Roberts 1993) have placed it there. This is supported by the similarity of *S. gigas* larvae and pelagic juveniles to those of *Polyprion* as shown by this study. Eggs and larvae of *S. gigas* have not been identified in CalCOFI samples although small juveniles are often captured in shallow water habitats (Fitch and Lavenberg 1971; Mochizuki 1984; Nelson 1994).

Polyprionids grow to more than 2 m in length and more than 250 kg. They have deep compressed bodies and a massive head with large jaws that bear bands of villiform teeth; the snout is blunt in *Stereolepis*. In *Stereolepis* the head and body are covered with small ctenoid scales and the head lacks armature except for an inconspicuous opercular spine. Fins are well developed, particularly in juveniles; the strong spinous dorsal rays equal (wreckfishes) or exceed (giant sea basses) the soft rays in number. The caudal fin is rounded in juveniles and truncate in adults. Adult giant sea bass prefer rocky bottom habitat ranging from the edge of kelp forests to about midshelf. They are primarily piscivorous. *Stereolepis gigas* is a desirable recreational and commercial species and is prized by sport divers. Commercial landings in California peaked at 391 mt in 1934 with most of the fish caught off Baja California. Sport and commercial catches have declined drastically in recent years; in California, the commercial catch is severely limited and no recreational catch is permitted (Fitch and Lavenberg 1971; Crooke 1992).

Polyprionids are oviparous and have planktonic eggs and larvae. Eggs are large (1.5–1.6 mm) and have homogeneous yolk and multiple oil globules that coalesce with development. Larvae are heavily pigmented with both black and yellow chromatophores. Early juveniles are disc-shaped, have large fins, and are distinctively pigmented (Fitch and Lavenberg 1971; Hardy 1978b; this study). Juvenile *S. gigas* go through several pigmentation phases. First, white blotches develop on the head, dorsum, abdominal region, and at the caudal fin base; the margin of the soft dorsal fin is white. Between 20 and 50 mm, they become orange to brick red with about six irregular rows of black spots on the body and head. At about 150 mm they become dusky with pale mottling; some of the black spots remain (this study). Juvenile *S. doederleini* have pale discontinuous stripes over a black background (Mochizuki 1984). Early juvenile wreckfish initially develop pale mottling, then develop a yellow background coloration with dark elongate spots (Heemstra 1986b).

The eggs, larvae and most of the juvenile *S. gigas* described here came from rearing experiments at Hubbs-Sea World Research Institute during June to October, 1993[2]. Some field-caught juveniles were obtained from S. H. Kramer (Kramer 1990). The descriptions are based on detailed examination of 40 eggs, 23 larvae (3.0–12.4 mm, yolk-sac through postflexion), and 4 juveniles (18.8–54.7 mm). Meristic and ecological information were obtained from Fitch and Lavenberg (1971), Miller and Lea (1972), Crooke (1992), and observations made during this study.

[1] Hubbs-Sea World Research Institute, 2595 Ingraham St., San Diego, California, 92109.

[2] We gratefully acknowledge the following: Donald Kent (Hubbs-Sea World Research Institute) and Richard Ford (San Diego State University), Principal Investigators of the Ocean Resources Enhancement and Hatchery Program (ORHEP), provided the specimens; California Department of Fish and Game, ORHEP administrator, provided the opportunity to experiment with this species; the Stephen Birch Aquarium and Museum (SIO) donated the breeding pair of giant sea bass to ORHEP.

MERISTICS

	Range	Mode
Vertebrae:		
Total	25–26	26
Precaudal	11–12	12
Caudal	14–15	14
Fins:		
Dorsal spines	XI+I–II	XI+I
Dorsal rays	9–10	10
Anal spines	III	III
Anal rays	8–9	8–9
Pelvic	I,5	I,
Pectoral	18–19	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	8–9
Lower	8	8
Gill rakers:		
Upper	2	2
Lower	7–8	
Branchiostegals	7	7

LIFE HISTORY

Range: Humboldt Bay, California, to Oaxaca, Mexico, including Isla de Guadalupe & Gulf of California; northern Japan & Sea of Japan

Habitat: Young in kelp forests & over sandy bottom near shore, older specimens over rocky bottom at ca. 30–50 m depth

Spawning season: Summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.6 mm in diameter (R. C. Walker)
Yolk-sac larva, 4,1 mm (R. C. Walker)
Preflexion larva, 4.2 mm (R. C. Walker)
Preflexion larva, 5.7 mm (N. Arthur)
Transformation specimen, 12.4 mm (R. C. Walker)
Juvenile, 18.8 mm (N. Arthur)

* Snout deformed.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.5–1.6 mm **Yolk:** Homogeneous
No. of OG: 1–9, coalescing to 1 **Diam. of OG:** 0.06–0.27 mm, coalescing to 1: 0.23–0.35 mm
Shell surface: Smooth
Pigment: Melanophores & xanthophores laterally & on dorsum of embryo except none on notochord tip; pigment on OG in later stages.
Diagnostic features: Diameter of chorion & oil globule(s)

LARVAE

Hatching length: 3.0–4.2 mm
Flexion length: >5.7 mm, <12.4 mm
Transformation length: ≥12.4 mm, <18.8 mm
Fin development sequence:
Pigmentation: *Yolk-sac & preflexion*—Heavy on head, trunk, & tail except little or none on last 3–4 myomeres; denser ventrolaterally with broad bar forming near midbody in preflexion stage; 2–4 on dorsal margin of notochord tip, disappearing by end of yolk-sac stage; few on yolk sac & OG; gut with few at terminus early in yolk-sac stage, becoming completely pigmented by end of stage; on P_1 base in preflexion stage; internally in roof of mouth & under brain, becoming dense stripe in preflexion stage. *Transformation & juvenile*—Body & fins completely pigmented except none on P_1 rays & only narrow band proximally on C; early juvenile orange to red with scattered black spots; P_2 & 1D intensely black.
Diagnostic features: Heavily pigmented except end of tail; myomeres 11–12+13–14 (usually 12+14); transformation specimens & juvenile deep-bodied with very large, black P_2; juveniles spotted.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	52–59	55–60				65–71
	56	57			67	68
BD/BL	6–13	21–23				46–48
	8	22			46	46
HL/BL	12–19	21–35				35–39
	15	27			47	37
HW/HL	55–106	69–109				59–82
	79	90			69	70
SnL/HL	10–22	21–27				24–28
	18	24			2*	25
ED/HL	43–66	38–44				25–38
	53	42			32	30
P_1L/BL	0–3					21–22
	1	6			22	21
P_2L/BL	0–0	0–0				31–43
	0	0			41	38

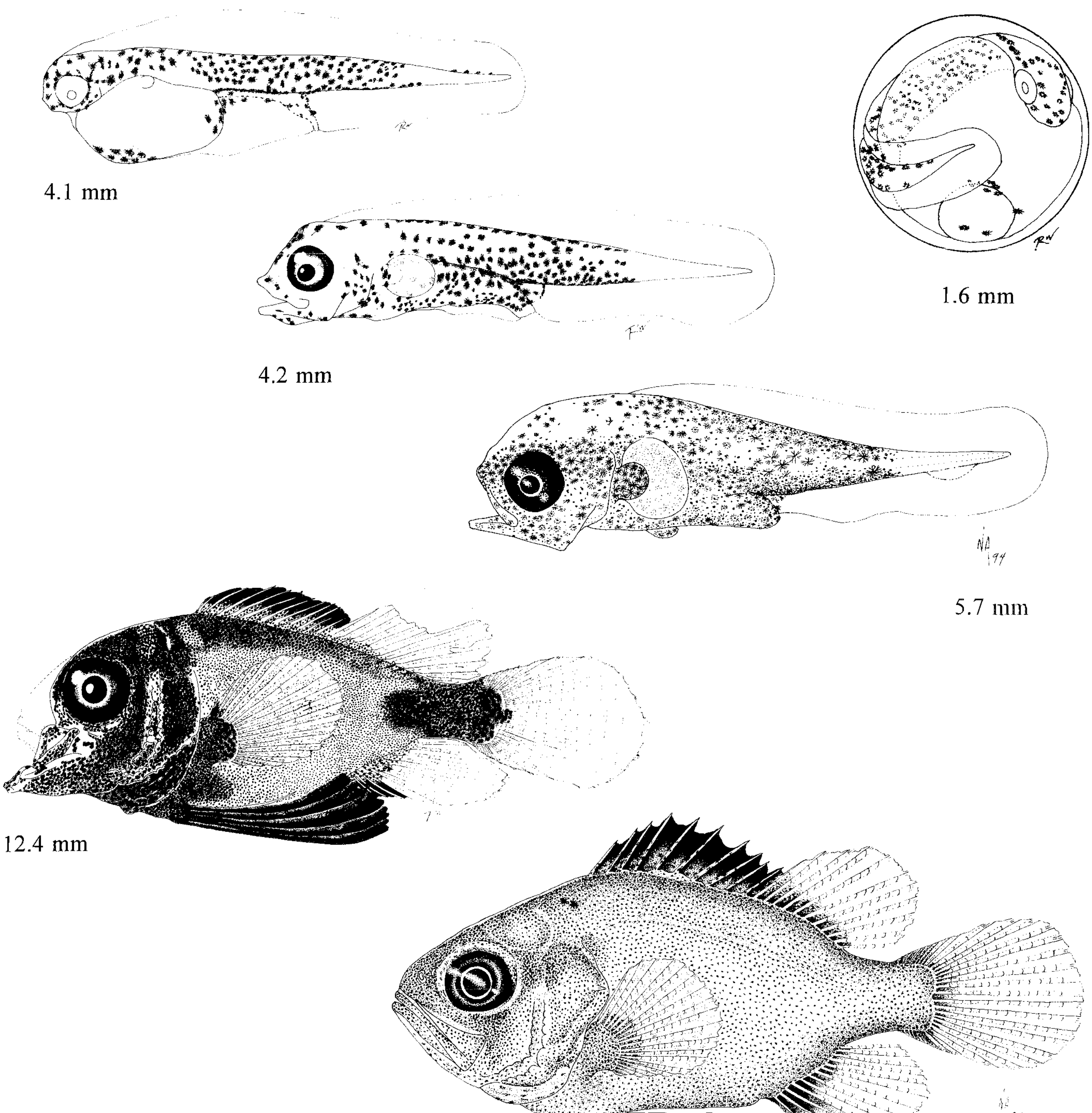


Figure Polyprionidae 1. Giant sea bass reared from aquarium-spawned eggs at Hubbs-Sea World Research Institute, June–July 1993: egg, 1.6 mm; newly hatched yolk-sac larva, 4.1 mm; preflexion larva, 4.2 mm, day 6, ; late preflexion larva, 5.7 mm, day 26, (specimen unavailable, drawn from a photographic slide); transformation specimen, 12.4 mm, day 47, (snout and jaws deformed; dashed line shows approximate profile if specimen had been normal). Field-collected epibenthic juvenile, 18.8 mm (SK, Agua Hedionda Lagoon, September 13, 1988).

SERRANIDAE: Sea basses

W. WATSON

Serranidae is a large and diverse family of fishes that has been repeatedly revised, often extensively, since its original recognition (e.g., Jordan and Eigenmann 1890; Gosline 1966; Randall et al. 1971; Kendall 1976, 1979; Johnson 1983; Baldwin 1990; Baldwin and Johnson 1993). The composition and limits of the family apparently are now largely settled although current classifications still differ in details of family composition. In this volume, for consistency we follow Eschmeyer's (1990) arrangement of the family in which the grammistines are accorded subfamilial status, although Johnson (1983), Kendall (1984) and Baldwin and Johnson (1993) demonstrated that the grammistines belong in the Epinephelinae.

At least 29 serranid species, representing four of the five subfamilies recognized by Eschmeyer (1990), occur in the CalCOFI study area (Table Serranidae 1; Heemstra 1995b). Larvae of ten genera, representing all four subfamilies, have been taken in CalCOFI ichthyoplankton surveys, sometimes in large numbers, primarily at inshore stations during summer.

Serranids are primarily marine tropical and warm temperate shorefishes that range in size from about 3 cm to at least 3 m. Some species school over rocky and coral reefs, while others are solitary reef inhabitants, and still others prefer soft-bottom habitats, eelgrass beds, etc. Serranids typically are moderately deep-bodied, somewhat compressed, with large heads and large mouths with exposed maxillary tips. The opercle bears three spines. The dorsal fin is continuous, often notched, and the caudal fin ranges in shape from rounded to lunate. The anal fin base is short, except in the grammistines. Many serranid species are of great value in sport and commercial fisheries (e.g. Heemstra and Randall 1993); some of the more colorful species are utilized in the aquarium trade.

Many (probably most) serranids are hermaphroditic (e.g., Smith 1965, 1971; Kendall 1984; Heemstra and Randall 1986). Eggs are known for several species (e.g., Kendall 1984); all are planktonic, spherical, ca. 0.7–1.0 mm in diameter, with a narrow perivitelline space, an unsegmented yolk, and a single oil globule ca. 0.1–0.2 mm in diameter (e.g., Ukawa et al. 1966; Kendall 1972, 1984; Suzuki et al. 1978; Butler et al. 1982). Larvae hatch at ca. 1.2–2.3 mm with unpigmented eyes, an unformed mouth, and a large yolk sac. The gut initially is a straight tube extending to midbody or beyond, but it commonly coils and shortens early in the preflexion stage. Larvae of the different subfamilies are morphologically distinct. Serranines are moderately elongate to slightly deep-bodied, with relatively few to many small, unornamented spines on the head and pectoral girdle, early development of one or more fins (spinous dorsal, pectoral, and pelvic), and third dorsal and pelvic fin spines that are only a little elongate, if at all. Anthiines are moderately deep-bodied, with many spines, some much enlarged (and often ornamented), on the head and pectoral girdle (the central spine on the posterior preopercular margin and the upper interopercular spine are especially large), early development of the spinous dorsal and pelvic fins, and moderately elongate third dorsal and pelvic spines. Epinephelines are moderately deep-bodied, with many spines on the head and pectoral girdle (the central spine on the posterior preopercular margin is much enlarged and ornamented), early development of the spinous dorsal and pelvic fins, and greatly elongate and ornamented second dorsal and pelvic fin spines. Grammistines are somewhat elongate, with a few to several relatively small, smooth spines on the opercular series bones, early development of pectoral and spinous dorsal fins, very large pectoral fins, and a greatly elongate, filamentous second dorsal spine.

Larval pigmentation is quite variable but typically is light to moderate. Melanophores occur most frequently on one or more areas: the head (most often on the tips of one or both jaws, at the angular, or on the dorsum), the gas bladder and gut (primarily dorsally, but often some ventrally on the hindgut or preanal finfold), dorsally on the trunk and/or tail (usually no more than two or three spots, but these can be prominent), laterally on or in the tail (usually little or none, but prominent and diagnostic in some), ventrally on the tail, and on one or more of the spinous dorsal, pectoral, and pelvic fins.

Larval epinephelines and grammistines are distinctive once the greatly elongate dorsal spine begins to develop early in the preflexion stage. In addition, grammistines have large, early developing pectoral fins while epinephelines have elongate pelvic fin spines. Neither is likely to be confused with the larvae of any other family in the CalCOFI study area. Some larval serranines and anthiines superficially resemble lutjanids and confusion may occasionally arise. Anthiines in the study area have 26 myomeres, while lutjanids and serranines have 24 (occasionally 25). Anthiines develop an elongate, usually ornamented, spine on the preopercular and interopercular bones, while lutjanids have an elongate, unornamented, preopercular spine and small interopercular spines, and serranines have relatively small, unornamented spines on both bones.

Serranid larvae are readily identifiable to the level of subfamily, and in many cases to genus, using morphological and meristic characters, but many of the species are not easily distinguishable. Meristic characters may be helpful in making probable identifications of postflexion stage larvae, since modal fin ray counts often differ among species, even though the ranges broadly overlap (e.g., Table Serranidae 2). Geographic location may occasionally help in making a probable identification, as well (Table Serranidae 2).

The following descriptions are based on detailed observations of 9–27 specimens of each species, and on published literature where applicable (Table Serranidae 3). Larvae of *Epinephelus analogus* and *Rypticus nigripinnis* are shown in Figure Serranidae 1 but are not described separately because too few specimens were available. Refer to Kendall (1977, 1979, 1984), Johnson and Keener (1984) and Baldwin (1990) for additional descriptions of eastern Pacific serranid larvae. Meristic data were obtained from several literature sources (Rosenblatt and Zahuranec 1967; Smith 1971; Rosenblatt and Johnson 1974; Bortone 1977; Kendall 1979; Fitch 1982; Johnson and Keener 1984; Baldwin 1990; Heemstra and Randall 1993), and from original counts made during this study. Ecological information was obtained from most of these same sources and from Feder et al. (1974), Thomson et al. (1979), Eschmeyer et al. (1983), and Heemstra (1995b).

Table Serranidae 1. Meristic characters for serranid species in the CalCOFI study area; Heemstra (1995b) showed additional species at, or near, the southern end of the study area. All have I,5 pelvic fin rays, 9+8 principal caudal fin rays, and 7 branchiostegal rays.

Species	Vertebrae			Fin rays				
	PrCV	CV	Total	D	A	P_1	C_2	GR
Serraninae								
Diplectrum eumelum	10	14	24	X,12–13	III,7–8	16–18	12–13+10–12	7–8+12–13
D. euryplectrum	10	14	24	X,11–12	III,8	17–18	10–12+9–11	7–8+15–17
D. labarum	10	14	24	X,11–13	III,6–8	15–18	11–13+11–12	6–9+13–15
D. macropoma	10	14	24	X,11–13	III,7	16–18	11–12+9–11	17–24 total
D. maximum	10	14	24	X,12	III,7	16–17	11–12+10	6–7+13–14
D. pacificum	10	14	24	X,11–13	III,7–8	16–18	10–13+10–12	8+12–14
D. rostrum	10	14	24	X,12–13	III,7–8	16–18	12–14+11	22–25 total
D. sciurus	10	14	24	X,11–13	III,7–8	16–18	12–13+10–12	32–41 total
Paralabrax auroguttatus	10	14	24	X,14–15	III,7	15–16	11–12+9–10	6–9+14–15
P. clathratus	10	14–15	24–25	X–XI,12–14	III,7–8	15–16	12–13+10–11	11–13+20–24
P. maculatofasciatus	10	14	24	X,13–14	III,6–8	16–17	10–11+8–9	6+13
P. nebulifer	10	14	24	X,13–15	III,7–8	17–18	11–12+9–11	8–9+14–18
Serranus psittacinus	10	14	24	IX–X,11–13	III,7	16–18	9–10+8–9	3–4+7–8
Anthiinae								
Hemanthias peruanus	10	16	26	IX–X,13–15	III,7–9	16–18	11+10–12	9–10+22–24
H. signifer	10	16	26	X,13–14	III,7–9	18–21	11–13+11–12	9–11+23–27
Pronotogrammus eos	10	16	26	X,14–15	III,7–8	17–19	8+7–8	11–13+27–30
P. multifasciatus	10	16	26	X–XI,14–15	III,6–8	17–21	10+9–10	10–12+26–30
Epinephelinae								
Dermatolepis dermatolepis	10	14	24	XI,18–20	III,9	19–20	7–8+7–8	20–24 total
Epinephelus analogus	10	14	24	X,16–18	III,8	19–20	9–10+8–10	8–10+15–18
E. labriformis	10	14	24	XI,16–18	III,8	17–19	8–9+8–9	7–9+15–17
E. niphobles	10	14	24	X–XI,13–15	III,9	17–21	8–9+7–8	8–9+15–17
Mycteroperca jordani	10	14	24	XI,16–17	III,10–11	16–18	10–11+10–11	21–26 total
M. prionura	10	14	24	X–XI,16–18	III,10–12	15–16	10+9–10	34–38 total
M. rosacea	10	14	24	XI,16–18	III,10–11	15–17	10–11+9–10	14–16+24–29
M. xenarcha	10	14	24	XI,15–16	III,10–12	16–18	10–11+9	9–12+18–23
Paranthias colonus	10	14	24	IX,16–21	III,9–11	19–23	11–12+10–11	12–14+22–29
Grammistinae								
Pseudogramma thaumasium	10	16	26	VII–VIII, 20–24	III,16–19	16–18	4–5+3–4	14–17 total
Rypticus bicolor	10	14	24	II–IV, 23–25	0–I,14–16	16–17	4+4	1–2+4–7
R. nigripinnis	10	14	24	I–III,24–27	0–I,14–16	15–17	4+4	7–8 lower

Table Serranidae 2. Meristic characters and approximate geographic ranges for serranid species in the CalCOFI study area; Heemstra (1995b) gave somewhat different ranges for some of these species and showed additional species at, or near, the southern end of the study area. Most common fin ray counts are given. Geographic abbreviations: BCS, Baja California Sur; CA, California; Gulf, Gulf of California; WA, Washington.

Species	Fin rays				Geographic range
	D	A	P_1	C_2	
Serraninae					
Diplectrum eumelum	X,12	III,7	17	12+11	Bahía Magdalena, BCS & Gulf to Ecuador & Galápagos Islands
D. euryplectrum	X,12	III,8	18	12+11	Bahía Magdalena, BCS to Ecuador & Galápagos Islands
D. labarum	X,12	III,7	16–17	12–13+11	Bahía Asunción, BCS & lower Gulf to Panama
D. macropoma	X,12	III,7	17	12+11	Bahía Magdalena, BCS & Gulf to Peru & Galápagos Islands
D. maximum	X,12	III,7	17	11+10	Bahía Magdalena & Punta del Marquis, BCS & Peru
D. pacificum	X,12	III,7	17	11–12+10–11	Bahía San Juanico, BCS & Gulf to Peru
D. rostrum	X,12	III,7	17	12–14+11	Cabo San Lazaro, BCS & Gulf to Peru & Galápagos Islands
D. sciurus	X,12	III,8	17	13+11	Bahía Magdalena, BCS & Gulf
Paralabrax auroguttatus	X,14	III,7	16	11+9–10	Southern California through Gulf
P. clathratus	X,13	III,7–8	15	12+10–11	Columbia River, WA to Bahía Magdalena, BCS
P. maculatofasciatus	X,14	III,7	16	11+9	Monterey, CA & Gulf to Mazatlán, Mexico
P. nebulifer	X,14	III,7	17	12+10	Santa Cruz, CA to Bahía Magdalena, BCS
Serranus psittacinus	X,12	III,7	17	9–10+8	Bahía Magdalena, BCS & throughout Gulf to Peru
Anthiinae					
Hemanthias peruanus	X,14	III,8	17	11+10	Hippolito Bank (27° N), BCS to Peru
H. signifer	X,14	III,8	19	12+11–12	Playa del Rey, CA to Peru
Pronotogrammus eos	X,15	III,8	17	8+7	Central Gulf to Panama; larvae to 23°36′ N on outer coast of BCS
P. multifasciatus	X,15	III,7	19–20	10+9	Portugese Bend (34° N), CA to Peru
Epinephelinae					
Dermatolepis dermatolepis	XI,18–19	III,9	18–19	7–8+8	Southern California to Equador, including offshore islands
Epinephelus analogus	X,17	III,8	19–20	10+9	San Pedro, CA & Gulf to Peru & Galápagos Islands
E. labriformis	XI,16–17	III,8	17–19	9+8–9	Bahía Magdalena, BCS & Gulf to Peru, including offshore islands
E. niphobles	XI,14	III,9	19	9+8	Piedras Blancas, CA to Peru
Mycteroperca jordani	XI,16	III,11	17	11+10	La Jolla, CA to Mazatlán, Mexico
M. prionura	XI,16–17	III,11	16	10+9–10	Bahía San Lucas, BCS & lower Gulf to Bahía Banderas, Jalisco, Mexico
M. rosacea	XI,17	III,11	16	10+10	Bahía Magdalena, BCS & Gulf to Bahía Banderas, Jalisco, Mexico
M. xenarcha	XI,15–16	III,11	17	10+9	San Francisco Bay, CA to Peru & Galápagos Islands
Paranthias colonus	IX,18–19	III,9–10	20	11–12+11	Bahía Magdalena, BCS & northern Gulf to Peru, including offshore islands
Grammistinae					
Pseudogramma thaumasium	VII,20–21	III,17	16–17	4+3	Central Gulf to Panama; larvae on outer coast to Todos Santos, BCS (23°27′ N)
Rypticus bicolor	III,24–25	I,16	16–17	4+4	Bahía Magdalena, BCS & throughout Gulf to Peru
R. nigripinnis	II,25–27	I,15	16	4+4	Bahía Magdalena, BCS & throughout Gulf to Peru

Table Serranidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the serranid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Diplectrum sp.	0	0	6 3.3–4.7	2 4.8,4.8	1 6.1	0	0
Paralabrax clathratus	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]
P. maculatofasciatus	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]
P. nebulifer	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]
Serranus sp.	0	0	8 2.5–4.0	3 4.2–5.2	4 5.9–7.1	0	0
Hemanthias signifer	0	0	9 3.4–4.5	3 4.4–5.4	10 6.6–16.1	1 18.0	4 26.2–32.5
Pronotogrammus multifasciatus	0	0	10 3.3–4.9	5 4.6–5.9	3 5.6–5.9	9 5.9–13.2	0
Paranthias colonus	0	0	4 4.6–5.2	3 5.8–5.9	3 7.7–11.9	0	5 34.5–37.7
Pseudogramma thaumasium	0	0	1 3.5	3 3.4–4.3	7 7.5–13.3	5 12.4–15.2	4 17.9–28.3

[a] Butler et al. 1982

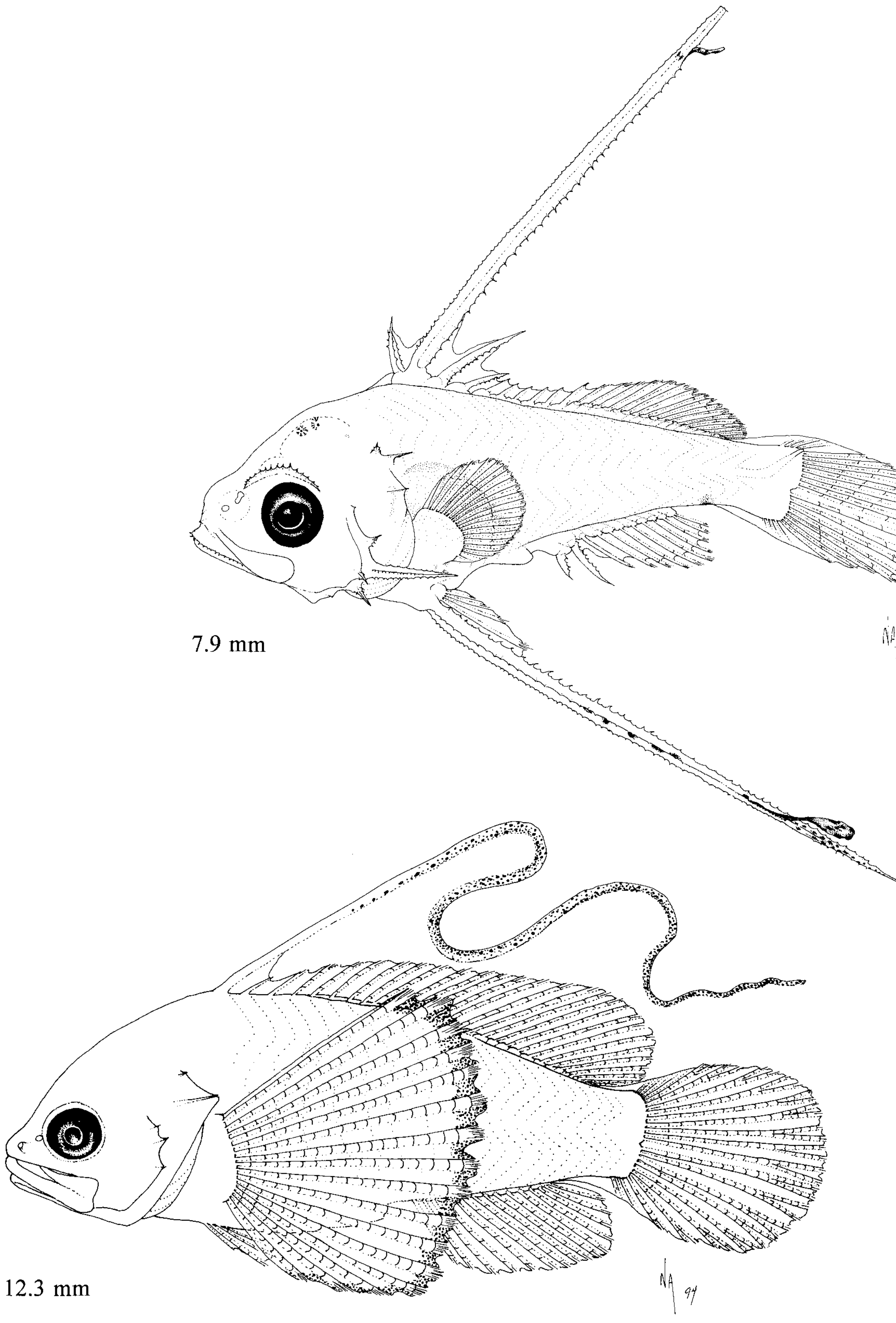


Figure Serranidae 1. Spotted cabrilla, *Epinephelus analogus*, 7.9 mm (CalCOFI 5706, station 133G.100; original illustration by N. Arthur); blackfin soapfish, *Rypticus nigripinnis*, 12.3 mm (CalCOFI 5708, station 133G.40; original illustration by N. Arthur).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	
Precaudal	10	
Caudal	14	
Fins:		
Dorsal spines	X	
Dorsal rays	11–13	
Anal spines	III	
Anal rays	6–8	
Pelvic	I,5	
Pectoral	15–18	
Caudal:		
Principal	9+8	
Procurrent:		
Upper	10–14	
Lower	9–12	
Gill rakers:		
Total	17–41	
Upper	6–9	
Lower	12–17	
Branchiostegals	7	

LIFE HISTORY

Range: Northern range limits along Pacific coast for CalCOFI species are Bahía Asunción (*D. labarum*), Bahía San Juanico (*D. pacificum*), vicinity of Cabo San Lazaro & Bahía Magdalena (*D. eumelum, D. euryplectrum, D. macropoma, D. maximum, D. rostrum, D. sciurus*)

Habitat: Over sandy or muddy bottom along continental shelf

Spawning season: Larvae collected July through January

ELH pattern: Oviparous, synchronous hermaphrodites; planktonic larvae

LITERATURE

Kendall 1977, 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.3 mm (R. C. Walker)
Flexion larva, 4.7 mm (R. C. Walker)
Postflexion larva, 6.1 mm (R. C. Walker)

* Eight species (*D. eumelum, D. euryplectrum, D. labarum, D. macropoma, D. maximum, D. pacificum, D. rostrum, D. sciurus*) occur in the CalCOFI area. Larvae included here are tentatively identified as *D. labarum* based on fin ray counts (primarily P_1), pigment pattern, & collection location of some specimens well north of Cabo San Lazaro, Baja California Sur. Meristic data above include all eight species.

EARLY LIFE HISTORY DESCRIPTION

EGGS

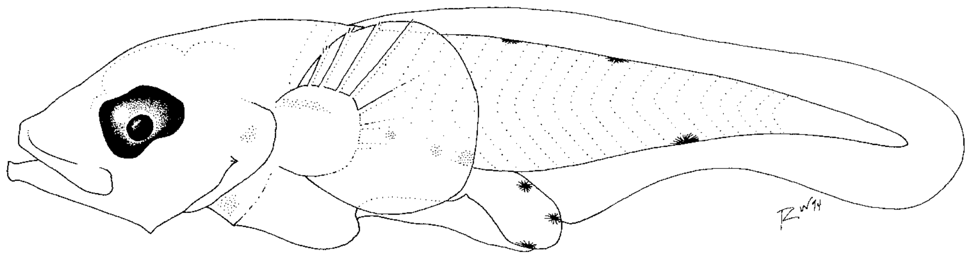
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

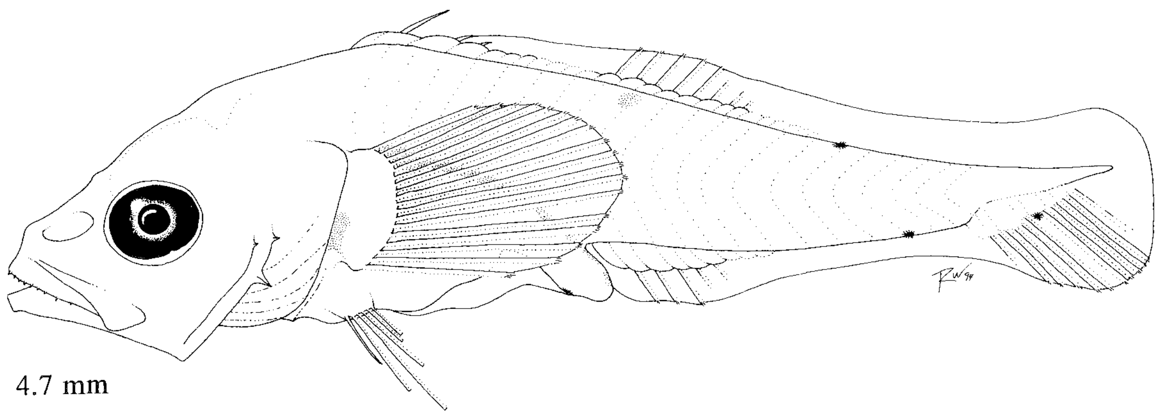
Hatching length: <3.3 mm
Flexion length: ca. 4.7 mm to <6 mm
Transformation length: <20 mm
Fin development sequence: P_1, P_2, C_1, A, D, C_2
Pigmentation: *Larvae*—1–3 on dorsal margin at myomeres 9–13 (usually 1 or 2 melanophores) & myomeres 16–18 (always 1 melanophore), extending internally by 3.5–4 mm & becoming entirely internal just below dorsal margin by ca. 6 mm; 1 on ventral margin at myomeres 18–21 (usually 19 or 20); 0–2 (usually 1–2) under middle of notochord tip, becoming located proximally between central C rays; anteriorly on gut & liver; dorsally on gas bladder & hindgut; few around hindgut near anus; usually 1 at angular; light peppering to none (usually none) on distal 20–30% of P_1.
Diagnostic features: Myomeres 9–12+12–15=24; large P_1 with early ray development; relatively few, small spines on head & pectoral girdle; pigment pattern consisting primarily of 1–3 (2) prominent dorsal melanophores, 1 ventrally on tail, & light pigment anteriorly & dorsally on gut & gas bladder.

MORPHOMETRICS (range & mean in %)

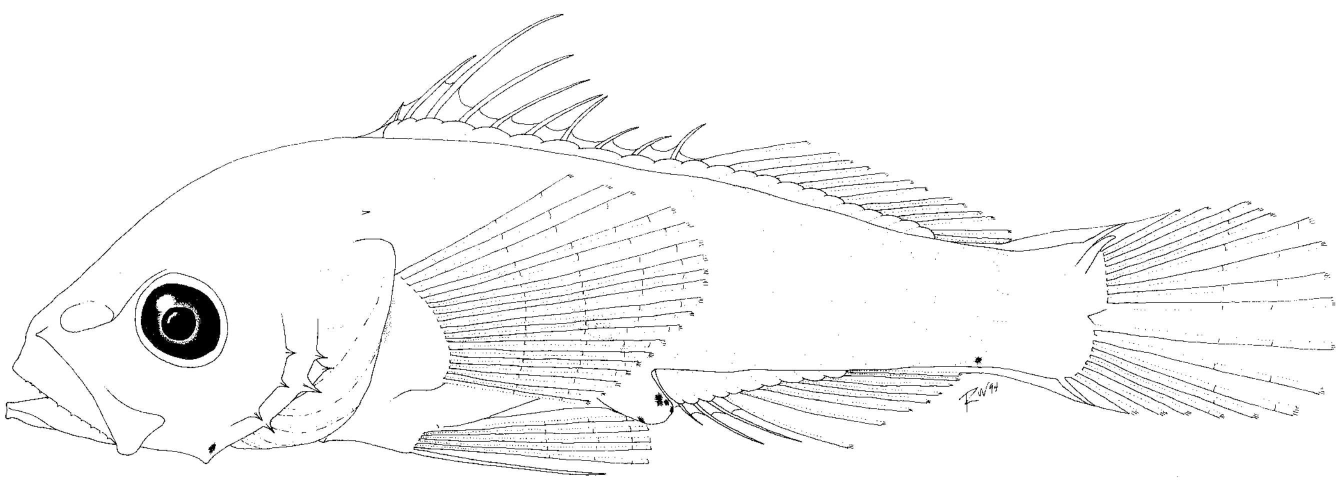
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		55–64 59	55–59 57	60		
BD/BL		24–27 25	24–27 26	28		
HL/BL		29–32 30	29–32 31	32		
HW/HL		53–59 55	52–58 55	53		
SnL/HL		26–34 30	30–36 33	39		
ED/HL		23–29 26	25–26 25	23		
P_1L/BL		14–22 17	23–26 24	23		
P_2L/BL		0–10 4	11–13 12	22		
DSL/BL		0–0 0	6–6 6	16		



3.3 mm



4.7 mm



6.1 mm

Figure Serranidae 2. Preflexion larva, 3.3 mm; early flexion larva, 4.7 mm (CalCOFI 5810, station 150.25); postflexion larva, 6.1 mm (CalCOFI 6712, station 137.35).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24–25	24
Precaudal	10	10
Caudal	14–15	14
Fins:		
Dorsal spines	X–XI	X
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	7–8	7–8
Pelvic	I,5	I,5
Pectoral	15–16	15
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	12–13	12
Lower	10–11	10–11
Gill rakers:		
Upper	11–13	
Lower	20–24	
Branchiostegals	7	7

LIFE HISTORY

Range: Columbia River to Bahía Magdalena, Baja California Sur

Habitat: Coastal waters to ca. 46 m depth, usually in or near kelp forests at depths ≤ ca. 21 m

Spawning season: May–June through September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Butler et al. 1982

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.95 mm in diameter (R. C. Walker)

* Values from Butler et al. (1982).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.94–0.97 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.20 mm
Shell surface: Smooth
Pigment: Melanophores on OG & dorsum of embryo in late-stage eggs
Diagnostic features:

LARVAE

Hatching length: ca. 2.2 mm
Flexion length: ca. 5.0–6.5 mm
Transformation length: ca. 11 mm
Fin development sequence: C_1, P_2, 1D & P_1, 2D & A, C_2
Pigmentation: *Yolk-sac*—Many dorsally on trunk & tail, becoming concentrated in 3 patches in vicinity of myomeres 1–4, 7–10, & midtail; 0–few on snout & anteriorly on head, none by end of stage; dorsally on gut; 1 on preanal finfold adjacent to anus; series on ventral margin of tail; few around OG. *Preflexion*—Posterior dorsal patch absent after 4.6 mm; dorsally on head by 4.6 mm; on angular by 4.1 mm; on isthmus by 4.6 mm; ventral tail pigment reduced to prominent blotch at midtail & few posteriorly. *Flexion–postflexion*—On upper jaw & gular region after 5 mm; on snout & opercle by 10 mm; increasing dorsally on head; dorsal trunk patches absent by ca. 7 mm; series of saddles forms along D base near end of stage; on P_1, P_2, 1D, A, & proximally on C. *Transformation*—Barred.
Diagnostic features: Myomeres 10+14–15; relatively few, small spines on head & pectoral girdle; relatively slender body; 3 prominent dorsal pigment patches in preflexion stage; melanophores form early on upper jaw; lateral pigment absent on trunk & tail until end of postflexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	52–64 58	50–55 53	53–61 56	57–62 59	59–63 61	60–61 61
BD/BL		13–20 16	22–32 26	26–35 30	27–32 29	30–30 30
HL/BL		20–28 24	31–36 34	29–40 36	37–41 39	35–38 37
HW/HL						
SnL/HL		24–28 26	27–31 29	22–31 27	22–33 27	21–27 24
ED/HL		28–43 34	24–31 28	25–31 27	21–29 25	25–27 26
P_1L/BL						
P_2L/BL						

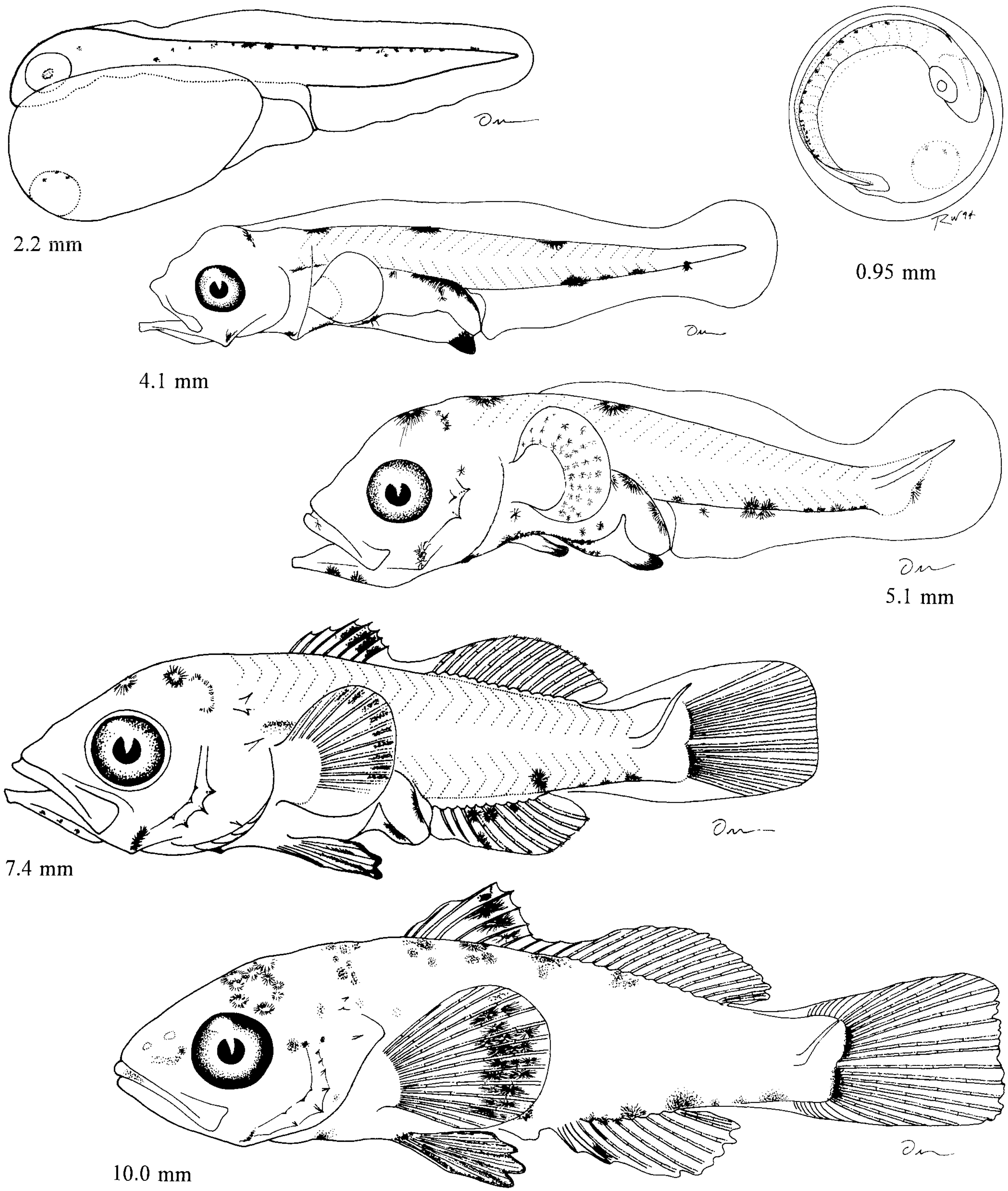


Figure Serranidae 3. Egg, 0.95 mm (reared at SWFSC, 36 hours old, June 24, 1978); yolk-sac larva, 2.2 mm; preflexion larva, 4.1 mm; flexion larva, 5.1 mm; postflexion larvae, 7.4 mm, 10.0 mm (Butler et al. 1982).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X	X
Dorsal rays	13–14	14
Anal spines	III	III
Anal rays	6–8	7
Pelvic	I,5	I,5
Pectoral	16–17	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–11	11
Lower	8–9	9
Gill rakers:		
Upper	6	6
Lower	13	13
Branchiostegals	7	7

LIFE HISTORY

Range: Monterey, California to Mazatlán, Mexico, including the Gulf of California

Habitat: Near soft bottom close to rocks, kelp forests, & eelgrass beds; intertidal to 61 m depth

Spawning season: Summer

ELH pattern: Oviparous, protogynous hermaphrodites; planktonic eggs & larvae

LITERATURE

Butler et al. 1982

* Values from Butler et al. (1982).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.80–0.89 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.16–0.19 mm
Shell surface: Smooth
Pigment: Melanophores on dorsum of embryo & OG in late-stage eggs
Diagnostic features:

LARVAE

Hatching length: ca. 2.2 mm
Flexion length: 4.3–5.8 mm
Transformation length: ca. 11 mm
Fin development sequence: C_1, P_1, P_2 & 1D, 2D & A, C_2
Pigmentation: *Yolk-sac*—Series on dorsum of trunk & tail condensing into patches anteriorly & posteriorly on trunk & at midtail; over gut; on oil globule. *Preflexion*—3 prominent dorsal blotches decreasing to 1 or 2 on trunk after 3.6 mm; present or absent on gular region; 1 on angular; dorsally on gas bladder & gut; on isthmus & ventral margin of gut; on margin of preanal finfold; few, larger anteriorly, in discontinuous ventral series on tail. *Flexion–postflexion*—On snout by 5.8 mm; over midbrain & on opercle by 7.9 mm; on jaws by 9.3 mm; dorsolaterally below 1D & on lateral midline of trunk by 5.8 mm; midlateral stripe from snout to C by 11 mm; ventrolaterally anteriorly on tail by 9.3 mm; 0–few on P_1 & P_2; few on 1D.
Diagnostic features: Myomeres 10–12+13–15=24–25; relatively few small spines on head & pectoral girdle; relatively slender body; 1–2 dorsal blotches after 3 mm; midlateral pigment absent before late flexion stage; nearly continuous marginal pigment along preanal finfold; discontinuous series of ca. 5–10 melanophores on ventral margin of tail in preflexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–56 52	52–62 55	60–65 61		61–65 63
BD/BL		14–20 17	19–29 23	27–31 29		29–32 30
HL/BL		21–24 22	26–35 30	34–36 35		34–39 37
HW/HL						
SnL/HL		20–27 23	20–27 24	23–27 25		19–26 22
ED/HL		31–35 34	24–30 28	27–30 28		27–34 30
P_1L/BL						
P_2L/BL						

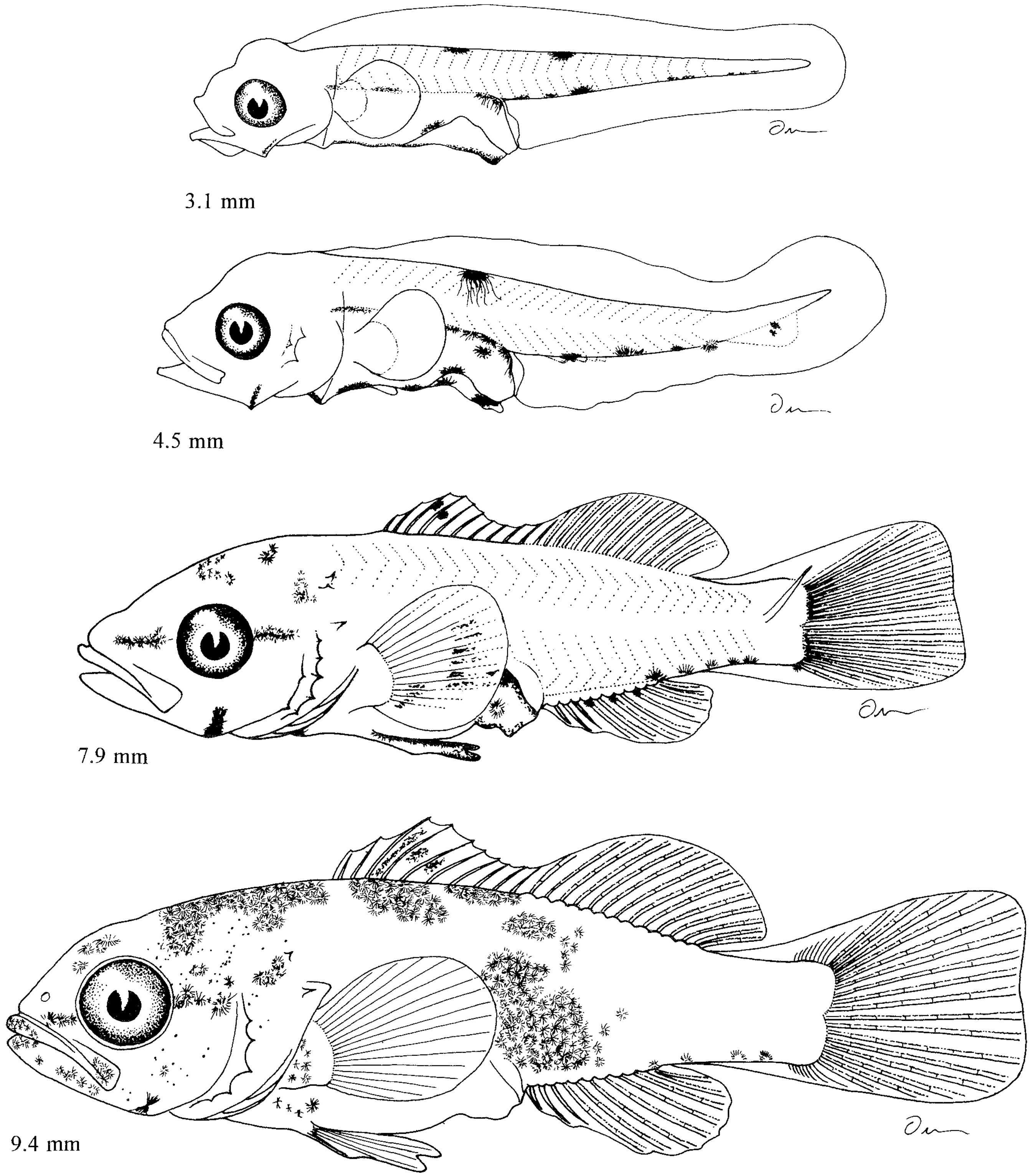


Figure Serranidae 4. Preflexion larvae, 3.1 mm, 4.5 mm; postflexion larvae, 7.9 mm, 9.4 mm (Butler et al. 1982).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X	X
Dorsal rays	13–15	14
Anal spines	III	III
Anal rays	7–8	7
Pelvic	I,5	I,5
Pectoral	17–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	11–12	12
Lower	9–11	10
Gill rakers:		
Upper	8–9	
Lower	14–18	
Branchiostegals	7	7

LIFE HISTORY

Range: Santa Cruz, California, to Bahía Magdalena, Baja California Sur

Habitat: Over rocky reefs & adjacent sandy bottom to 183 m depth, most abundant at depth ≤37 m

Spawning season: Summer–early fall

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Butler et al. 1982

* Values from Butler et al. (1982).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.94–0.97 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.20 mm (mean diam.)
Shell surface: Smooth
Pigment: On dorsum of embryo & around OG in late-stage eggs
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 4.9–6.8 mm
Transformation length: ca. 11 mm
Fin development sequence: C_1, P_2 & P_1, & 1D, 2D & A, C_2
Pigmentation: *Yolk-sac*—Dorsally on trunk & tail, concentrating into anterior & posterior trunk & midtail patches; dorsally on gut; few on OG. *Preflexion*—2 dorsal patches by 3.4 mm, at ca. myomeres 1–3 & 6–8; on gular region & angular; series over gas bladder & gut, continuing along full length of ventral margin of tail; midlaterally above anus by 3.6 mm; ventrally on isthmus & gut; often heavy on preanal finfold; on P_1 near end of stage. *Flexion–postflexion*—Internally on midbrain by ca. 5 mm; externally by 6.8 mm; on snout & opercle by ca. 9 mm; dorsolaterally below 1D, increasing to form saddle by ca. 9 mm; increasing along lateral midline; decreasing on tail; increasing on P_1; on P_2; little or none on 1D.
Diagnostic features: Myomeres 9–12+13–15=24–25; relatively few, small spines on head & pectoral girdle; relatively slender body; 2 prominent dorsal blotches on trunk after 3.4 mm, saddle forming below 1D in postflexion stage; melanophores form midlaterally on trunk during preflexion stage; continuous series of 11–20 melanophores on ventral margin of tail in preflexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–53 51	55–60 58	57–61 58		60–62 61
BD/BL		16–22 18	20–27 26	27–31 29		29–30 30
HL/BL		24–27 26	31–37 34	35–39 37		37–39 38
HW/HL						
SnL/HL		15–31 25	22–29 26	21–27 24		20–24 22
ED/HL		25–36 30	27–33 30	24–29 27		26–29 28
P_1L/BL						
P_2L/BL						

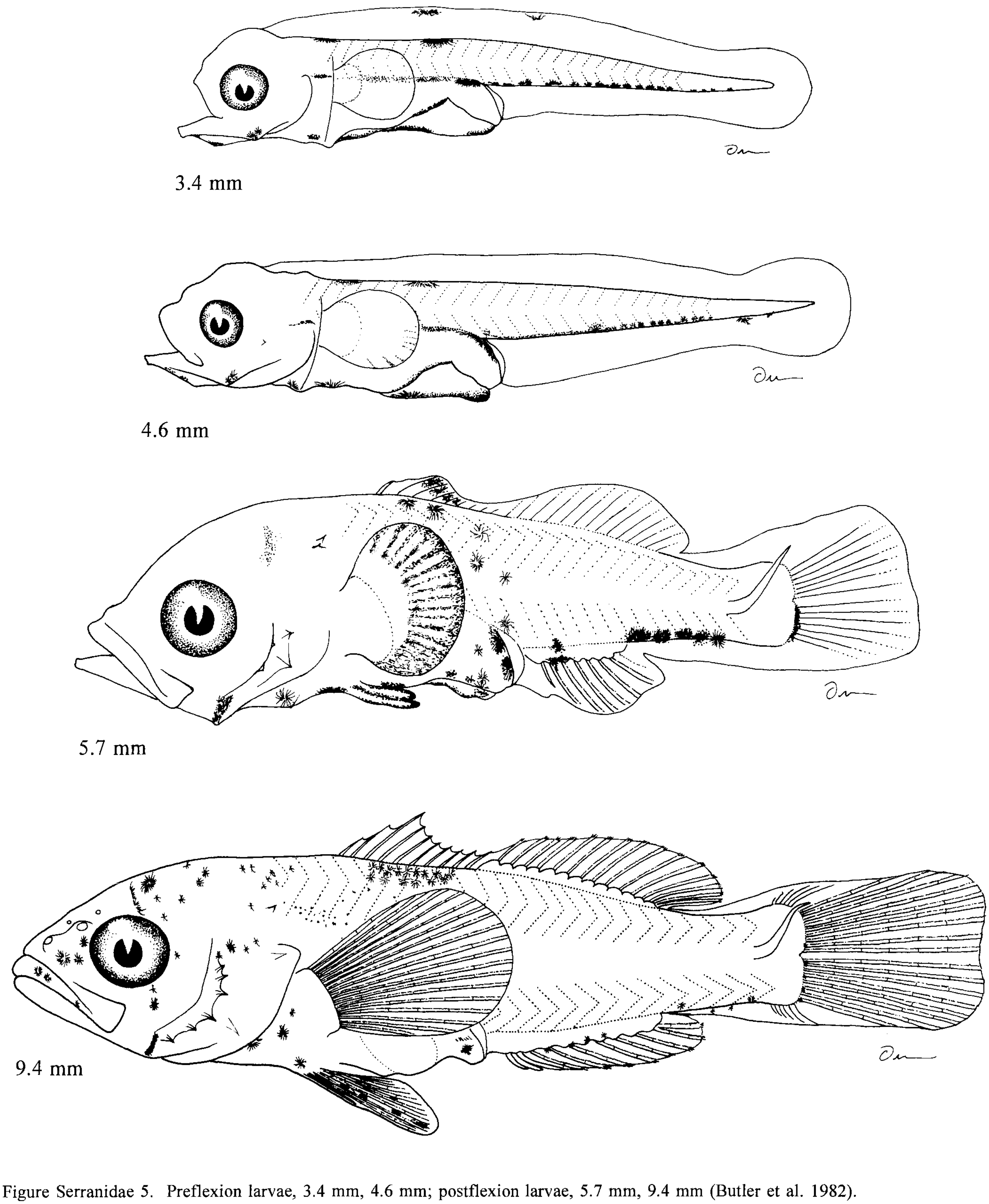


Figure Serranidae 5. Preflexion larvae, 3.4 mm, 4.6 mm; postflexion larvae, 5.7 mm, 9.4 mm (Butler et al. 1982).

MERISTICS

	Range	Mode
Myomeres:		
Total	24	
Precaudal	10	
Caudal	14	
Fins:		
Dorsal spines	X	
Dorsal rays	12	
Anal spines	III	
Anal rays	7	
Pelvic	I,5	
Pectoral	16–17	
Caudal:		
Principal	9+8	
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	

LIFE HISTORY

Range: *S. psittacinus* ranges from Bahía Magdalena & throughout Gulf of California to Peru; *Serranus* sp. larvae collected as far north as vicinity of Bahía San Juaníco, Baja California Sur

Habitat: *S. psittacinus* near bottom in vicinity of reefs to ca. 61 m depth

Spawning season: Larval *Serranus* sp. collected in summer & fall

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.5 mm, 3.8 mm (R. C. Walker)
Flexion larva, 4.6 mm (R. C. Walker)
Postflexion larva, 7.1 mm (R. C. Walker)

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* Larvae included here may be *S. psittacinus* based on collection locations & meristic characters, but small juvenile *S. psittacinus* are pigmented much differently from the largest larvae & transformation specimens were unavailable. Meristic data above are for postflexion stage larvae.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 4.0–5.5 mm
Transformation length:
Fin development sequence: P_2, 1D, C_1, P_1 & 2D & A, C_2
Pigmentation: *Preflexion*—2–3 dorsally on trunk, 1 each usually in vicinity of myomeres 1–2 (usually internal when present), myomeres 4–5 (usually internal after ca. 3.5 mm), & myomeres 7–10 (external); 1 on angular; 1 on isthmus near cleithral symphysis; 1 between P_2 bases; 1–6 on ventral margin of gut; dorsally on gas bladder & hindgut; usually 4–5 on ventral margin of tail; light to moderate on distal 25–50% of P_1; on P_2 margin. *Flexion–postflexion*—1 dorsally on trunk at myomere 9–11, becomes internal; number on ventral margin of tail usually reduced to 2–3; on 1D, initially distally between spines III–IV, forming band to D IX by 6.4 mm; distal blotch between A II–III by 5.9 mm; series along A base beginning at first ray between 4.2–5.9 mm; increasing on P_1 & P_2.
Diagnostic features: Myomeres 9–11+13–15=24; deep-bodied in comparison with other serranines; small spines on head & pectoral girdle; early development of P_2 & 1D; prominent dorsal melanophore in vicinity of myomeres 7–10; pigmented P_1, P_2, 1D; no dorsal head pigment to at least 7.1 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		55–61 59	56–60 58	58–60 59		
BD/BL		29–32 31	31–37 33	33–38 35		
HL/BL		31–37 33	33–35 34	32–35 33		
HW/HL		57–74 64	54–61 58	54–56 55		
SnL/HL		26–33 30	28–36 33	28–31 29		
ED/HL		28–30 29	22–26 25	25–28 26		
P_1L/BL		9–11 10	16–19 17	21–26 22		
P_2L/BL		0–7 3	18–20 19	25–25 25		

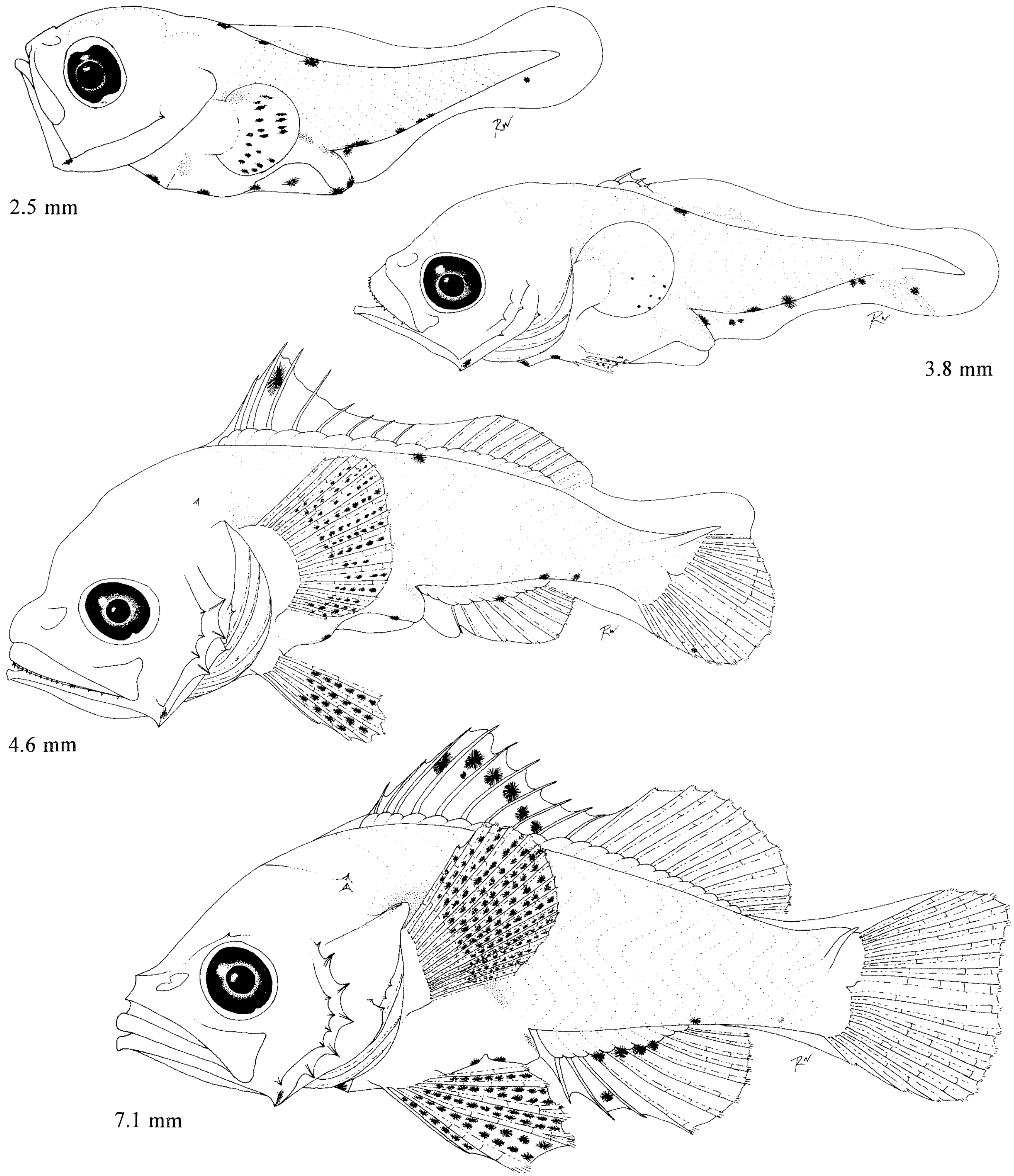


Figure Serranidae 6. Preflexion larvae, 2.5 mm, 3.8 mm (CalCOFI 5708, station 105G.70); flexion larva, 4.6 mm (CalCOFI 6310, station 133.21); postflexion larva, 7.1 mm (CalCOFI 5708, station 103G.55).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	X	X
Dorsal rays	13–14	14
Anal spines	III	III
Anal rays	7–9	8
Pelvic	I,5	I,5
Pectoral	18–21	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	11–13	12
Lower	11–12	11–12
Gill rakers:		
Upper	9–11	
Lower	23–27	
Branchiostegals	7	7

LIFE HISTORY

Range: Playa del Rey, California (34° N), & Gulf of California to Paita, Peru (5° S)

Habitat: Over reefs in waters ca. 23–306 m deep

Spawning season: Larvae collected in summer & fall (June–October)

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Baldwin 1990
Kendall 1977, 1979, 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.2 mm (N. Arthur)
Flexion larva, 4.4 mm (N. Arthur)
Postflexion larva, 6.6 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 4.5–5.5 mm
Transformation length: ca. 18 mm to <24 mm
Fin development sequence: 1D & P_2, C_1 & A, 2D, P_1, C_2
Pigmentation: *Preflexion*—Prominent blotch on tip of lower jaw; 2–few internally over hindbrain; anteriorly & dorsally on gas bladder & gut; 0–1 ventrally at anus; internally over notochord at ca. myomeres 11–13 by 4.2–4.5 mm; 6–10 ventrally on last half of tail; 1–2 caudal; 0–few distally on P_2. *Flexion*—Notochord series extends from myomeres 8–10 through 16–17 by end of stage; ventral margin series decreases to 2–3. *Postflexion*—Over midbrain by 6.6 mm, increasing & spreading over forebrain by 7.7 mm; internal dorsal patch at level of D 5–11 by 7.4–7.7 mm, few externally in same area by 9.9 mm; few adjacent to some D spines by 12.4 mm.
Diagnostic features: Myomeres 26 (9–10+16–17 through early flexion stage, shifting to 12+14); D & P_2 spines smooth, 3rd D spine elongate; pointed supraoccipital crest becoming low serrate ridge by 11–12 mm; interopercular spine 60–80% length of longest preopercular spine by postflexion stage; melanophore series over notochord; dorsal blotch below 2D in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		51–58 55	55–56 55	57–70 64	 62	58–60 59
BD/BL		28–36 32	35–37 36	39–41 39	 34	30–31 30
HL/BL		30–36 34	35–38 37	38–43 42	 39	33–37 35
HW/HL		58–69 63	53–66 59	42–61 53	 49	46–52 48
SnL/HL		29–37 34	31–38 35	27–35 30	 27	23–29 26
ED/HL		26–32 29	28–29 29	25–33 30	 29	33–35 34
P_1L/BL		5–8 7	8–8 8	11–22 16	 23	25–27 27
P_2L/BL		8–17 13	10–18 14	16–26 21	 26	23–26 25
DSL/BL		9–19 14	14–20 17	16–21 19	 21	14–18 16

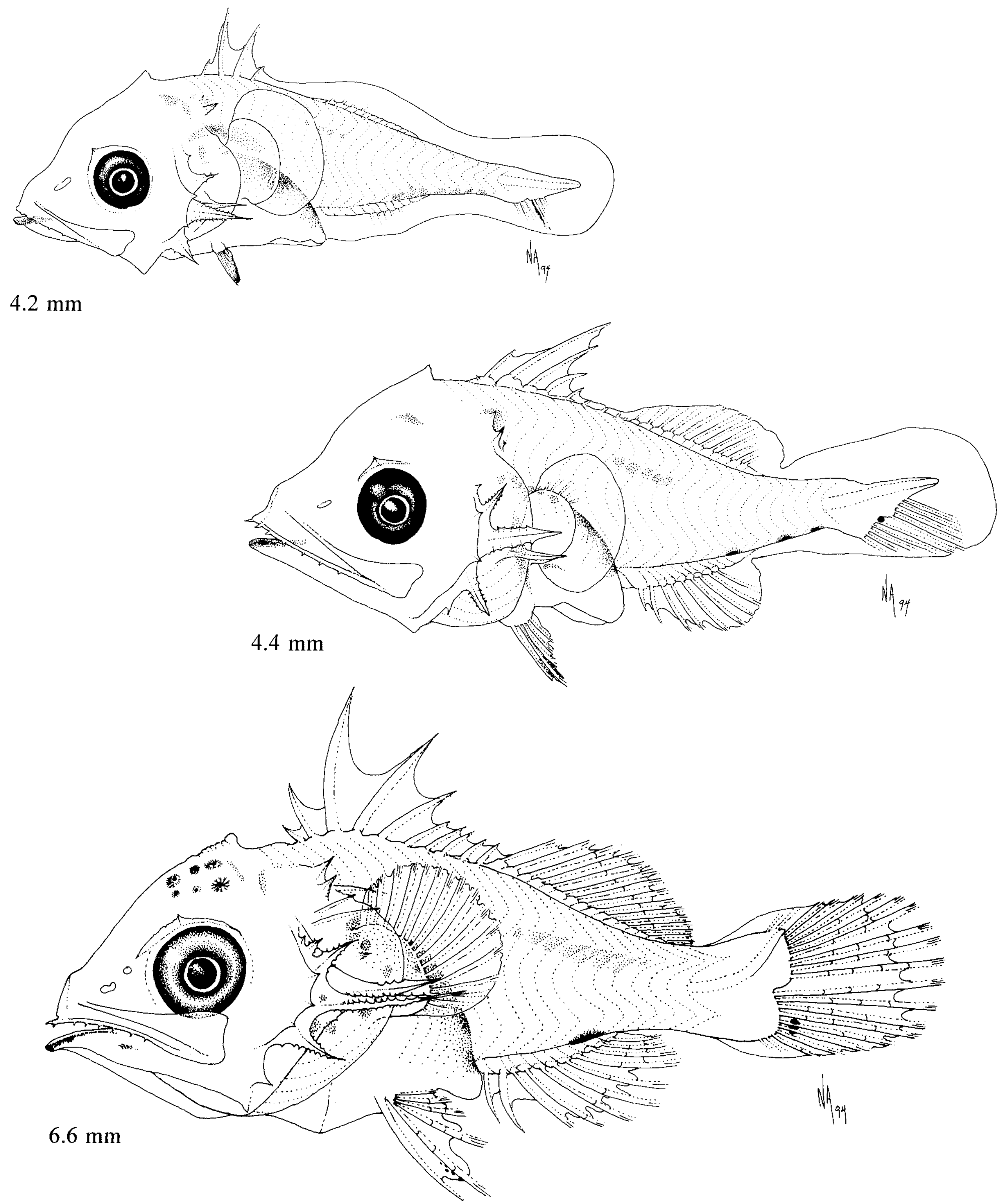


Figure Serranidae 7. Preflexion larva, 4.2 mm (IATTC 90019, station MSH2 #1 Grn); flexion larva, 4.4 mm (CalCOFI 5708, station 109G.12); postflexion larva, 6.6 mm (CalCOFI 5706, station 125G.30).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	X–XI	X
Dorsal rays	14–15	15
Anal spines	III	III
Anal rays	6–8	7
Pelvic	I,5	I,5
Pectoral	17–21	19–20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10	10
Lower	9–10	9
Gill rakers:		
Upper	10–12	
Lower	26–30	
Branchiostegals	7	7

LIFE HISTORY

Range: Portugese Bend, California (34° N), & lower Gulf of California to northern Peru

Habitat: Over rocky bottom at ca. 40–205 m depth

Spawning season: Larvae collected April–December with larger catches in summer & fall

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Baldwin 1990
Kendall 1977, 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.1 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.3 mm
Flexion length: ca. 4.6–4.9 mm through ca. 5.6–5.9 mm
Transformation length: ca. 20 mm
Fin development sequence: 1D & P_2, C_1 & A, 2D & P_1, C_2
Pigmentation: *Preflexion–postflexion*—At tip of lower jaw; internally over hindbrain, spreading onto midbrain between 4.2–5.9 mm; externally over midbrain between 5.9–6.8 mm; on gas bladder; anteriorly & dorsally on gut except little or none over hindgut; on preanal finfold adjacent to anus, usually absent after 4.2 mm; often 1–2 on dorsal margin at ca. myomere 5–7 before 3.4–3.6 mm, none between ca. 3.6–11.0 mm, then few along D base; 5–8 on ventral margin of tail, decreasing to 1–2 during flexion stage; 1–few under notochord tip becoming located proximally on lower C rays; on P_2; on D between spines III–IV (spine III forms first), spreading to spine VI–VII during postflexion stage.
Diagnostic features: Myomeres 26 (9–10+16–17); D & P_2 spines smooth, 3rd D spine elongate; no supraoccipital crest; longest interopercular spine 52–100% length of longest preopercular spine by postflexion stage; 1D & P_2 pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		51–55 53	51–58 55	58–60 59	57–61 59	
BD/BL		27–34 31	34–40 37	38–42 40	38–43 40	
HL/BL		29–35 32	35–39 37	39–40 39	37–46 40	
HW/HL		64–77 69	57–75 66	59–69 64	55–65 61	
SnL/HL		21–37 30	32–36 35	28–34 31	25–37 31	
ED/HL		27–33 29	26–32 29	28–30 29	24–33 29	
P_1L/BL		5–10 8	8–10 9	10–12 11	9–16 12	
P_2L/BL		5–13 10	13–19 15	18–20 19	18–24 21	
DSL/BL		11–20 14	15–21 19	19–22 21	20–24 21	

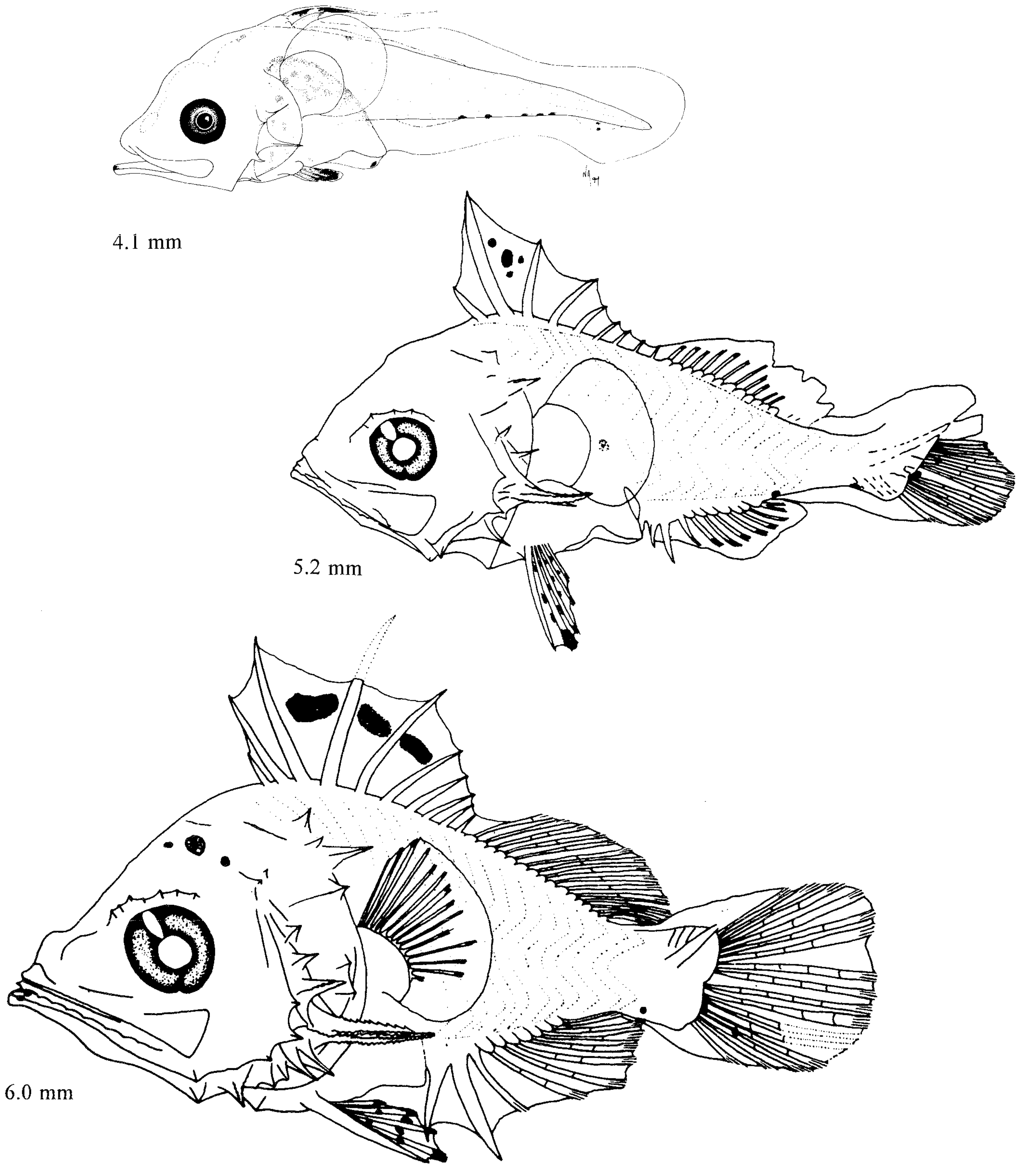


Figure Serranidae 8. Preflexion larva, 4.1 mm (CalCOFI 5704, station 127G.90); flexion larva, 5.2 mm; postflexion larva, 6.0 mm (Kendall 1977, as *Anthias gordensis*).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	IX	IX
Dorsal rays	16–21	18–19
Anal spines	III	III
Anal rays	9–11	9–10
Pelvic	I,5	I,5
Pectoral	19–23	20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	11–12	11–12
Lower	10–11	11
Gill rakers:		
Upper	12–14	
Lower	22–29	
Branchiostegals	7	7

LIFE HISTORY

Range: South from Bahía Magdalena, Baja California Sur, & Puerto Lobos, Sonora to Peru, including offshore Islands

Habitat: Swims in small groups above deep reefs (to ca. 60 m depth)

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Johnson & Keener 1984
Kendall 1977, 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.2 mm (N. Arthur)
Flexion larva, 5.9 mm (N. Arthur)
Postflexion larva, 8.1 mm (N. Arthur)

* The Pacific creole fish, *P. colonus*, commonly is considered synonymous with the creole fish, *P. furcifer*, from the western Atlantic; however, Johnson & Keener (1984) presented evidence that the Atlantic & Pacific forms are different & Heemstra & Randall (1993) & Heemstra (1995b) accepted *P. colonus* as a valid species.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: >5.2, <5.8 mm through >5.9, <8.1 mm
Transformation length: >15.8, <34 mm
Fin development sequence: 1D & P_2, C_1, P_1, A, 2D, C_2
Pigmentation: *Larvae*—Internally over hindbrain by 4.9 mm; dorsally on posterior part of midbrain by 5.9 mm; on upper half of gut, spreading ventrad to cover upper 80% by 5.9 mm; 1 on ventral margin of tail at myomeres 17–18, becoming internal during flexion stage & moving upward & caudad to myomere 19–20 during postflexion stage; several each on distal tabs of second dorsal spine & pelvic spines.
Diagnostic features: Moderately small, thin, straight spinules along posterior margins & small, thin, straight spinules along anterior margin of second dorsal spine; outer margins of pelvic spines with moderately small, thin, slightly curved spinules, inner margins with small, thin, straight spinules; dorsal spines IX (present by ca. 8 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–50 49	48–55 51	52–57 55		57–62 59
BD/BL		30–32 31	31–34 33	33–37 35		33–35 34
HL/BL		29–32 30	30–37 34	34–37 35		31–35 34
HW/HL		54–62 59	53–58 55	46–55 52		41–52 49
SnL/HL		26–35 31	35–36 36	32–36 34		23–27 25
ED/HL		26–31 29	27–30 28	24–30 28		28–30 29
P_1L/BL		8–9 8	8–10 9	13–20 16		26–28 27
P_2L/BL		37–54 45	52–59 57	36–55 49		22–23 22
DSL/BL		62–74 68	77	82		14–16 15

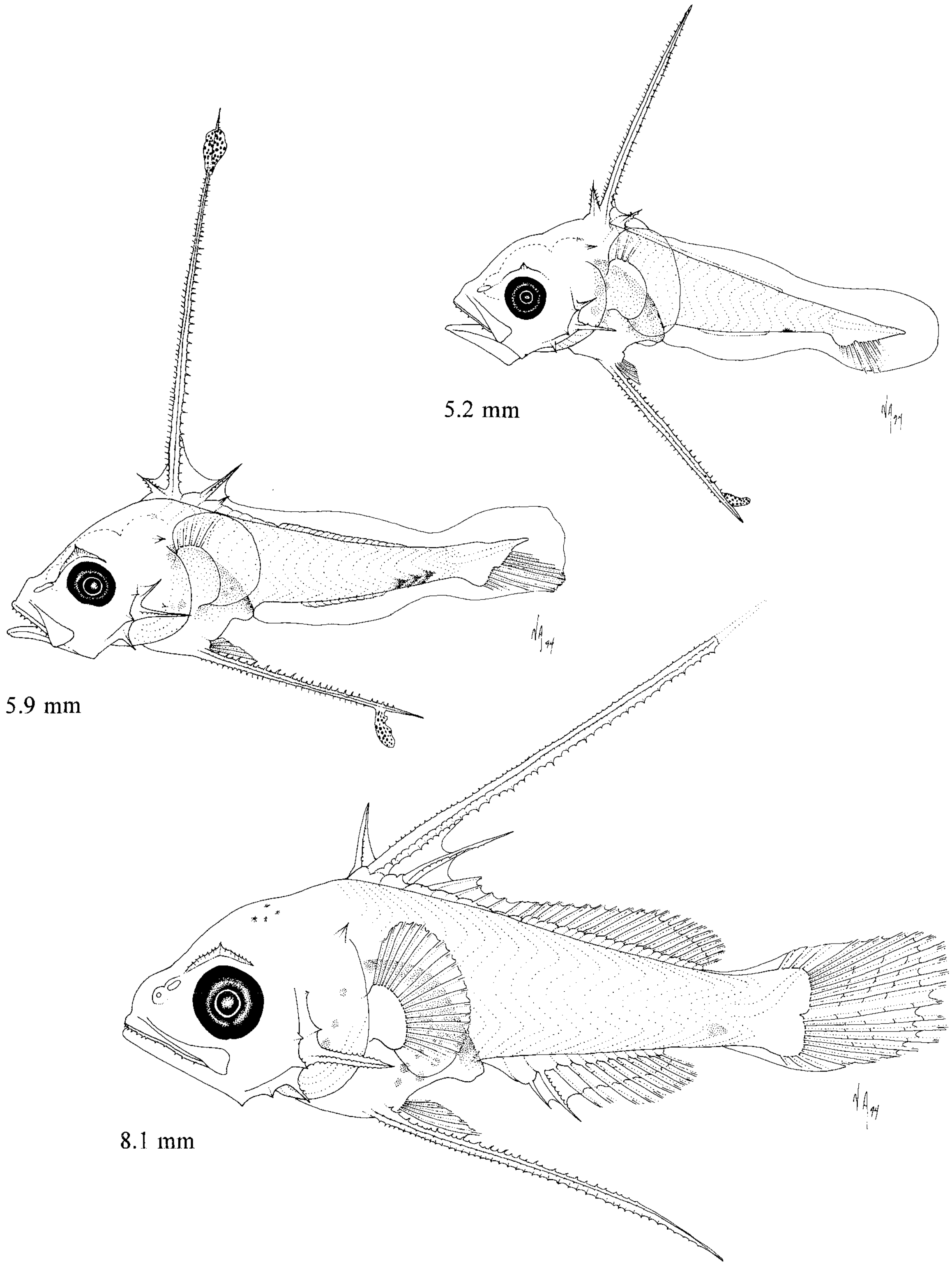


Figure Serranidae 9. Preflexion larva, 5.2 mm (CalCOFI 5706, station 140G.20); flexion larva, 5.9 mm (IATTC 90018, station AAB1 #1 Grn); postflexion larva, 8.1 mm (CalCOFI 5706, station 141G.29).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	VII–VIII	VII
Dorsal rays	20–24	20–21
Anal spines	III	III
Anal rays	16–19	17
Pelvic	I,5	I,5
Pectoral	16–18	16–17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	4–5	4
Lower	3–4	3
Gill rakers:		
Total	14–17	
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Central Gulf of California to Panama; larvae collected as far north as vicinity of Todos Santos, Baja California Sur on outer coast (23°27′ N)

Habitat: Shelters in crevices & caves in rocky reefs

Spawning season: Larvae collected in summer & fall (August–October)

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.5 mm (N. Arthur)
Flexion larva, 3.7 mm (N. Arthur)
Postflexion larva, 13.3 mm (N. Arthur)

* Eye somewhat oval, becoming round or nearly so in postflexion stage; horizontal axis is given first, vertical axis second.

† DII broken & partially missing in all flexion stage specimens & in all but two each of the postflexion stage & transformation specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

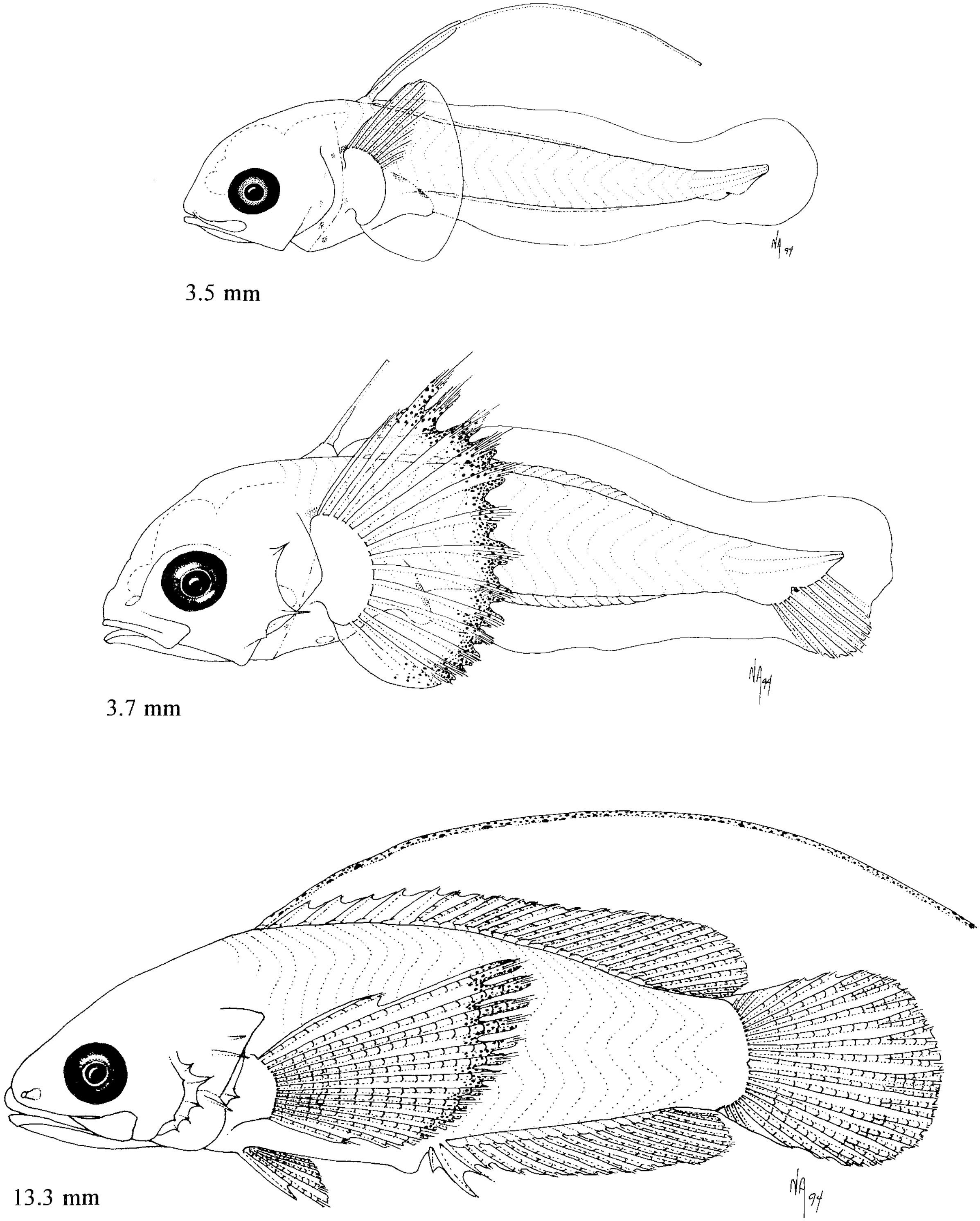
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 3.5–4.5 mm
Transformation length: ca. 12.5–15 mm
Fin development sequence: P_1 & 1D, C_1, A, 2D, C_2 & P_2
Pigmentation: *Larvae*—Dorsally on gas bladder; 1–few dorsally on hindgut, usually not visible after 4.3 mm; few on liver, usually not visible after 4.3 mm; on distal 20–25% of P_1 by 3.7 mm; discrete patches on sheath covering elongate dorsal spine by 7.5 mm; none to few on tips of central P_2 rays after 13 mm. *Transformation*—Becoming completely pigmented on body & fins; distinct black blotch on upper opercle; light striping around eye.
Diagnostic features: Early development of elongate, slender dorsal spine (spine II, but appears as first spine) & large, fan-like P_1 with marginal pigmentation; myomeres 25–26 (7–8+17–18 through mid-flexion, 12–13+12–13 in postflexion stage); larvae unpigmented except on P_1, on elongate D spine, & little on gas bladder & gut.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			46–54	49–59	51–59	58–60
		43	50	54	56	59
BD/BL			29–32	24–31	24–30	28–33
		24	30	28	26	30
HL/BL			26–30	24–32	33–36	32–37
		27	28	29	35	35
HW/HL			58–67	43–57	36–43	43–59
		58	64	46	40	48
SnL/HL			26–31	22–33	17–24	15–18
		30	30	26	20	16
ED/HL*			30–35×	23–29×	21–23×	20–22×
			26–31	23–29	21–22	19–22
		32×27	34×30	26×25	22×22	21×21
P_1L/BL			29–40	29–40	28–35	23–28
		19	34	36	32	26
P_2L/BL			0–1	10–16	10–14	11–13
		0	0.3	14	13	12
DSL/BL†				57–>99	5–>7	6–7
		40				6



3.5 mm

3.7 mm

13.3 mm

Figure Serranidae 10. Preflexion larva, 3.5 mm (CalCOFI 5708, station 139G.22); flexion larva, 3.7 mm (CalCOFI 5708, station 137G.30); postflexion larva, 13.3 mm (CalCOFI 5708, station 133G.40).

PRIACANTHIDAE: Catalufas, bigeyes

W. Watson

Priacanthidae contains about 18 species in four genera (Starnes 1988); four species representing all four genera occur in the California Current vicinity (Table Priacanthidae 1). *Pristigenys serrula* is endemic to the eastern Pacific, ranging from Oregon to Chile along the continental shelf and at offshore islands. *Priacanthus alalaua* is a Pacific species known from Baja California Sur, the Islas Revillagigedos, and Hawaii. *Cookeolus japonicus* and *Heteropriacanthus cruentatus* are circumglobal species that range northward in the CalCOFI study area to Baja California Sur and Baja California, respectively; both species are most common in insular habitats (Starnes 1988). Larvae of two species (*P. serrula* and an unidentified species) have been taken in CalCOFI and other ichthyoplankton collections, all from stations along both coasts of Baja California Sur and farther south.

Adult priacanthids are medium-size (most ca. 25–35 cm, maximum ca. 50 cm) residents of reef habitats on the continental shelf and upper slope and around oceanic islands, from the shallow subtidal zone to depths of at least 400 m. Priacanthids are deep-bodied and compressed, with a large oblique mouth, large eyes, a continuous dorsal fin composed of both spines and rays, and modified spiny scales (Starnes 1988). Most are bright red to reddish with silvery bars or blotches.

Spawning has not been documented for the eastern Pacific priacanthids, but some other *Pristigenys* and *Priacanthus* species spawn small spherical planktonic eggs from which small larvae hatch with a large yolk sac, unpigmented eyes, and an undeveloped mouth (Leis and Rennis 1983). Larval priacanthids are moderately deep-bodied with a coiled compact gut that lengthens with development (preanal length ca. 50% BL in the preflexion stage, ca. 66% BL during the postflexion stage). The head is large, with a large eye and short snout, and with well-developed serrate preopercular and supraoccipital spines, as well as numerous smaller spines on much of the head and pectoral girdle. Maximum relative spine lengths are attained during the postflexion stage and the supraoccipital crest and spine gradually disappear during the transformation and pelagic juvenile stages. Pelvic fins are large. Larval pigment typically is heavy dorsally and laterally on the head and gut and, beginning in the postflexion stage, on the lateral surfaces of the trunk and tail and on the spiny dorsal and pelvic fins. Barred or mottled patterns are common in pelagic juveniles.

Larval priacanthids are distinctive and are unlikely to be confused with most other fish larvae in the CalCOFI study area. Early preflexion stage priacanthid larvae superficially resemble young holocentrid larvae, but have fewer myomeres (usually 23 versus usually 26) and lack the rostral spine that typifies larval holocentrids larger than ca. 2 mm. Postflexion stage and older *Pristigenys serrula* are easily distinguished from the other eastern Pacific priacanthid species by their lower dorsal and anal fin-ray counts (Table Priacanthidae 1); it is unknown how younger larvae might differ. Preflexion and flexion stage larvae identified here as *P. serrula* were collected primarily from the Gulf of California where only *P. serrula* commonly occurs (*Cookeolus japonicus* and *Heteropriacanthus cruentatus* may occur in the Cabo San Lucas area: Fitch and Crooke 1984; Starnes 1995). Larval *P. serrula* usually have few to no melanophores on the ventral margin of the tail (usually only on the last few myomeres when present) in contrast to the larvae (preflexion stage) of the unidentified species (possibly *H. cruentatus*) which have a series of ca. 10–12 melanophores extending along the length of the tail.

The following description of *P. serrula* is based on detailed examinations of 17 larvae (5 preflexion, 2.9–3.6 mm; 5 flexion, 3.3–4.1 mm; 2 postflexion, 4.5–4.8 mm; 5 transformation, 6.5–8.6 mm) and 3 pelagic juveniles (14.1–23.1 mm). Larvae of the other species were not identified in samples and are not described. Larval *Cookeolus japonicus* and *Heteropriacanthus cruentatus* are described and illustrated (as *C. boops* and *Priacanthus cruentatus*) in Kinoshita (1988b), and are shown here in Figure Priacanthidae 1. Meristic data and ecological information were obtained from the literature (Fritzsche 1978b; Thomson et al. 1979; Fitch and Crooke 1984; Starnes 1988, 1995) and from observations made during the present study.

Table Priacanthidae 1. Meristic characters for the priacanthid species that may be encountered in the California Current vicinity. All have 10+13 vertebrae, 8+8 principal caudal fin rays, I,5 pelvic fin rays, and 6 branchiostegal rays.

	Fin rays				
Species	D	A	P_1	C_2	Gill rakers
Cookeolus japonicus	X,12–14	III,12–14	17–19	4+4	5–8+17–20
Heteropriacanthus cruentatus	X,12–13	III,13–15	17–19	4+4	4–6+17–20
Priacanthus alalaua	X,12–14	III,13–14	17–19	5+5	4–6+14–18
Pristigenys serrula	X,10–12	III,10–11	17–18	3–5+3–4	6–8+15–18

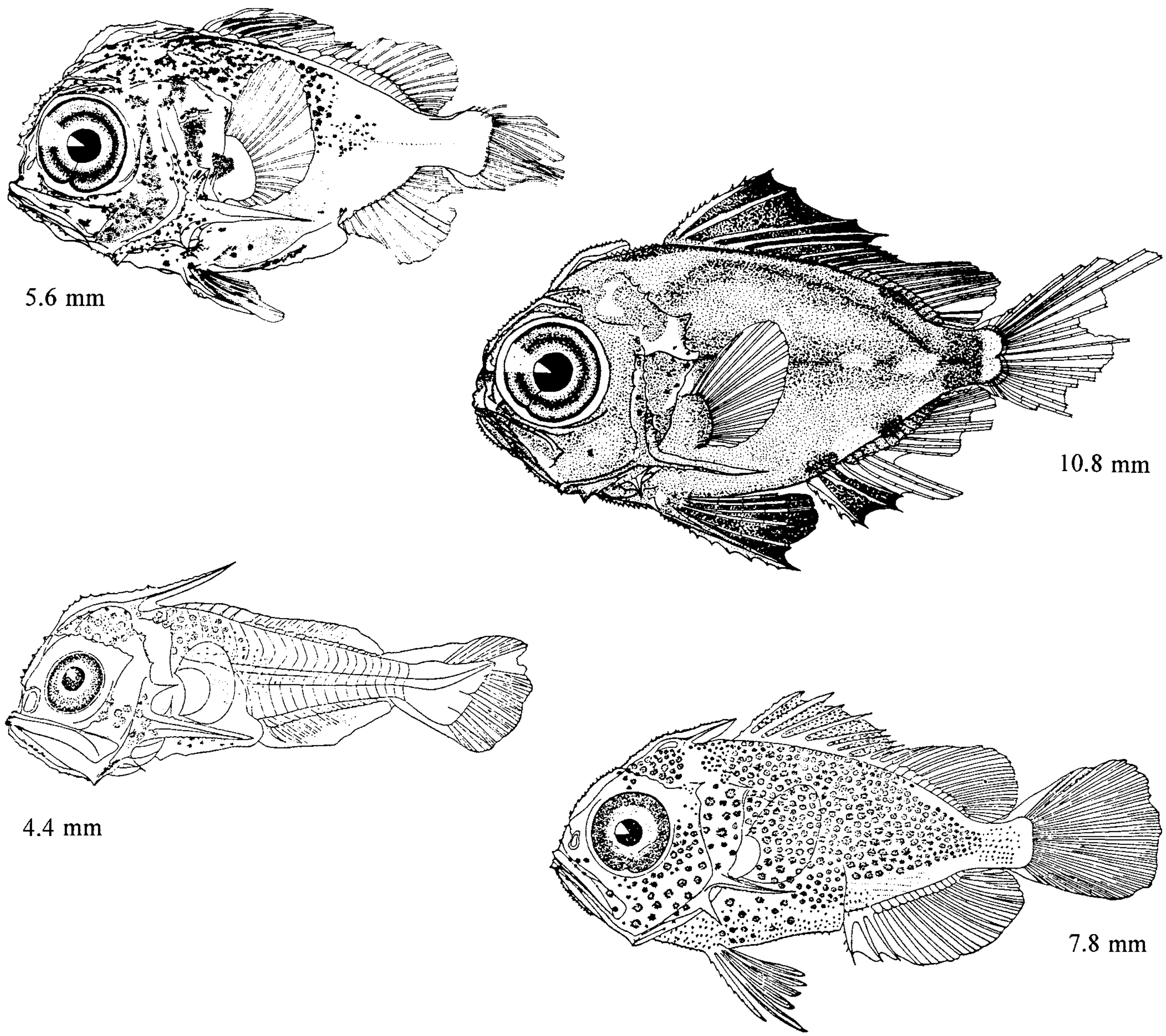


Figure Priacanthidae 1. *Cookeolus japonicus* (above) postflexion larvae, 5.6 mm, 10.8 mm; *Heteropriacanthus cruentatus* (below) flexion larva, 4.4 mm, and postflexion larva, 7.8 mm (Kinoshita 1988b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	23	23
Precaudal	10	10
Caudal	13	13
Fins:		
Dorsal spines	X	X
Dorsal rays	10–12	11
Anal spines	III	III
Anal rays	10–11	10
Pelvic	I,5	I,5
Pectoral	17–18	17
Caudal:		
Principal	8+8	8+8
Procurrent:		
Upper	3–5	4
Lower	3–4	3–4
Gill rakers:		
Upper	6+8	
Lower	15–18	16–17
Branchiostegals	6	6

LIFE HISTORY

Range: Newport, Oregon, to Antofagasta, Chile; primarily southern California to Peru

Habitat: Rocky reefs on continental shelf & around islands, <5 m depth to 100 m or more, typically ca. 25–75 m depth

Spawning season: Larvae occur primarily from August–December

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.9 mm (B. Sumida MacCall)
Flexion larva, 4.0 mm (B. Sumida MacCall)
Postflexion larva, 4.5 mm (B. Sumida MacCall)
Transformation specimen, 7.2 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk diam.:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.9 mm
Flexion length: 3.3–3.6 mm through ca. 4.2 mm
Transformation length: ca. 6.5–14 mm
Fin development sequence: C_1, D & A & P_1, P_2, C_2
Pigmentation: *Preflexion*—Heavy over forebrain, midbrain, & anteriorly over hindbrain; under mid- & hindbrain; heavy on inner surface of gill cover, especially under preopercle; 0–2 on gular area (usually 0); internally at nape; heavy dorsally, dorsolaterally, & anteriorly on gut, few along ventral margin of gut; 0–10 on ventral margin of tail, usually only on last few myomeres & under notochord tip. *Flexion–postflexion*—Increasing on head, spreading along lower part of supraoccipital spine; increasing on gut, completely surrounding it by 4.5 mm; decreasing ventrally on tail, usually none by ca. 4 mm; forming on P_2 at ca. 3.9 mm & on 1D by ca. 4.5 mm. *Transformation*—Heavily pigmented except on end of caudal peduncle, P_1, A, 2D, & C.
Diagnostic features: Myomeres usually 10–11+12–13=23; D rays usually 11, A rays usually 10 (present in postflexion stage); pigment light or absent ventrally on tail; usually little or no pigment on gular area.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	PJuv
Sn-A/BL		50–58 55	53–60 56	62–63 63	64–68 66	66–68 67
BD/BL		31–42 37	35–41 38	45–48 47	56–60 58	65–66 66
HL/BL		32–43 38	35–43 38	43–46 44	40–46 43	39–44 42
HW/HL		62–86 73	69–79 76	68–78 73	67–88 76	69–99 84
SnL/HL		17–28 22	18–24 21	18–18 18	12–19 16	11–23 16
ED/HL		36–41 39	35–41 39	41–44 42	42–51 46	39–46 40
P_1L/BL		6–12 9	9–12 11	13–14 14	19–21 20	18–24 21
P_2L/BL		0–2 0.4	0–7 3	18–19 18	26–33 31	37–42 39
PrSL/HL		23–51 39	50–54 52	55–57 56	21–51 37	15–18 16
SoCL/HL		51–75 61	57–76 70	 53	23–39 33	0–3 1

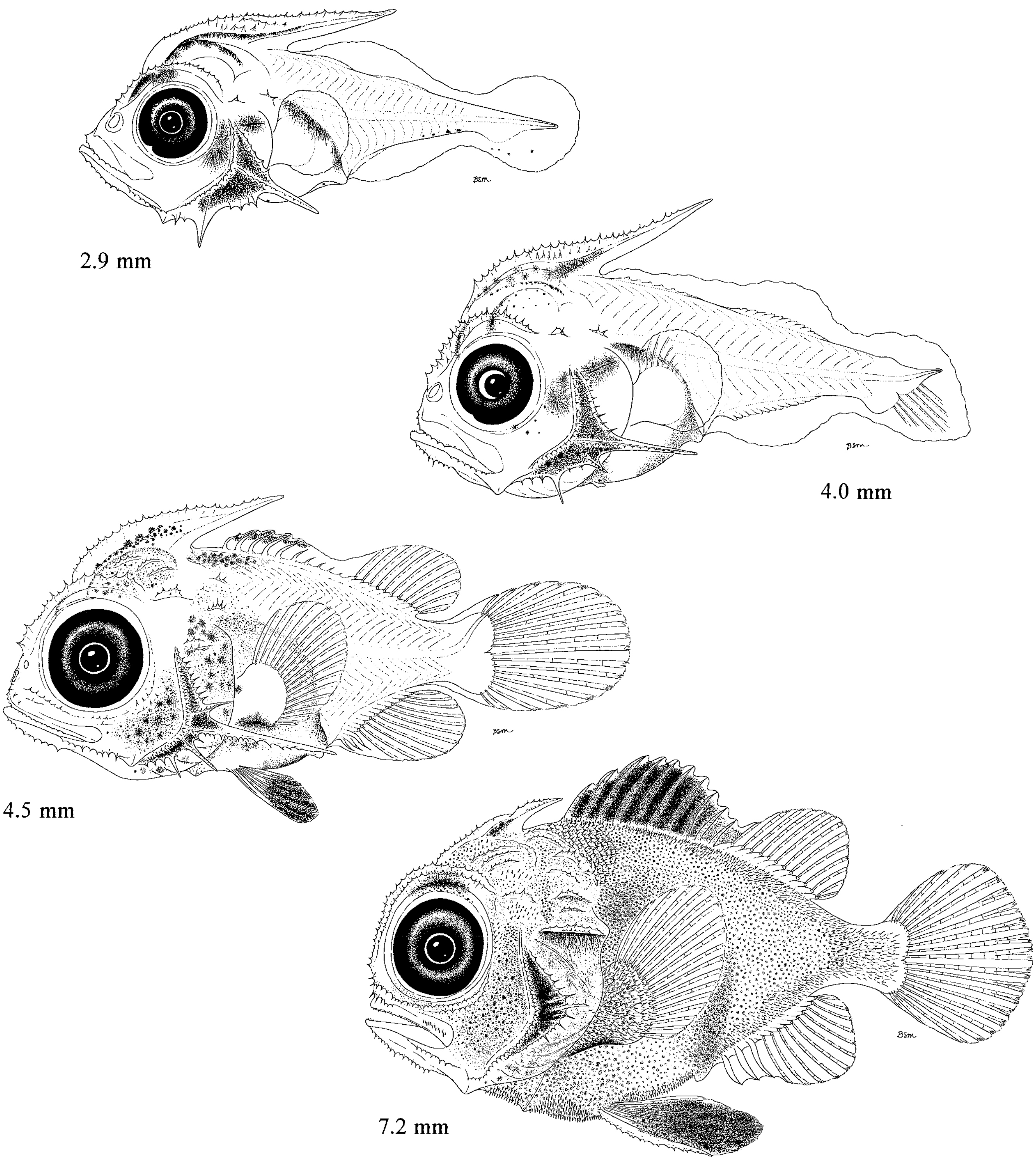


Figure Priacanthidae 2. Preflexion larva, 2.9 mm (CalCOFI 5209, station 144.5G.10); flexion larva, 4.0 mm (CalCOFI 5612, station 167G.50); postflexion larva, 4.5 mm (CalCOFI 5209, station 130.5G.43); transformation specimen, 7.2 mm (CalCOFI 5110, station 137.23; scales on flank are not shown).

APOGONIDAE: Cardinalfishes

E. M. SANDKNOP AND W. WATSON

Apogonidae, as presently understood, consists of two subfamilies containing a total of about 122 species in 22 genera (Nelson 1994). Three *Apogon* species range into the CalCOFI study area (Table Apogonidae 1) primarily off southern Baja California Sur, although *A. guadalupensis* has been recorded as far north as San Clemente Island, California (Hobson 1969). A few larvae of *A. atricaudus* and *A. guadalupensis* have been identified in CalCOFI collections taken from summer through early winter at stations in the vicinity of Isla de Guadalupe and between about Punta San Pablo and Todos Santos, Baja California Sur; larvae of all three species have been collected from the Gulf of California and the Pacific coast farther south.

Apogonids are small (most species <10 cm), usually nocturnal, predatory residents of reefs and shallow coastal waters in all warm seas. A few species occur in estuaries and a few others are restricted to freshwater. Apogonids are moderately compressed, ranging in form from moderately deep-bodied to moderately elongate. In most, preanal length is a little more than half of body length. All have large eyes, a large mouth, and two separate dorsal fins. Pigmentation is varied, ranging from a more or less uniform translucent pink to red, to various patterns of stripes, bars, or spots. Shades of orange to red are common, as the vernacular name implies. Some species are utilized in the aquarium trade.

Cardinalfishes are oviparous. Most, perhaps all, orally incubate egg clusters. Individual eggs are spherical, less than 1 mm in diameter, and are attached to one another via adhesive threads arising from one pole (e.g., Breder and Rosen 1966; Charney 1976; Johnson 1984). Larvae hatch at ca. 2.5–3 mm with pigmented eyes, a functional mouth, and a small yolk sac (Allen 1975; Miller et al. 1979). Although the family includes a wide variety of larval types in both appearance and development (e.g., Leis and Rennis 1983), within the CalCOFI study area all are very similar in both respects. They are compressed, moderately elongate initially but becoming less so with development, and have preanal length about half of body length. The gas bladder is prominent throughout development. The head is large, with moderately large eyes and large mouth. Small spines form along the posterior preopercular margin late in the preflexion stage. There are two basic initial pigmentation (melanophore) patterns in the CalCOFI species: 1) a few around the brain, moderate to heavy covering on the branchiostegal membranes, and on the gas bladder and gut; and 2) dorsally on the head, on the gas bladder and gut, and series along the dorsal margin, lateral midline, and ventral margins of the gut and tail. Ontogenetic changes in the first pattern (*A. guadalupensis*, *A. retrosella*) consist primarily of a gradual increase in pigmentation of the head and gut. In the second pattern (*A. atricaudus*), the longitudinal series melanophores are gradually lost so that during the postflexion stage the larvae become pigmented only on the head and gut.

Larval apogonids in the CalCOFI study area superficially resemble the larvae of several percoid families, most notably the opistognathid species that have heavily pigmented branchiostegal membranes, and some of the carangids, which have longitudinal melanophore series like those of *A. atricaudus*. Compared with the opistognathids, apogonids have somewhat smaller eyes, a smaller mouth, fewer myomeres (24 vs. 25–30 in opistognathids), and lower dorsal and anal fin-ray counts (difference apparent by midflexion). *A. atricaudus* is easily distinguished from carangids by its somewhat shorter preanal length, lack of preopercular spines before late preflexion stage and presence of only a few small spines thereafter vs. early development of several spines, one (or more) of which becomes large. *A. atricaudus* lacks a supraoccipital crest, which many carangid species develop in the preflexion stage. Dorsal and anal fin-ray counts readily distinguish apogonids (fewer rays) from carangids (more rays) by midflexion. The apogonid species are distinguishable from one another primarily by pigment pattern, eye diameter, and caudal peduncle depth, as shown in the following species descriptions. The differences between larval *A. guadalupensis* and *A. retrosella* are small and unequivocal identification is not always possible.

Species descriptions are based on detailed examination of 18–29 specimens of each species (Table Apogonidae 2). Meristic data were obtained from Allen and Robertson (1994) and from counts made during this study. Ecological information was from Thomson et al. (1979) and Allen and Robertson (1994).

Table Apogonidae 1. Meristic characters for the apogonid species in the CalCOFI study area.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	P_2	C_2
Apogon atricaudus	10	14	24	VI+I,9	II,8	11–12	I,5	8–10+8–9
A. guadalupensis	10	14	24	VI+I,9	II,8	11–12	I,5	6–9+7–8
A. retrosella	10	14	24	VI+I,9–10	II,8	11–12	I,5	8+8

Table Apogonidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the apogonid species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Apogon atricaudus	0	0	5 2.7–3.3	6 3.3–4.6	9 5.0–9.6	0	3 20.8–28.3
A. guadalupensis	0	0	2 3.0–3.0	4 3.6–4.5	9 4.5–7.7	0	3 21.8–25.2
A. retrosella	0	0	6 3.0–3.7	7 3.4–4.3	10 4.1–10.6	3 11.0–16.3	3 14.5–18.8

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VI+I	VI+I
Dorsal rays	9	9
Anal spines	II	II
Anal rays	8	8
Pelvic	I,5	I,5
Pectoral	11–12	11–12
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	9
Lower	8–9	8
Gill rakers:		
Upper	5	5
Lower	13	13
Branchiostegals	7	7

LIFE HISTORY

Range: Adult range reported as Cabo San Lucas to Punta Pescadero, Baja California Sur and Islas Revillagigedo; larvae have been collected from the vicinity of Isla de Guadalupe and south of Punta Abreojos, Baja California Sur, and in the Gulf of Panama

Habitat: Rocky reefs in shallow water (ca. 3–50 m depth)

Spawning season: Larvae collected June–December

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.0 mm (R. C. Walker)
Flexion larva, 4.6 mm (R. C. Walker)
Postflexion larvae, 6.0 mm, 9.6 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.7 mm
Flexion length: ca. 3.3–4.8 mm
Transformation length: >9.6 mm, <21.7 mm
Fin development: C_1, 2D & A & 1D, P_1, P_2 & C_2
Pigmentation: *Preflexion*—Anteriorly over forebrain; anteriorly & posteriorly over midbrain, spreading from both areas toward center along longitudinal midline to form medial band over midbrain by 3 mm; internally over hindbrain by 2.7 mm & laterally on hindbrain by 3 mm; internal series along base of skull, decreasing after 3 mm; 0–1 at angular; 11–15 on dorsal margin at myomeres 1 through 15–16; ca. 9–10 along lateral midline at myomeres 1–5 through 16–17; 7–8 on ventral margin of tail at postanal myomeres 1 through 6–8; over gas bladder & hindgut; on gular membrane, isthmus, & ventral margin of gut. *Flexion*—Increasing over fore- & midbrain & internally posteriorly on midbrain and hindbrain; little or none ventrally on skull; decreasing on dorsal margin, lateral midline, & ventrum. *Postflexion*—Little or none on trunk & tail after 5 mm; slowly increasing dorsally on head & internally on mid- & hindbrain.
Diagnostic features: Series of melanophores on dorsal & ventral margins & along lateral midline through at least early postflexion stage; no branchiostegal membrane pigment; 24 myomeres (8 preanal in preflexion stage, 9–10 in postflexion stage).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		49–56 52	54–66 59	54–57 55		53–55 54
BD/BL		22–29 24	29–37 34	31–39 35		29–31 30
HL/BL		26–34 29	32–35 34	33–37 35		35–38 37
HW/HL		38–49 43	28–44 38	47–54 49		44–47 45
SnL/HL		24–29 27	25–30 28	20–28 25		23–27 25
ED/HL		29–38 33	26–35 28	29–34 31		30–32 31
P_1L/BL		5–9 7	6–9 7	8–14 12		21–23 22
P_2L/BL		0–0 0	0–4 2	7–15 12		19–21 20

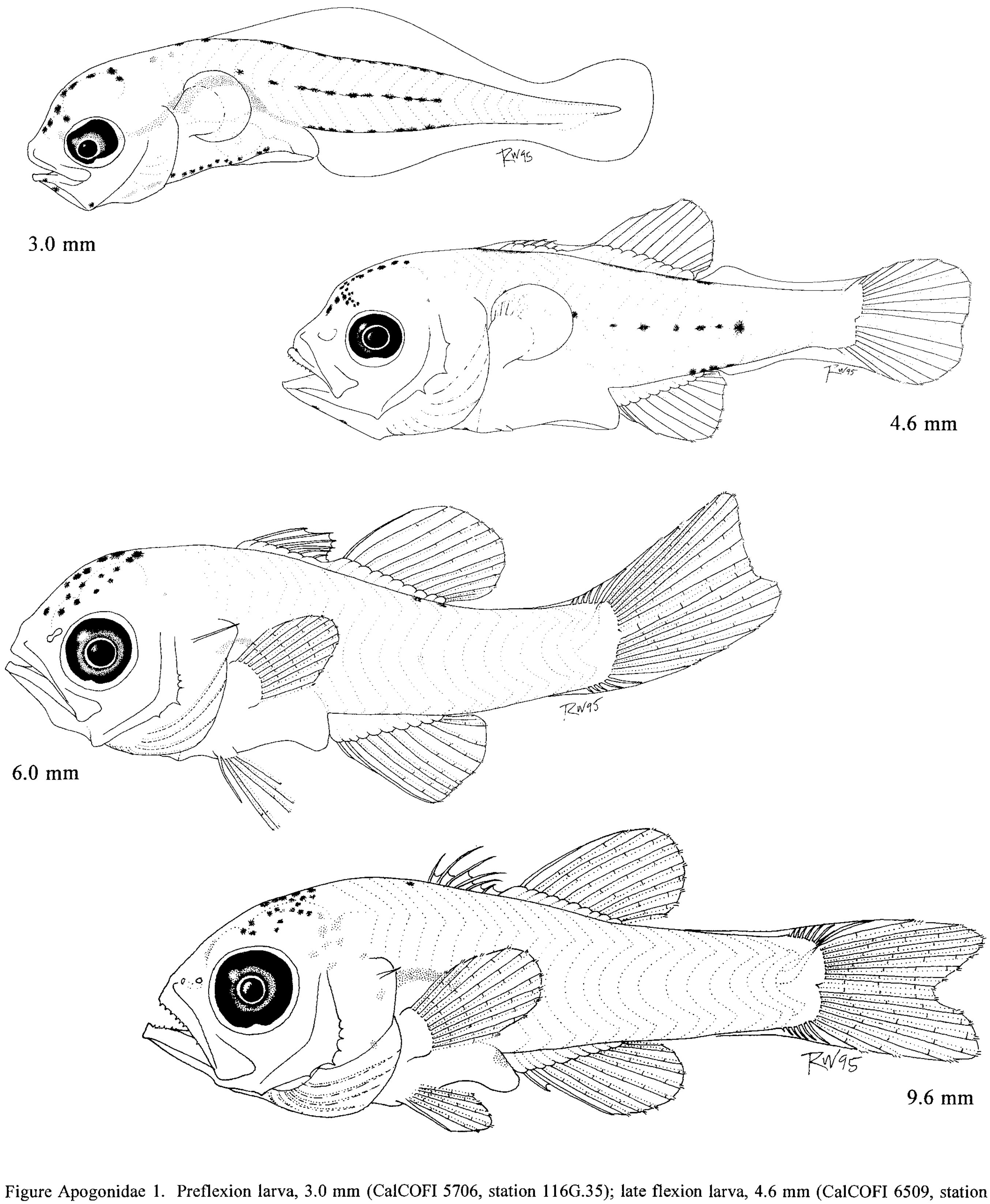


Figure Apogonidae 1. Preflexion larva, 3.0 mm (CalCOFI 5706, station 116G.35); late flexion larva, 4.6 mm (CalCOFI 6509, station 133.50); postflexion larvae, 6.0 mm (CalCOFI 5810, station 150.25), 9.6 mm (CalCOFI 5910, station 127.50).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VI+I	VI+I
Dorsal rays	9	9
Anal spines	II	II
Anal rays	8	8
Pelvic	I,5	I,5
Pectoral	11–12	12
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	6–9	8–9
Lower	7–8	7–8
Gill rakers:		
Upper	5	5
Lower	13	13
Branchiostegals	7	7

LIFE HISTORY

Range: San Clemente Island, California, to Isla de Guadalupe, Isla Benito, and Rocas Alijos, Mexico

Habitat: Rocky reefs in shallow water

Spawning season: Larvae collected June–December

ELH pattern: Oviparous; eggs orally incubated by parent; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.0 mm (R. C. Walker)
Postflexion larvae, 4.5 mm, 7.7 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3 mm
Flexion length: ca. 3.5–4.5 mm
Transformation length: >7.7 mm, <21.8 mm
Fin development sequence: C_1, 2D & A, P_1, 1D, C_2, P_2
Pigmentation: *Preflexion*—Internally on posterior margin of midbrain after 3 mm; 1–2 on ventral margin of isthmus; on branchiostegal membrane, beginning as posteroventral patch & spreading to cover membrane; dorsally on gas bladder & hindgut; 1–few on ventrum of gut. *Flexion*—Over forebrain by 4.1 mm, spreading posteriorly over midbrain; increasing internally around posterior margin of midbrain; spreading down anterior margin of gut; 0–1 ventrally on gut. *Postflexion*—Increasing over fore- & midbrain, primarily along longitudinal midline; internally ventrolaterally on hindbrain at 4.5 mm, surrounding it by 5.2 mm; spreading upward from branchiostegal membrane onto gill cover.
Diagnostic features: Pigmented branchiostegal membranes; dorsal pigment on head primarily medial; compared with *A. retrosella*, eyes tend to be smaller & more oval & caudal peduncle slightly longer.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–52 50	52–56 54	47–52 50		54–54 54
BD/BL		30–30 30	32–37 35	31–35 33		26–30 28
HL/BL		29–32 30	30–35 33	33–39 35		37–39 38
HW/HL		41	58–58 58	36–36 52		43–44 43
SnL/HL		31–34 33	27–34 31	27–33 29		22–24 23
ED/HL		29–30 29	31–32 31	28–32 30		31–35 32
P_1L/BL		7–7 7	6–7 6	8–18 10		23–24 23
P_2L/BL		0–0 0	2–2 2	2–13 7		20–21 20
CPL/BL				32–37 34		30–31 30

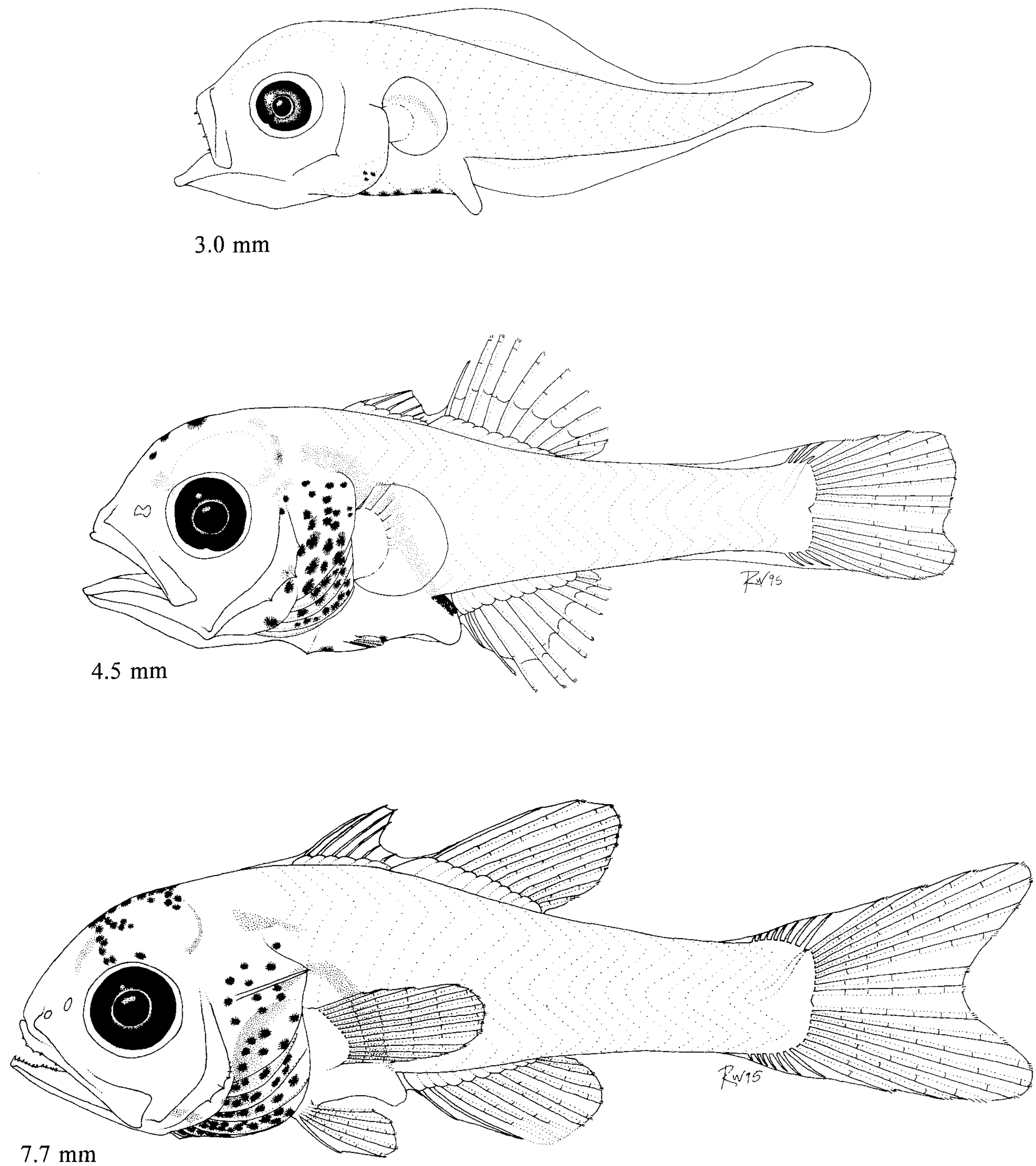


Figure Apogonidae 2. Preflexion larva, 3.0 mm (CalCOFI 5610, station 140.30); postflexion larvae, 4.5 (CalCOFI 5612, station 171G.38), 7.7 mm (CalCOFI 5706, station 129G.31).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VI+I	VI+I
Dorsal rays	9–10	9
Anal spines	II	II
Anal rays	8	8
Pelvic	I,5	I,5
Pectoral	11–12	11
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8	8
Lower	8	8
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Bahía Santa Maria, Baja California Sur, & throughout Gulf of California to Panama

Habitat: Rocky reefs in shallow water (to 61 m depth)

Spawning season: Larvae collected May–December

ELH pattern: Oviparous; egg mass orally incubated by parent; planktonic larvae

LITERATURE

Thomson et al. 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.1 mm (R. C. Walker)
Flexion larva, 3.9 mm (R. C. Walker)
Transformation specimen, 16.2 mm (R. C. Walker)
Juvenile, 17.8 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment: Live eggs bright orange
Diagnostic features:

LARVAE

Hatching length: <3 mm
Flexion length: 3.4–3.7 mm through 4.1–4.3 mm
Transformation length: ca. 11 mm through 14.5–16.3 mm
Fin development sequence: C_1, 2D & A, 1D, P_1 & C_2, P_2
Pigmentation: *Preflexion*—Anteriorly on forebrain; few to many in longitudinal medial band over midbrain; laterally on posterior margin of midbrain; dorsally & dorsolaterally posteriorly on hindbrain by 3.4 mm; 0–2 on gular area; 2–several on isthmus; on branchiostegal membranes, primarily on lower half; dorsally on gas bladder & hindgut; 1–several ventrally on anterior half of gut. *Flexion*—On anterior margin of forebrain by 4.3 mm; ventrolaterally on hindbrain by 4.3 mm; spreading upward from branchiostegal membrane onto gill cover by 4.1 mm; internally on anterior margin of gut. *Postflexion*—Spreading laterally from medial midbrain band to cover all of midbrain area by 8 mm; hindbrain covered by 7.5 mm; 1 below mideye at 8 mm; internally anterior to heart by 4.7 mm; usually none ventrally on gular area, isthmus, & gut after 5 mm. *Transformation*—Patch forms over hypural area at 11 mm; bar begins to form below D 1–3 at the end of transformation stage; decreasing on branchiostegal membrane after 12 mm.
Diagnostic features: Pigmented branchiostegal membranes; pigment dorsally on head spreads laterally in postflexion stage; compared with *A. guadalupensis*, eyes tend to be larger & rounder & caudal peduncle slightly shorter.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–64 50	50–57 52	49–54 51	48–52 51	53–55 54
BD/BL		27–31 30	33–35 34	31–37 35	31–33 32	32–34 33
HL/BL		30–35 33	34–38 35	35–37 36	36–38 37	37–40 38
HW/HL		42–48 45	36–56 47	50–60 55	45–57 53	48–49 48
SnL/HL		28–31 29	28–31 31	19–32 27	23–31 26	21–25 23
ED/HL		30–31 31	27–33 30	31–37 33	27–36 32	32–35 33
P_1L/BL		5–8 7	7–11 8	11–16 13	21–23 22	22–25 24
P_2L/BL		0–0 0	0–6 1	5–16 11	16–17 17	20–23 21
CPL/BL				30–36 33	31–33 32	30–33 31

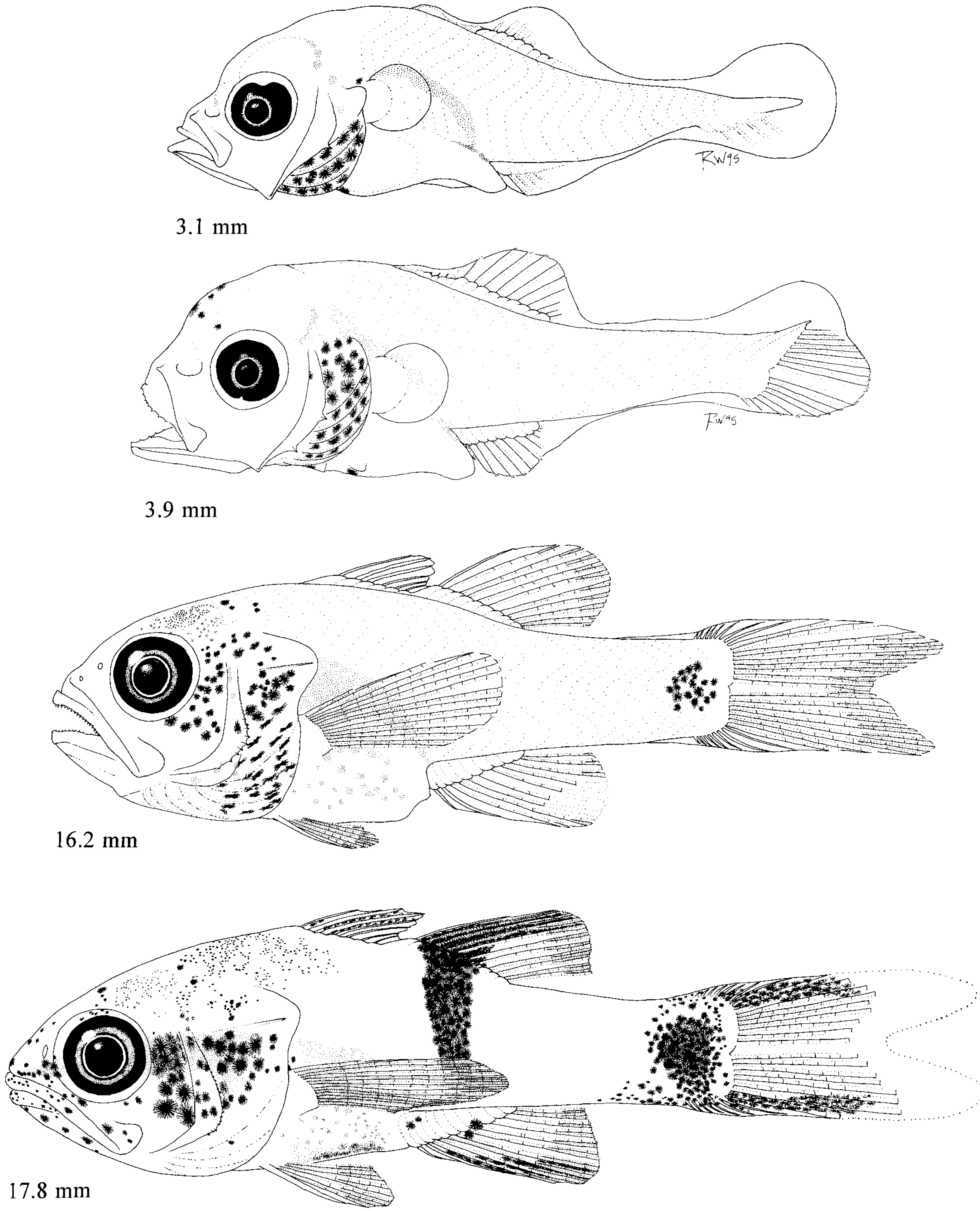


Figure Apogonidae 3. Preflexion larva, 3.1 mm (CalCOFI 7210, station 157G.150); flexion larva, 3.9 mm (CalCOFI 5708, station 128G.27); transformation specimen, 16.2 mm (IATTC 89012, station D1 Red); juvenile, 17.8 mm (SIO 65–340). Developing scales on the transformation specimen and scales on the juvenile not shown.

ECHENEIDAE: Remoras

W. WATSON

Echeneidae contains eight species in four genera (Nelson 1994); seven of the eight occur in the California Current vicinity (Table Echeneidae 1). All seven range widely in warm waters of the Indo-Pacific (*Remorina albescens*) or worldwide (the others). In the eastern Pacific, *Remora australis* ranges northward to British Columbia, *R. remora* and *Remorina albescens* reach central California, and the others range only as far north as southern California (Miller and Lea 1972; Eschmeyer et al. 1983). Spawning may not occur in the CalCOFI study area: no remora larvae have been identified in CalCOFI ichthyoplankton samples.

Remoras are small to large (maximum sizes range from about 20–100 cm) marine fishes that commonly attach themselves to hosts such as large fishes, marine mammals, or sea turtles. Some species are strongly host-specific. Most are free-swimming at least occasionally. Remoras use a sucking disc on the head for attachment to a host. The laminae of the disc, modified from the spines of the spinous dorsal fin, provide the necessary suction. Remoras are elongate, roughly cylindrical but with a flattened head, and with dorsal and anal fins opposite one another posteriorly. Remoras typically are grey or grey-blue to brown; some are striped.

Remoras are oviparous, with planktonic eggs and larvae (e.g., Johnson 1984). Eggs are separate and spherical, 2.1–2.7 mm in diameter, have a smooth to slightly sculptured chorion, a narrow perivitelline space, and contain a colorless homogeneous yolk with 1–5 yellow oil globules ca. 0.1–0.3 mm in diameter (Delsman 1926a, 1931; John 1950; Akazaki et al. 1976). Newly hatched larvae are ≤7.5 mm, with a large yolk sac, unpigmented eyes, and an unformed mouth (John 1950; Akazaki et al. 1976). The elongate larvae have a preanal length initially of 60–73% BL, shortening to 50–62% BL by the postflexion stage (Akazaki et al. 1976; Leis and Trnski 1989). The head is moderately small with an elongate snout. Large hook-like, horizontally oriented dentary teeth form during the latter part of the preflexion stage or during notochord flexion and characterize remoras throughout the remaining larval period (Johnson 1984; Leis and Trnski 1989). There are no spines on the head or pectoral girdle. The cephalic disk begins to form above the level of the pectoral fins just before, or during notochord flexion, broadening and shifting forward on the head as it develops (Akazaki et al. 1976; Leis and Trnski 1989). Anlagen of the anal and second dorsal fins originate in the respective finfolds near, but separated from, the body margin. Both are in contact with the body margin by the time fin rays begin to form during notochord flexion (Leis and Trnski 1989). Larvae are moderately to heavily pigmented, with melanophores on the dorsum and ventrum and along the lateral midline, or spread more generally over the entire body. The gut commonly is less heavily pigmented, at least ventrally, than the trunk and tail.

Larval remoras are easily recognized by their characteristic dentary teeth, cephalic disc (in the postflexion stage, at least), elongate shape with Sn-A length ca. 50–70% BL, lack of spination on the head and pectoral girdle, 26–30 myomeres (ca. 40 in *Phtheirichthys*), and moderate to heavy pigmentation. They are unlikely to be confused with any other larvae in the CalCOFI study area.

Because remora larvae have not been identified from the CalCOFI study area, individual species descriptions are not given here. Instead, example illustrations of *Echeneis naucrates* are shown in Figure Echeneidae 1. Refer to John (1950), Akazaki et al. (1976), Martin and Drewry (1978), Johnson (1984), and Leis and Trnski (1989) for additional information.

Table Echeneidae 1. Meristic characters for the echeneid species in the California Current vicinity. Dorsal counts are given as the number of laminae plus the number of articulated fin rays. All remoras have 9+8 principal caudal fin rays and I,5 pelvic fin rays. Data are from Miller and Lea (1972), Heemstra (1986f) and counts made during this study.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers
Echeneis naucrates	12–14	16–17	29–30	20–28+31–34	30–38	21–24	10–11+10–12	11–16 (lower)
Phtheirichthys lineatus	19	20–22	39–41	9–11+30–40	29–38	17–21	10+9	1–3+10–17
Remora australis	12	15	27	24–28+20–27	20–26	21–24	12–15+13–15	1–3+13–19
R. brachyptera	12–13	14–15	27	14–17+27–34	25–34	23–27	10–11+9–12	12–14 (lower)
R. osteochir	13	14	27	16–20+20–27	20–26	20–24	7–9+7–9	
R. remora	11–12	15–16	27	16–20+21–27	21–25	26–30	11–13+11–13	4–6+25–28
Remorina albescens	12–13	13–14	26	12–14+17–22	16–26	16–21	9–10+10–12	10 (lower)

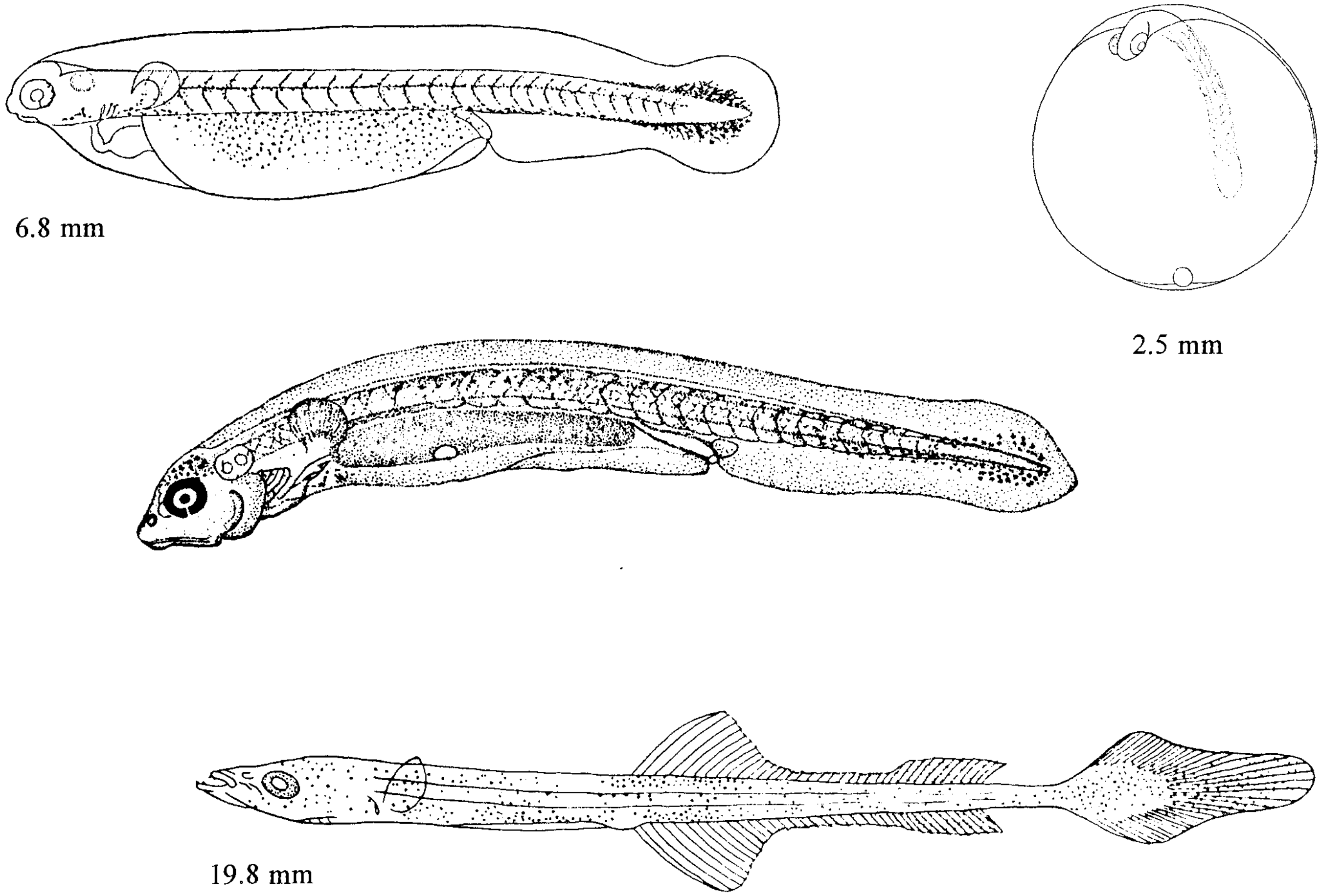


Figure Echeneidae 1. *Echeneis naucrates*: egg, 2.5 mm; late-stage embryo dissected from egg, 6.8 mm (Delsman 1931); late yolk-sac larva, length not given (John 1950); postflexion larva, 19.8 mm (Akazaki et al. 1976).

CARANGIDAE: Jacks

W. WATSON, S. R. CHARTER, H. G. MOSER,
D. A. AMBROSE, AND E. M. SANDKNOP

Carangidae contains about 140 species in 32 genera, usually separated into four tribes (Smith-Vaniz 1984; Gushiken 1988) or subfamilies (Nelson 1994). Monophyly of the family, based primarily on the separation of the first two anal fin spines (one spine in *Elagatis* and *Seriolina*) from the third (Smith-Vaniz 1984), is generally accepted and the composition of the tribes (or subfamilies) is fairly well settled. At least 32 carangid species in 16 genera, representing all four tribes, occur within the CalCOFI study area (Table Carangidae 1), primarily near its southern limit off Baja California Sur. Fourteen species range as far north as southern California and three of them reach British Columbia or Alaska (Table Carangidae 2). Larval *Trachurus symmetricus* are collected regularly during CalCOFI surveys, mainly from late winter through early summer (May–June maximum) at stations ca. 185–555 km offshore between Point Conception and Punta Eugenia. Larval *Seriola lalandi* also occur relatively commonly but in smaller numbers, during summer (August maximum), usually within ca. 370 km from shore off the Baja California peninsula. Larvae of the other carangid species rarely occur in CalCOFI collections; none has been taken north of Punta Abreojos, Baja California Sur. Larvae of several carangid species have been collected (occasionally in large numbers) during various ichthyoplankton surveys in the Gulf of California and along the Pacific coast of mainland Mexico and Central America, and during the EASTROPAC surveys of the eastern tropical Pacific.

Carangids are medium-size to large (ca. 30–150 cm or more) coastal and epipelagic, usually schooling residents of all warm seas. A few species may enter brackish or fresh water. Carangids are of considerable value to man: some (e.g., *Trachurus*) support large commercial fisheries, many others are important in smaller commercial and subsistence fisheries, and some (e.g., *Seriola*) are among the most highly prized of sport fishes. Carangids exhibit a variety of forms, ranging from deep-bodied and strongly compressed to elongate and broadly oval in cross section. Most commonly, they are moderately deep-bodied and compressed, with preanal length about half of body length. The dorsal fin is composed of a short-based spinous portion slightly separated from, or connected by a low membrane to, the long-based second dorsal which contains a spine and several soft rays. The first two anal spines (one, in *Elagatis* and *Seriolina*) are separated from the third anal spine. The caudal peduncle is slender and the caudal fin is deeply forked. Pelvic fins are lacking in adults of two species (P_2 present in all eastern Pacific species). Most species have small cycloid scales; the thoracic area is partially scaled or lacks scales in some species. In the tribe Carangini, the scales along the posterior part of the lateral line are modified to form enlarged, spiny, platelike scutes. Carangids commonly are green to blue or grey dorsally and silvery to white below, with golden highlights in some, and with barred or striped patterns in some. Juveniles commonly are barred.

Carangids are oviparous, spawning spherical planktonic eggs that have a smooth chorion 0.6–1.5 mm in diameter, and that contain a coarsely segmented yolk with one or more oil globules (usually one, ca. 0.2–0.4 mm in diameter) (e.g., Delsman 1926b; Laroche et al. 1984; Ikeda and Mito 1988; Leis and Trnski 1989; Olivar and Fortuño 1991). Larvae hatch at a length of ca. 1.3–4.3 mm with a large yolk sac containing the oil globule anteriorly, and lacking a mouth, pectoral fin buds, and eye pigmentation (e.g., Delsman 1926b; Ahlstrom and Ball 1954; Uchida et al. 1958b; de Ciechomski and Weiss 1973; Miller and Sumida 1974; Sumida et al. 1985; Ikeda and Mito 1988; Leis and Trnski 1989). The gut initially is a straight tube extending to 50–70% BL; it coils during the preflexion stage but preanal length remains within the 50–70% BL range in most species (it gradually decreases to <50% in *Alectis* and *Selene*). Carangid larvae initially are slender, but the majority of carangins, some naucratins, and some *Trachinotus* species soon become at least moderately deep-bodied. The carangins *Alectis* and *Selene* become extremely deep-bodied during the postflexion stage. The head is moderate to large and well armed with various spines and ridges. Two series of spines form on the preopercle; the spines of the posterior series are larger and the longest of them, at the preopercular angle, is the first head spine to form, early in the preflexion stage. This spine may become quite long, especially in some carangins, naucratins, and *Trachinotus*, and it may be ornamented with serrations or accessory spines (scomberoidins, some naucratins). The supraocular ridge of the frontal commonly bears a small spine; it bears large spines in *Naucrates* and is serrate in a few genera (e.g., Laroche et al. 1984). The supracleithral and posttemporal bones typically acquire one or two (occasionally more) small spines each during the preflexion or flexion stage; these may become moderately large in *Seriola* and *Trachinotus* and are quite large in *Naucrates*. A supraoccipital crest forms early in the preflexion stage in most carangids and commonly is serrate in carangins. In most carangid larvae the principal caudal rays are the first fin rays to begin forming, late in the preflexion stage. Next, soft rays of the dorsal and anal fins begin forming simultaneously, just before to just after the beginning of pectoral ray formation. Addition of rays is posteriad in the dorsal and anal fins and ventrad in the pectoral fins. Procurrent caudal rays begin forming at the end of notochord flexion, and pelvic rays typically form last. However, in *Selene* and eastern Pacific *Alectis* the pelvic fins are first to begin forming (elsewhere, the elongate dorsal and anal soft rays precede the pelvic rays in *Alectis*: e.g., Aboussouan 1968; Laroche et al. 1984; Leis and Trnski 1989). Pigmentation in larval carangids ranges from light to nearly complete. Naucratins, scomberoidins, and *Trachinotus* typically are quite heavily pigmented except on the caudal peduncle, either initially or by the end of the preflexion stage. Carangins tend to be more lightly pigmented, at least through notochord flexion, with melanophores primarily on the dorsum, gas bladder, and gut, along the lateral midline and ventral margin of the tail, and often internally above and/or below the notochord, most often near midtail. Pigmentation usually increases rapidly during the postflexion stage, with the upper half commonly becoming generally dark and the lower half remaining lighter. Bars may begin to form late in the postflexion stage. In *Alectis* and *Selene* the elongate dorsal, anal and pelvic fin rays are moderately to heavily pigmented through much of the larval period.

Carangid eggs in the CalCOFI study area closely resemble those of many other species that spawn spherical planktonic eggs near 1 mm in diameter with a single oil globule, and general characters that would allow reasonably certain identification are unknown. The number of potential identifications can be reduced by elimination of taxa that lack the coarsely segmented yolk typical of carangids, but this character is not always readily visible in the carangid eggs themselves. Carangid larvae in the CalCOFI study area are more easily distinguished from other fish larvae. Key characters include the number of myomeres (23–26 total; the most common myomere formula is 10+14), fin ray counts and the separation of the first two anal spines from the third (this becomes more apparent with development after spine formation) in older larvae, the supraoccipital crest (present in most species), the preopercular spines, the lack of interopercular and subopercular spines, the moderately deep and compressed body with preanal length ca. 50–70% BL typical of the majority of species, and the most common pigmentation pattern of melanophores on the dorsum, gut, and lateral midline and ventral margin of the tail. Families in the CalCOFI study area whose larvae most resemble carangids are the serranids (serranines and anthiines), lutjanids, nematistiids, chaetodontids, nomeids, and stromateids. None of these displays the carangid condition of a wider separation between the first two and third anal spines (some of the nomeids have only two anal spines), and only the anthiines share with the carangids the presence of a supraoccipital crest. The anthiine larvae lack the dorsal and lateral pigment typical of carangids, have a large interopercular spine (none in carangids), and have lower dorsal and anal fin-ray counts than the carangids. Larval serranines and lutjanids likewise lack pigmentation on the lateral midline, have an interopercular spine, and have lower dorsal and anal fin-ray counts than the carangids. Larvae of some of the serranines have pigmented pectoral fins, while carangids lack pectoral pigment (except on the P_1 base) before transformation. *Nematistius* resembles the naucratins and *Trachinotus* in general morphology and pigmentation, but has much smaller preopercular spines, fewer and smaller spines or serrations on the supraocular ridge, lacks a pterotic ridge, and has only single, very small supracleithral and posttemporal spines. In the postflexion stage the first seven dorsal spines elongate in *Nematistius*, but in the naucratins and *Trachinotus* they remain short. Chaetodontid larva in the CalCOFI area develop a single, very broad preopercular spine in contrast to the more numerous, thinner spines of the carangids, and they develop broad, bony supracleithral and posttemporal plates in contrast to the spines of carangids. Both the nomeids and stromateids have more myomeres than carangids (nomeids with 30–42, stromateids 29–37, carangids 23–26), much smaller preopercular spines, and they lack supracleithral and posttemporal spines. Larvae of the carangid tribes in the CalCOFI study area usually can be distinguished by body shape, spination of the head and pectoral girdle, and pigmentation. The carangin larvae tend to be deeper-bodied, more compressed, less heavily pigmented (at least during the preflexion and flexion stages), and to have a more ornate supraoccipital crest than larvae of the other tribes. Naucratins typically are rather heavily pigmented throughout development and they usually have larger supracleithral, posttemporal, and supraocular spines than larvae of the other tribes. Scomberoidins (*Oligoplites*) also become rather heavily pigmented, and they are the only carangids in the CalCOFI study area to develop accessory spines on the longest preopercular spine (*Elagatis* has serrate pre opercular spines which may superficially resemble those of *Oligoplites*). Trachinotins (*Trachinotus*) are heavily pigmented as well, and they develop a pterotic ridge which most of the other carangid larvae in the CalCOFI area lack.

Several of the following descriptions are taken from literature, supplemented in some cases with measurements of additional specimens; the remainder are original descriptions based on examination of 10–31 specimens of each species (Table Carangidae 3). Meristic and ecological data were obtained from a variety of sources including Jordan and Evermann (1896), Meek and Hildebrand (1925), Miller and Lea (1972), Aprieto (1974), Eschmeyer et al. (1983), Laroche et al. (1984), Smith-Vaniz (1984, 1995), Allen and Robertson (1994), Lea and Walker (in press), and H. J. Walker, Jr. (SIO Marine Vertebrates Collection, pers. comm., October 1995). Additional meristic counts were made as part of this study.

Table Carangidae 1. Meristic characters for the carangid species in the California Current vicinity. All have I,5 pelvic fin rays, 9+8 principal caudal fin rays, and 7 branchiostegal rays (occasionally 6 in *Gnathanodon speciosus* and 8 in *Oligoplites saurus inornatus*, *Trachinotus paitensis*, *T. rhodopus*, and *Trachurus symmetricus*).

Taxon	Vertebrae			Fin rays				Gill rakers
	PrCV	CV	Total	D	A	P_1	C_2	
Carangini								
Alectis ciliaris	10	14	24	VII–VIII+I,18–22	II+I,15–20	19–20	9–10+9	4–6+12–17
Caranx caballus	10	15	25	VIII+I,21–25	II+I,17–24	20	9–10+8–9	14–16+27–30
C. caninus	10	14	24	VII–VIII+I,18–23	II+I,18–21	20–21	9+8–9	3–6+15–17
C. lugubris	10	14	24	VIII+I,20–22	II+I,16–19	20–21	6+20	6–8+17–22
C. melampygus	10	14	24	VIII+I,21–25	II+I,17–20	21–22	9–10+6–8	7–9+17–22
C. otrynter	10	14	24	VIII+I,18–19	II+I,16–17	21	10+9	
C. sexfasciatus	10	15	25	VII–VIII+I,19–22	II+I,14–17	18–21	8–9+7–9	4–8+15–19
C. vinctus	10	15	25	VII–VIII+I,22–24	II+I,18–21	19	9+8–9	11–12+28–30
Chloroscombrus orqueta	10	14	24	VII–VIII+I,26–30	II+I,25–30	19–21	9–10+9–10	8–10+30–37
Decapterus macarellus	10	14	24	VIII+I,30–36+1	II+I,26–30+1	22–24	9–10+9–10	10–13+34–41
D. macrosoma	10	14	24	VIII+I,32–38+1	II+I,26–30+1	22	9+8–9	10–12+34–38
D. muroadsi	10	14	24	VII–VIII+I,29–33+1	II+I,25–29+1	22–23	10–11+9–10	13–16+37–42
Gnathanodon speciosus	10	14	24	VII+I,18–21	II+I,15–18	20–23	8–9+7–8	7–9+18–22
Hemicaranx leucurus	10	14–15	24–25	VIII+I,25–30	II+I,20–26	20–22	9–10+9	7–10+20–22
H. zelotes	10	15	25	VII–VIII+I,25–31	II+I,22–25	21	7–9+7–8	7–10+18–23
Selar crumenophthalmus	10	14	24	VIII+I,24–27	II+I,20–23	19–23	7–8+7–8	9–12+27–37
Selene brevoortii	10	14	24	VII–VIII+I,20–24	II+I,17–19	18–19	9+7	5–9+28–34
S. oerstedii	10	14	24	VI–VII+I,17–18	II+I,15	20–21	8+7–8	5–7+14–17
S. peruviana	10	14	24	VIII+I,20–24	II+I,16–19	17–19	8–10+6–8	7–9+28–34
Trachurus symmetricus	9–10	14–15	23–25	VIII+I,28–38	II+I,22–33	21–24	9–10+9–10	7–15+25–42
Uraspis helvola	10	14	24	VIII+I,25–30	II+I,19–22	25	9+9	5–8+13–17
Naucratini								
Elagatis bipinnulata	10	14	24	V–VI+I,25–30	I+I,18–22	19–22	7–11+10–11	9–12+25–29
Naucrates ductor	10	15	25	III–VI+I,24–29	II+I,15–18	18–20	9–12+8–11	5–8+12–19
Seriola lalandi	11	14	25	VI–VII+I,29–39	II+I,19–25	19–20	12+11	5–10+15–22
S. peruana	10	14	24	VII+I,31–35	II+I,20–22	20–22	8–10+6–8	9–11+21–23
S. rivoliana	10	14	24	VIII+I,26–33	II+I,18–22	19–22	11–13+8–12	6–9+16–19
Scomberoidini								
Oligoplites altus	10	16	26	IV–V+I,20–21	II+I,19–20	16–17	10+9	2–5+8–13
O. refulgens	10	16	26	IV–V+I,19–21	II+I,19–22	15–17	8–10+8–10	6–8+19–22
O. saurus inornatus	10	16	26	IV–VI+I,19–21	II+I,19–21	15–17	8–11+8–11	5–7+14–18
Trachinotini								
Trachinotus kennedyi	10	14	24	VI+I,17–19	II+I,16–17	18–19	8+8	5–8+9–12
T. paitensis	10	14	24	VI–VIII+I,20–27	II+I,20–25	16–18	8–9+8	9–11+14–17
T. rhodopus	10	14	24	V–VI+I,19–20	II+I,17–21	18–19	7–9+7–8	8–10+13–16

Table Carangidae 2. Approximate geographic ranges for the carangid species in the California Current vicinity.

Taxon	Geographic range
Carangini	
Alectis ciliaris	Worldwide in tropical seas
Caranx caballus	Southern California to Peru & Galápagos Islands
C. caninus	Southern California to Equador
C. lugubris	Circumtropical
C. melampygus	Indo-Pacific from East Africa to the Americas
C. otrynter	Baja California to Panama
C. sexfasciatus	Tropical Indo-Pacific to tropical eastern Pacific & north to southern California
C. vinctus	Baja California to Peru
Chloroscombrus orqueta	Southern California to Peru, including Gulf of California
Decapterus macarellus	Worldwide in tropical seas
D. macrosoma	Southern Baja California Sur to Peru, including Gulf of California
D. muroadsi	Central California to Peru & Galápagos Islands
Gnathanodon speciosus	Gulf of California to Colombia & tropical Indo-Pacific
Hemicaranx leucurus	Baja California to Peru
H. zelotes	Baja California to Ecuador
Selar crumenophthalmus	Worldwide in tropical & subtropical seas
Selene brevoortii	San Diego, California to Peru, including Gulf of California
S. oerstedii	Southern Baja California Sur to Colombia
S. peruviana	Southern California to Peru, including Gulf of California
Trachurus symmetricus	Gulf of Alaska to Gulf of California
Uraspis helvola	Southern California to Costa Rica and circumglobal in warm seas
Naucratini	
Elagatis bipinnulata	Circumtropical
Naucrates ductor	Vancouver Island, British Columbia to Galápagos Islands and circumtropical
Seriola lalandi	British Columbia to Chile and worldwide in warm seas
S. peruana	Mazatlán, Mexico to Peru & Galápagos Islands
S. rivoliana	Circumtropical; southern California to Peru, including Gulf of California
Scomberoidini	
Oligoplites altus	Southern Baja California Sur to Peru, including Gulf of California
O. refulgens	Baja California Sur to Ecuador, including Gulf of California
O. saurus inornatus	Baja California Sur to Ecuador, including Gulf of California & Galápagos Islands
Trachinotini	
Trachinotus kennedyi	Baja California Sur to Peru, including Gulf of California
T. paitensis	Southern California to Peru, including Gulf of California & Galápagos Islands
T. rhodopus	Southern California to Peru, including Gulf of California & Galápagos Islands

Table Carangidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the carangid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Alectis ciliaris	0	0	3 2.7–3.9	2 5.0–6.3	5 6.9–11.2	4 13.4–16.3	3 34.0–44.7
Caranx caballus	0	0	L[a]	L[a]	L[a]	L[a]	L[a]
C. sexfasciatus	0	0	L[a]	L[a]	L[a]	L[a]	L[a]
Chloroscombrus orqueta	0	0	L[a]	L[a]	L[a]	L[a]	L[a]
Decapterus spp.	0	0	1 4.7	2 4.9–5.0	4 5.2–7.2	1 14.1	5 41.4–68.4
Elagatis bipinnulata	0	0	L[b], 5 3.5–4.3	L[b], 3 4.4–5.9	L[b]	L[b]	L[b], 3 14.1–18.4
Gnathanodon speciosus	0	0	L[c,d,e], 10 2.2–4.4	L[c,d,e], 4 4.3–6.1	L[c,d,e], 10 6.8–17.2	L[d], 3 24.4–33.8	L[d], 4 48.7–70.5
Naucrates ductor	0	0	L[d,e,f,g,h,i], 7 3.0–4.1	L[d,e,f,g,h,i], 5 4.1–6.4	L[d,e,f,g,h,i], 9 6.8–16.2	L[d], 5 15.9–45.4	L[d], 3 74.0–93.0
Oligoplites saurus inornatus	0	0	8 2.4–3.6	5 3.9–5.2	9 5.3–11.0	5 14.2–21.0	2 24.8–57.0
Selar crumenophthalmus	L[j,k]	L[j,k]	L[j,k], 5 2.5–3.8	L[j,k], 5 3.7–4.4	L[j,k], 6 4.7–5.2	4 17.5–20.0	5 17.8–21.2
Selene brevoortii	0	0	5 2.9–3.7	3 4.7–6.0	3 7.5–8.1	3 8.2–38.2	1 101.3
S. peruviana	0	0	10 2.6–4.6	5 4.6–5.2	10 4.9–8.9	5 9.2–15.4	3 19.3–44.2
Seriola lalandi	L[l]	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]
Trachinotus kennedyi	0	0	0	L[d], 4 4.9–5.3	L[d], 1 5.5	L[d,m], 6 11.2–41.2	L[d,m], 2 55.4–63.4
T. paitensis	0	0	0	L[d], 1 5.8	L[d], 2 6.5–7.4	L[d,m], 4 16.2–24.5	L[d,m], 3 28.3–43.0
T. rhodopus	0	0	0	L[d], 5 3.3–6.0	L[d], 1 8.9	L[d,m], 6 9.4–38.4	L[d,m], 3 43.0–73.2
Trachurus symmetricus	L[n]	L[n]	L[n]	L[n]	L[n]	L[n]	L[n]

[a] Sumida et al. 1985
[b] Aprieto 1974
[c] Miller et al. 1979
[d] Laroche et al. 1984
[e] Ahlstrom and Sumida 1985
[f] Matarese et al. 1989
[g] Olivar and Fortuño 1991
[h] Padoa 1956b
[i] Sanzo 1931c
[j] Delsman 1926b
[k] Zvyagina and Rass 1977
[l] Brownell 1979
[m] Behrstock 1975
[n] Ahlstrom and Ball 1954

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VII–VIII+I	VIII+I
Dorsal rays	18–22	18–19
Anal spines	II+I	II+I
Anal rays	15–20	16
Pelvic	I,5	I,5
Pectoral	19–20	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–10	9–10
Lower	9	9
Gill rakers:		
Upper	4–6	
Lower	12–17	
Branchiostegals	7	7

LIFE HISTORY

Range: Worldwide in tropical seas

Habitat: Coastal waters, generally shoreward of 100 m isobath

Spawning season: Larvae collected June–October in eastern Pacific

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Laroche et al. 1984
Manabe & Ozawa 1988c

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.7 mm, 3.9 mm (W. Watson)
Postflexion larva, 6.9 mm (R. C. Walker)
Transformation specimen, 13.4 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatchiug length: <2.7 mm
Flexion length: ca. 5–6 mm
Transformation length: ca. 13 mm to <34 mm
Fin development sequence: P_2, 2D & 1D & A, C_1, P_1, C_2
Pigmentation: *Preflexion*—Anteriorly on midbrain; over midbrain, usually in V-shaped pattern; at tips of jaws; on ethmoid cartilage; under hindbrain; on angular; present or absent on gular area; series on isthmus; dorsally & dorsolaterally at myomeres 4–5; few dorsally at myomeres 16–17 by 3.9 mm; 1 to few on lateral midline at myomeres 17–19; over notochord at myomeres 16–19 & at myomeres 1–3 by 3.9 mm; series on ventral margin to middle of notochord tip, becoming double row along A base; internally on hypurals by 3.9 mm; dorsally on gas bladder & gut; anteriorly on gut; 1 between P_2 bases by 2.9 mm; on P_2. *Flexion*—Many over entire brain area; increasing on upper jaw; series on articular; few on lower half of preopercle; at bases of D III, D 2–4, D 16–insertion, gradually filling in between patches beginning anteriorly; few dorsolaterally on trunk; few laterally at myomeres 17–19; spreading along spinal cord & notochord, caudad from trunk & cephalad from midtail; several ventrally on gut; on D 2 & patch between D 2–3; on A 1; proximally on C; increasing on P_2. *Postflexion*—covering most of upper half of head & trunk; series on gular area; few on branchiostegals; saddles form below D II–VII, D 2–5 & D 16–17 & patch over hypural area by ca. 10 mm; covering most of gut, lighter ventrally; on P_1 base & upper rays by ca. 10 mm; increasing on D 1, A 1, P_2 & proximally on C. *Transformation*—6 or 7 saddles or bars on trunk & tail.
Diagnostic features: Early forming, enlarged, pigmented P_2; early forming, elongate, pigmented D 1 & A 1; becoming very deep-bodied in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		52–53 53	48–51 50	44–52 48	46–52 49	39–52 44
BD/BL		29–34 31	38–41 39	50–67 58	72–85 78	87–100 95
HL/BL		27–32 30	32–38 35	32–36 33	33–36 34	33–36 34
HW/HL		48–64 56	40–46 43	40–58 50	44–56 48	48–53 51
SnL/HL		24–32 28	29–32 31	22–35 30	29–30 30	21–33 26
ED/HL		33–37 35	31–32 32	30–40 35	31–37 34	33–42 39
P_1L/BL		6–8 7	8–9 8	15–21 18	21–25 23	29–33 31
P_2L/BL		20–38 27	 57	30–76 62	63–83 76	55–62 58

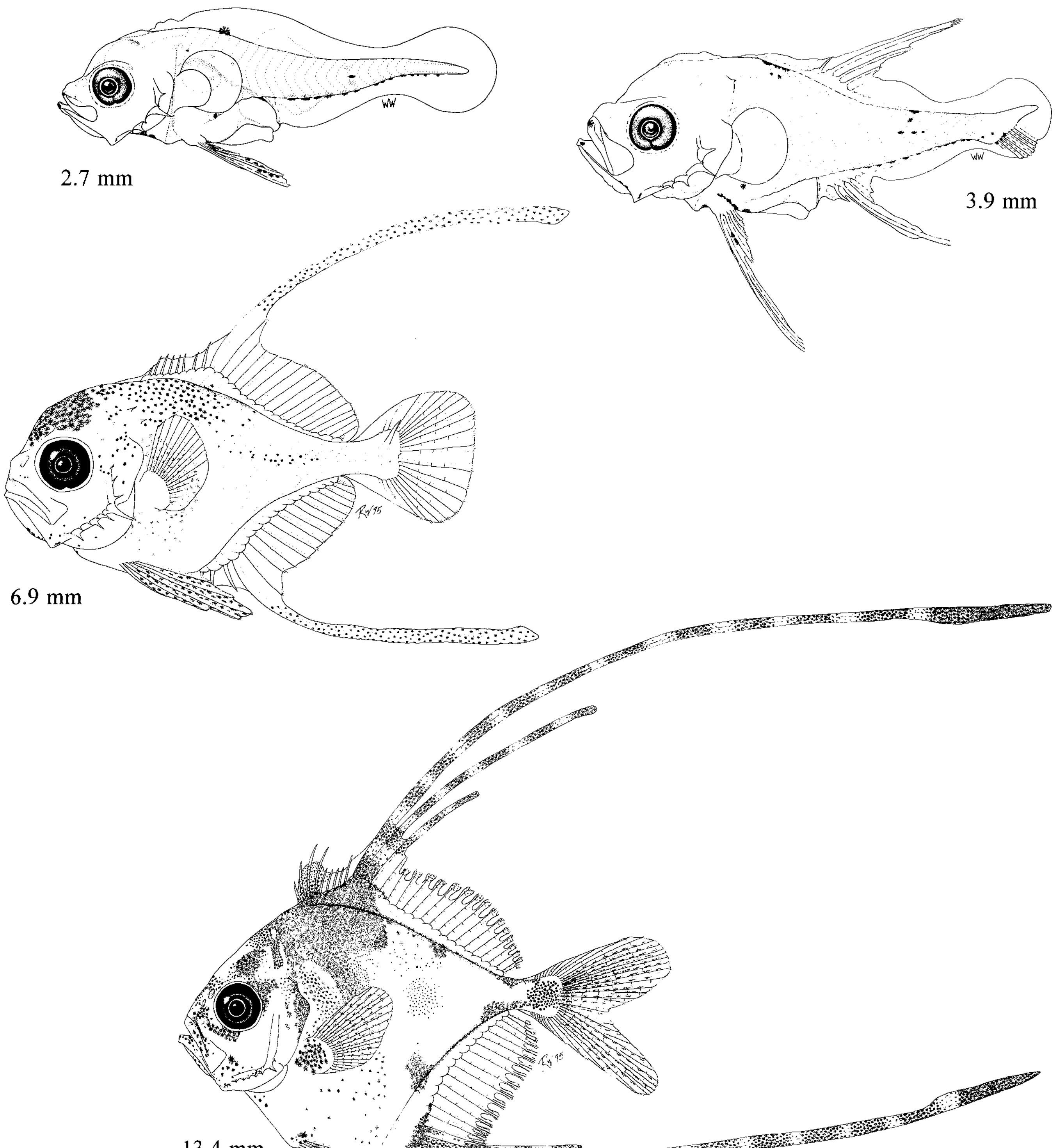


Figure Carangidae 1. Preflexion larvae, 2.7 mm (CalCOFI 5708, station 155G.144), 3.9 mm (EASTROPAC II, station 45.135); postflexion larva, 6.9 mm (CFRD Ref. Coll., RR61–41, Gulf of California, 22VI61); transformation specimen, 13.4 mm (MOPS 8710JD, station III–42).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	21–25	23
Anal spines	II+I	II+I
Anal rays	17–24	19
Pelvic	I,5	I,5
Pectoral	20	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–10	9
Lower	8–9	9
Gill rakers:		
Upper	14–16	
Lower	27–30	
Branchiostegals	7	7

LIFE HISTORY

Range: Southern California to Peru, including Galápagos Islands

Habitat: Shallow pelagic, inshore to offshore schools

Spawning season: Larvae collected year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Sumida et al. 1985

* Calculated from data in Sumida et al. (1985).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: 3.9–4.9 mm
Transformation length: ca. 13–18 mm
Fin development sequence: C_1 & D & A, P_1 & P_2 & C_2
Pigmentation: *Preflexion*—By 2.2 mm, blotch above gas bladder, 2 (large) above terminal gut section, 3 on ventral margin of gut (1 posterior to cleithrum, 1 posteriorly on gut coil, & 1 on terminal section near anus), 1 on dorsal margin at midtrunk, short opposing streaks on dorsal & ventral margins of tail with streak between them on lateral midline, series of ca. 9 on ventral midline of tail, 1–3 below tip of notochord, & 1 (usually) above tip; by 3.0 mm, 1 above midbrain; by end of stage, 1 to several more above midbrain, a pair on snout, 1 on tip of lower jaw, 1 or more on trunk above gut. *Flexion*—Scattered lightly over head & body; laterally on lower jaw; 1 to several at angular & on branchiostegal membrane; more ventrally & laterally on gut; streaks on tail longer; embedded series above spinal column of tail; series on A base. *Postflexion*—By 5.5 mm, becoming heavier on head & body, on P_2 & spinous part of A, bar forming in region of tail streaks; by ca. 6.2 mm, on 1D, & most of head & body covered except for caudal region; by ca. 13.0 mm, on caudal peduncle; by ca. 17 mm, series of bars on body (1 at nape, 3 at 1D, 4 at 2D & 1 on C base).
Diagnostic features: Total vertebrae 25; deep-bodied; dorsal, lateral & ventral streaks on tail; strong preopercular spination, a maximum of 5–6 above the enlarged spine at angle & 8–9 below angle in posterior series & a maximum of 1 above & 5 below the angle in anterior series; 1 posttemporal & 1–2 supracleithral spines; no spines on supraocular & pterotic ridges; scalloped supraoccipital crest forms at ca. 3.0 mm.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		58–61 60	55–59 57	54–58 56	52–55 53	53
BD/BL		33–37 35	41–44 42	42–46 45	42–43 42	39
HL/BL		33–36 35	33–36 35	34–39 36	33–36 35	36
HW/HL						
SnL/HL		28–32 29	25–29 27	21–32 26	22–25 23	26
ED/HL		28–29 28	31–34 33	30–36 34	35–40 38	35
P_1L/BL						
P_2L/BL						

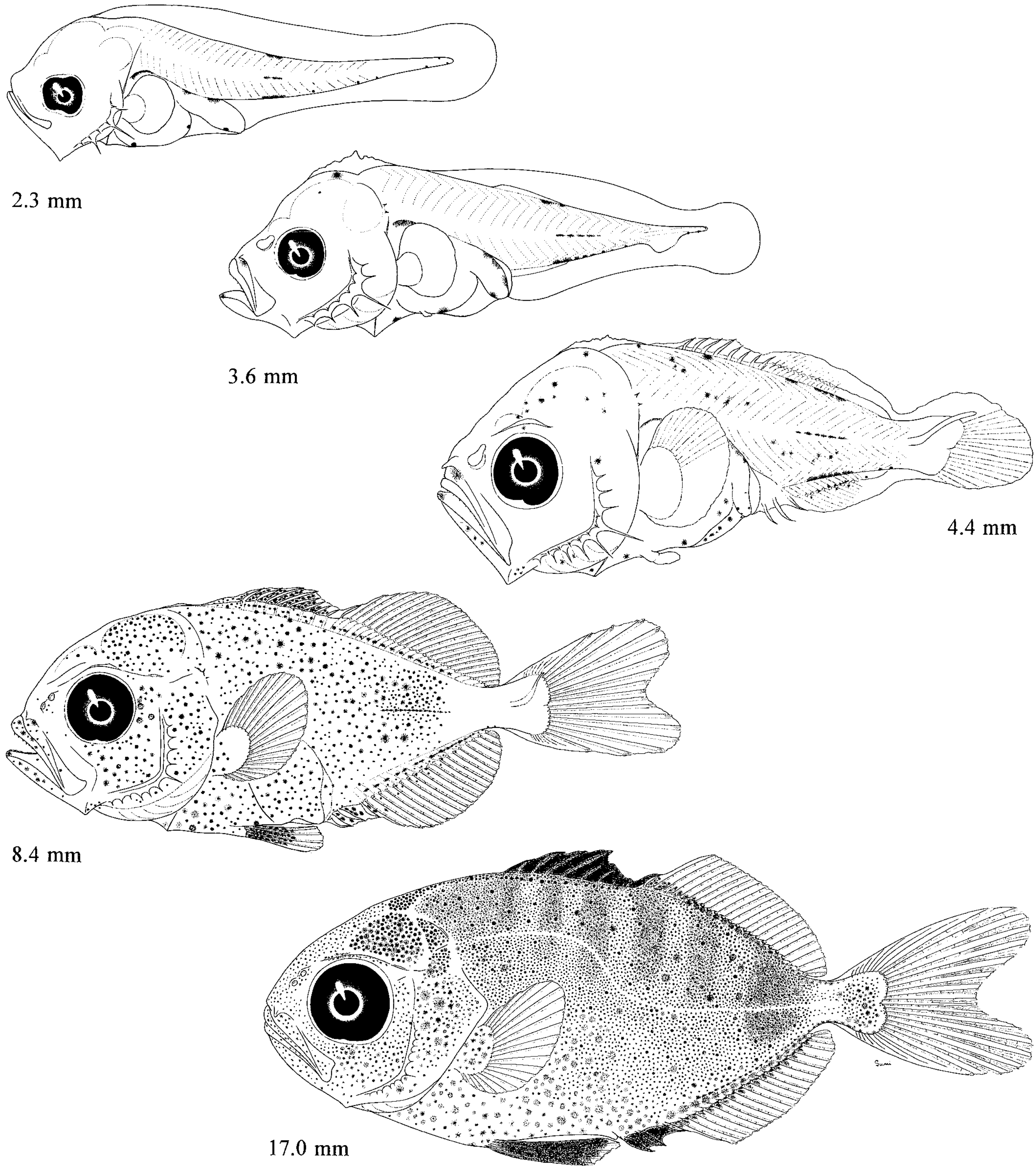


Figure Carangidae 2. Preflexion larvae, 2.3 mm, 3.6 mm; flexion larva, 4.4 mm; postflexion larva, 8.4 mm; transformation specimen 17.0 mm (Sumida et al. 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	VII–VIII+I	VIII+I
Dorsal rays	19–22	20
Anal spines	II+I	II+I
Anal rays	14–17	16
Pelvic	I,5	I,5
Pectoral	18–21	21
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	9
Lower	7–9	8
Gill rakers:		
Upper	4–8	
Lower	15–19	
Branchiostegals	7	7

LIFE HISTORY

Range: Tropical Indo-Pacific to eastern Pacific

Habitat: Shallow, in schools near reefs

Spawning season: Larvae collected year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Sumida et al. 1985
Kojima 1988a

* Calculated from data in Sumida et al. (1985).

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.5 mm
Flexion length: 4.0–4.4 mm
Transformation length: ca. 10–16 mm
Fin development sequence: C_1 & D & A & P_1, C_2, P_2
Pigmentation: *Preflexion*—By 2.5 mm, above gas bladder & gut, several on ventral margin of gut coil, 1 on terminal gut section anterior to anus, opposing blotches on dorsal & ventral margins of tail, series (minute) of ca. 7 posteriorly on ventral margin of tail, & 1 to several (minute) below notochord tip; by 3.0 mm, 1 to several above midbrain, 1 or more on supraoccipital crest, a pair at tip of snout, 1 on dorsum at midtrunk, streaks on dorsal & ventral margins of tail with lateral streak forming between them; by end of stage, many above brain, laterally on upper jaw, on tip of lower jaw, on gular & branchiostegal membranes, posteriorly on isthmus, on preanal finfold, spreading ventrad on trunk from dorsum, spreading onto tail & D & A fin bases from midline streaks, & embedded above spinal column at lateral streak. *Flexion*—Scattered over upper half of head & on trunk & tail except for caudal region; heavier laterally in region of tail streaks; streaks on dorsum & ventrum extend on each side of D & A. *Postflexion*—By 5.5 mm, entire head & body covered except for caudal peduncle, & blotch forming on 1D. *Transformation*—By ca. 14 mm, caudal peduncle covered & bars beginning to form. *Juvenile*—6 bars (1 at nape, 2 at 1D, 3 at 2D)
Diagnostic features: Total vertebrae 25; deep bodied; pigmented, peaked supraoccipital crest forms at ca. 3 mm; heavily pigmented preanal finfold; strong preopercular spination, up to 6 below & 4 above elongate angle spine in posterior series & up to 1 above & 4 below angle in anterior series; single spines on posttemporal & supracleithrum but none on supraocular or pterotic ridge.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–56 55	57–60 58	54–62 58	51–55 53	46–50 48
BD/BL		29–42 36	45–56 50	49–57 54	51–53 52	41–46 43
HL/BL		29–37 32	33–38 35	34–40 38	37–38 37	31–34 33
HW/HL						
SnL/HL		27–33 29	27–30 29	22–28 26	20–28 24	24–26 25
ED/HL		29–34 32	31–35 34	33–38 35	33–36 34	33–35 34
P_1L/BL						
P_2L/BL						

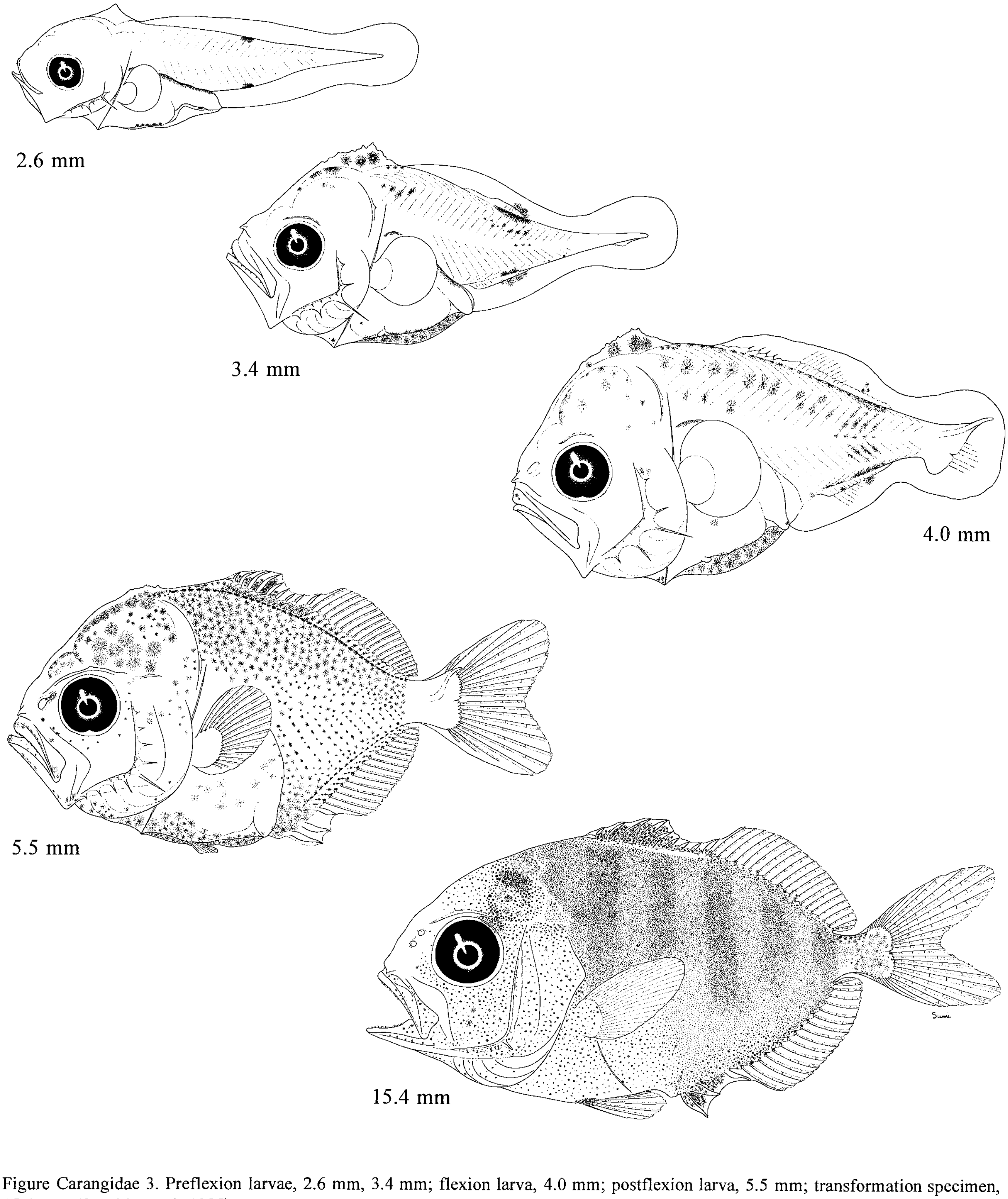


Figure Carangidae 3. Preflexion larvae, 2.6 mm, 3.4 mm; flexion larva, 4.0 mm; postflexion larva, 5.5 mm; transformation specimen, 15.4 mm (Sumida et al. 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VII–VIII+I	VIII+I
Dorsal rays	26–30	28
Anal spines	II+I	II+I
Anal rays	25–30	26
Pelvic	I,5	I,5
Pectoral	19–21	20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–10	9
Lower	9–10	9
Gill rakers:		
Upper	8–10	
Lower	30–37	
Branchiostegals	7	7

LIFE HISTORY

Range: Southern California to Peru, including Gulf of California

Habitat: Shallow coastal waters & estuaries; in schools

Spawning season: In CalCOFI area, larvae collected in summer & fall; possibly year-round in tropics

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Sumida et al. 1985

* Calculated from data in Sumida et al. (1985).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.7 mm
Flexion length: ca. 3.7–4.6 mm
Transformation length: ca. 13–15 mm
Fin development sequence: C_1, D & A & P_1, C_2, P_2
Pigmentation: *Preflexion*—By 2.2 mm, 0–1 medially posteriorly above midbrain, at angular, isthmus, below P_1 base, on ventral margin of gut, distally on preanal finfold, above gas bladder & terminal section of gut, 11–13 on ventral margin of tail (smaller posteriorly), 4 patches on dorsal midline; by 3.0 mm, on tip of lower jaw, pair on snout (usually), ≥1 laterally on lower jaw, 1–3 on lateral midline anteriorly on tail; by end of stage, several posteriorly above midbrain & anteriorly above hindbrain, medially on gular membrane, 3–6 in lateral midline series, series above spinal column medial to lateral midline series. *Flexion*—Above forebrain; 0–1 on opercle; 2 rows on postanal ventral margin; series forming on ventral margin of A base; forming on hypaxial myosepta of tail. *Postflexion*—By 7.0 mm, more above brain & on snout, series on each side of D base, forming in myosepta above lateral midline streak, laterally on abdomen, on lower hypural region; by 9.0 mm, brain covered, myoseptal zone expanding, solid sheath forming on nape & shoulder region, a blotch forming anteriorly on A; by 11.0 mm, dorsal half of head, & body nearly covered, D & A pterygiophores outlined, & distally on D, A, & C. *Juvenile*—Late-postflexion stage pattern augmented.
Diagnostic features: Relatively deep-bodied; terminal gut section curves anteriad in flexion stage yielding short preanal distance; 4 distinct dorsal melanophores in preflexion larvae; strong preopercular spination, a maximum of 6–7 above & 8–10 below angle spine in posterior series & 3–4 upper & 9–11 lower spines in anterior series; multiple spines on supraocular ridge, posttemporal & supracleithrum; pronounced, scalloped supraoccipital crest.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		56–60 57	57–59 57	48–55 52	44–46 45	39–42 40
BD/BL		30–38 35	39–45 42	41–46 43	45–45 45	42–42 42
HL/BL		30–35 33	37–39 38	33–38 36	30–31 30	29–32 30
HW/HL						
SnL/HL		27–33 31	27–29 28	23–29 26	23–28 26	27–29 28
ED/HL		31–33 32	34–39 36	32–40 36	38–40 39	32–34 33
P_1L/BL						
P_2L/BL						

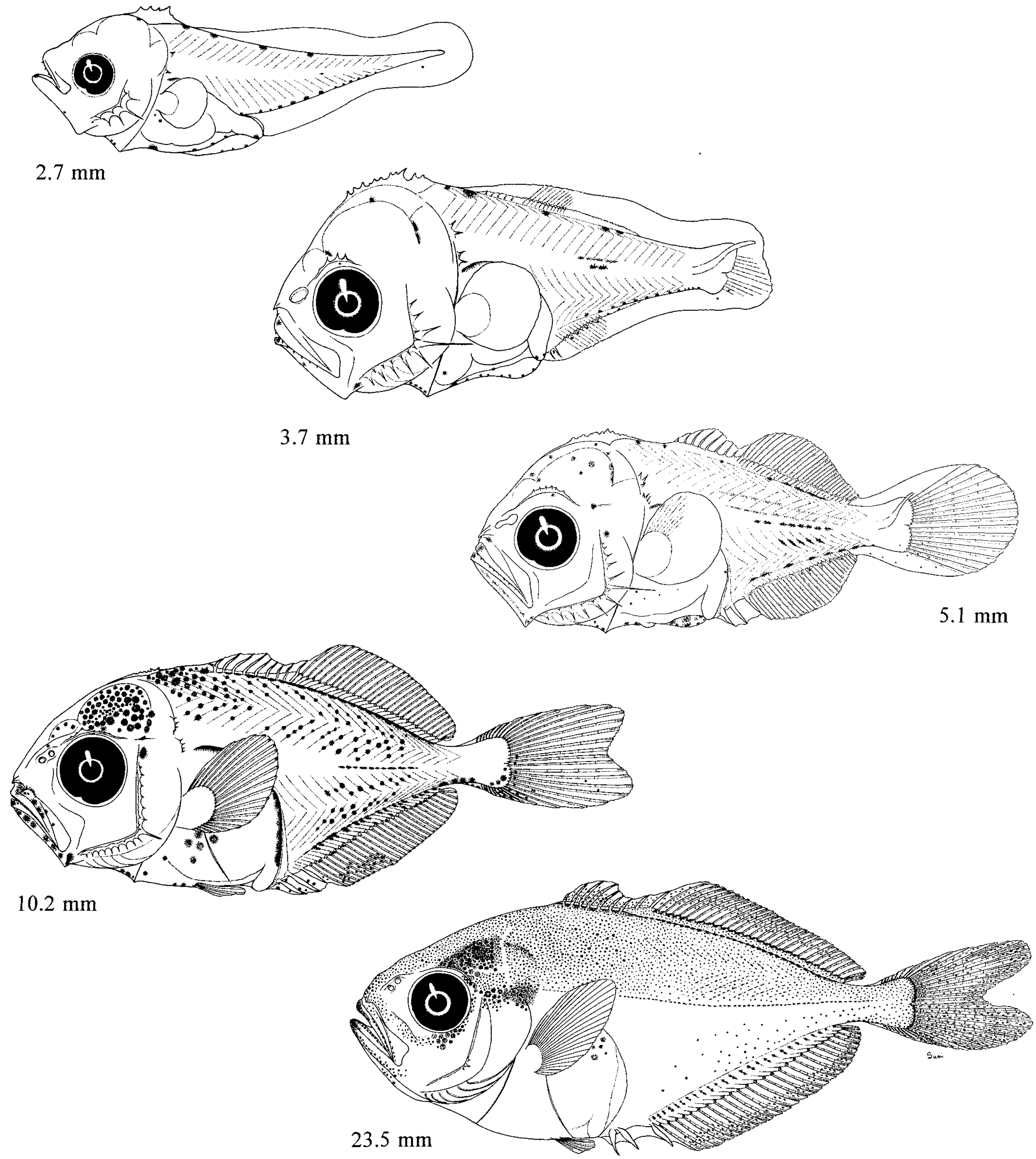


Figure Carangidae 4. Preflexion larva, 2.7 mm; flexion larva, 3.7 mm; postflexion larvae, 5.1 mm, 10.2 mm; juvenile, 23.5 mm (Sumida et al. 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VII–VIII+I	VIII+I
Dorsal rays	29–38+1	33–34,33,29–32+1
Anal spines	II+I	II+I
Anal rays	25–30+1	29,27,26+1
Pelvic	I,5	I,5
Pectoral	22–24	23,22–23,24
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–11	9,9,10
Lower	8–10	9,8–9,9–10
Gill rakers:		
Upper	10–16	
Lower	34–42	
Branchiostegals	7	7

LIFE HISTORY

Range: *D. macarellus*: Worldwide in tropical seas; in eastern Pacific, Gulf of California to Ecuador; *D. macrosoma*: Bahía Magdalena & Gulf of California to Peru & tropical Indo-Pacific; *D. muroadsi*: Pacific Grove, California, to Peru & Galápagos Islands

Habitat: All school in coastal waters

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.7 mm (R. C. Walker)
Flexion larva, 4.9 mm (R. C. Walker)
Postflexion larva, 6.5 mm (R. C. Walker)

* Three species, *D. macarellus*, *D. macrosoma*, & *D. muroadsi*, have been reported from the area of interest. The ranges of meristic characters given above include all three species; modal counts of D, A, P_1 & C_2 rays are given in the order: *D. macarellus*, *D. macrosoma*, *D. muroadsi*. Larvae described here appear to be a single species, but they presently cannot be identified below the level of genus with any degree of certainty. Although none of the postflexion larvae has full complements of dorsal & anal fin rays, it appears that their final counts would correspond with the modal counts of *D. macrosoma*.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 4.8–5.1 mm
Transformation length: >7.2 mm, <41.4 mm
Fin development sequence: C_1, 2D & A, 1D & P_1, C_2, P_2
Pigmentation: *Preflexion*—2–3 dorsolaterally on each side of midbrain; internally posteriorly on midbrain; at tips of jaws; 1 at angular; 1 on isthmus; dorsally on gas bladder & hindgut; anteriorly on liver; anteroventrally on gut; double row on dorsal margin of myomeres 8–11; 1 over notochord tip; internally over notochord at myomeres 15–17; on lateral midline at myomere 16; 1 on hypural margin. *Flexion*—Gradually increasing dorsally over midbrain area & on gas bladder & gut. *Postflexion*—Spreading from midbrain over forebrain by 7.2 mm; at upper end of preopercle; increasing on jaws; series on articular by 7.2 mm; few laterally on gut by 7.2 mm; along D base anteriorly & posteriorly, gradually spreading along full length of base; gradually spreading forward along lateral midline; internally over & under vertebral column in vicinity of myomeres 15–17; external dorso- & ventrolateral series forming on tail by 7.2 mm; anteriorly & posteriorly on A base, gradually spreading along full length of base; patch forming laterally over hypural area. *Transformation*—Upper half generally covered (except fins), little ventrally; scattered over opercular area; series on both jaws; patch below eye; proximally on central C rays.
Diagnostic features: Little or no ventral or ventrolateral pigment externally on tail through early postflexion stage; high D & A soft ray counts (apparent by ca. 5.5 mm although full ray complements are not completed until after 7.2 mm); relatively elongate compared with most carangins.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			60–62	61–64		51–54
		61	61	62	56	53
BD/BL			35–35	33–38		19–22
		33	35	35	29	20
HL/BL			34–36	34–37		26–32
		33	35	36	31	28
HW/HL			47–49	42–49		42–53
		51	48	47	45	47
SnL/HL			29–31	27–31		32–36
		31	30	28	28	34
ED/HL			32–35	34–36		27–30
		33	34	35	33	28
P_1L/BL			6–8	7–8		15–16
		8	7	8	14	15
P_2L/BL			1–1	1–4		12–14
		0	1	3	13	13

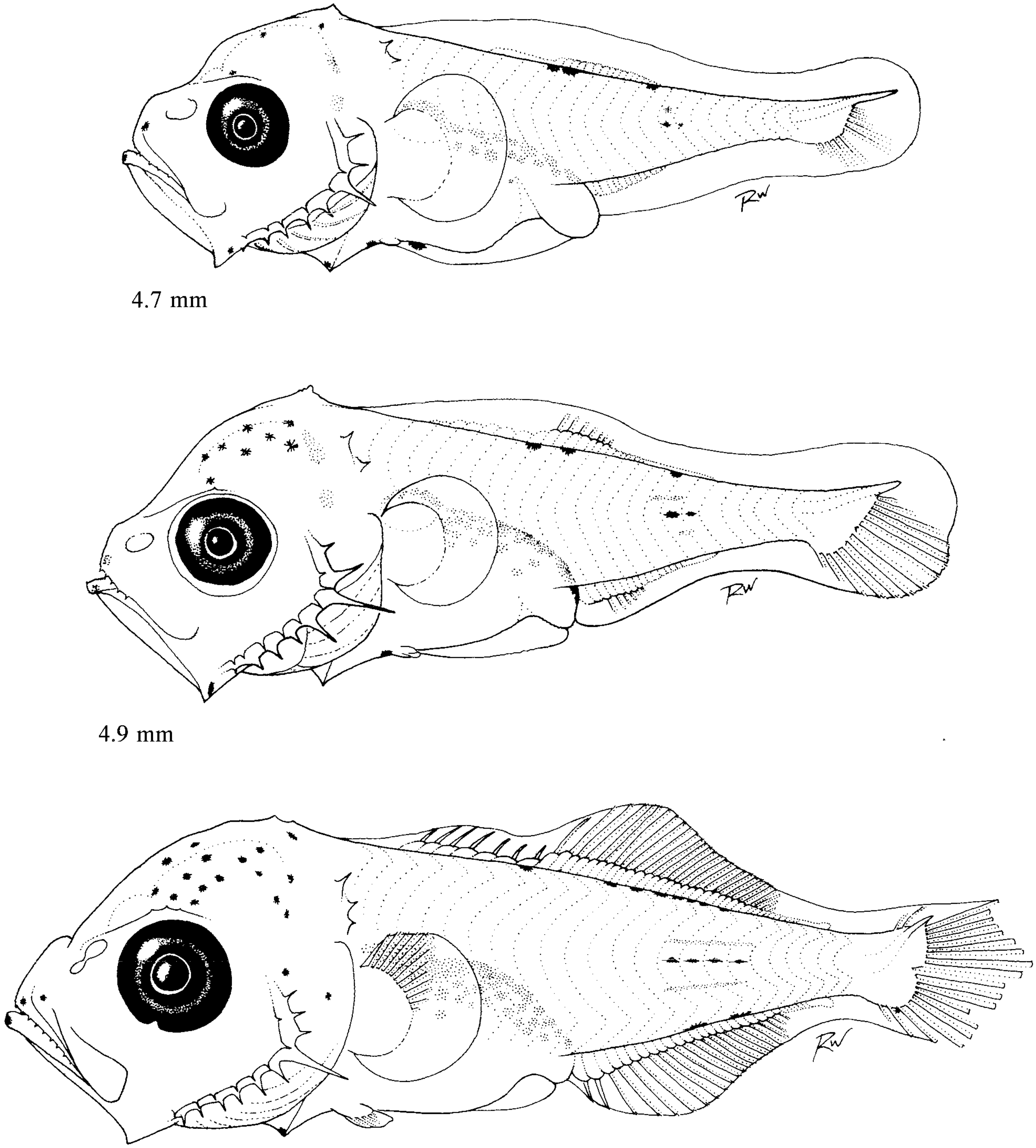


Figure Carangidae 5. Late preflexion larva, 4.7 mm; early flexion larva, 4.9 mm; postflexion larva, 6.5 mm (CalCOFI 6410, station 137.23).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	V–VI+I	VI+I
Dorsal rays	25–30	26
Anal spines	I+I	I+I
Anal rays	18–22	19
Pelvic	I,5	I,5
Pectoral	19–22	20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–11	
Lower	10–11	
Gill rakers:		
Upper	9–12	
Lower	25–29	
Branchiostegals	7	7

LIFE HISTORY

Range: Circumtropical; in eastern Pacific from vicinity of Cabo San Lucas to Peru, Galápagos & Cocos Islands

Habitat: Epipelagic; juveniles often associated with *Sargassum*

Spawning season: Throughout the year with March maximum in Indo-Pacific

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Aprieto 1974
Laroche et al. 1984
Okiyama 1970

* Morphometric ranges include values calculated from Aprieto (1974) as well as those based on measurements of eastern Pacific specimens. Mean values in parentheses were calculated from Aprieto (1974); those without parentheses are based on eastern Pacific specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.5 mm
Flexion length: ca. 4.4–5.9 mm
Transformation length: ca. 10.0–14.0 mm
Fin development sequence: C_1, 1D & A, 2D & P_1, C_2, P_2
Pigmentation: *Preflexion*—Scattered on snout, jaws, & over midbrain; dorsally on gas bladder & gut; series along ventral margin of isthmus & gut; series on dorsal margin of trunk & tail, ventral margin of tail, & lateral midline on tail; last 1–6 myomeres unpigmented. *Flexion*—Increasing on upper half of head & on jaws; few on preopercle; spreading ventrolaterally on gut & on trunk & tail; spreading dorsolaterally from ventral margin of tail. *Postflexion*—Nearly completely covered, lighter on lower half of head & laterally on abdominal area; little or none on posterior half of caudal peduncle. *Transformation*—Increasing on all areas; caudal peduncle covered except small dorsolateral & ventrolateral patches may be unpigmented.
Diagnostic features: Serrate preopercular spines; supraoccipital crest with single point; 2 A spines; heavily pigmented.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		50–59 50 (64)	59–70 65 (62)	60–64 62	58–66 61	56–66 60 (65)
BD/BL		28–33 31 (31)	31–42 38 (31)	33–38 35	30–35 32	28–32 30 (29)
HL/BL		26–37 31 (34)	34–40 38 (35)	33–37 35	30–38 35	32–36 34 (35)
HW/HL		42–52 (46)	45–46 (45)			50–55 (52)
SnL/HL		26–32 26 (29)	23–30 28 (27)	24–27 25	24–30 27	26–35 32 (28)
ED/HL		24–31 25 (30)	25–34 29 (28)	26–31 29	26–35 31	23–34 26 (32)
P_1L/BL		7–8 (7)	6–8 (7)			17–18 (18)
P_2L/BL		0–0 (0)	0–0 (0)			17–18 (18)

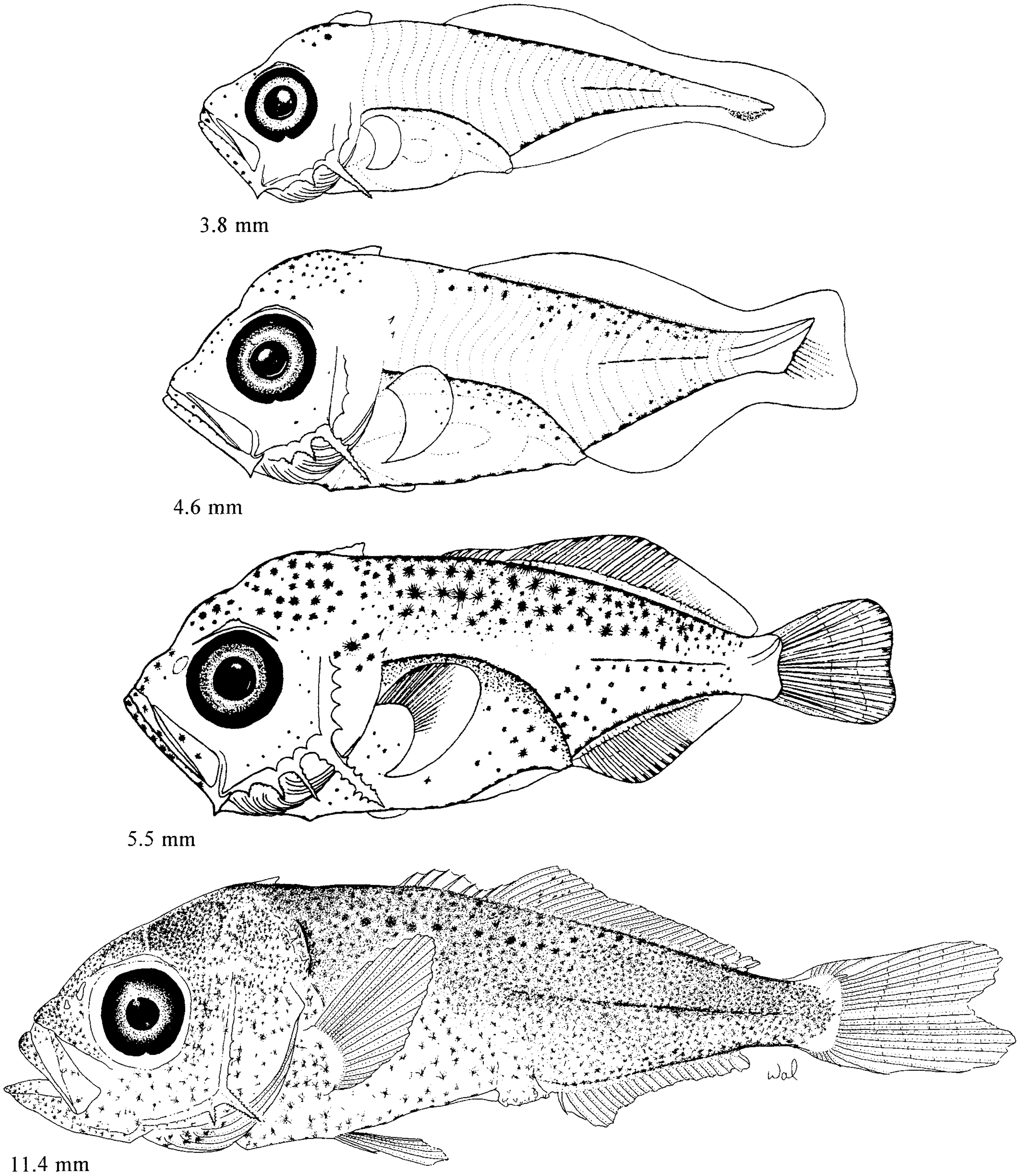


Figure Carangidae 6. Preflexion larva, 3.8 mm; flexion larva, 4.6 mm (Aprieto 1974); postflexion larvae, 5.5 mm (Aprieto 1974) and 11.4 mm (Laroche et al. 1984).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VII+I	VII+I
Dorsal rays	18–21	19
Anal spines	II+I	II+I
Anal rays	15–18	16
Pelvic	I,5	I,5
Pectoral	20–23	21
Caudal:		
Principal	8–9+7–8	9+8
Procurrent:		
Upper	8–9	8
Lower	7–8	8
Gill rakers:		
Upper	7–9	8
Lower	18–22	19
Branchiostegals	6–7	7

LIFE HISTORY

Range: Tropical Indo-Pacific & eastern Pacific; Gulf of California to Colombia

Habitat: Adults—deep lagoons & seaward reefs; aggregate in shallow water to spawn; tiny juveniles symbiotic among tentacles of jellyfish

Spawning season: Kaneohe Bay, Oahu—mid-February to mid-November, maximum abundance late April to early May; Palau—November–May, around a full moon

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Sumida 1985
Laroche et al. 1984
Manabe & Ozawa 1988c
Miller et al. 1979
Watson & Leis 1974

* Eye is slightly oval, becoming round in juveniles; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.78–0.90 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.23–0.30 mm
Shell surface: Smooth
Pigment: On embryo—scattered dorsally; on OG in late-stage.
Diagnostic features: Size; weakly segmented yolk; white to yellow granules on yolk sac & embryo; melanophores on embryo scattered dorsally & on OG; OG opposite embryo.

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 4.3–6.1 mm
Transformation length: 24.4–33.8 mm
Fin development sequence: C_1, 2D & A, 1D, P_2, C_2, P_1
Pigmentation: *Preflexion*—Heavy on middorsal line, with development, expanding ventrad along epaxial myosepta; scattered on head; on snout; distally on lips; ventrally on gut & body; few posteriorly on lateral midline anterior to caudal peduncle; internally dorsally on gas bladder. *Flexion*—Scattered on head & body ending anterior to caudal peduncle, light on gut; lacking under eye; on P_2 & A pterygiophores; dashes beginning even with gut on dorsal midline & on lateral midline ending anterior to caudal peduncle. *Postflexion*—Scattered on entire head & body; on 1D & P_2; on P_1 base & proximally on rays; anteriorly on A; proximally on C; silver coloration beginning on cheek & gut (gold in fresh specimens). *Transformation*—5–6 vertical bars forming; may have a blotch on each C lobe. *Juvenile*—Silver with ca. 13 vertical bars alternating between heavy & light, beginning across eye, ending on caudal peduncle.
Diagnostic features: D VII+I,18–21; A II+I, 15–18; large head; early development of 2 series of preopercular spines & median supraoccipital crest; relatively deep-bodied.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		56–69 62	58–63 62	56–63 60	52–53 52	48–54 50
BD/BL		32–41 37	34–41 39	38–46 44	37–39 38	35–39 37
HL/BL		29–38 34	34–39 36	35–41 37	32–36 34	34–36 35
HW/HL		49–77 58	41–52 47	41–48 44	35–41 37	40–45 42
SnL/HL		26–33 29	28–31 30	29–38 34	32–33 32	31–36 33
ED/HL*		28–44× 30–41 34×34	31–32× 30–33 32×32	23–33× 23–33 28×28	24–31× 24–28 28×26	26–30 28
P_1L/BL		2–10 7	7–9 8	9–18 14	17–18 18	19–26 22
P_2L/BL		0–0 0	0–7 2	8–17 15	14–15 15	13–14 13

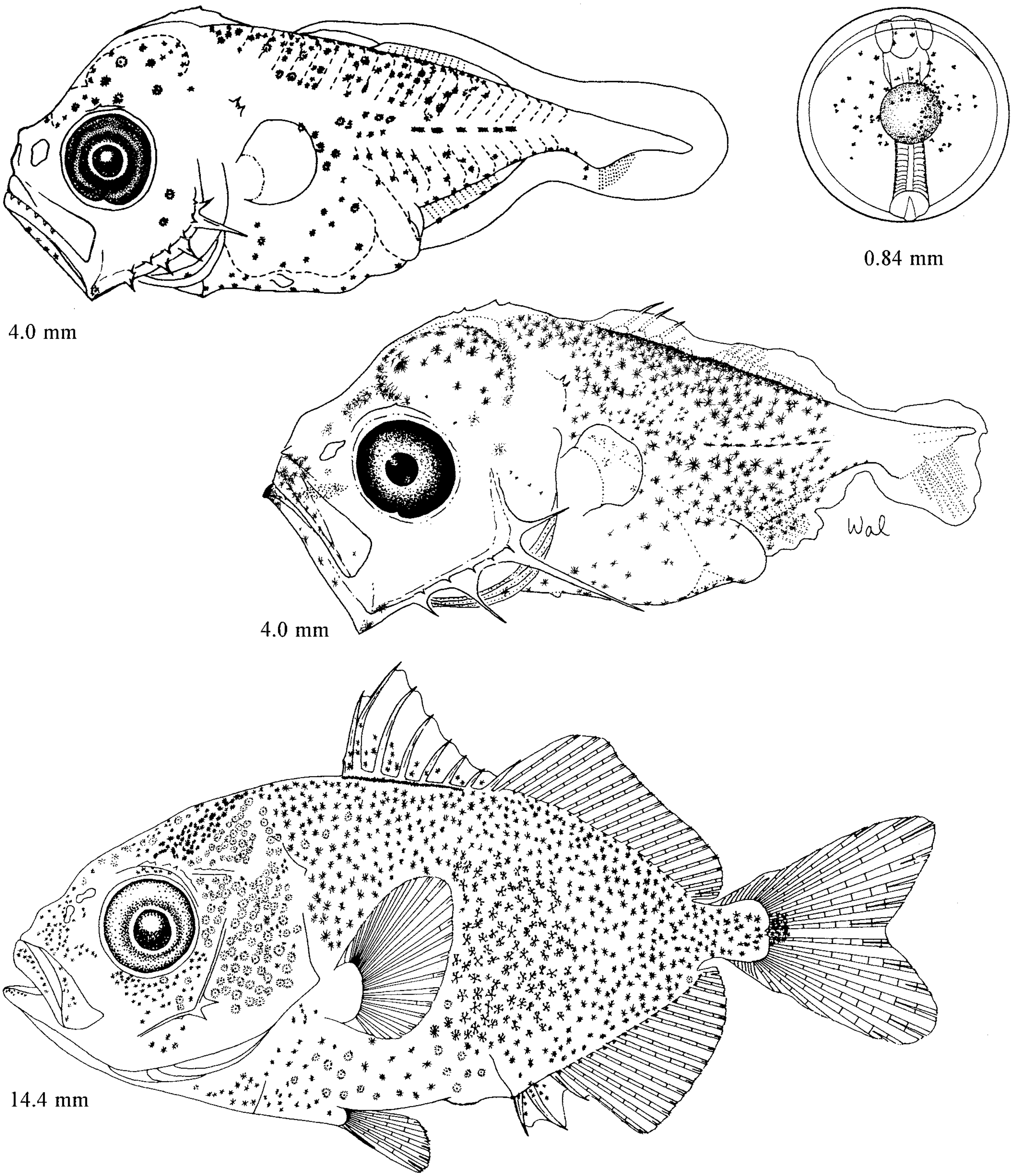


Figure Carangidae 7. Egg, 0.84 mm (Watson and Leis 1974); preflexion larva, 4.0 mm (Miller et al. 1979); early flexion larva, 4.0 mm (Laroche et al. 1984); postflexion larva, 14.4 mm (Miller et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	III–VI+I	V+I
Dorsal rays	24–29	25
Anal spines	II+I	II+I
Anal rays	15–18	16
Pelvic	I,5	I,5
Pectoral	18–20	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–12	10
Lower	8–11	9
Gill rakers:		
Upper	5–8	
Lower	12–19	
Branchiostegals	7–8	7

LIFE HISTORY

Range: Warm & temperate seas; eastern Pacific—British Columbia to Galápagos Islands

Habitat: Epipelagic; usually around floating or moving objects; young associated with jellyfish & drifting seaweeds

Spawning season: In CalCOFI & EASTROPAC areas, larvae collected February to October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Sumida 1985
Laroche et al. 1984
Matarese et al. 1989
Olivar & Fortuño 1991
Padoa 1956b
Sanzo 1931c

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.9 & 4.1 mm (H. M. Orr)
Flexion larva, 5.9 mm (B. Sumida MacCall)
Postflexion larva, 15.0 mm (H. M. Orr)
Juvenile, 20.3 mm (H. M. Orr)

* Eye is slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.3 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.28 mm diam.
Shell surface: Smooth
Pigment:
Diagnostic features: Smooth chorion; segmented yolk; narrow perivitelline space; 1.3 mm diameter; 0.28 mm diameter OG.

LARVAE

Hatching length: <3.0 mm
Flexion length: 4.1–6.4 mm
Transformation length: 15.9–16.2 mm through 45.4 mm
Fin development sequence: C_1, 2D & A, 1D, P_2, C_2, P_1
Pigmentation: *Preflexion*—On snout, vomer & lower jaw; on edge of opercle & branchiostegal membrane; dorsally on head, continuing to caudal peduncle, spreading laterally with development; ventrally on gular region & gut & on body to caudal peduncle, spreading laterally with development; internally dorsally on gut; developing on lateral midline from over gut to caudal peduncle. *Flexion*—On upper & lower jaws; scattered over head, increasing with development; laterally from cleithrum to caudal peduncle, lighter from A posteriad; on P_1 base. *Postflexion*—Over entire head & body to hypurals; on D rays; on P_2 base & rays. *Transformation*—Bars form (5–7), continue on D & A; proximally on P_1; on P_2; may have a blotch on each C lobe.
Diagnostic features: Total vertebrae 25; D usually V+I,25; A II+I, 16; large head; early development of prominent supraocular ridge & spines; other prominent spines are posttemporal & supracleithral (3 total) & 2 series of preopercular spines; lacks median supraoccipital crest; relatively slender-bodied; heavily pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		61–67 63	60–75 64	67–74 69	61–67 63	58–62 59
BD/BL		28–37 33	39–49 42	39–46 43	28–40 34	25–28 26
HL/BL		27–34 31	32–41 36	36–42 38	29–39 34	24–31 29
HW/HL		52–64 58	54–65 60	49–66 57	48–57 52	41–53 46
SnL/HL		22–29 26	14–27 20	18–26 22	23–29 25	24–28 26
ED/HL*		32–40× 29–38 37×34	40–44× 40–42 41×41	32–42× 32–41 38×37	30–32× 29–32 31×31	20–28× 20–27 26×23
P_1L/BL		7–10 8	9–21 13	15–25 20	16–21 18	13–14 13
P_2L/BL		0–1 0.1	0–18 7	16–29 24	20–26 23	16–18 18

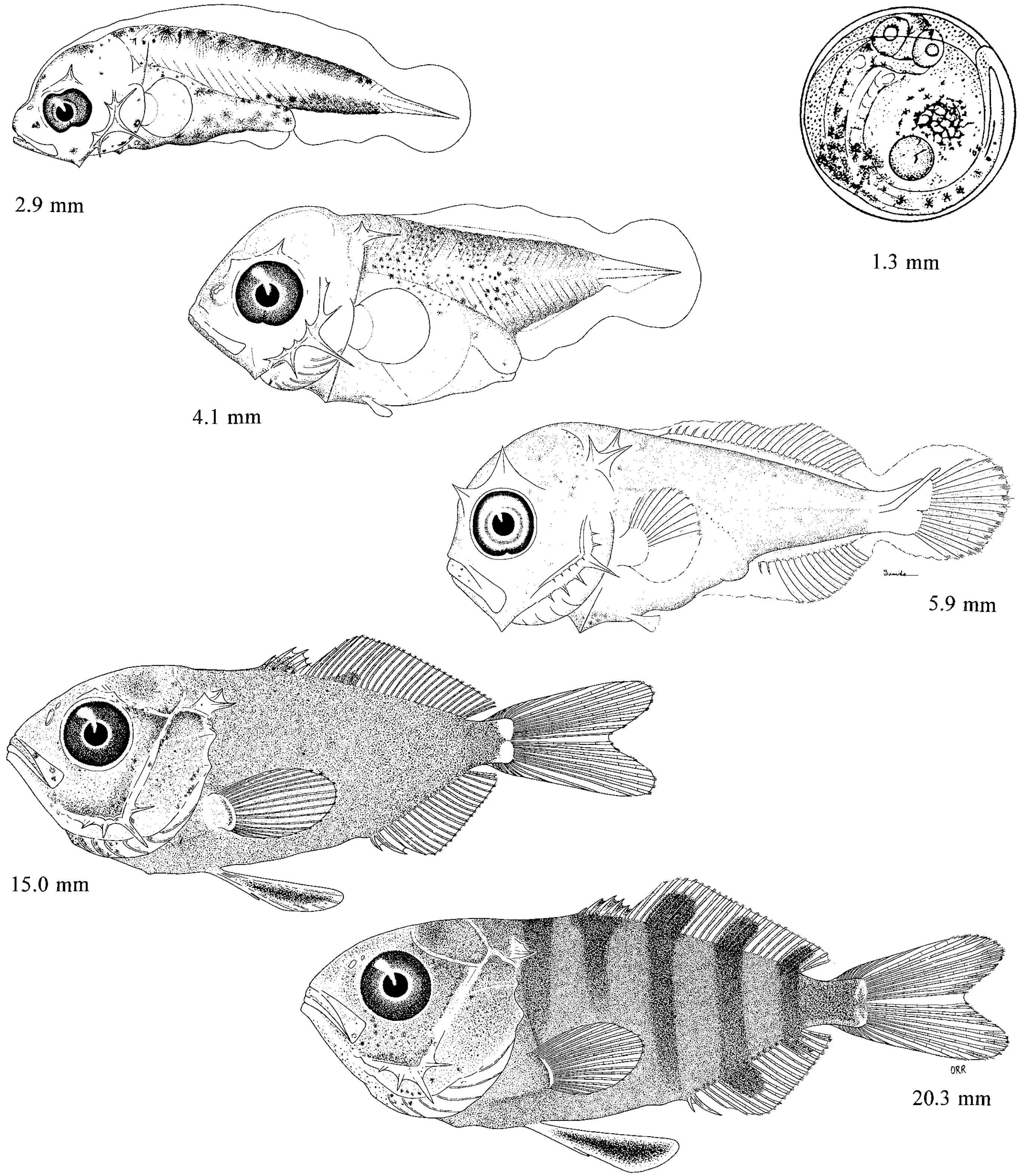


Figure Carangidae 8. Egg, 1.3 mm (Sanzo 1931c); preflexion larvae, 2.9 mm, 4.1 mm (EASTROPAC II, station 47.035); flexion larva, 5.9 mm (CalCOFI 5910, station 123.60); postflexion larva, 15.0 mm (EASTROPAC I, station 14.041); juvenile, 20.3 mm (EASTROPAC I, station 14.041).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	IV–VI+I	V+I
Dorsal rays	19–21	19–20
Anal spines	II+I	II+I
Anal rays	19–21	20
Pelvic	I,5	I,5
Pectoral	15–17	15
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–11	9
Lower	8–11	8
Gill rakers:		
Upper	5–7	5
Lower	14–18	15–16
Branchiostegals	7–8	7

LIFE HISTORY

Range: In the eastern Pacific, from Bahía Magdalena & the Gulf of California to Ecuador & the Galápagos Islands

Habitat: Schools along sandy beaches & in muddy estuaries

Spawning season:

ELH pattern: Oviparous; planktonic eggs; planktonic, primarily neustonic larvae

LITERATURE

Aprieto 1974 (for *O. saurus saurus*)

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.3 mm (R. C. Walker)
Flexion larva, 5.6 mm (B. Sumida MacCall)
Postflexion larva, 10.0 mm (R. C. Walker)

* Preflexion specimens slightly shrunken; proportions of Sn-A, BD, HL, & P_1L to BL may be overestimates.
† Eye slightly elongate (horizontally), becoming round by postflexion stage; horizontal axis is given first, vertical axis second.

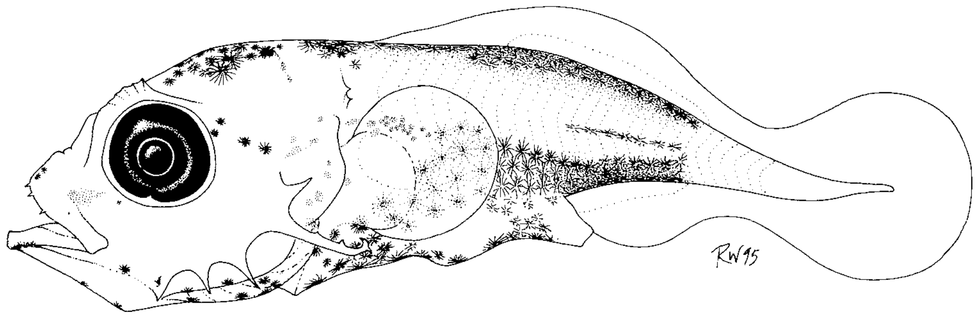
EARLY LIFE HISTORY DESCRIPTION

EGGS (*O. saurus saurus*—Western Atlantic subspecies)
Shell diam.: 0.87–0.88 mm **Yolk:** Unsegmented
No. of OG: 1 **Diam. of OG:** 0.33–0.34 mm
Shell surface: Smooth, transparent
Pigment: Along back & upper sides of body; large melanophores at posterior ventral midline
Diagnostic features: Egg & OG size; pigment

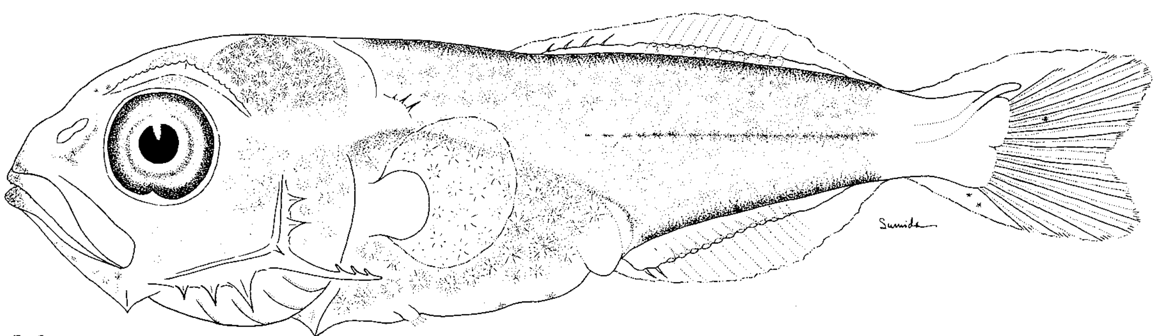
LARVAE
Hatching length: <2.4 mm
Flexion length: ca. 3.9–5.2 mm
Transformation length: ca. 14–21 mm
Fin development sequence: C_1, 2D & A, 1D & P_1, C_2, P_2
Pigmentation: *Preflexion–flexion*—On snout, lower jaw, roof of mouth, & gular & isthmus regions; over & at base of mid- & hindbrain; on preopercle & opercle; dorsolaterally on gut, sparce ventrally on gut; dorsolaterally, ventrolaterally, & along lateral midline to ca. midtail; scattered ventrally in finfold near end of tail. *Postflexion*—Spreading over body; absent from ventrum in trunk region & from near hypurals. *Transformation–juvenile*—Spreading on 2D, on hypurals; lighter ventrally on body; becoming silvery ventrally.
Diagnostic features: Total vertebrae 26; D IV–VI+I, 19–21; P_1 15–17; GR 5–7+14–18; preflexion to flexion stage larvae relatively slender & heavily pigmented except for caudal region; supraoccipital crest absent; unlike *O. saurus* larvae from the Atlantic as described by Aprieto (1974), our specimens have a larger supraocular crest, a well developed posttemporal crest, & well developed accessory hooks on the 1st preopercular spine.

MORPHOMETRICS (range & mean in %)

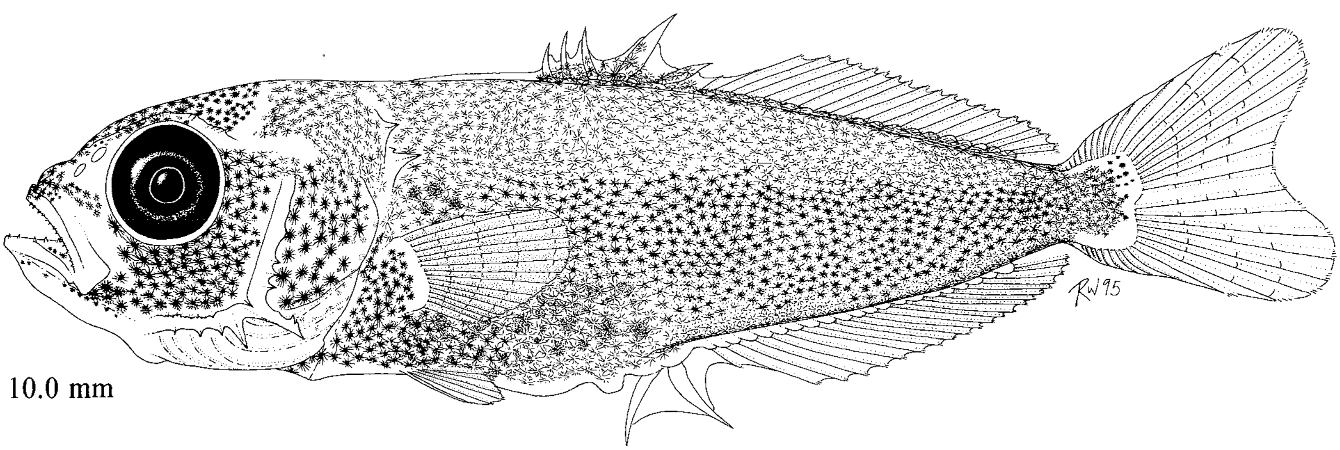
	Y-S	PrF*	F	PoF	Tr	Juv
Sn-A/BL		56–64 62	58–62 59	56–63 59	49–57 53	47–50 49
BD/BL		26–33 29	28–33 30	28–31 29	27–31 29	25–30 28
HL/BL		30–37 34	35–39 37	32–37 35	29–34 32	26–30 28
HW/HL		50–81 65	47–54 51	39–52 48	39–45 42	35–40 38
SnL/HL		15–27 23	23–28 24	23–28 25	27–30 28	23–27 25
ED/HL†		30–43× 27–32 34×30	28–32× 27–29 30×28	29–32 30	26–28 27	25–27 26
P_1L/BL		5–8 6	6–11 7	8–13 10	11–16 14	14–15 14
P_2L/BL		0–0 0	0–2 1	2–10 5	14–14 14	14–16 15



3.3 mm



5.6 mm



10.0 mm

Figure Carangidae 9. Preflexion larva, 3.3 mm (CalCOFI 7205, station 157G.150); flexion larva, 5.6 mm (CalCOFI 7205, station 157G.150); postflexion larva, 10.0 mm (CalCOFI 7205, station 157G.150).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	24–27	
Anal spines	II+I	II+I
Anal rays	20–23	
Pelvic	I,5	I,5
Pectoral	19–23	21
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–8	8
Lower	7–8	8
Gill rakers:		
Upper	9–12	
Lower	27–37	
Branchiostegals	7	7

LIFE HISTORY

Range: Worldwide in warm seas; in eastern Pacific, throughout Gulf of California to Panama

Habitat: Schools in coastal waters

Spawning season: In eastern Pacific, larvae collected August through November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Delsman 1926b
Laroche et al. 1984
Manabe & Ozawa 1988b
Miller et al. 1979
Zvyagina & Rass 1977

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.78 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.24 mm
Shell surface: Smooth
Pigment: Oil globule yellowish; melanophores dorsally & laterally on late stage embryo & on OG & surface of yolk
Diagnostic features:

LARVAE

Hatching length: 1.7–1.8 mm
Flexion length: 3.7–4.5 mm through 4.7–5.6 mm
Transformation length:
Fin development sequence: C_1, 2D & A, 1D, P_1, C_2, P_2
Pigmentation: *Yolk-sac*—Initially on dorsum, OG, & yolk sac; condensing to fewer, larger discrete melanophores on dorsum; series forming over gut, on ventral margin of tail, & ≥1 on lateral midline of tail by end of stage. *Preflexion*—Few over midbrain area; pair anterolaterally on each side of hindbrain; under hindbrain; at tips of jaws; dorsally on gas bladder & gut; anteroventrally on liver; anteriorly on ventral margin of gut; double row dorsally on trunk & tail, commonly restricted to myomere 7–14 area; internally at nape; internally over notochord at midtail by 3.8 mm; 1–3 on lateral midline at midtail; 0–few on hypaxial myosepta in midtail area; series on ventral margin of tail. *Flexion*—Gradually increasing dorsally on head & on jaws; on isthmus; spreading along dorsal margin; spreading posteriorly over spinal cord & forward over notochord; spreading forward along lateral midline; few distally on some A ray bases; internally under urostyle; laterally over hypural area; on hypural margin. *Postflexion*—Increasing on all areas, becoming heavy on upper half & remaining light below except heavy on A base & hypural area. *Transformation*—Generally dark on upper half; very light on lower half of head except heavy on gular area & lower jaw; little or none externally on abdominal area; on D I–III; on C, primarily lower half; series outlining most hypaxial myosepta of tail.
Diagnostic features: Usually at least a few melanophores on hypaxial myosepta of tail through notochord flexion, increasing in postflexion stage; relatively elongate compared with most carangins.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		57–64 62	59–64 60	56–62 59	48–54 50	48–51 50
BD/BL		32–36 33	32–35 34	33–39 35	27–30 28	28–29 28
HL/BL		33–41 36	34–37 35	35–39 37	29–33 31	30–32 31
HW/HL		46–57 52	45–52 49	40–48 43	38–46 40	39–43 41
SnL/HL		25–35 29	29–33 32	28–35 32	28–32 30	27–31 29
ED/HL		31–34 32	31–37 33	29–35 33	29–32 30	30–31 30
P_1L/BL		7–9 8	6–8 7	6–8 7	14–16 15	14–15 15
P_2L/BL		0–0 0	0–0 0	1–2 1	13–14 13	13–14 13

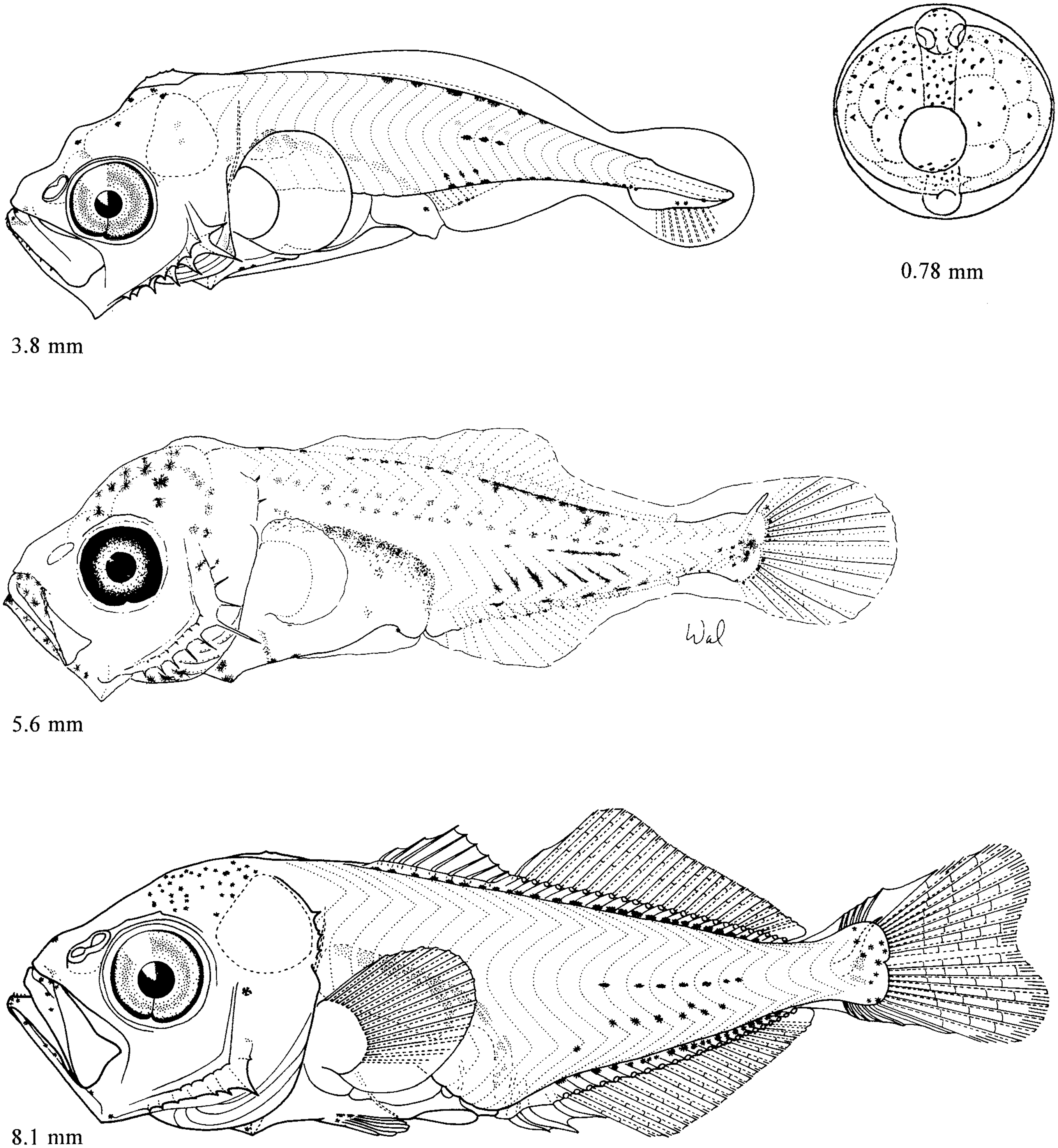


Figure Carangidae 10. Egg, 0.78 mm (Delsman 1926b); preflexion larva, 3.8 mm (modified from Miller et al. 1979); late flexion larva, 5.6 mm (Laroche et al. 1984); postflexion larva, 8.1 mm (modified from Miller et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VII–VIII+I	VIII+I
Dorsal rays	20–24	22
Anal spines	II+I	II+I
Anal rays	17–19	18
Pelvic	I,5	I,5
Pectoral	18–19	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9	9
Lower	7	7
Gill rakers:		
Upper	5–9	
Lower	28–34	
Branchiostegals	7	7

LIFE HISTORY

Range: San Diego, California & Gulf of California to Peru

Habitat: Coastal waters, including bays & estuaries

Spawning season: Larvae collected January–April

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.7 mm (W. Watson)
Flexion larva, 4.4 mm (B. Sumida MacCall)
Postflexion larva, 6.4 mm (B. Sumida MacCall)
Transformation specimen, 8.2 mm (W. Watson)

* Eye initially oval, becoming round by flexion stage; horizontal axis is given first, vertical axis second for preflexion stage.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.9 mm
Flexion length: ca. 4–7 mm
Transformation length: ca. 8.2 mm through >38 mm
Fin development sequence: P_2, 1D, C_1, 2D & A, P_1 & C_2
Pigmentation: *Preflexion*—At tips of jaws; in roof of mouth; posteriorly on midbrain; dorsally on hindbrain by 3.7 mm; gular patch by 3.6 mm; 1 on isthmus; dorsally on gas bladder & hindgut; patch ventrally at midgut; heavy on P_2; on D II–III; 1 or 2 each dorsally at myomeres 1–3 & 17 & 0–1 at myomeres 10–11; on spinal cord at myomeres 1–3 & 17, spreading caudad from anterior site; 0–2 on lateral midline near myomere 17; ventral series on tail. *Flexion*—Increasing on & over brain; 1 at angular; ventrally on preopercle, spreading dorsad; on lower branchiostegal rays; increasing dorsally on trunk & tail & internally on spinal cord; bars forming on trunk & midtail by 6.5 mm; on D I–IV, D 3–5, & A 2–7; heavy on P_2. *Postflexion*—Spreading on jaws; on snout; patch below eye; scattered on opercular area; increasing on gular area & isthmus; few on P_1 base; trunk bar denser, extends onto D I–IV; tail bar broader & denser, extends onto D & A; patch laterally over hypural area. *Transformation*—Increasing on head & gut; filling in between bars & extending posteriorly from tail bar; becoming spotted.
Diagnostic features: Large, pigmented, early forming P_2; elongate, pigmented, early forming D II & III; D III 64–68% D II length in preflexion, ≤60% (usually <50%) from flexion to transformation; D II length >BL by postflexion stage; D I & IV slightly elongate; becoming deep-bodied; barred in flexion or postflexion & spotted late in transformation stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		52–59	53–59	53–60	40–56	
		56	55	56	47	35
BD/BL		34–42	38–47	52–56	51–88	
		38	43	54	67	67
HL/BL		32–34	32–35	35–39	34–41	
		33	33	37	38	38
HW/HL		53–56	45–47	38–43	26–46	
		55	46	41	38	27
SnL/HL		26–32	30–36	33–34	36–49	
		29	34	34	41	51
ED/HL*		32–38× 26–36	29–32	30–33	20–33	
		34×31	31	31	27	24
P_1L/BL		6–8	8–9	14–15	17–25	
		7	8	14	21	36
P_2L/BL		20–27	28–29	32–32	33–38	
		25	29	32	35	6
DSL/BL		0–26	32–127	127–230	181–221	
		18	85	164	198	8

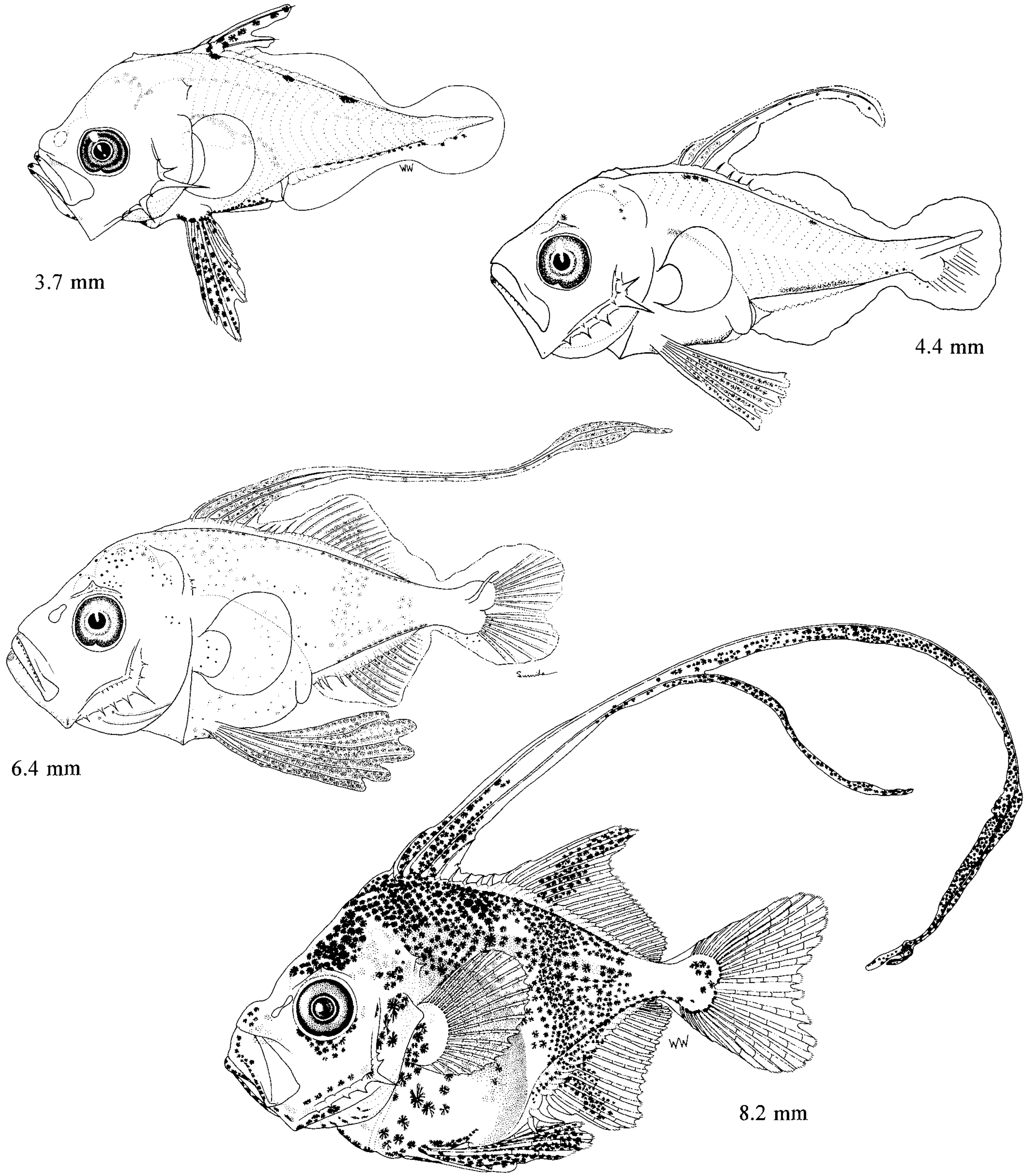


Figure Carangidae 11. Preflexion larva, 3.7 mm; flexion larva, 4.4 mm; postflexion larva, 6.4 mm (EASTROPAC I, station 13.019); transformation specimen, 8.2 mm (IATTC 90010, station PSL2 Red).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	20–24	23
Anal spines	II+I	II+I
Anal rays	16–19	18
Pelvic	I,5	I,5
Pectoral	17–19	18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	8
Lower	6–8	7
Gill rakers:		
Upper	7–9	
Lower	28–34	
Branchiostegals	7	7

LIFE HISTORY

Range: Redondo Beach, California, & Gulf of California to Peru; rare north of Baja California Sur

Habitat: Schools in shallow coastal waters

Spawning season: Larvae collected in most months

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Guzmán & Ayón 1995

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.8 & 3.4 mm (W. Watson)
Flexion larva, 4.6 mm (B. Sumida MacCall)
Postflexion larva, 6.8 mm (B. Sumida MacCall)
Transformation specimen, 15.2 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.6 mm
Flexion length: 4.6 mm through 4.9–5.2 mm
Transformation length: ca. 9–19 mm
Fin development sequence: P_2, 1D, 2D & A & C_1, P_1, C_2
Pigmentation: *Preflexion*—Ventrally on articular; by 2.8 mm, at tip of lower jaw & series on isthmus; by 3.7 mm, at tip of upper jaw, anteriorly on palatines, anterolaterally & posteriorly on midbrain, ventrally on preopercle, & below hypohyals; on lower branchiostegal rays by end of stage; dorsally on gas bladder & hindgut & series ventrally on gut; dorsally at myomeres 3–4 & 15–16 by 2.8 mm; anteriorly on spinal cord by 3.7 mm; on lateral midline near midtail; series on ventral margin of tail to notochord tip; few to many on anal finfold by 3.7 mm; on P_2 by 2.8 mm. *Flexion*—Increasing on midbrain; over & under spinal cord near midtail by 4.7 mm; spreading caudad from anterior patch on spinal cord; forming on D II–IV; D 1–3, A 1–4, & proximally on lower C rays. *Postflexion–transformation*—Spreading on jaws & preopercle; increasing over & on brain; on snout, below eye, & scattered on opercle by 8.9 mm; increasing on gut; increasing on P_2; on nape & trunk, increasing; series on D base; spreading on D to nearly full length of fin; increasing over & under spinal cord; lateral patch near midtail; increasing on A base; patch over hypural area in transformation stage.
Diagnostic features: Large, early forming, pigmented P_2; elongate, pigmented D I–VI; D III 77–100% D II length through transformation; D II length usually <BL; becoming very deep-bodied in postflexion & transformation stages; prominent blotch forms on tail in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–53 50	42–52 48	38–47 42	38–50 43	43–44 43
BD/BL		28–38 34	36–51 43	52–80 63	87–99 92	79–100 88
HL/BL		28–32 30	30–34 32	33–36 34	35–41 38	32–38 34
HW/HL		47–59 51	40–48 45	42–52 47	34–58 41	28–35 32
SnL/HL		28–33 30	30–32 31	30–35 33	32–41 38	33–39 36
ED/HL		30–35 32	26–35 31	29–36 33	28–36 32	27–33 30
P_1L/BL		6–8 7	6–10 8	11–21 15	20–30 26	23–29 26
P_2L/BL		12–34 24	31–41 36	36–50 42	30–38 32	9–23 16
DSL/BL		0–42 17	39–63 52	58–98 78	64–106 90	14–64 34

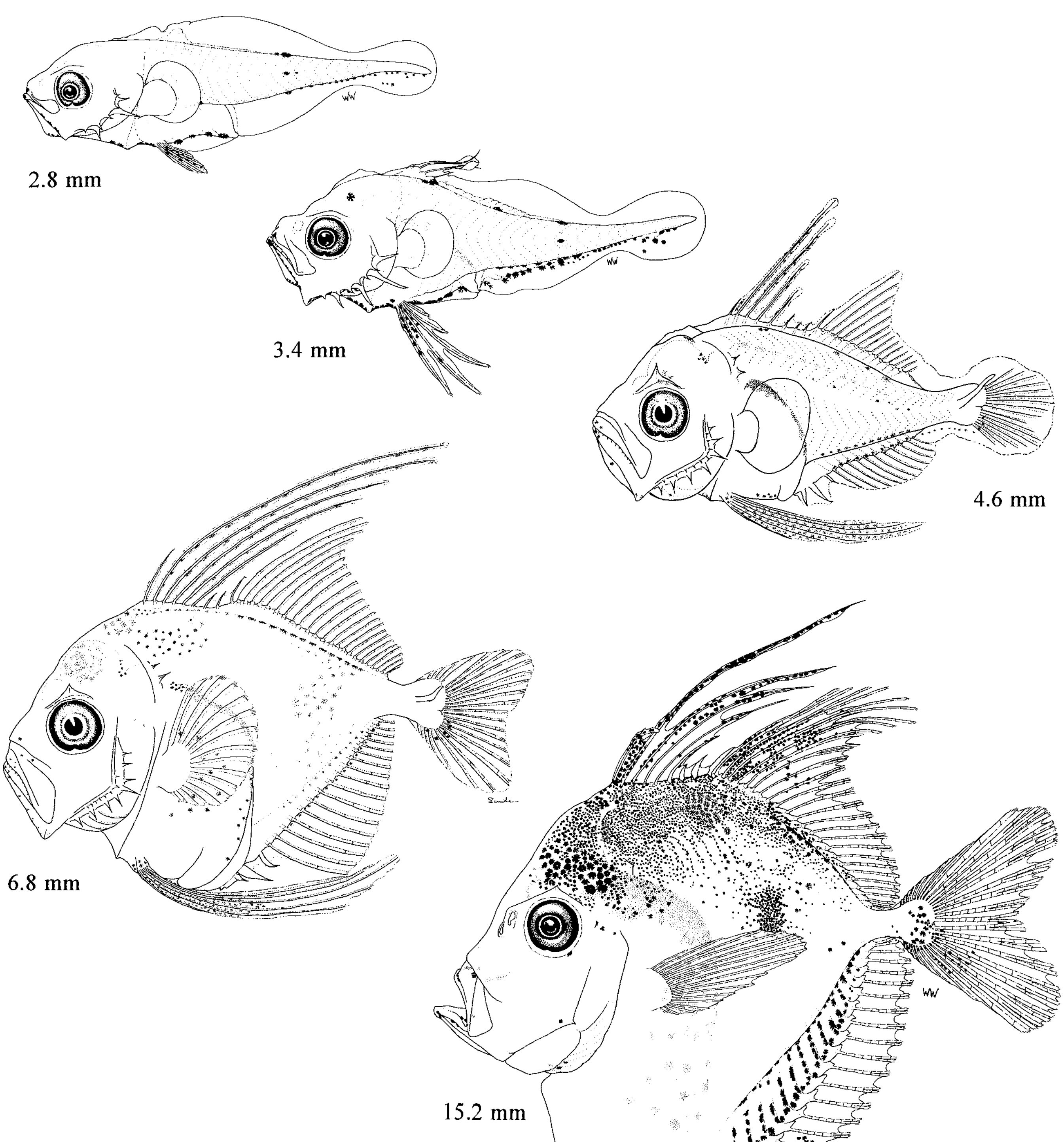


Figure Carangidae 12. Preflexion larvae, 2.8 mm (IATTC 90027, station T2), 3.4 mm (IATTC 90028, station MSL #2 Grn); flexion larva, 4.6 mm (CFRD Ref. Coll.); postflexion larva, 6.8 mm (CFRD Ref. Coll.); transformation specimen, 15.2 mm (CFRD Ref. Coll., 18°05–06′ N, 102°57.5–59.8′ W, 20I73).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	11	11
Caudal	14	14
Fins:		
Dorsal spines	VI–VII+I	VII+I
Dorsal rays	29–39	32
Anal spines	II+I	II+I
Anal rays	19–25	21
Pelvic	I,5	I,5
Pectoral	19–20	
Candal:		
Principal	9+8	9+8
Procurrent:		
Upper	12	12
Lower	11	11
Gill rakers:		
Upper	5–10	
Lower	15–22	
Branchiostegals	7	7

LIFE HISTORY

Range: Circumglobal in subtropical to temperate seas; in eastern Pacific, from British Columbia to Chile

Habitat: Coastal reefs to offshore islands; kelp forests & drifting kelp; in schools from surface to >100 m depth

Spawning season: In CalCOFI area, larvae captured during May–October with highest abundance in July–September & a peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Brownell 1979
Laroche et al. 1984
Manabe & Ozawa 1988a
Sumida et al. 1985

* Calculated from data in Sumida et al. (1985).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: ca. 1.4 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.32 mm
Shell surface: Smooth
Pigment: In late-stage embryos, scattered on head & moderately heavy on body, except light on tip of tail; on OG
Diagnostic features: Large shell & OG diameter; segmented yolk; relatively long gut; pigmentation of embryo

LARVAE

Hatching length: ca. 3–4 mm
Flexion length: ca. 6.6–8.6 mm
Transformation length: ca. 22 mm
Fin development sequence: C_1, 1D & A & P_1, 2D & C_2, P_2
Pigmentation: *Yolk-sac*—Scattered over fore- & midbrain; series lateral to hindbrain continuing as irregular double row on dorsum to caudal region; paired series above gut continuing posteriad as double row; none on posterior 25% of tail; some posteriorly on yolk sac & OG. *Preflexion*—By 5.0 mm, above entire brain, on & in snout, in otic & gular regions, on branchiostegal membranes, ventrally & laterally on isthmus, on ventral margin of gut, spreading laterally onto trunk & tail from dorsum & ventrum, series on lateral midline centered above anus, & minute series above & below notochord in caudal region, spreading onto hypurals; by end of stage, most of body covered except caudal region, series on distal margins of 2D & A, on opercular region, & in caudal finfold. *Flexion*—Spreading onto 2D & A fins from bases. *Postflexion*—By 10.0 mm, on P_2; by 12.0 mm, on 1D; by 14.0 mm, 1D, 2D, & hypural region nearly covered. *Juvenile*—6 bars (nape, 1D, 3 below 2D & caudal peduncle) become doubled with growth; basally on P_1; some on C.
Diagnostic features: Total vertebrae 25; large size (4.0 mm) at hatching; in yolk-sac larvae, yolk segmented, OG anterior, & gut relatively long; pigment series on dorsal & ventral margins; preflexion to postflexion larvae relatively slender & heavily pigmented, except for caudal region; prominent spination on preopercular margin, 3 posterior spines above & below angle at ca. 8 mm; 2 spines in anterior preopercular series, 1 at angle & 1 below; supraocular ridge & spine prominent in preflexion larvae; juveniles distinctly barred.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		58–61	61–63	63–66	63–65	
	52	60	61	65	63	60
BD/BL		19–20	21–26	27–31	29–31	
	9	19	23	29	30	29
HL/BL		27–30	31–33	35–36	32–34	
	12	28	32	35	33	31
HW/HL						
SnL/HL		28–33	29–31	25–30	26–31	
	19	31	31	26	28	27
ED/HL		28–33	29–32	30–34	28–30	
	50	31	31	32	29	33
P_1L/BL						
P_2L/BL						

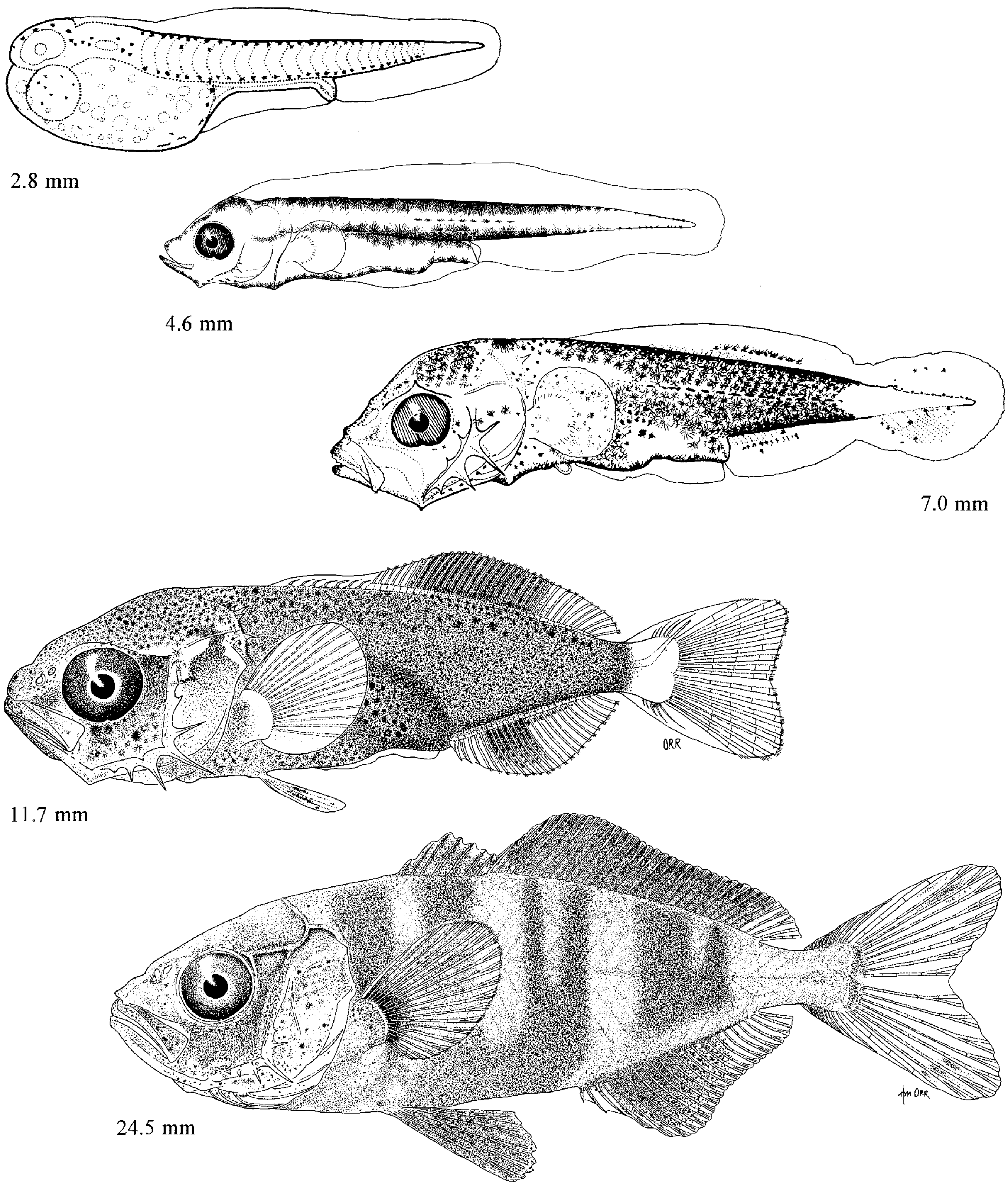


Figure Carangidae 13. Yolk-sac larva, 2.8 mm; preflexion larvae, 4.6 mm, 7.0 mm; postflexion larva, 11.7 mm; juvenile, 24.5 mm (Sumida et al. 1985).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VI+I	VI+I
Dorsal rays	17–19	18
Anal spines	II+I	II+I
Anal rays	16–17	17
Pelvic	I,5	I,5
Pectoral	18–19	18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8	8
Lower	8	8
Gill rakers:		
Upper	5–8	
Lower	9–12	
Branchiostegals	7	7

LIFE HISTORY

Range: Punta Abreojos, Baja California Sur to Peru, including Gulf of California

Habitat: Shallow inshore sandy areas

Spawning season: May–August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Behrstock 1975
Laroche et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 5.0 mm (R. C. Walker)
Postflexion larva, 5.5 mm (R. C. Walker)
Transformation specimen, 11.2 mm (R. C. Walker)

* Eye initially oval, becoming round by juvenile stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5.0–5.5 mm
Transformation length: <11.2 mm – >41.2 mm
Fin development sequence: C_1, 2D & A, 1D, P_2, C_2, P_1
Pigmentation: *Flexion*—Scattered on head & body to ca. 75% BL; rows on each side of D & A bases; on 1D & anterior 2D pterygiophores; on 1D & A spine membranes; on lateral midline; lacking on P_1 base. *Postflexion*—On body spreading posteriad to caudal peduncle. *Transformation*—Covering entire body & caudal peduncle; lacking on 2D, A, P_1, & C rays & P_1 & C membranes. *Late transformation*—On hypurals; on 2D, A & P_2.
Diagnostic features: D VI+I,17–19, A II+I,16–17; heavily pigmented; pterotic ridge present. Compared to other *Trachinotus* species in region: short-based D; longer, wider, serrated supraoccipital ridge; relatively wider, serrated pterotic ridge; posttemporal/supracleithral ridges & spines increasing to series of ridges; deeper BD than other 2 species in transformation & juvenile specimens (55–65% BL vs. 35–46% BL); 1D, 2D & A pigmented in juvenile specimens.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			56–60 58	 57	47–64 56	43–48 46
BD/BL			36–44 41	 43	55–65 61	57–57 57
HL/BL			36–41 38	 33	31–41 36	30–32 31
HW/HL			53–62 58	 73	51–63 57	53–53 53
SnL/HL			16–22 20	 17	18–23 20	19–19 19
ED/HL*			33–38× 31–36		32–36× 32–34	30–30
			35×33	36×42	34×33	30
P_1L/BL			9–12 10	 12	20–22 21	19–21 20
P_2L/BL			3–5 4	 5	11–15 13	13–13 13

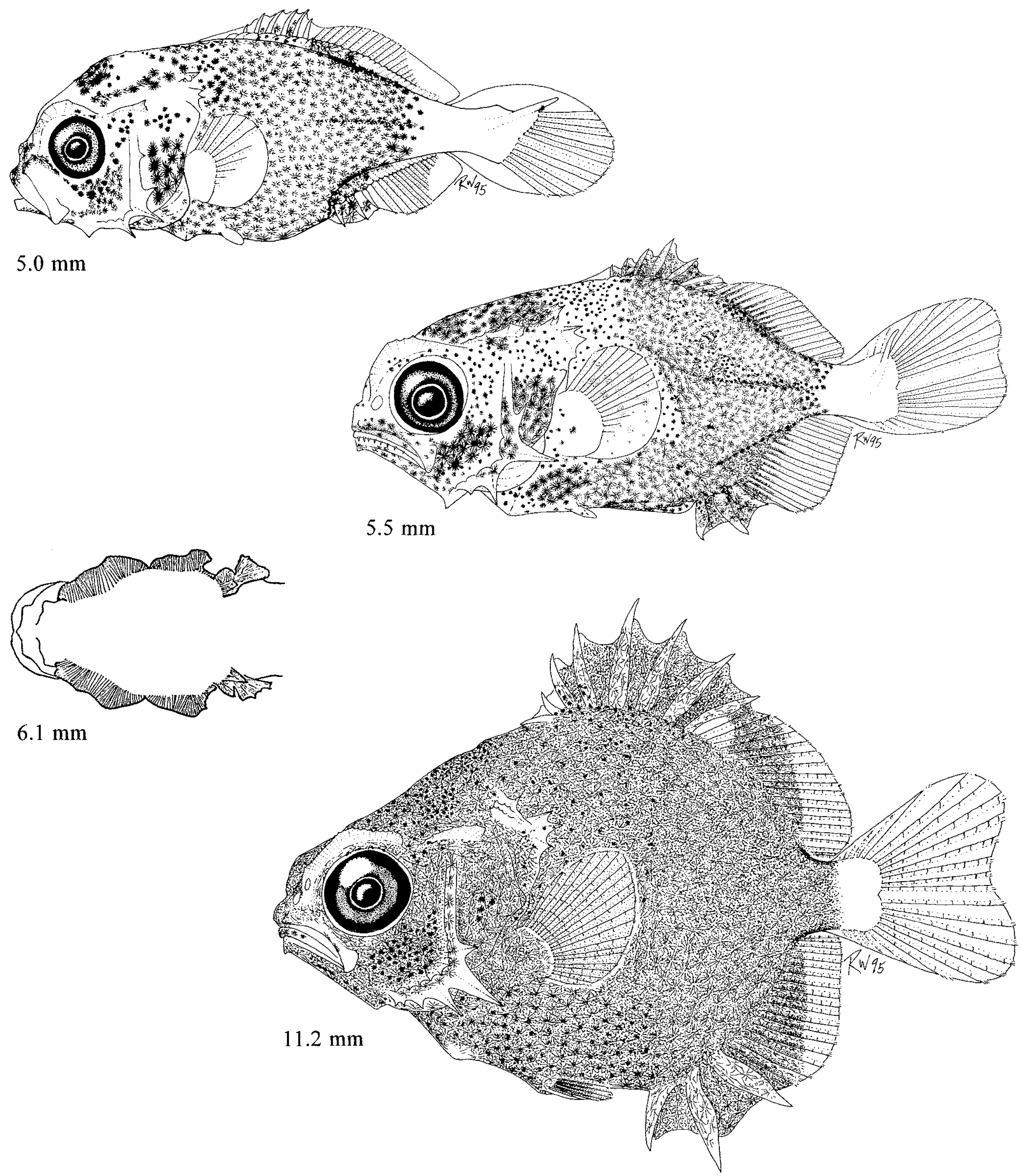


Figure Carangidae 14. Flexion larva, 5.0 mm (IATTC 90034, station ASB #2 Manta); postflexion larva, 5.5 mm (MOPS 8710JD, station III–42), dorsal view of head, 6.1 mm (Behrstock 1975); transformation specimen, 11.2 mm (CFRD Ref. Coll., Mazatlán, night-light, 12–19–68).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VI–VIII+I	VI+I
Dorsal rays	20–27	26
Anal spines	II+I	II+I
Anal rays	20–25	21
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	8
Lower	8	8
Gill rakers:		
Upper	9–11	
Lower	14–17	
Branchiostegals	7–8	7

LIFE HISTORY

Range: Redondo Beach, California to Peru, including Gulf of California & Galápagos Islands

Habitat: Usually in shallow inshore sandy areas

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Laroche et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 5.8 mm, with dorsal view of head (R. C. Walker)
Postflexion larva, 7.4 mm (R. C. Walker)

* Eye slightly oval; becoming round by juvenile stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5.8 mm
Transformation length: <16.2 mm – ca. 25 mm
Fin development sequence: C_1, 2D & A, 1D, P_2, C_2, P_1
Pigmentation: *Flexion*—On head & body to caudal peduncle; on lateral midline; internally on notochord dorsally & ventrally; lacking on P_1 base & all fin rays & membranes. *Postflexion*—Increasing posteriorly on body; proximally on P_1 base; on D & A pterygiophores. *Transformation*—Scattered over entire head & body, heavier dorsally, lighter ventrally; blotch anteriorly on 2D; lacking on 1D, posteriorly on 2D, on P_1, P_2, A, & C.
Diagnostic features: D usually VI+I,26, A II+I,21; heavily pigmented; pterotic ridge present. Compared to other *Trachinotus* species in area: long-based D; longer, narrower, serrated supraoccipital ridge; pterotic & supracleithral spines form 2 narrow ridges; 2 small posttemporal spines; more slender through most larval stages (BD 30–40% vs. 31–65% BL); 2D pigmented anteriorly in juvenile specimens.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				57–58	51–58	53–58
			55	58	54	55
BD/BL				30–30	35–40	38–41
			32	30	38	40
HL/BL				34–38	32–37	31–38
			34	36	35	34
HW/HL				54–55	43–76	45–67
			53	54	58	58
SnL/HL				20–24	21–24	20–22
			21	22	22	21
ED/HL*				30–32× 27–30	22–27× 22–27	25–28
			32×30	31×28	26×25	26
P_1L/BL				9–19	16–20	17–19
			8	14	18	18
P_2L/BL				4–10	16–16	16–18
			3	7	16	17

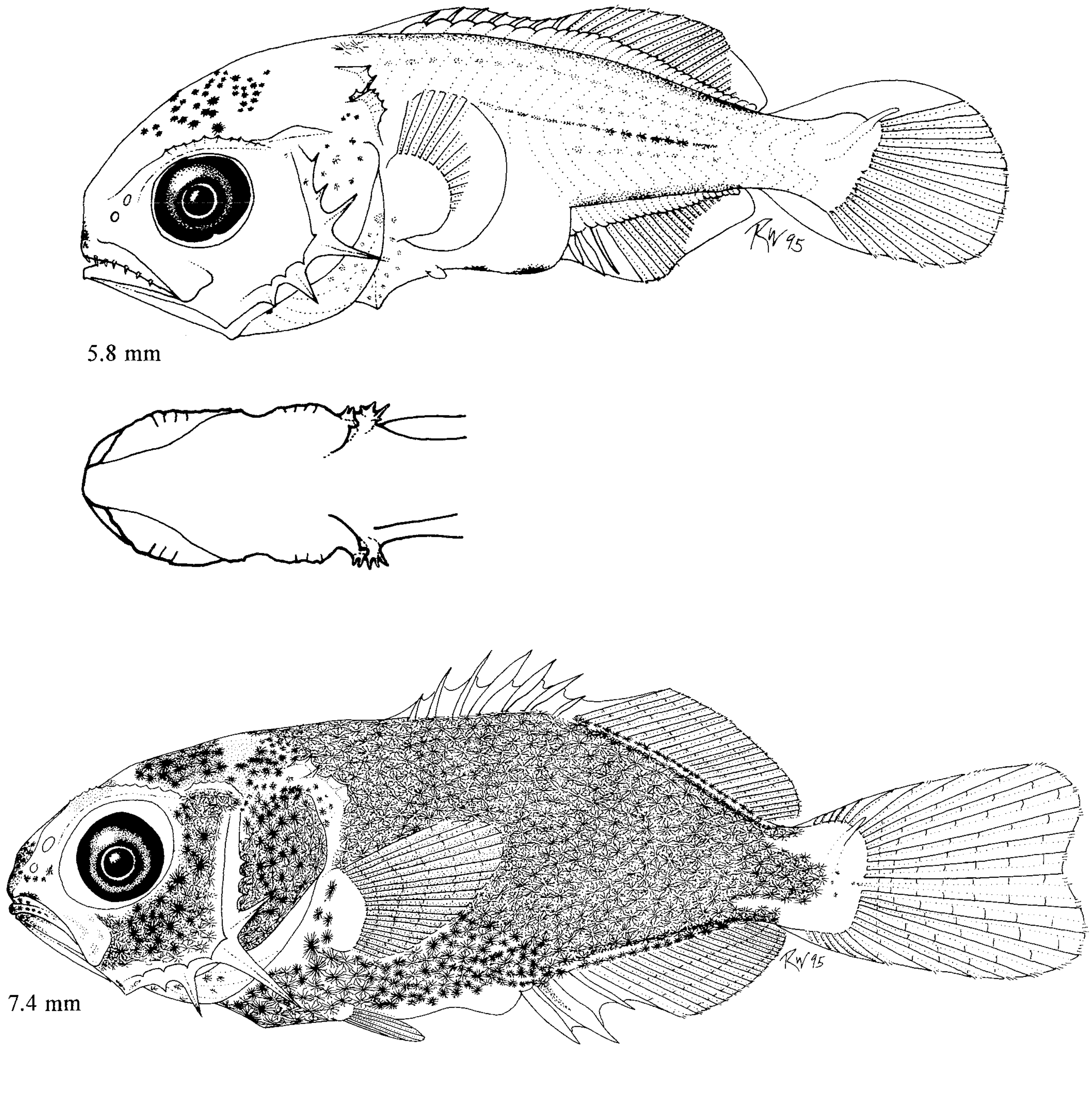


Figure Carangidae 15. Flexion larva, 5.8 mm, and dorsal view of head (CalCOFI 5808, station 137.30); postflexion larva, 7.4 mm (CFRD Ref. Coll., MARMAP 75–04, station 11).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	V–VI+I	VI+I
Dorsal rays	19–20	20
Anal spines	II+I	II+I
Anal rays	17–21	18
Pelvic	I,5	I,5
Pectoral	18–19	18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–9	8
Lower	7–8	8
Gill rakers:		
Upper	8–10	
Lower	13–16	
Branchiostegals	7–8	7

LIFE HISTORY

Range: Zuma Beach, California to Peru, including Gulf of California & Galápagos Islands

Habitat: Inshore sandy areas; also around reefs & rocky areas

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Laroche et al. 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 4.4 mm (R. C. Walker)
Late flexion larva, 5.2 mm, with dorsal view of head (R. C. Walker)
Postflexion larva, 8.9 mm (R. C. Walker)

* Eye slightly oval, becoming round during juvenile stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 3.3–6.0 mm
Transformation length: ca. 9.4 mm – ca. 38.4 mm
Fin development sequence: C_1, 2D & A, 1D, P_2, C_2, P_1
Pigmentation: *Flexion*—On head & opercle; laterally on gut; on P_1 base; on body ending anterior to caudal peduncle; rows on each side of D & A bases; on lateral midline; internally dorsally & ventrally on notochord. *Late flexion*—On 1D & A spines. *Postflexion*—Increasing on body posteriad to hypurals. *Transformation*—Scattered evenly over entire body; on P_1 base, 1D & anteriorly on 2D; on A spines & anterior rays.
Diagnostic features: D usually VI+I,19–20, A II+I,20; heavily pigmented; pterotic ridge present. Compared to other *Trachinotus*: shorter supraoccipital ridge with large central peak; pterotic ridge relatively large with 1 large peak; large preopercular spinal column develops by 3.3 mm; posttemporal & supracleithrum with 3–4 spines, each developing into spiny ridges; 1D & anterior 2D & A pigmented in juvenile specimens.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			54–62		51–62	49–66
			59	60	56	56
BD/BL			31–43		39–46	36–38
			36	44	43	37
HL/BL			34–37		32–44	31–34
			35	40	37	32
HW/HL			57–69		46–63	45–50
			61	57	51	48
SnL/HL			13–26		16–25	20–23
			20	22	22	21
ED/HL*			33–39×		27–34×	24–30×
			29–38		25–34	24–27
			36×34	33×31	30×28	26×26
P_1L/BL			5–12		18–22	18–19
			9	22	21	19
P_2L/BL			0–7		14–17	15–17
			4	14	16	16

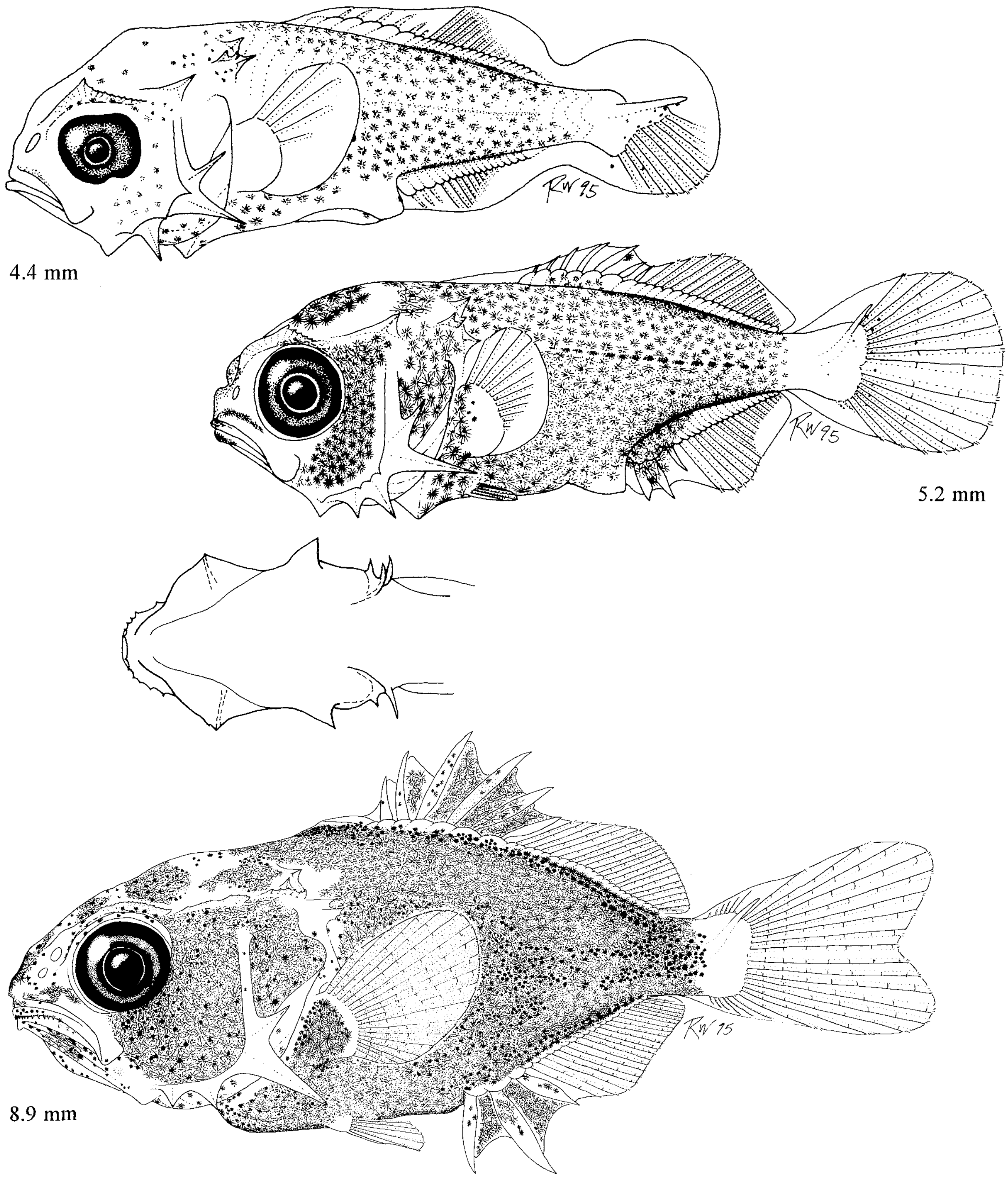


Figure Carangidae 16. Flexion larva, 4.4 mm (EASTROPAC I, station 13.019); late flexion larva, 5.2 mm, and dorsal view of head (IATTC 89021, station ASB #1 Red); postflexion larva, 8.9 mm (CFRD Ref. Coll., RABMEX, station 5–10).

MERISTICS

	Range	Mode
Vertebrae:		
Total	23–25	24
Precaudal	9–10	10
Caudal	14–15	14
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	28–38	33
Anal spines	II+I	II+I
Anal rays	22–33	29
Pelvic	I,5	I,5
Pectoral	21–24	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–10	
Lower	9–10	
Gill rakers:		
Upper	7–15	
Lower	25–42	
Branchiostegals	7–8	

LIFE HISTORY

Range: Gulf of Alaska to southern Baja California; reported from the Galápagos Islands

Habitat: Primarily epipelagic but reported to ca. 400 m depth; offshore to >1000 km

Spawning season: Primarily February–July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Ball 1954
Ahlstrom 1965, 1969a
Laroche et al. 1984
Matarese et al. 1989

* Data from Ahlstrom & Ball (1954); range of means is given for size classes within each stage.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.90–1.08 mm **Yolk:** Irregularly segmented; 0.68–0.92 mm diam.
No. of OG: 1 **Diam. of OG:** 0.18–0.35 mm
Shell surface: Smooth
Pigment: Double row on dorsum of embryo; series on ventral margin of tail in late-stage embryos; on proximal surface of OG.
Diagnostic features: Shell & OG diam.; dorsal & ventral pigment; lack of yolk pigment; yolk segmentation

LARVAE

Hatching length: 1.9–2.4 mm
Flexion length: ca. 7.5–11.0 mm
Transformation length: ca. 16–20 mm
Fin development sequence: C_1, 2D & A, 1D & P_1, C_2, P_2
Pigmentation: *Yolk-sac*—Initially, few scattered on snout & forebrain continuing posteriad as irregular dorsal double row to end of tail, series above gut continuing on ventral margin to end of tail, & some laterally on trunk; at end of stage, lateral hindbrain series has migrated to ventrolateral surface, coalescence within dorsal & ventral tail series, & cluster ventrally on foregut. *Preflexion*—By 3.5 mm, patches above mid- & hindbrain, pair in snout, at lower jaw tip & angular, on isthmus continuing posteriad to midgut, patch embedded anterior to gut, & those in dorsal & ventral series much larger anterior to midtail; by 4.5 mm, on forebrain, more in snout & on lower jaw, on ventral margin from isthmus to anus, shield forming above gut & gas bladder, & ≥1 in lateral midline anterior to midtail; by end of stage, up to ca. 6 in lateral series, more on dorsum, & embedded above spinal column in region of lateral series. *Flexion*—Filling in laterally between bases of 2D & A; top of head covered. *Postflexion*—By ca. 8.0 mm, head & body covered except lower part of head, ventrolateral region of gut, & caudal peduncle; by 10.0 mm, hypurals & branchiostegals outlined. *Juvenile*—Upper half heavily pigmented, ventral half pale; on membranes of C, 1D (distally), 2D, & P_1 (dorsally).
Diagnostic features: In yolk-sac larvae, yolk segmented, OG anterior, relatively long gut, & pigment on dorsal & ventral margins; triangular-shaped body & gut & unique pigment pattern in preflexion larvae; serrated dorsal crest on head most evident at 4–8 mm; double row of preopercular spines; in posterior series, the spine at angle largest, with up to 4 above & 7 below.

MORPHOMETRICS (range of means in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–60	59–61	51–60	55	54–55
BD/BL		17–26	26–28	28–29	26	24–25
HL/BL		17–32	33–35	34–38	35	28–31
HW/HL						
SnL/HL						
ED/HL		36–51	34–37	32–37	35	31–33
P_1L/BL						
P_2L/BL						

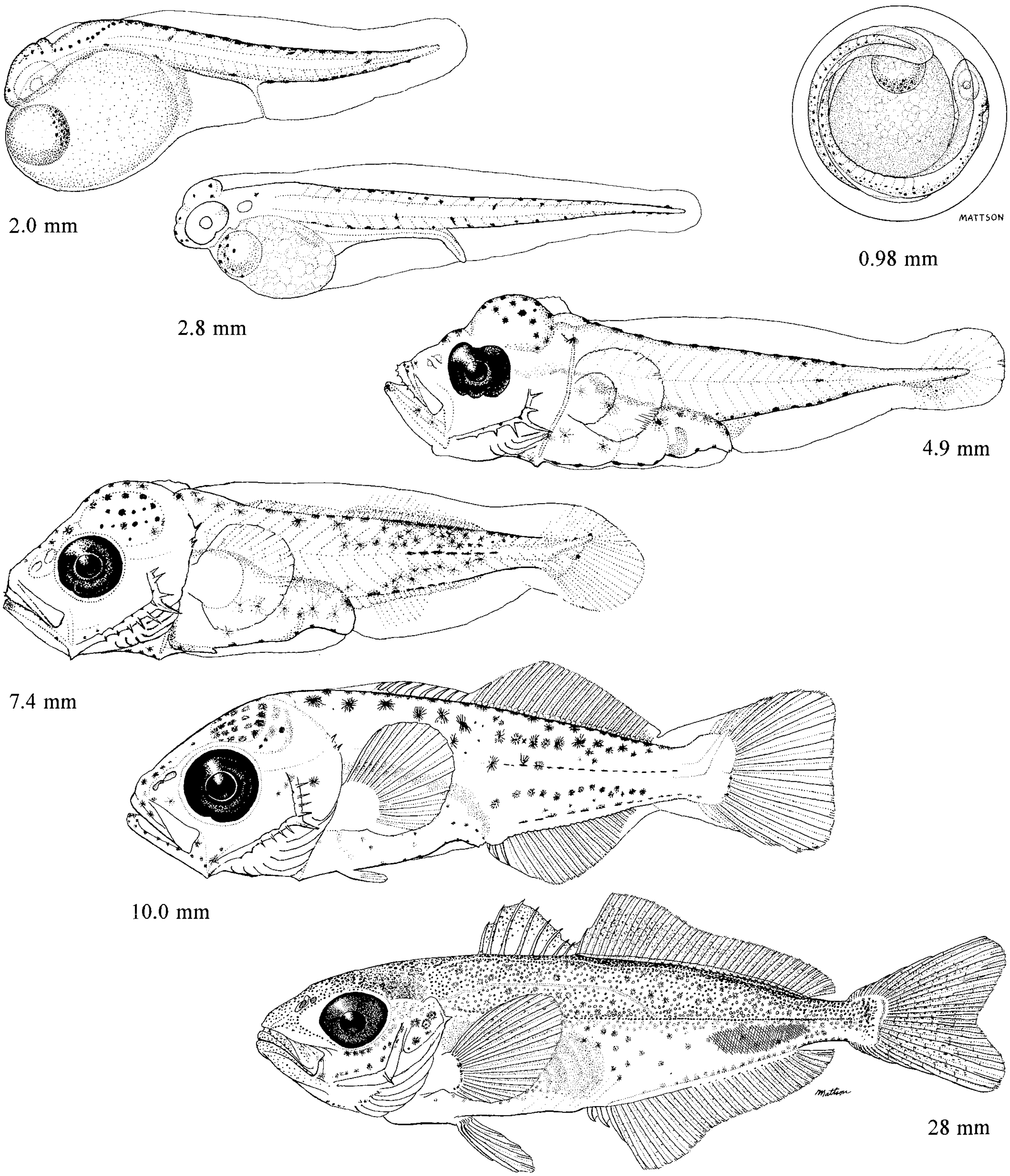


Figure Carangidae 17. Egg, ca. 0.98 mm; yolk-sac larvae, 2.0 mm, 2.8 mm; preflexion larva, 4.9 mm; flexion larva, 7.4 mm; postflexion larva, 10.0 mm; juvenile 28 mm (Ahlstrom and Ball 1954).

NEMATISTIIDAE: Roosterfish

H. G. MOSER

Nematistiidae consists of a single species, *Nematistius pectoralis*, the roosterfish, a large predaceous fish found off sandy shores in the eastern tropical Pacific. Adults and juveniles have been taken as far north as San Clemente Island, California. Larvae of *N. pectoralis*, unknown before this study, have not been identified in CalCOFI samples but may occur near shore in the southernmost regions of the survey pattern.

The systematic relationships of *N. pectoralis* have been a subject of great interest to ichthyologists for more than a century, with some workers regarding the roosterfish as a carangid and others placing it in a separate family. Rosenblatt and Bell (1976) marshalled evidence for familial status based on the presence of paired otophysic connections through basioccipital foramina (Starks 1908), a ramus lateralis pattern different from that of carangids (Freihofer 1963), and the lack of a lamellar expansion on the coracoid, resulting in a large interosseus space. Nematistiidae, like other carangoids (Carangidae, Coryphaenidae, Rachycentridae, and Echeneidae) has small adherent scales and has a unique anterior extension of the lateralis canal system of the snout but differs from other carangoids in having only a single prenasal canal unit (vs. two in other carangoids) and in having a bony stay posterior to the ultimate dorsal and anal pterygiophores, a structure present in most other non-carangoid percoids (Freihofer 1978; Johnson 1984). Also, Johnson (1984) pointed out that carangid larvae are moderate to deep-bodied and complete formation of dorsal and anal fin rays soon after notochord flexion unlike echenoid larvae (Echeneidae, Rachycentridae, Coryphaenidae) that are very elongate and complete dorsal fin rays at two to three times the size at flexion. Leis (1994) described the larvae and developmental osteology of the jack-like, monotypic Indo-Pacific species, *Lactarius lactarius*, and concluded that it is a sister taxon to carangoids but is not closely related to *N. pectoralis*. The latter conclusion is supported by the dissimilarity of *L. lactarius* larvae to those of *N. pectoralis* (this study).

The roosterfish is jack-like with a compressed and deep head and body. Adults may exceed 1 m in length and weigh more than 35 kg. The first seven dorsal rays are elongate and thread-like and form a comb when erected from their sheath. The pectoral fins are long and falcate and the caudal is deeply forked. The anal fin has two or three spinous rays. The pelvic fin formula is I,5; however, the last soft ray is divided near the base giving the appearance of two rays. The body is dusky dorsally and silvery laterally and ventrally with two distinct stripes that curve caudad from the base of the spinous dorsal fin. The roosterfish is highly prized by recreational anglers (Walford 1937; Miller and Lea 1972; Eschmeyer et al. 1983).

There is no information on spawning and eggs have not been identified. Roosterfish larvae resemble carangids (see above) and many other percoids in having a moderately deep, compressed body and in completing median fin formation soon after notochord flexion. They lack the large thorny multinucleate epithelial cells found by Johnson (1984) in coryphaenids and rachycentrids; whether or not they have clusters of bumplike epithelial structures found in naucratine and trachinotine carangids awaits study using scanning electron microscopy. Roosterfish larvae develop anterior and posterior series of relatively weak preopercular spines. Body pigmentation begins as a wedge-shaped patch extending ventrad from the dorsal fin base; the patch expands posteriorly, eventually reaching the caudal fin base. The gut membrane is pigmented in flexion larvae but the body surface over the gut is the last region to develop pigmentation. Roosterfish larvae lack the dorsal, lateral, and ventral series of tail melanophores present in most carangid larvae. The spinous dorsal becomes enlarged and heavily pigmented in early postflexion larvae, allowing easy identification.

The following description of *N. pectoralis* is based on detailed examination of 11 larvae (5.0–16.1 mm, flexion through postflexion) and 2 juveniles (28.4 and 35.0 mm). Meristic data and ecological information were obtained from the literature (Walford 1937; Miller and Lea 1972; Rosenblatt and Bell 1976; Eschmeyer et al. 1983) and from observations made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VIII–IX	IX
Dorsal rays	26–28	28
Anal spines	II–III	III
Anal rays	15–17	16
Pelvic	I,5	I,5
Pectoral	16–17	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10	10
Lower	9	9
Gill rakers:		
Upper	6–7	
Lower	10–13	
Branchiostegals	7	7

LIFE HISTORY

Range: San Clemente Island, California, to Peru including Gulf of California & Galápagos Islands

Habitat: Pelagic; shallow inshore areas off sandy beaches

Spawning season:

ELH pattern: Oviparous; planktonic larvae & pelagic juveniles

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larvae, 5.2 mm, 7.7 mm, 12.5 mm (M. T. Vona)
Pelagic juvenile, 28.4 mm (M. T. Vona)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5 mm
Transformation length: >16.1 mm, <28.4 mm
Fin development sequence: C_1, D & A, P_1 & P_2 & C_2
Pigmentation: *Flexion*—Patch above snout & brain; ventrolaterally on brain; on postocular rim; on opercular region (surface & embedded); along lower jaw & at angular; embedded at cleithral symphysis; sheath over gut membrane; on body from nape to A origin but not over gut region; heaviest along 1D, myosepta & accentuated lateral midline; ca. 7 in postanal ventral series; 2 dorsally at caudal peduncle; on hypural edge & embedded laterally; a few on C rays. *Postflexion*—1D heavily pigmented by 6.3 mm; by 7.3 mm, isthmus covered, spreading dorsally from chest region, body covered to caudal peduncle, except over gut, heavy along 2D & A bases & lateral midline; by 9.8 mm, pale areas in 1D & blotch forming in 2D; by 12.5, pigment solid except for 2D & other fins, nasal, & gular areas. *Juvenile*—At 28.4 mm, bar on top of head, a diagonal nape bar, & four blotches on either side of D; becomes silvery.
Diagnostic features: Heavy body pigment in wedge-shaped patch enlarging posteriad to C; gut membrane pigmented but surface over gut unpigmented until late in larval period; enlarged, heavily pigmented 1D; inconspicuous preopercular spination, a maximum of ca. 4 spines in anterior series & 12 (usually <8) in posterior series.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	PJuv
Sn-A/BL				62–66		64–70
			56	64		67
BD/BL				30–35		34–35
			30	33		35
HL/BL				30–37		30–32
			32	34		31
HW/HL				48–65		52–56
			63	60		54
SnL/HL				19–23		23–26
			19	21		25
ED/HL*				33–45× 29–41		35×35
			44×39	41×37		35×35
P_1L/BL				9–18		15–18
			9	15		17
P_2L/BL				3–23		24–25
			2	12		25

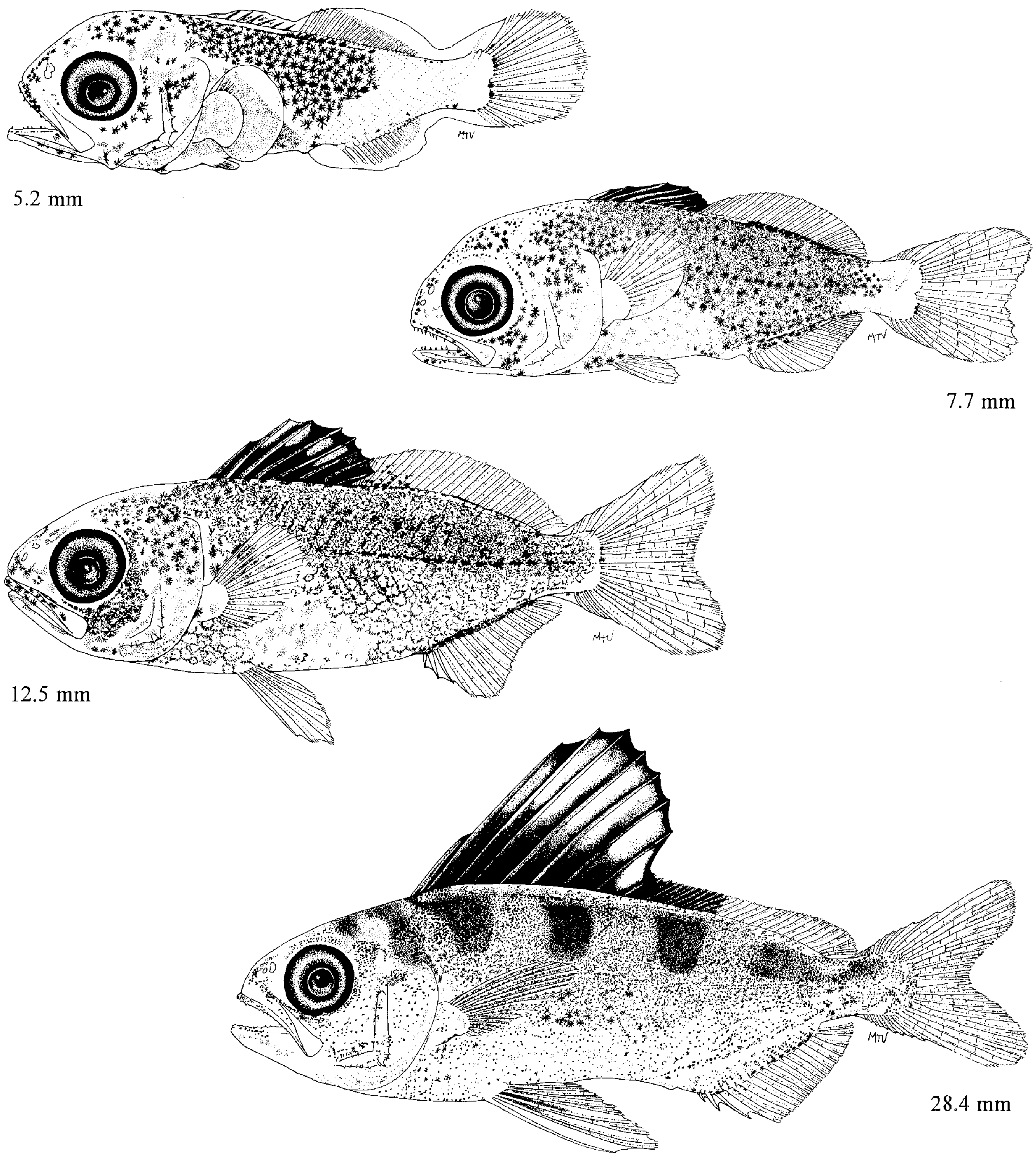


Figure Nematistiidae 1. Postflexion larvae, 5.2 mm, 7.7 mm (IATTC, nightlight station, 91–VIII–02), 12.5 mm (IATTC, nightlight station, 91–VIII–01); pelagic juvenile, 28.4 mm (IATTC, nightlight station, 90–VI–18).

CORYPHAENIDAE: Dolphinfishes

D. A. AMBROSE

Coryphaenidae consists of two species: *Coryphaena hippurus*, the common dolphinfish, and *C. equiselis*, the pompano dolphinfish. Both are distributed world wide in tropical and subtropical seas (Palko et al. 1982). Only *C. hippurus* ranges into the CalCOFI study area; pompano dolphinfishes are more pelagic and tropical (Gibbs and Collette 1959). Larval *C. hippurus* are collected off central and southern Baja California and occasionally off southern California in warm years, with peak abundance in August and September.

Dolphinfishes are large (ca. 65 cm, *C. equiselis*; >200 cm, *C. hippurus*) fast-swimming pelagic predators. They are elongate and compressed with cycloid scales. The large mouth has bands of teeth on the jaws, vomer, and palatines. The dorsal fin is long-based, originating on the nape and continuing almost to the caudal fin. The long-based anal fin originates just behind the anus at about midbody and extends almost to the deeply forked caudal fin. Pelvic fins are thoracic and fit into a groove on the body. Meristics for the family are V 30–34; D 52–66; A 23–31; P_1 17–21; P_2 I,5; C_1 9+8, C_2 10–14; Br 7. In life, both species are spectacularly colored with golden hues on the sides, metallic blues and greens on the back and upper sides, and with white and yellow ventrally. Males have a high rounded forehead; it is less steep in females. The more abundant *C. hippurus* is an important sport and commercial species. Johnson (1984) suggests that *Coryphaena* and *Rachycentron* (the cobia) are sister groups and that they are part of a monophyletic group which includes the echeneids (the remoras).

Larval development of both *Coryphaena* species has been well described (e.g., Potthoff 1980; Ditty et al. 1994b). Larvae hatch at ca. 4 mm with unpigmented eyes, undeveloped jaws, and a large yolk sac containing the posteriorly located oil globule. The slender body is heavily pigmented and the gut extends beyond midbody. Fin rays develop early; however, there is a delay in the completion of the dorsal fin which is unique to the echenoids—*Coryphaenidae*, *Rachycentridae*, and *Echeneidae* (Johnson 1984). By preflexion stage, minute epithelial spicules cover the body. Head spination forms early and consists of a single spine (sometimes two or three in *C. equiselis*) on the supraorbital ridge, moderate to large spines on the posterior margin of the preopercle (four in *C. hippurus*, five in *C. equiselis*) and three smaller spines on the inner shelf of the preopercle. The pterotic area is swollen in both species by 5 mm. *C. equiselis* larvae are always more advanced in fin ray development than in *C. hippurus* of equal size (Potthoff 1980). Larval *C. hippurus* develop pigmentation on the pelvic fin and vertical bars on the body which are absent in *C. equiselis*.

The following descriptions are based on the literature. Morphometric data were taken from Ditty et al. (1994b). The presentation of ranges as a percentage of body length grouped by size (instead of developmental stage) deviates from the standard format of this guide. Meristic data were obtained from Collette et al. (1969), Miller and Lea (1972), Potthoff (1980), Smith (1986), and Konishi (1988b). Ecological information was obtained primarily from Palko et al. (1982) and Eschmeyer et al. (1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–34	33
Precaudal	13–14	13
Caudal	19–20	20
Fins:		
Dorsal spines		
Dorsal rays	52–59	53
Anal spines		
Anal rays	23–29	26
Pelvic	I,5	I,5
Pectoral	18–21	20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–13	12
Lower	10–14	13
Gill rakers:		
Upper		
Young	1–2	
Adults	0	
Lower		
Young	10–11	
Adults	8–10	
Branchiostegals	7	7

LIFE HISTORY

Range: Cosmopolitan in seas warmer than ca. 20 °C, but usually >24 °C

Habitat: Open ocean, rarely captured in coastal waters

Spawning season: Year-round in waters ≥24 °C

ELH pattern: Oviparous, pelagic eggs & larvae

LITERATURE

Aoki & Ueyanagi 1989
Ditty et al. 1994b
Gibbs & Collette 1959
Johnson 1984
Konishi 1988b
Palko et al. 1982
Potthoff 1971, 1980

* The morphometrics presentation differs from the usual format; data from Ditty et al. (1994b) who calculated body proportions for length intervals (mm).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: ca. 1.35 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:**
Shell surface: Spherical, smooth, transparent
Pigment:
Diagnostic features: Egg & OG size; heavy pigmentation

LARVAE

Hatching length: <4 mm
Flexion length: ca. 7.5–9.0 mm
Transformation length: ca. 13–18 mm
Fin development sequence: C_1, P_1, D & A, C_2 & P_2
Pigmentation: *Preflexion*—Heavy on body, present on caudal finfold & notochord tip in larvae <4 mm; on premaxilla, snout, brain, lower jaw, isthmus, roof of mouth, & branchiostegals; light laterally on hindgut. *Flexion–postflexion*—Increasing on gut; by 7.5 mm, row of enlarged melanophores dorso- & ventrolaterally adjacent to D & A bases; absent on P_2; only on proximal third of C. *Transformation*—Heavy laterally on body; no banding; still absent on P_2. *Juvenile*—Pigment absent on P_2 & from entire posterior margin of C.
Diagnostic features: Myomeres usually 33; D 52–59; at ca. <4 mm, pigment on end of tail & finfold; by 8 mm, pigment on P_2; by ca. 9 mm, 5 outer preopercular spines present; morphometric values generally greater than in *C. hippurus*; pigment absent on P_2 in transformation specimens & juveniles. No lateral bands of pigment at any size.

MORPHOMETRICS* (range in % for BL intervals in mm)

	3.7–4.9	5.0–6.1	7.5–8.9	9.0–10.9	11.0–12.9	13.0–15.0
Sn-A/BL	60–65	60–62	46–47	56–60	55–60	55–60
BD/BL	19–21	16–20	16–22	25–29	27–29	26–28
HL/BL	23–28	23–24	19–22	27–30	25–30	27–30
HW/BL						
SnL/BL	5–6	5–6	4–5	5–5	4–5	4–5
ED/BL	10–10	9–10	8–10	12–12	12–14	13–13
P_1L/BL						
P_2L/BL	0–0	0–0	bud-6	9–14	13–15	16–19

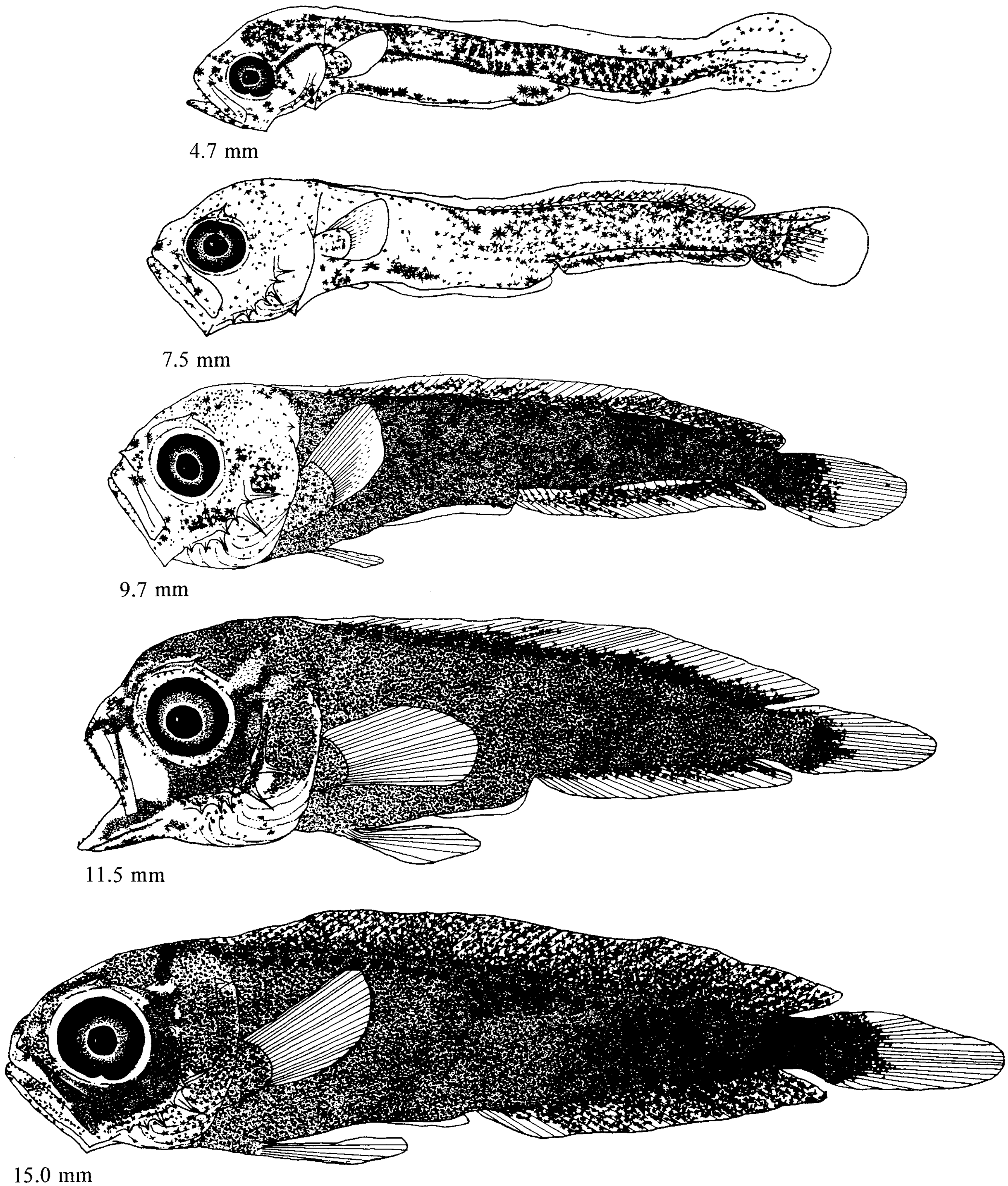


Figure Coryphaenidae 1. Preflexion larva, 4.7 mm; flexion larva, 7.5 mm; postflexion larvae, 9.7 mm, 11.5 mm; transformation specimen, 15.0 mm (Ditty et al. 1994b).

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–31	31
Precaudal	13–14	13
Caudal	17–18	18
Fins:		
Dorsal spines		
Dorsal rays	58–66	60
Anal spines		
Anal rays	24–31	27
Pelvic	I,5	I,5
Pectoral	17–21	20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–14	13
Lower	11–14	13
Gill rakers:		
Upper		
Young	1–2	
Adult	0	
Lower		
Young	6–11	
Adult	8–9	
Branchiostegals	7	7

LIFE HISTORY

Range: Cosmopolitan in seas warmer than ca. 20 °C, but rare north of southern California

Habitat: Open ocean in upper 30 m; near islands; occasionally in estuaries & harbors; associated with floating & drifting objects

Spawning season: Year-round in waters ≥24 °C

ELH pattern: Oviparous, pelagic eggs & larvae

LITERATURE

Aboussouan 1969
Aoki & Ueyanagi 1989
Ditty et al. 1994b
Gibbs & Collette 1959
Johnson 1978, 1984
Konishi 1988b
Miller et al. 1979
Mito 1960
Palko et al. 1982
Potthoff 1971, 1980

* The morphometrics presentation differs from the usual format; data from Ditty et. al (1994b) who calculated body proportions for length intervals (mm).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.28–1.66 **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** 0.3–0.4 mm
Shell surface: Spherical, smooth, transparent
Pigment: On embryo, yolk, & OG
Diagnostic features: Egg & OG size; segmented yolk; heavy pigmentation

LARVAE

Hatching length: ca. 3.9 mm
Flexion length: ca. 7.5–9.0 mm
Transformation length: ca. 14–24 mm
Fin development sequence: C_1, P_1, D & A, C_2 & P_2
Pigmentation: *Preflexion*—Heavy on body, except absent on posterior 15–20% of tail in larvae <4 mm; on premaxilla, snout, brain, lower jaw, isthmus, roof of mouth, & branchiostegals; light laterally on hindgut. *Flexion–postflexion*—Increasing on gut; by ca. 8 mm, on P_2 & vertical bars form along D & A; by 10 mm, on all but distal tips of C & 12–13 bars across body. *Transitional*—Barring more distinct. *Juvenile*—Pigment heavy on P_2 & absent only from tips of caudal fin lobes.
Diagnostic features: Myomeres usually 31; D 58–66; at ca. <4.5 mm, pigment absent at end of tail; by 8 mm, pigment on P_2; bands laterally on body & median fins; by 10.5 mm, 4 preopercular spines present; morphometric values generally less than *C. equiselis*; pigment present on P_2 in transformation specimens & juveniles.

MORPHOMETRICS* (range in % for BL intervals in mm)

	3.5–4.9	5.0–6.9	7.0–8.9	9.0–10.9	11.0–12.9	13.0–14.9
Sn-A/BL	57–65	61–65	60–63	56–59	54–57	54–57
BD/BL	17–19	17–22	16–20	19–21	20–23	21–23
HL/BL	23–25	24–27	23–27	25–28	24–27	25–28
HW/BL						
SnL/BL	4–6	5–6	5–6	6–6	5–6	4–5
ED/BL	9–10	8–10	7–9	10–11	10–11	11–12
P_1L/BL						
P_2L/BL	0–0	bud	bud-3	5–11	11–15	17–19

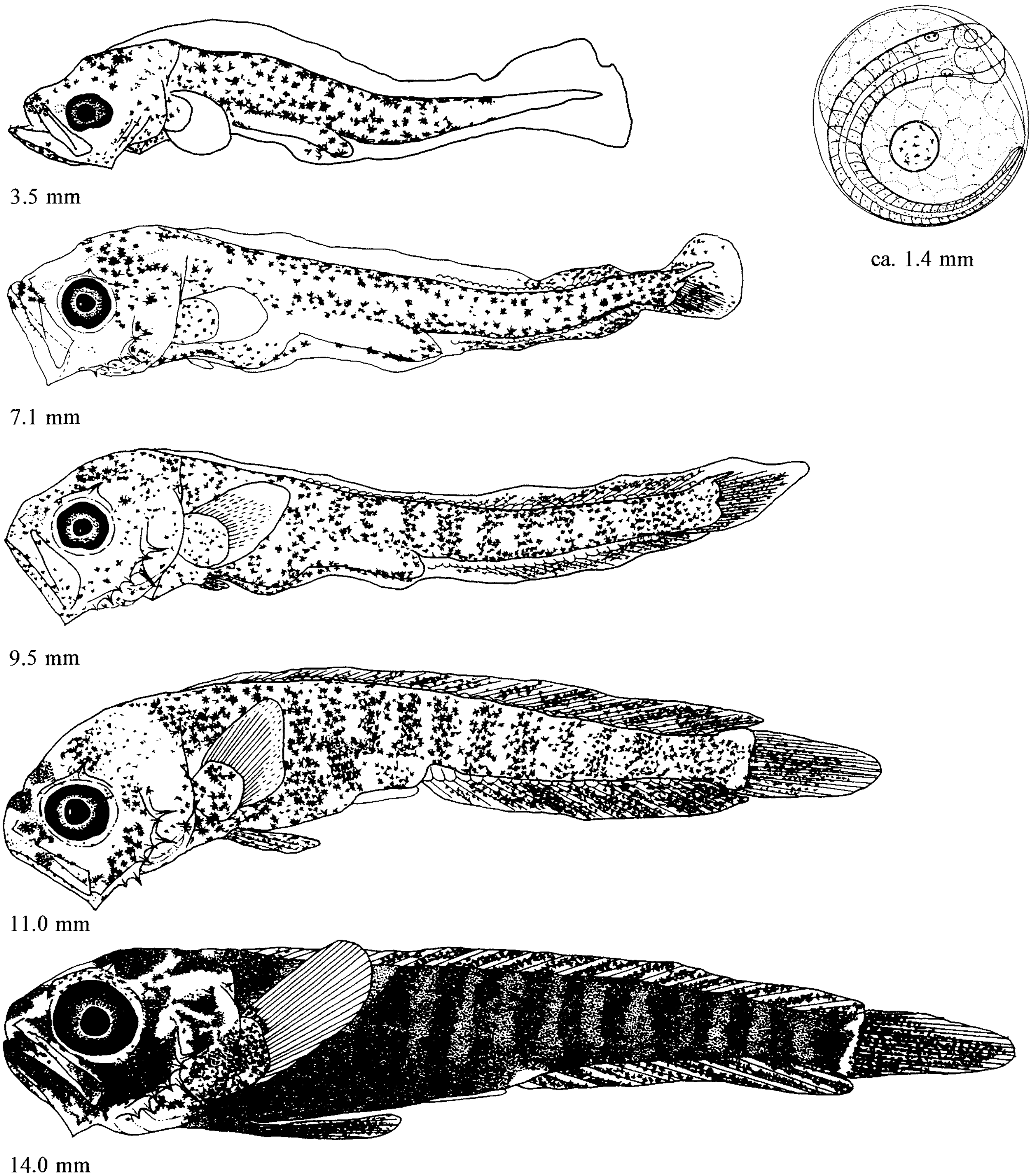


Figure Coryphaenidae 2. Egg, ca. 1.4 mm (Mito 1960); preflexion larva, 3.5 mm; flexion larva, 7.1 mm; postflexion larvae, 9.5 mm, 11.0 mm; transformation specimen, 14.0 mm (Ditty et al. 1994b).

BRAMIDAE: Pomfrets

H. G. MOSER AND B. C. MUNDY[1]

Bramids are an oceanic family of 21 species and seven genera placed in the subfamilies Braminae and Pteraclinae (Yatsu and Nakamura 1989; Nelson 1994; Moteki et al. 1995). Four species are known from the California Current region: *Brama japonica*, *B. dussumieri*, *Pteraclis aesticola*, and *Taractichthys steindachneri* (Table Bramidae 1). *Brama japonica*, the Pacific pomfret, is a common species inhabiting subarctic-transitional waters across the North Pacific; its larvae are fairly common in offshore stations in the center of the CalCOFI survey pattern. *B. dussumieri*, the lowfin pomfret, is a warm-water cosmopolite whose larvae occur in the southern part of the CalCOFI pattern and more commonly in the eastern tropical Pacific. *Pteraclis aesticola*, the Pacific fanfish, is endemic to tropical/subtropical waters of the North and southeast Pacific; its larvae are rarely captured in offshore CalCOFI stations. Adults of the sickle pomfret, *T. steindachneri*, have been captured occasionally off southern California, however, its larvae have not been identified in CalCOFI samples and it probably does not spawn in the region.

Bramids are medium to large (up to 1 m), compressed fishes with a blunt, rounded head and oblique mouth; bramins are deep-bodied and pteraclins are elongate. The dorsal and anal fins are long-based; in Braminae, the anterior dorsal and anal rays usually are elongate and in pteraclins the dorsal and anal fins originate on the snout and are huge and fan-like. The pectoral fins are long and somewhat falcate and the caudal fin is forked. The pelvic fins are thoracic or jugular and contain I, 5 rays. One or more of the anterior dorsal and anal rays are stout and, although they lack segmentation, are considered to be soft-rays by most workers. Bramids are covered with large, often keeled scales that extend onto the dorsal and anal fins in bramids or, in pteraclins, form a sheath for the dorsal and anal rays when depressed. Most species are black or silvery. There is an important Spanish longline fishery for *Brama brama* in the Atlantic and large numbers of *B. japonica* are caught incidentally in the high-seas squid and salmon gill-net fisheries of the North Pacific. A large proportion of this catch is discarded and the species is considered to be underutilized (Pearcy et al. 1993). Bramids feed on crustaceans, squid, and fish.

The scanty information on reproduction in bramids indicates they are oviparous and spawn planktonic eggs. *B. japonica* is hypothesized to undergo extensive migrations between summer feeding grounds in the subarctic zone and winter spawning grounds in the subtropical frontal zone (Shimazaki and Nakamura 1981; Seki and Mundy 1991; Seki and Bigelow 1993; Pearcy et al. 1993). Planktonic eggs of *B. japonica* are relatively large (1.6–1.7 mm diameter) with homogeneous yolk, a single oil globule, and smooth chorion (Matarese et al. 1989; this study). Embryos are relatively advanced at hatching with most of the yolk utilized and the gut beginning to coil. The highly distinctive preflexion larvae of bramids have a large, round, heavily pigmented head and gut mass with a slender tail, sparsely pigmented at the tip. Caristiids have a similar "tadpole" appearance; however, they have distinct bars on the tail. Larvae of *B. dussumieri* are deeper bodied than those of *B. japonica* and hatch, undergo notochord flexion, and transform at smaller sizes (ca. 3 mm, 4.2–5.3 mm, 7.6–8.6 mm) than *B. japonica* (ca. 4.0 mm, 6.5–8.0 mm, ca. 15 mm, respectively). *Brama dussumieri* larvae lack pectoral fin pigment whereas the pectorals of *B. japonica* are lightly pigmented. Also, pigment is present above and below the notochord tip in *B. japonica* and only below the tip in *B. dussumieri*. Larvae of the highly precocious *P. aesticola* hatch at ca. <2.8 mm, undergo notochord flexion at ca. 4.8–6.0 mm, and transform at ca. 7.5 mm. Compared with the two *Brama* species, they have a relatively larger head and gut mass and shorter tail. Also, an enlarged, black branchiostegal membrane and longer pigment series at the notochord tip distinguish them from known *Brama* larvae.

The following descriptions are based on detailed observations of 8–26 specimens of each species (Table Bramidae 2) and on literature (Mead 1972; Johnson 1984; Kinoshita 1988c; Olivar and Fortuño 1991; Seki and Mundy 1991). Meristic data were obtained from

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several literature sources (Mead 1972; Miller and Lea 1972; Matarese et al. 1989; Moteki et al. 1995) and from original counts made during this study. Ecological information was obtained from Mead (1972), Fitch and Lavenberg (1971), Seki and Mundy (1991), Seki and Bigelow (1993), and Pearcy et al. (1993).

Table Bramidae 1. Meristic characters for the bramid species in the California Current vicinity. All have I,5 pelvic fin rays, 9+8 principal caudal fin rays, and 7 branchiostegal rays.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	Gill Rakers
Brama dussumieri	14–17	22–27	38–43	32–36	25–29	18–22	6–8+6–9	3–6+9–14
Brama japonica	15–17	22–26	37–42	32–37	27–30	20–23	7–8+7–9	2–8+12–13
Pteraclis aesticola	22	23	45	46–55	40–43	15–20	3–4+3–4	1–2+7–8
Taractichthys steindachneri	19–21	22–26	42–46	33–37	26–28	19–22		2–3+7–9

Table Bramidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the bramid species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Brama dussumieri	0	0	3 3.4–3.8	4 4.2–5.3	5 5.1–7.0	3 7.6–8.6	5 10.7–16.7
Brama japonica	7 1.6–1.7	3 4.0–4.1	9 4.2–6.2	4 6.7–7.7	2 10.8–11.0	1 15.5	0
Pteraclis aesticola	0	0	5 2.8–4.8	2 5.2–6.0	1 7.4	0	0

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–43	41–42
Precaudal	14–17	15–16
Caudal	22–27	24
Fins:		
Dorsal spines	0	0
Dorsal rays	32–36	33
Anal spines	0	0
Anal rays	25–29	27
Pelvic	I,5	I,5
Pectoral	18–22	19–20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	6–8	7
Lower	6–9	7
Gill rakers:		
Upper	3–6	
Lower	9–14	
Branchiostegals	7	7

LIFE HISTORY

Range: Circumglobal between 35° N & 35° S

Habitat: Epi- & mesopelagic at 1–300 m depth

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Mead 1972
Kinoshita 1988c

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.4 mm, 3.8 mm (B. Sumida MacCall)
Postflexion larva, 5.0 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3 mm
Flexion length: ca 4.2–5.3 mm
Transformation length: 7.6–8.6 mm
Fin development sequence: P_1, C_1, P_2, D & A, C_2
Pigmentation: *Preflexion*—Initially, covering brain & nape, extending ventrad to postorbital patch, over entire gut, on outer surface of P_1 base, & ventrally at notochord tip; by 4.0 mm, on opercle, preopercle branchiostegal membrane, & beginning to expand ventrad & posteriad from nape to form trunk sheath. *Flexion–postflexion*—Trunk sheath extends to D origin by 5.0 mm & to posterior margin of gut by 6.0 mm; heavy internally along D base, lighter internally at A base. *Early juveniles*—Covered except on snout & caudal peduncle.
Diagnostic features: Large, rounded, heavily pigmented head & gut mass with slender tail; tail unpigmented except ventrally at notochord tip; stouter & deeper-bodied than *B. japonica*; hatching, notochord flexion, & transformation occur at smaller sizes than in *B. japonica*; canines not enlarged as in *Pteraclis*; no tail bars as in *Caristius*; ca. 6–10 evenly graded spines on preopercle, those at angle largest; several spines on interopercle.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–38 37	43–47 44	49–55 54	51–53 52	47–55 52
BD/BL		26–30 27	34–36 35	42–47 45	43–51 48	47–53 51
HL/BL		20–26 24	27–30 28	29–33 31	28–29 29	28–34 31
HW/HL		47–100 81	80–100 90	91–113 98	87–95 90	70–88 80
SnL/HL		20–29 24	20–25 22	20–27 23	26–29 27	20–24 23
ED/HL		42–47 44	47–48 47	45–52 49	52–52 52	43–55 48
P_1L/BL		6–14 10	16–26 22	33–35 34	34–38 36	35–40 37
P_2L/BL		0–3 1	5–16 12	24–27 26	33–37 35	29–33 31

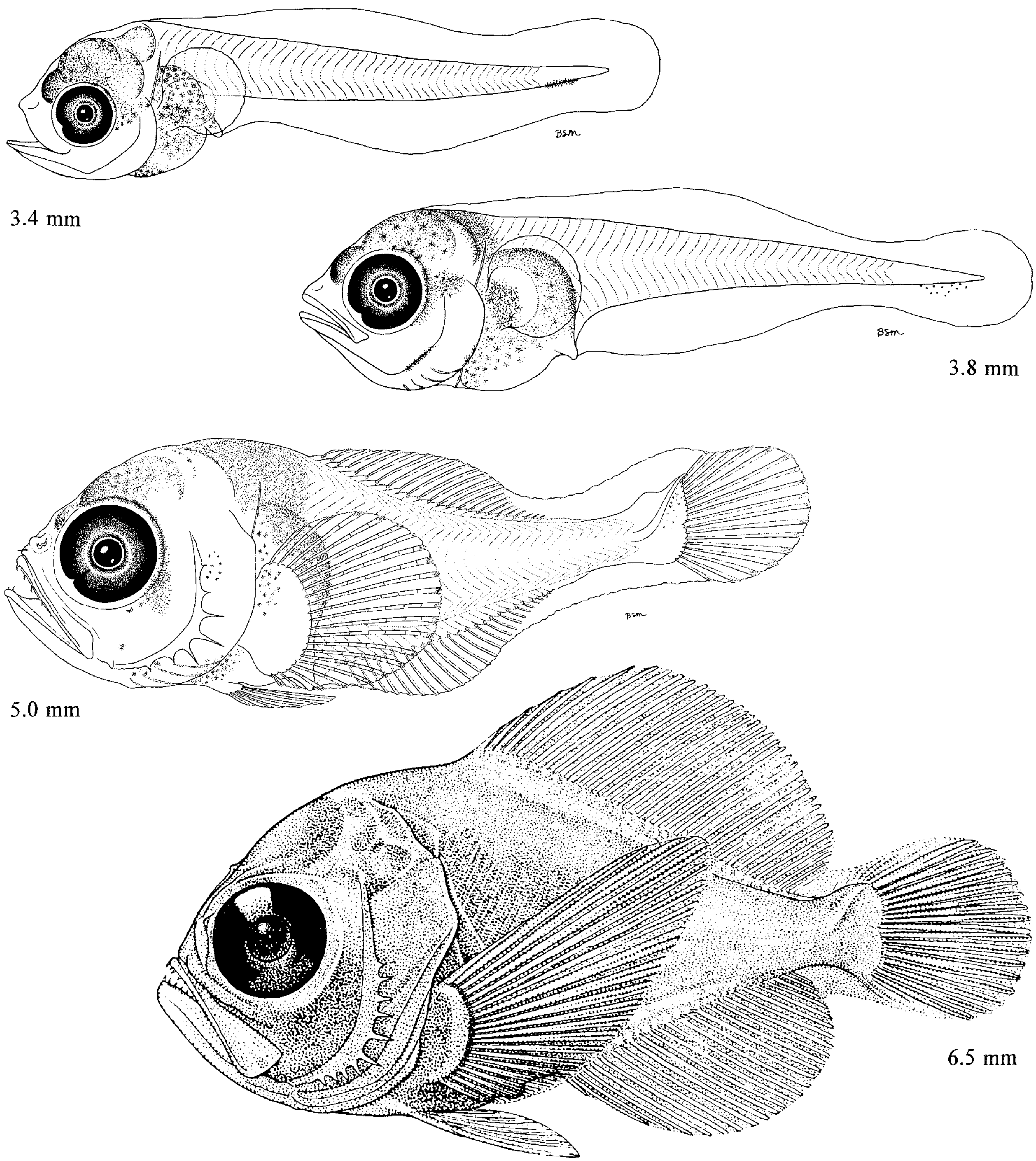

Figure Bramidae 1. Preflexion larvae, 3.4 mm, 3.8 mm (EASTROPAC II, station 46.024); postflexion larva, 5.0 mm (EASTROPAC II, station 46.034); juvenile, 6.5 mm (Mead 1972).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–42	40
Precaudal	15–17	16
Caudal	22–26	24
Fins:		
Dorsal spines	0	0
Dorsal rays	32–37	35
Anal spines	0	0
Anal rays	27–30	28–29
Pelvic	I,5	I,5
Pectoral	20–23	22
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–8	8
Lower	7–9	8
Gill rakers:		
Upper	2–8	
Lower	12–13	
Branchiostegals	7–8	7

LIFE HISTORY

Range: North Pacific endemic, from the Bering Sea & Gulf of Alaska south to central Baja California in the eastern Pacific, to the Okinawa trough in the western Pacific, & to ca. 25° N in the central Pacific

Habitat: Epi- to mesopelagic at 1–620 m depth

Spawning season: Winter to early summer in central Pacific; in CalCOFI area, larvae most abundant August–November with a peak in October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Mead 1972
Matarese et al. 1989
Kinoshita 1988c
Seki & Mundy 1991
Seki & Bigelow 1993

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.6 mm (R. C. Walker)
Yolk-sac larva, 4.0 mm (B. Sumida MacCall)
Preflexion larva, 5.5 mm (B. Sumida MacCall)
Juvenile, 15.5 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.6–1.7 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.30–0.36
Shell surface: Smooth
Pigment: Mid- to late-stage embryos, on dorsal surface of yolk (later migrating ventrad); heavy beneath hindbrain, along gut, dorsally on brain & snout (latest stages); heavy on OG
Diagnostic features: Large size; single large OG; smooth orangish chorion; heavy pigment below hindbrain

LARVAE

Hatching length: ca. 4.0 mm
Flexion length: ca. 6.5–8.0 mm
Transformation length: ca. 15 mm
Fin development sequence: P_1, C_1, D & A & P_2, C_2
Pigmentation: *Yolk-sac*—Entire head & gut mass covered; dorsal & ventral series at notochord tip, ventral series longer & denser; on lateral & inner surfaces of P_1 base. *Preflexion*—Brain covered; on nape; from top of head ventrad to postorbital, preopercle, opercle, & branchiostegal membrane; only laterally at insertion of P_1 base; light speckling on P_1 blade; gut covered except ventrally; snout, mouth, & gular region unpigmented; ventral series at notochord tip spreading to finfold. *Flexion*—Trunk shield (on surface & embedded) expanding posteriad from nape to D origin. *Postflexion*—Trunk shield reaches posterior margin of gut by 10.0 mm; heavy internally & superficially at D base; several at posterior margin of hypurals; on jaws by ca. 14 mm.
Diagnostic features: Round, heavily pigmented head & gut mass with slender tail; dorsal & ventral notochord tip pigment; ca. 10 preopercular spines, those at angle slightly larger; preopercular spines increasing to >15 at transformation; series of interopercular spines; no enlarged canine teeth; larger at hatching, notochord flexion, & transformation than *B. dussumieri.*

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	25–29 27	26–36 32	33–40 35	51–53 52		53
BD/BL	18–22 20	20–28 25	26–35 31	37–41 39		40
HL/BL	12–17 14	14–24 20	21–27 24	28–31 29		30
HW/HL	86–122 99	83–109 97	91–107 97	88–93 91		98
SnL/HL	4–14 10	13–33 23	21–24 23	26–27 27		26
ED/HL	43–52 46	42–53 46	45–51 47	50–53 52		45
P_1L/BL	3–4 3	6–18 10	14–29 21	31–37 34		34
P_2L/BL	0–0 0	0–6 2	9–17 13	28–30 29		28

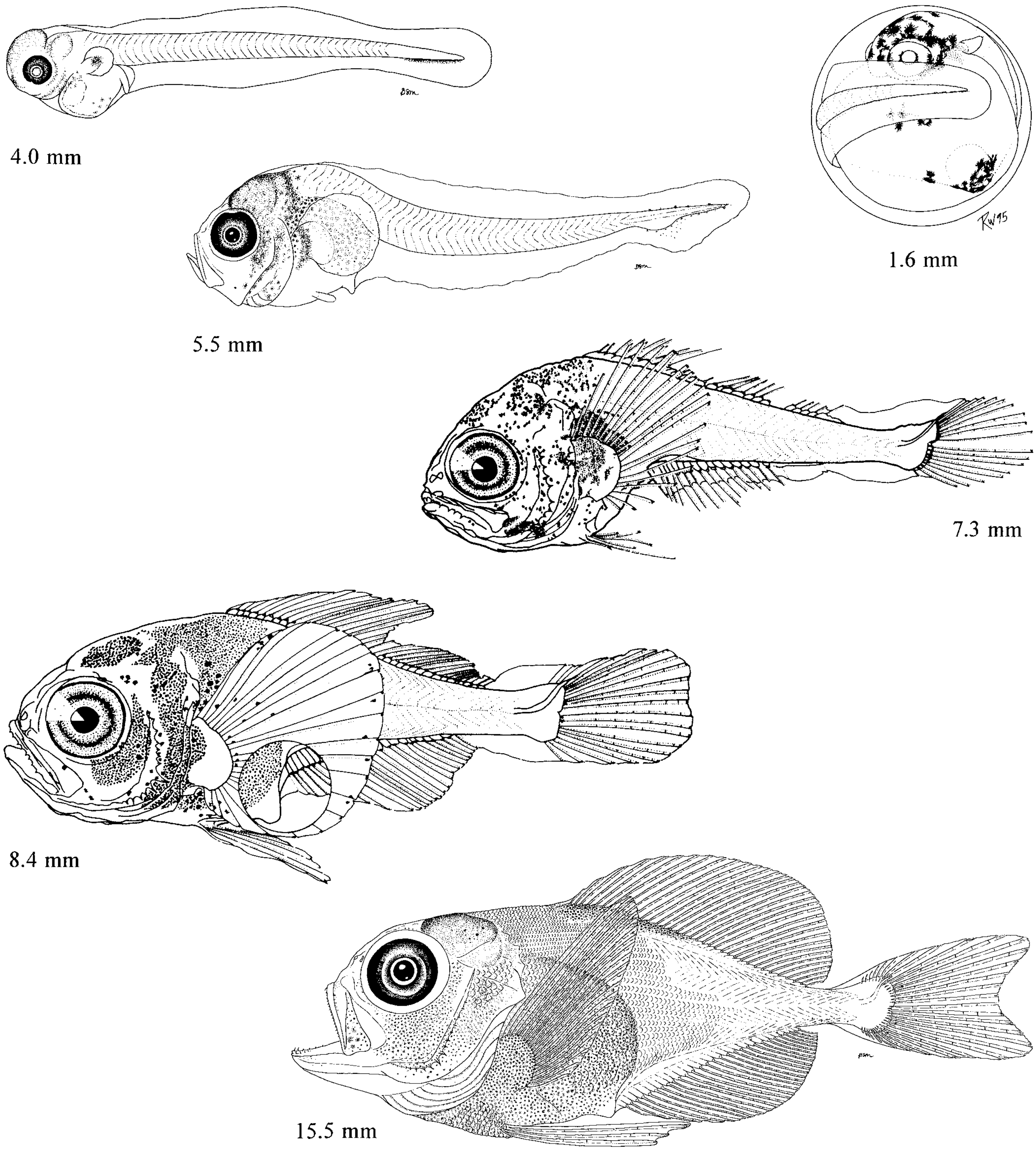

Figure Bramidae 2. Late-stage egg, 1.6 mm (CalCOFI 8101, station 100.90); yolk-sac larva, 4.0 mm (CalCOFI 6608, station 123.55); preflexion larva, 5.5 mm (CalCOFI 6310, station 107.65); flexion larva, 7.3 mm; postflexion larva, 8.4 (Kinoshita 1988c); juvenile, 15.5 mm (SIO 63–409).

MERISTICS

	Range	Mode
Vertebrae:		
Total	45	
Precaudal	22	
Caudal	23	
Fins:		
Dorsal spines	0	0
Dorsal rays	46–55	
Anal spines	0	0
Anal rays	40–43	
Pelvic	I,5	I,5
Pectoral	15–20	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	3–4	
Lower	3–4	
Gill rakers:		
Upper	1–2	
Lower	7–8	
Branchiostegals	7	7

LIFE HISTORY

Range: Pacific endemic from southern Japan eastward to Hawaii & California; in the eastern Pacific south to Easter Island & Sala-y-Gómez Ridge

Habitat: Oceanic; epipelagic at 1–100 m depth

Spawning season: Summer in central Pacific

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Mead 1972
Seki & Mundy 1991

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.9 mm (B. Mundy)
Flexion larva, 5.2 mm (B. Mundy)
Postflexion larva, 7.4 mm (B. Mundy)

* Eye initially slightly oval (variously vertically or horizontally elongate, or round), becoming round by flexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 4.8–6.0 mm
Transformation length: ca. 7.5 mm
Fin development sequence: P_1 & C_1, D & A, P_2 & C_2
Pigmentation: *Early preflexion*—Covering brain & nape, extending ventrad to postorbital, preopercular, & opercular regions; heavy on branchiostegal membrane; covering entire gut; series at ventral midline of tail extending from notochord tip anteriad to ca. midpoint of tail; series on dorsal midline of tail shorter & sparser than ventral series; snout, mouth, & gular region lack pigment. *Mid-preflexion to flexion*—Trunk sheath enlarging posteriad to slightly beyond posterior margin of gut mass by end of flexion stage; dorsal & ventral series lost at tip of tail. *Postflexion*—Body covered to midtail with band on caudal peduncle.
Diagnostic features: Large, round, heavily pigmented head & gut mass with sharply tapered, relatively short tail; enlarged black branchiostegal membrane; a pair of recurved, fanglike teeth at tip of upper jaw; notochord tip pigment extends well anteriad in early preflexion stage; preopercular spines increasing from ca. 4 to 8 with spines at angle & below angle large & curved; hatching, notochord flexion, & transformation at small size; higher counts for myomeres & D & A rays than in *Brama* species in region.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–41	33–38			
		39	36	37		
BD/BL		31–41	46–53			
		36	50	55		
HL/BL		23–31	33–42			
		27	37	39		
HW/HL		85–105	72–77			
		92	74	86		
SnL/HL		19–33	12–26			
		25	19	28		
ED/HL*		44–54× 44–54	44–53			
		49×50	49	45		
P_1L/BL		6–15	18–25			
		10	21	23		
P_2L/BL		0–0	2–7			
		0	4	16		

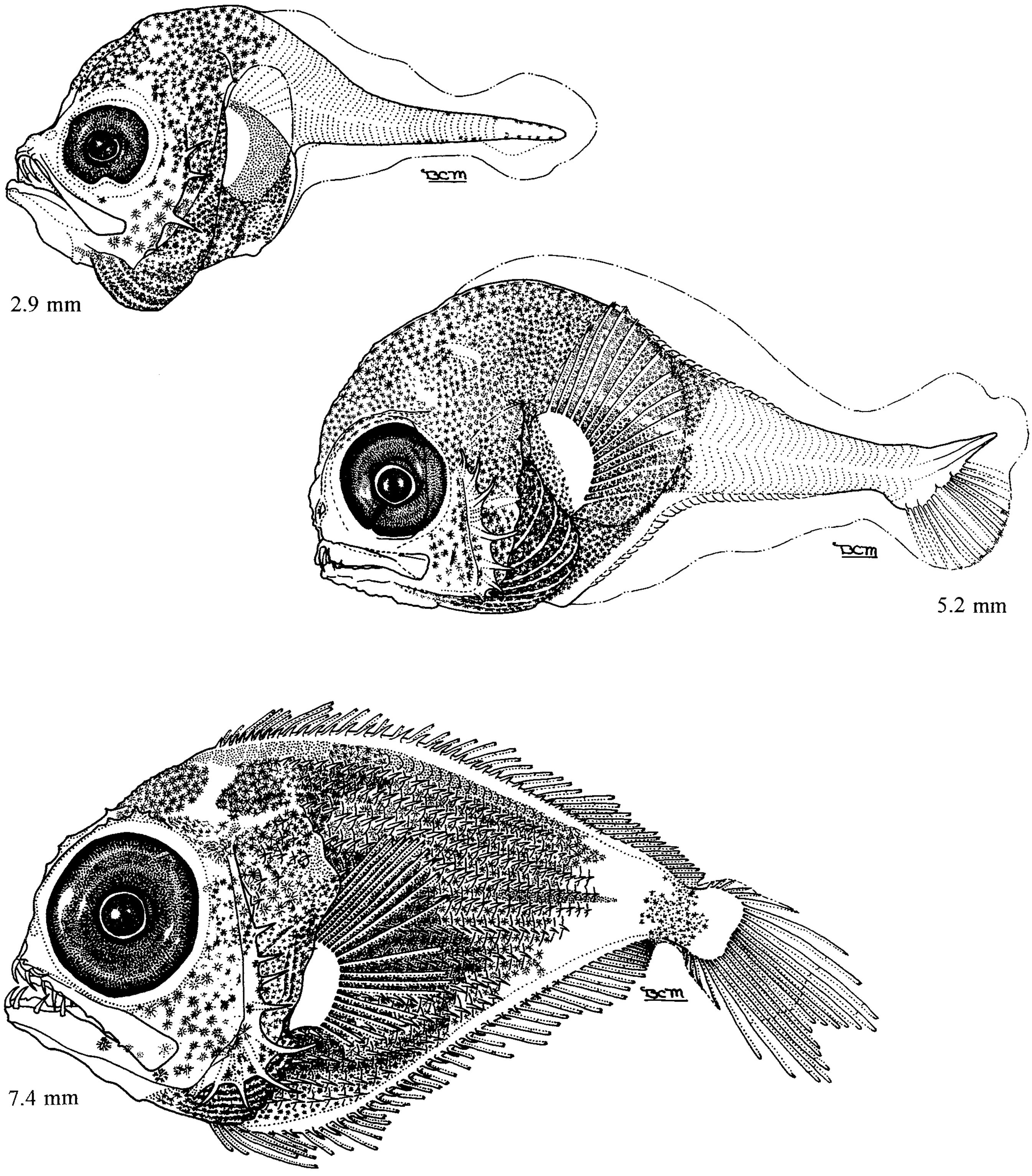

Figure Bramidae 3. Preflexion larva, 2.9 mm (TC 8405, station 72); flexion larva, 5.2 mm (NORPAC, station 102); late-transformation specimen, 7.4 mm (TC 8605, station 35).

CARISTIIDAE: Manefishes or Veilfins

H. G. Moser

The family Caristiidae is represented in the California Current region by two species, *Caristius macropus* and *C. maderensis* (Berry and Perkins 1966; Eschmeyer et al. 1983). Apparently, *C. macropus* ranges widely in the Pacific and Atlantic Oceans (Scott et al. 1970). *C. maderensis* is a warm-water species that is distributed widely in tropical-subtropical seas (Tolley 1990). In the eastern Pacific, it ranges northward to about the Southern California Bight and westward to Hawaii. Larvae of *C. maderensis* are collected rarely on CalCOFI surveys, mostly off central Baja California. Published information pertaining to these species in the California Current region should be viewed with caution because of misidentifications, mixing of meristic characters of the two species, and the overall problem of species composition in the family. A badly needed family revision awaits the collection of additional material and may result in a different name for the species referred to here as *C. maderensis*.

Caristiids are moderate-sized (to ca. 60 cm, usually <30 cm), deep-bodied fishes, with a steep frontal profile. Adult *C. macropus* have an oval shape while *C. maderensis* are squarish in profile and have a relatively deeper caudal peduncle and bigger head. The dorsal fin is sail-like and the anal and pelvic fins are elongate. The dorsal fin originates on the head, has an elongate base, and the rays, when depressed, fit into a groove along the dorsum. The anal fin has an elongate base and the pelvic fin (I, 5 rays) is thoracic; both fins fit into grooves when depressed. The anterior rays of the dorsal and anal fins lack segmentation but are considered to be soft-rays. Scales are cycloid, thin, and deciduous and the skin is dark brown. Head bones are fragile. Manefishes are meso- to bathypelagic and little is known of their habits. They are known to associate with siphonophores and feed on them (Janssen and Gibbs 1989).

Manefishes are oviparous and have planktonic eggs and larvae. Eggs of *C. maderensis* are large (1.9–2.0 mm diameter), with homogeneous yolk, a single oil globule (ca. 0.34 mm), and a smooth chorion; newly hatched larvae have fully pigmented eyes, functional mouths, and characteristic pigment blotches on the tail. Preflexion larvae have a short, rounded head and gut mass, slender elongate tail, and most closely resemble bramid larvae. The heavily pigmented bars on the tail clearly distinguish them from bramid larvae. Larvae become deep-bodied and hatchet-shaped at notochord flexion. All larvae from the California Current region were identified as *C. maderensis* based on meristics and on morphology and pigmentation of transformation series. Larvae of *C. macropus* were not found in the California Current region; however, they should be easily separable from *C. maderensis* on the basis of meristics. Counts for total vertebrae and dorsal and anal fin rays are higher in *C. macropus* than in *C. maderensis* (V 37–40, D 33–35, A 21–23 in *C. macropus*; V 35–36, D 26–31, A 15–20 in *C. maderensis*). Two larvae (7.5 and 14.0 mm) with meristic counts matching those of *C. macropus* were found at equatorial stations (EASTROPAC I, station 11.072; EASTROPAC II, station 30.085). These larvae were similar in shape and pigmentation to larvae from the western tropical Pacific described as *C. macropus* (Belyanina 1982a). These larvae have a club-shape profile and slightly different placement of the tail bars than in *C. maderensis*.

The description of *C. maderensis* larvae is based on the literature (Johnson 1984; Matarese et al. 1989) and on detailed examination of 13 specimens (1 yolk-sac, 3.7 mm; 5 preflexion, 4.2–6.2 mm; 1 flexion, 6.5 mm; 2 postflexion, 7.7, 10.8 mm; 1 transformation, 11.7 mm; 2 juveniles, 15.6, 19.7 mm). Four eggs (1.9–2.0 mm diameter) were examined. Meristic data and ecological information were obtained from the literature (Fitch and Lavenberg 1971; Eschmeyer et al. 1983; Johnson 1984; Fujii 1984e; Heemstra 1986e; Post 1986a, 1990; Matarese et al. 1989; Tolley 1990; Nelson 1994) and from observations made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–36	35
Precaudal	16–17	16–17
Caudal	18–20	18
Fins:		
Dorsal spines	0	0
Dorsal rays	26–31	29–30
Anal spines	0	0
Anal rays	15–20	18
Pelvic	I,5	I,5
Pectoral	16–18	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	6–8	7
Lower	7	7
Gill rakers:		
Upper	7	
Lower	16	
Branchiostegals	7	7

LIFE HISTORY

Range: Eastern tropical Pacific northward to northern Baja California & westward to Hawaii; widespread in tropics; first described from the Atlantic

Habitat: Epi- to bathypelagic

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Johnson 1984
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.9 mm (R. C. Walker)
Preflexion larva, 4.2 mm (R. C. Walker)
Preflexion larva, 5.8 mm (H. M. Orr)
Flexion larva, 6.5 mm (R. C. Walker)
Early juvenile, 18.0 mm (R. C. Walker)

* Eye initially oval, becoming round by preflexion or flexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.9–2.0 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.34 mm
Shell surface: Smooth
Pigment: Late-stage embryos have pattern similar to that of yolk-sac larvae (see below); heavy on OG; shell orangish
Diagnostic features: Large size; single OG; pigment pattern in late-stage embryos

LARVAE

Hatching length: ca. 4.0 mm
Flexion length: ca. 6.0–7.0 mm
Transformation length: ca. 12.0 mm
Fin development sequence: C_1 & P_1 & A & D & P_2, C_2
Pigmentation: *Yolk-sac*—On cerebellum & nape; extending ventrad to postorbital region & internally throughout otic region; on lower jaw; on inner & outer surface of P_1 base; peppering on yolk sac; blotch in ventral midline one-third of the distance posteriad on tail; apposing dorsal & ventral midline blotches two-thirds of the distance posteriad on tail (extending onto finfold); at tip of tail, extending onto finfold. *Preflexion–flexion*—A few on gill arches; gut mass covered except terminal section; posterior apposing tail blotches expand to form bar; single ventral tail blotch expands dorsad to form anterior bar in flexion larvae; above gas bladder; on P_2. *Postflexion*—Bar forms on trunk above gut, slants slightly anteriad; bar-like saddle extends ventrad to back of head from anterior D rays; on cheek; mouth & snout lack pigment; posterior tail bar widens; anteriorly on D rays & on D & A rays adjacent to bars. *Transformation*—Areas between bars become dusky; increases on D rays.
Diagnostic features: Total vertebrae 35–36; short rounded head & gut mass with slender tail in preflexion stage; head & gut become deeper & flexion–postflexion larvae are hatchet-shaped; elongate D & A with 26–31 & 15–20 rays, respectively; unique pigment pattern with 2 bars on tail & diagonal bar on trunk.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		26–36		46–57		56–58
	32	31	43	51	51	57
BD/BL		21–27		55–64		69–69
	24	24	42	59	62	69
HL/BL		17–25		35–39		39–41
	18	20	29	37	36	40
HW/HL		70–103		63–64		57–69
	91	80	68	64	67	63
SnL/HL		15–28		29–30		28–31
	30	22	32	29	31	29
ED/HL*		31–42× 26–40		44–48		46–52
	42×39	38×34	39	46	50	49
P_1L/BL		6–7		23–30		27–32
	5	6	13	27	28	29
P_2L/BL		0–4		23–31		32–44
	0	2	12	27	36	38

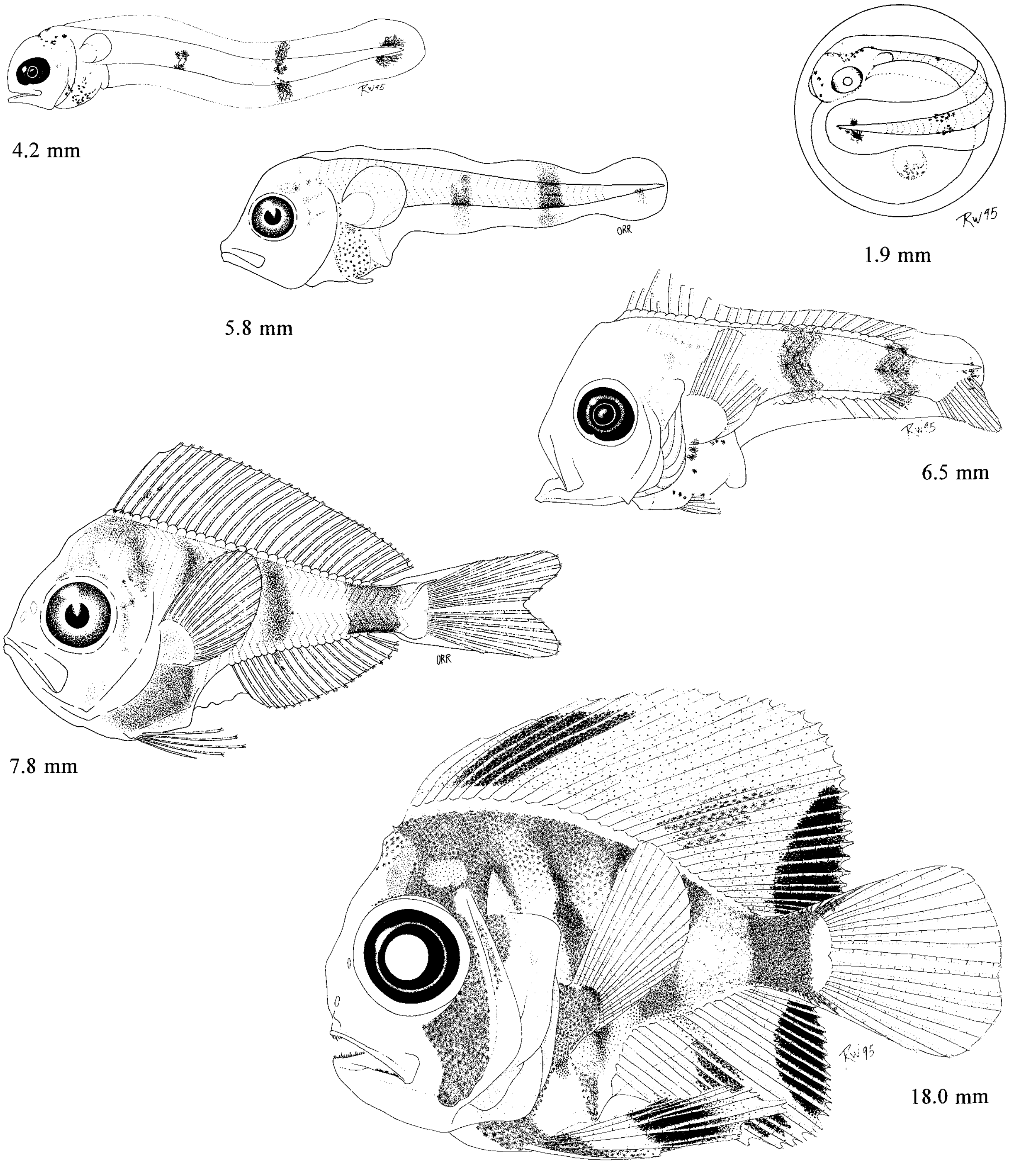

Figure Caristiidae 1. Late-stage egg, 1.9 mm (MOPS 8710, station 45 Manta); preflexion larvae, 4.2 mm (CalCOFI 6601, station 97.45), 5.8 mm (CalCOFI 6509, station 103.65); flexion larva, 6.5 mm (EASTROPAC II, station OP.076); postflexion larva, 7.8 mm (Johnson 1984, as 10.1 mm); early juvenile, 18.0 mm (LACM 44274–1).

LUTJANIDAE: Snappers

W. WATSON AND M. W. BROGAN[1]

All eastern Pacific snappers are members of the Lutjaninae, one of five lutjanid subfamilies. Ten species occur in the CalCOFI study area (Table Lutjanidae 1), primarily off southern Baja California. *Lutjanus argentiventris* and *L. colorado* occur as far north as southern and central California, respectively, but are rare north of Bahía Magdalena. Five other *Lutjanus* spp. and *Hoplopagrus guentherii* range northward in the CalCOFI area to between Bahía Magdalena and Punta Eugenia. *Lutjanus inermis* and *L. jordani* are more southern species occasionally collected in the Cabo San Lucas region. A few *H. guentherii* larvae and moderate numbers of *Lutjanus* larvae (ca. 7 spp.) have been taken in CalCOFI collections south of Punta Eugenia, in the Gulf of California, and in other plankton samples from the Gulf and to the south.

Adult lutjanids are medium to large (17.5–140 cm) residents of nearshore habitats in tropical to warm temperate regions. Juveniles of many species enter estuaries or even freshwater, but as adults most species are associated with shallow to moderate depth (<50 m) marine reefs. Lutjanid body shapes range from elongate and fusiform to deep and compressed. There is a single dorsal fin, pelvic fins are thoracic, and the caudal fin is truncate to deeply forked. Scales are ctenoid. The jaws of most species bear enlarged canines anteriorly, and the maxilla slips under the lacrymal when the mouth is closed. Colors vary from drab to bright, and barred or striped patterns are common. Many lutjanids are important in sport or commercial fisheries (Allen 1985).

Spawning occurs in summer months or year-round, depending on locality, and may follow a lunar cycle. Typically, spawners form aggregations in late afternoon and spawning is completed by shortly after dark. The eggs are pelagic, spherical, and 0.65–1.02 mm in diameter, with a narrow perivitelline space, smooth chorion, unsegmented yolk, and a single oil globule 0.12–0.20 mm in diameter. Newly hatched larvae are 1.8–2.3 mm BL, have a large yolk sac, unpigmented eyes, and no mouth. By the end of the yolk-sac stage, the eyes are pigmented and the mouth is functional. Body depth initially is 11–13% BL and preanal length is 40–45% BL. Relative body depth increases with growth, reaching a maximum of 30–45% BL shortly after flexion, and then may decrease somewhat before settlement. Preanal length increases to 60–67% BL before settlement. The gut begins to coil soon after hatching and becomes compact and triangular before flexion. Spines develop on several bones of the head and shoulder girdle. The preopercular spines are first to form (early preflexion), are the longest, and with few exceptions lack serrations. The anterior dorsal fin spines, pelvic fin spine, and pelvic fin ray 1 are the first fin elements to form (mid-preflexion), and become moderately to extremely elongate (especially D II and P_2 1). Dorsal, anal, and pelvic fin spines have smooth or serrate margins, depending on species, and may develop distinctive structure internally. Pigment initially is scattered over the body, but by the end of the yolk-sac stage it is mainly restricted to over the gut and along the ventral midline. By late preflexion stage, ventral pigment typically consists of melanophores at the cleithral symphysis, on the hindgut just anterior to the anus, and posteriorly on the tail. Other pigmented regions may include the jaws, snout, over the brain, around the orbit, along the base of the dorsal fin, internally over the urostyle, laterally on the caudal peduncle, and along the hypural margin, depending on size and species. Distinctive pigment often forms in association with the elongate fin spines and rays. Among lutjanines, size at settlement varies from ca. 10 to 30 mm. The protracted transformation to the juvenile stage begins before settlement and usually is completed after settlement by ca. 30 to 35 mm, as indicated by loss of the last larval specialization, the enlarged preopercular angle spine.

Early preflexion lutjanids are likely to be confused with larvae of several other families with ca. 24 myomeres, preanal length ca. 50% BL, and light pigmentation (e.g., serranids, carangids, gerreids, haemulids, sciaenids, sparids, and pomacentrids). By mid-preflexion, the long, smooth preopercular spines and the early development of spines in the dorsal and pelvic fins will distinguish lutjanids from most similar

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larvae. Other taxa in the CalCOFI area that develop dorsal fin spines before the soft rays include the pomacentrid *Abudefduf troschelii* (26 myomeres, dorsal pigment) several *Melamphaes* species (26–30 myomeres, no spines on the head or pectoral girdle, dorsal pigment by the flexion stage), and several scombroid species (all with >31 myomeres). Some carangid larvae (*Alectis* and *Selene* spp.) have early developing, elongate spines or rays in the pelvic and dorsal fins, but they have a supraoccipital crest lacking in lutjanids and they are pigmented differently than lutjanids (e.g., see Carangidae, this volume). Lutjanid larvae most closely resemble epinepheline and anthiine serranids, but can be distinguished from them by differences in the morphology and stage at formation of head and fin spines and by characteristic differences in pigmentation (see Serranidae, this volume).

The larvae of five lutjanid species are described here (Table Lutjanidae 2). Three other rare larval types (probably *L. colorado*, *L. jordani*, and *L. viridis*) have been recognized in our material but are not described (see Brogan, in press, for comments). Larvae of *L. aratus* and *L. inermis* are unknown, but meristics (Table Lutjanidae 1) should aid in the identification of older larvae. Recently settled specimens of *L. aratus* lack serrations on the fin spines and have a very elongate (50–58% BL), heavily pigmented P_2 ray 1, whereas recently settled *L. inermis* have serrated fin spines, accessory spines on the margins of the preopercular angle spine, little or no pigment on the P_2, and an elongate body (BD 25–30% BL) (Brogan pers. obs.). The general description of lutjanid eggs and larvae is based on a review by Leis (1987) and recent papers (Hamamoto et al. 1992; Leis and Lee 1994; Richards et al. 1994; Yokoyama et al. 1994; Leis and Bray 1995; Riley et al. 1995; Brogan in press). Meristic and adult distribution data are based on Jordan and Evermann (1896), Thomson et al. (1979), Allen (1985), Franke and Acero (1992), Allen and Robertson (1994), Brogan (in press, see for complete list) and Brogan (pers. obs.). Counts of secondary caudal fin rays, gill rakers and lateral line scales are based primarily on a survey of small juveniles (Brogan pers. obs.). Information on spawning is from Bell and Colin (1986), Grimes (1987), Hamamoto et al. (1992), and Yokoyama et al. (1994). Ecological information is based primarily on Thomson et al. (1979) and Franke and Acero (1992).

Table Lutjanidae 1. Meristic characters for the lutjanid species in the California Current vicinity. All species have 9+8 principal caudal fin rays, I,5 pelvic fin rays, 7 branchiostegal rays, and 10+14 vertebrae. Lateral line (LL) scales counted from the shoulder girdle to the posterior margin of the hypurals.

Species	Fin rays				Gill rakers	LL scales
	D	A	P_1	C_2		
Hoplopagrus guentherii	X, 13–14	III, 9–10	16–17	8–9+8–9	5–6+9–13	47–48
Lutjanus aratus	XI–XII, 12–13	III, 7–8	15–17	9–10+8–10	6–8+10–14	43–46
L. argentiventris	X–XI, 13–14	III, 7–9	16–18	7–9+7–9	6–7+10–15	45–48
L. colorado	X, 13–15	III, 7–8	15–18	8–9+7–8	6–7+11–14	44–47
L. guttatus	X–XI, 11–13	III, 8–9	15–17	9–11+8–10	6–8+13–17	47–50
L. inermis	X, 12–14	III, 10–11	17–18	9–10+8–10	5–6+11–13	50–53
L. jordani	X–XI, 13–15	III, 8–9	15–17	8+8	5–7+12–14	46
L. novemfasciatus	X–XI, 13–15	III, 7–8	15–17	8–10+8–9	6–7+9–13	47–49
L. peru	X, 12–14	III, 8–9	17–18	10–12+10–11	5–7+10–15	48–49
L. viridis	X, 14–15	III, 8	16–17	10–11+9	7+14–15	50–51

Table Lutjanidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the lutjanid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Hoplopagrus guentherii	0	0	0	L[a], 1 5.3	0	L[a], 5 18.0–33.0	3 49.1–75.4
Lutjanus argentiventris	0	0	16[b] 3.6–4.3	12 4.1–4.7	9 5.1–10.8	10 14.2–31.3	3 36.5–38.0
L. guttatus	0	0	5 3.8–4.4	7 4.5–5.4	9 5.1–10.9	10 19.3–29.6	3 35.3–45.7
L. novemfasciatus	0	0	11 3.1–4.4	16 4.2–5.9	9 5.3–12.4	10 15.7–20.4	3 27.9–29.1
L. peru	0	0	11 2.7–4.8	11 4.7–6.2	17 5.8–14.8	3 18.8–19.3	0

[a] Brogan, in press.
[b] Thirteen of the *L. argentiventris* measured 2.1–3.6 mm but were excluded from the size range given here and from morphometric analysis because of severe shrinkage. These specimens were included in the descriptions of pigment and fin development sequence.

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X	X
Dorsal rays	13–14	14
Anal spines	III	III
Anal rays	9–10	9
Pelvic	I,5	I,5
Pectoral	16–17	16–17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	8–9
Lower	8–9	8–9
Gill rakers:		
Upper	5–6	5–6
Lower	9–13	10–11
Branchiostegals	7	7

LIFE HISTORY

Range: Bahía Abreojos, Baja California Sur, & Gulf of California to Isla Gorgona, Colombia

Habitat: Over shallow rocky reefs, ca. 3–27 m depth (primarily <9 m); shelters in crevices & caves during the day

Spawning season: Larvae collected July–September

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Brogan, in press

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length:
Transformation length: <18 mm through ca. 33 mm
Fin development sequence:
Pigmentation: *Flexion*—Internally at nape; internally, posteriorly over center of midbrain by 5.3 mm; 0–1 anteriorly on gular; 1 on isthmus; anteriorly on gut; dorsally on gas bladder & hindgut; 1 ventrally at terminus of hindgut; 2 on ventral margin of tail at myomeres 18 & 21; 1 proximally on lower C_1; on posterior margin of distal ca. 70% of D II; on P_2 along distal 75–80% of ray 1. *Transformation*—Anteriorly on upper jaw; external patches over fore- & midbrain & on nape; on upper preopercle; little or none on isthmus; on bases of D spines & along posterior margin of D II; on dorsal margin spreading cephalad & caudad from level of D VIII–IX; dorsally & laterally on caudal peduncle; internal series over spinal cord; proximally on lower C_1; on P_2, primarily along ray 1.
Diagnostic features: Margins of all fin spines smooth; D II ca. 240–275% D III length; P_2 ray 1 ca. 190–255% spine length; D X,14; A usually III,9; two spines on dorsal limb of anterior preopercular series in postflexion stage; dorsal postemporal spine forms before ventral postemporal spines; bilobed pigment patch on caudal peduncle during transformation stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			49–50 50		57–64 61	62–63 62
BD/BL			34–41 37		34–40 37	42–45 44
HL/BL			32–38 35		37–42 39	38–40 39
HW/HL			42–46 44		39–46 41	39–42 41
SnL/HL			31–31 31		26–34 29	29–34 31
ED/HL			31–33 32		24–31 27	26–28 27
P_1L/BL			8–10 9		20–25 21	25–28 27
P_2L/BL			45–58 52		31–62 51	26–29 27
DSL/BL			46–58 52		16–51 30	14–18 16

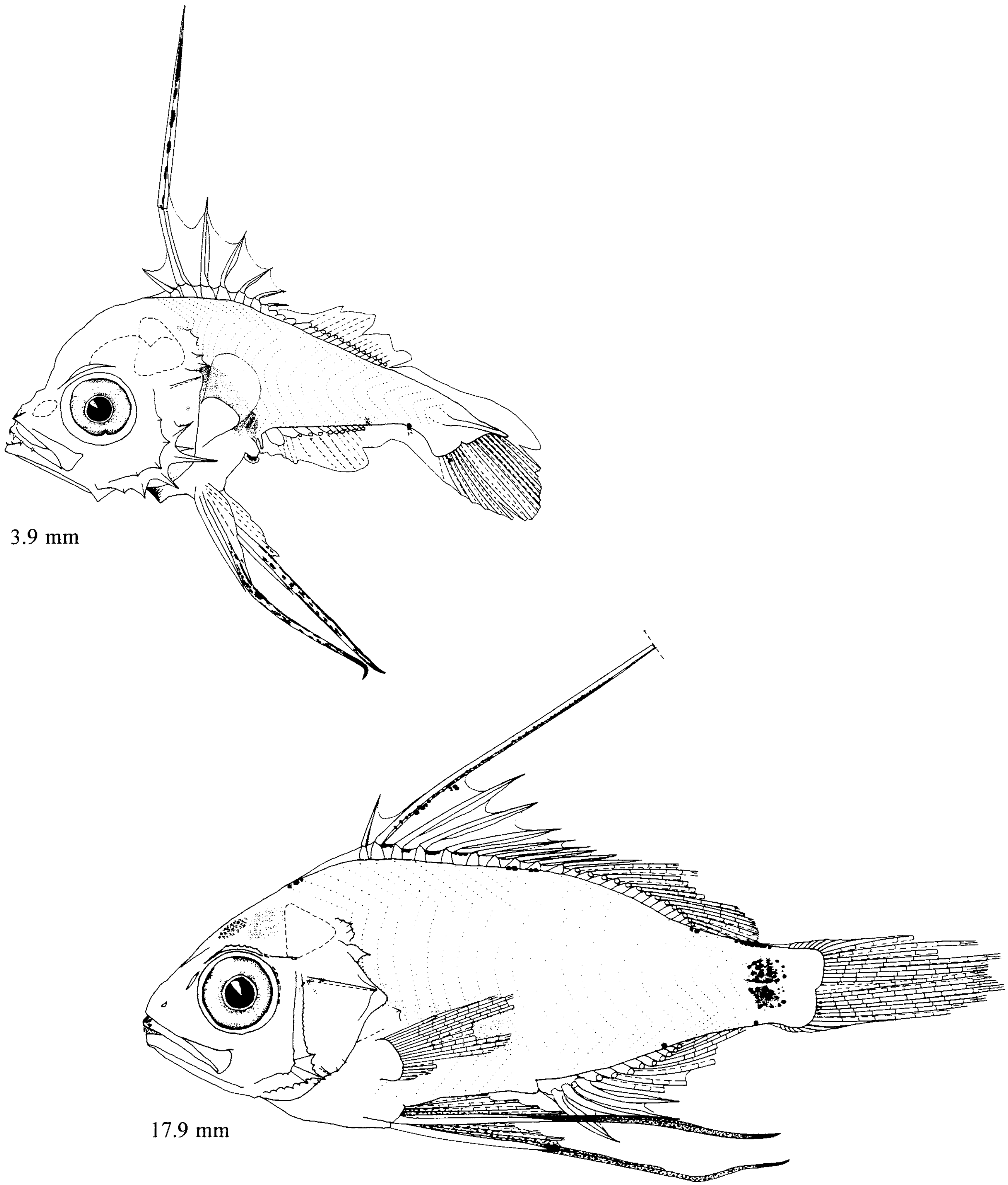

Figure Lutjanidae 1. Flexion larva, 3.9 mm (specimen somewhat shrunken); and transformation specimen, 17.9 mm (Brogan, in press).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X–XI	X
Dorsal rays	13–14	14
Anal spines	III	III
Anal rays	7–9	8
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–9	8
Lower	7–9	7–8
Gill rakers:		
Upper	6–7	6–7
Lower	10–15	11–14
Branchiostegals	7	7

LIFE HISTORY

Range: Southern California & throughout Gulf of California to Peru; rare north of Bahía Magdalena, Baja California Sur, on Pacific coast

Habitat: Coastal waters over rocky bottom, occasionally enters estuaries or freshwater; young juveniles common in estuaries & tide pools

Spawning season: Larvae collected July–September in Gulf of California, nearly year-round off Central America

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Brogan, in press

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.6 mm (R. C. Walker)
Flexion larva, 4.7 mm (R. C. Walker)
Postflexion larva, 8.5 mm (R. C. Walker)
Transformation specimen, 17.0 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface: **Pigment:**
Diagnostic features:

LARVAE

Hatching length: <3.6 mm
Flexion length: 4.1–4.3 mm through ca. 5 mm
Transformation length: <14.2 mm through ca. 31.3 mm
Fin development sequence: P_2, 1D, C_1, 2D & A, P_1, C_2
Pigmentation: *Preflexion*—Internally at nape; under hindbrain; 0–few distally on D II; variably between bases of D III–V; medial on maxillaries & anterolateral on dentaries by ca. 4.3 mm; 0–1 on gular; anteriorly on gut; dorsally on gas bladder & hindgut to near anus; on isthmus near cleithral symphysis; ventrally on hindgut near anus; 11–13 on ventral margin of tail, decreasing to 1–few anteriorly on A base, 1 at A insertion, & 2–3 on caudal peduncle by end of stage; 1–2 ventrally on notochord tip becoming 1 proximally on lower C rays; few proximally on P_2, increasing to 4–6 along proximal 30–50% of P_2 spine or ray 1. *Flexion*—Over midbrain by ca. 4.5–4.7 mm; medially on lower jaw by 4.7 mm; 0–few in branchial cavity; spreading ventrolaterally over gas bladder; proximally on A II & variably on A I & A III. *Postflexion*—Externally over forebrain by 8.5 mm; 0–few distally on D III; series along bases of D III–IV spreading to D VII; dorsolateral patch below D IX or X to D 1 or 2 by 6.3–8.5 mm; on upper preopercle by 5.9 mm; internally over urostyle by 6.3 mm & externally by 8.5 mm.
Diagnostic features: Serrate fin spines; P_2 spine serrate first, beginning on posterior margin & then on anterior margin; D II next, initially with posterior serrations, & anterior serrations forming by the time D V develops; serrations on anterior of D I–VI & posterior of D I–VIII by 6.3 mm; A I–II with serrate anterior & posterior margins by 5.9 mm; P_2 pigment proximal, primarily on spine & first ray; D III length ≥D II length by 8.5 mm; pigment anteriorly on A base early, spreading down posterior surface of A II; D X, 14; A III, 8.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–52 50	52–56 54	59–64 60	62–66 64	63–69 66
BD/BL		35–39 37	35–41 37	38–43 41	35–40 38	36–37 36
HL/BL		33–38 35	35–37 36	38–40 39	36–39 37	36–39 38
HW/HL		41–48 43	38–45 42	37–42 39	40–47 45	39–46 42
SnL/HL		28–37 33	29–35 32	32–36 34	27–32 29	27–30 29
ED/HL		28–32 30	30–32 31	28–32 30	30–35 32	29–34 31
P_1L/BL		7–8 7	8–10 8	10–17 12	19–24 22	22–25 24
P_2L/BL		21–23 22	18–29 25	24–30 27	26–29 28	24–29 27
DSL/BL		21–25 23	21–30 27	24–31 28	10–18 13	11–12 12

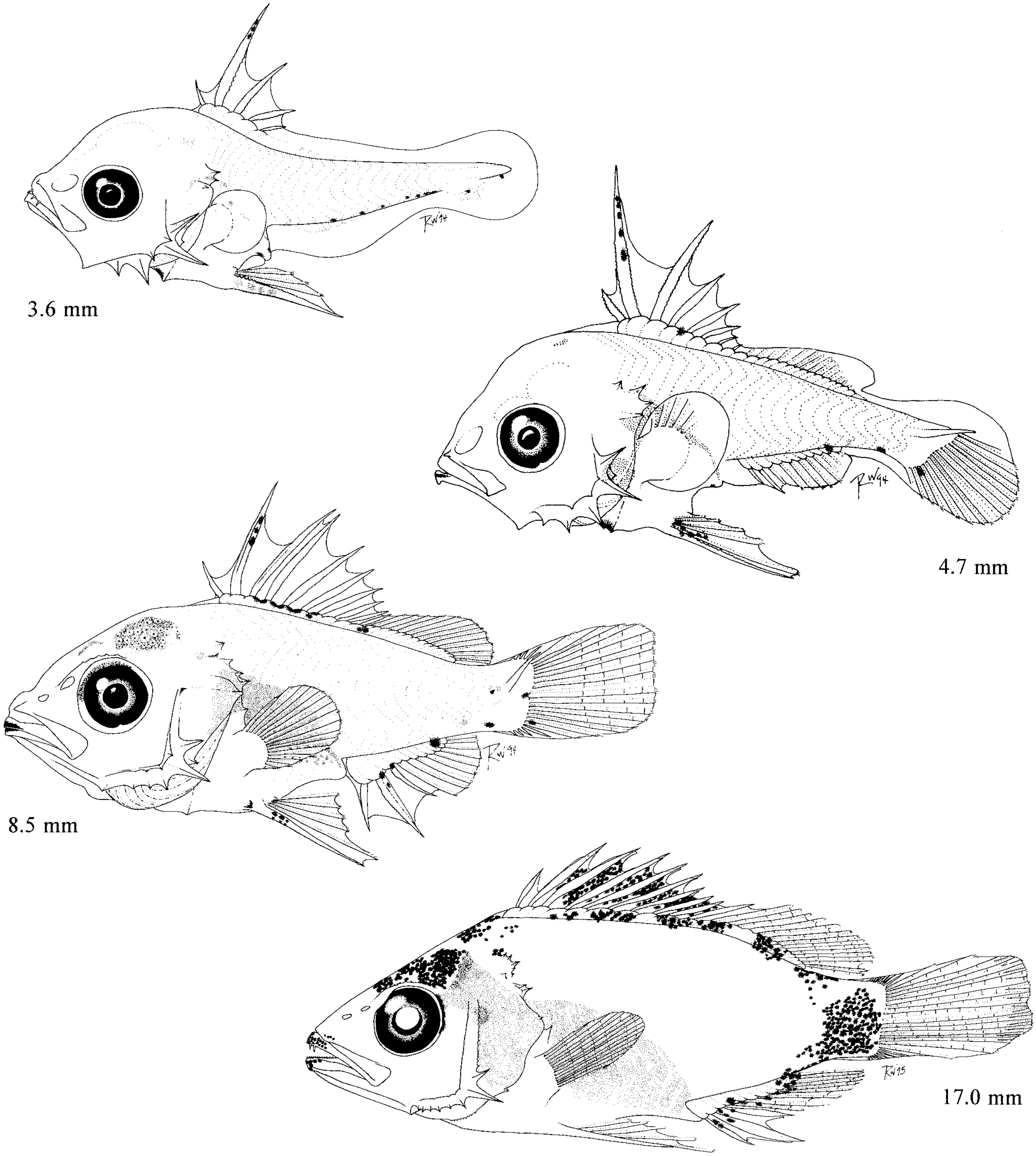

Figure Lutjanidae 2. Preflexion larva, 3.6 mm (CalCOFI 5708, station 133G.105); flexion larva, 4.7 mm (CalCOFI 5209, station 135.5G.19); postflexion larva, 8.5 mm (CalCOFI 5209, station 137G.23); transformation specimen, 17.0 mm (MWB–071690–PL–100; scales are not shown).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X–XI	X
Dorsal rays	11–13	12
Anal spines	III	III
Anal rays	8–9	8
Pelvic	I,5	I,5
Pectoral	15–17	16
Caudal:		
Principal	9–8	9–8
Procurrent:		
Upper	9–11	9–10
Lower	8–10	9
Gill rakers:		
Upper	6–8	7
Lower	13–17	14–15
Branchiostegals	7	7

LIFE HISTORY

Range: Bahía Magdalena, Baja California Sur, & throughout Gulf of California to Peru; larvae collected as far north as vicinity of Punta San Juanico, Baja California Sur

Habitat: Coastal waters over both sandy bottom & reefs; juveniles commonly over soft bottom of bays

Spawning season: Larvae collected in summer & autumn in Gulf of California, February–May off Central America

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (R. C. Walker)
Flexion larva, 5.3 mm (R. C. Walker)
Postflexion larva, 7.5 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: ca. 4.5 mm through 5.1–5.4 mm
Transformation length: <19.3 mm through ca. 29.6 mm
Fin development sequence: 1D & P_2, C_1, 2D, A, P_1, C_2
Pigmentation: *Preflexion*—Internally at nape; internal posteriorly above & below midbrain by 4.3 mm; 1 on isthmus adjacent to cleithral symphysis; dorsally on gas bladder; anteriorly & dorsally on gut; 1 ventrally on hindgut near terminus; 2–5 on ventral margin of posterior half of tail, usually reduced to 1 each at A insertion & myomere 21–22 by 4.3 mm; 1–few on posterior margin of D spine II; few on P_2 usually scattered along full length of ray 1. *Flexion*—Externally over midbrain by 5 mm; 0–1 at upper end of preopercle by 5 mm; spreading ventrolaterally to cover gas bladder; 1–2 along lower hypural margin; 1 over proximal end of urostyle by 5 mm. *Postflexion*—Increasing over midbrain; over forebrain by 7.5 mm; internally under mid- & hindbrain by 5.8 mm; spreading ventrolaterally on gut; on dorsal margin of caudal peduncle by 5.9–7.5 mm; on margin of spinous D membrane by 7.5 mm; increasing on P_2.
Diagnostic features: Serrate fin spines; posterior margins of D I serrate after ca. 5 mm and anterior margin with few serrations between 5.3–10.9 mm; posterior margins of D II serrate after 4 mm & anterior margin serrate between 4.5–10.9 mm; D III–X anterior margins always smooth; anterior margins of A I & II smooth before 5.9–7.5 mm, posterior margins usually serrate after 5–6 mm; D X,12; A III, 8; P_2 pigment relatively light, scattered along full length of fin, primarily along outer rays to at least 7.5 mm, absent by 10.9 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–54 51	49–55 53	54–61 58	60–64 62	60–63 61
BD/BL		30–36 34	31–38 35	35–41 38	32–36 34	35–37 36
HL/BL		31–34 33	32–37 35	34–41 38	36–42 39	37–41 39
HW/HL		46–49 48	41–48 45	39–43 41	39–47 44	40–45 42
SnL/HL		28–31 30	25–32 29	29–33 31	24–27 26	24–26 25
ED/HL		33–35 34	22–32 29	28–33 31	30–35 33	31–35 32
P_1L/BL		6–7 6	7–9 8	8–17 10	21–23 22	21–25 24
P_2L/BL		15–19 17	20–27 23	21–28 24	23–27 25	24–27 26
DSL/BL		12–21 16	18–22 19	17–24 21	11–14 13	11–14 12

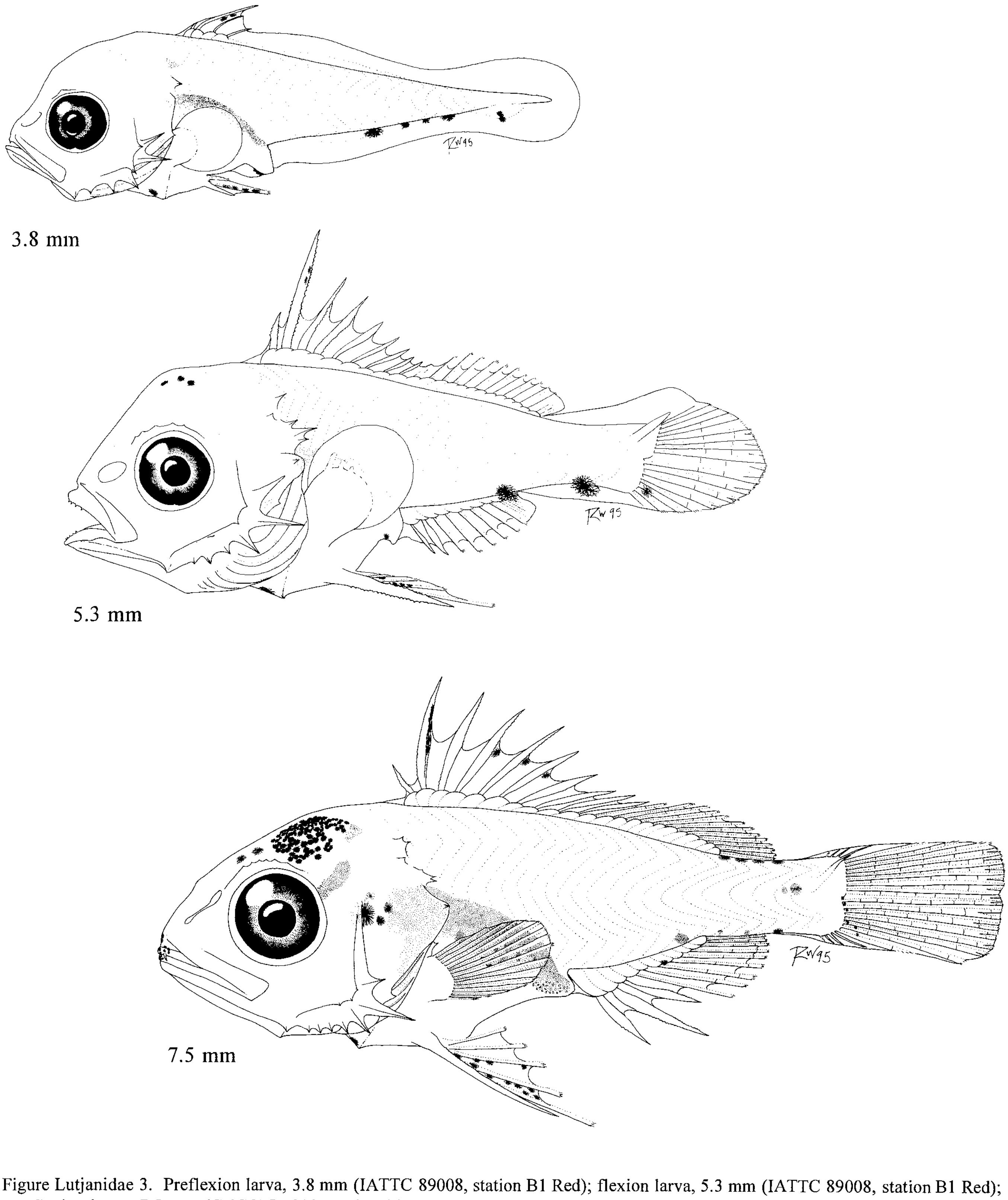

Figure Lutjanidae 3. Preflexion larva, 3.8 mm (IATTC 89008, station B1 Red); flexion larva, 5.3 mm (IATTC 89008, station B1 Red); postflexion larva, 7.5 mm (CalCOFI 5209, station 144.5G.26).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X–XI	X
Dorsal rays	13–15	14
Anal spines	III	III
Anal rays	7–8	8
Pelvic	I,5	I,5
Pectoral	15–17	16–17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	9
Lower	8–9	8–9
Gill rakers:		
Upper	6–7	6–7
Lower	9–13	11–12
Branchiostegals	7	7

LIFE HISTORY

Range: Bahía Santa Maria, Baja California Sur, & throughout Gulf of California to Peru

Habitat: Over shallow reefs ca. 5–30 m depth; juveniles in bays & estuaries

Spawning season: Larvae collected in summer in Gulf of California, year-round off Costa Rica

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (R. C. Walker)
Flexion larva, 5.7 mm (R. C. Walker)
Postflexion larva, 7.8 mm (R. C. Walker)
Transformation specimen, 16.7 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.1 mm
Flexion length: ca. 4.2–5.9 mm
Transformation length: <15.7 mm to <27.9 mm
Fin development sequence: P_2, 1D, C_1, 2D & A, P_1, C_2
Pigmentation: *Preflexion*—Internally at nape; under hindbrain; 1 or 2 embedded posteriorly over midbrain by 3.5 mm; externally over midbrain by 4.0 mm; 0–few in branchial cavity; 1 on isthmus near cleithra; on liver & anteriorly on gut; dorsally on gas bladder & hindgut; 1 ventrally on hindgut near anus; 7–8 on ventral margin of tail, decreasing to 2–3 by 4.0 mm; on posterior margin of D II by 3.7 mm, usually on distal half; on P_2, usually on distal half of rays 1 & 2. *Flexion*—Spreading forward over midbrain; spreading ventrolaterally on gas bladder & gut; internal anteriorly over urostyle by 4.3 mm; at upper end of preopercle by 5.1–5.9 mm; spreading proximally on D II; usually none ventrally on hindgut by end of stage. *Postflexion*—Increasing over midbrain; 0–2 over forebrain until 6.2 mm, then increasing; on snout by 7.5 mm; on tip of upper jaw by 12.4 mm; laterally on caudal peduncle by 6.2 mm; internally over last two vertebrae between 7.8–12.4 mm; on dorsal margin from D insertion to mid-peduncle by 7.5 mm; increasing on 1D membrane after 7.5 mm; spreading along dorsal margin, ventral margin of caudal peduncle, hypural margins, & on bases of A rays by 12.4 mm.
Diagnostic features: Margins of all fin spines smooth; D II 100–164% D III length (usually 130–145%); D X, 14; A III, 8; P_2 pigment usually on distal half, primarily on ray 1, spreading to rays 1–3; isolated proximal melanophore on P_2 in 40–50%; bilateral pair of melanophores usually present posteriorly over midbrain by late preflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–53 49	50–60 54	56–66 60	62–65 63	65–67 66
BD/BL		26–34 30	33–39 35	34–40 38	33–37 35	37–37 37
HL/BL		27–33 30	33–37 35	35–41 38	36–40 38	38–41 40
HW/HL		42–60 51	40–46 43	34–42 38	40–46 42	37–44 40
SnL/HL		25–36 28	26–35 30	28–36 31	24–28 25	24–28 26
ED/HL		24–35 32	28–33 30	26–34 29	27–35 31	28–30 29
P_1L/BL		5–8 7	7–11 8	10–19 13	18–20 19	21–22 21
P_2L/BL		3–26 12	22–33 28	26–35 31	24–31 27	26–26 26
DSL/BL		0–24 17	23–32 27	24–33 29	15–20 18	11–12 12

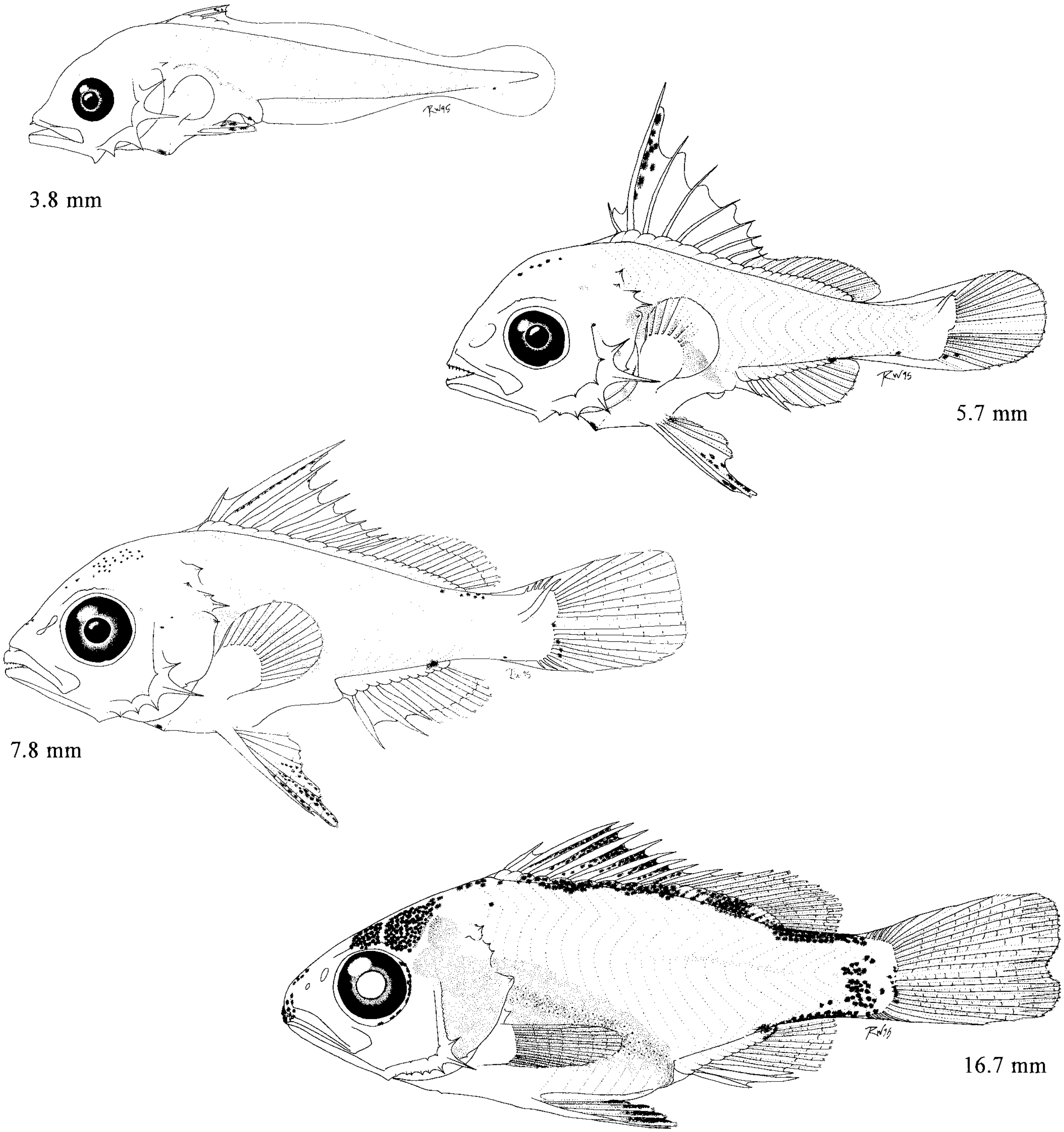

Figure Lutjanidae 4. Preflexion larva, 3.8 mm; flexion larva, 5.7 mm (CalCOFI 5209, station 133.5G.33); postflexion larva, 7.8 mm (IATTC 89003, station A2 Red); transformation specimen, 16.7 mm (MWB–071790–5).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	X	X
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	8–9	8
Pelvic	I,5	I,5
Pectoral	17–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–12	10
Lower	10–11	10
Gill rakers:		
Upper	5–7	
Lower	10–15	
Branchiostegals	7	7

LIFE HISTORY

Range: Bahía Santa Maria, Baja California Sur, & throughout the Gulf of California to Peru

Habitat: Over reefs in coastal waters to 91 m depth, more common in deeper part of depth range

Spawning season: Larvae collected in summer in Gulf of California, year-round in tropics

ELH pattern: Oviparous; planktonic larvae

LITERATURE

Brogan, in press

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (N. Arthur)
Flexion larva, 5.2 mm (N. Arthur)
Postflexion larva, 10.7 mm (N. Arthur)
Transformation specimen, 19.0 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.7 mm
Flexion length: 4.7–4.8 mm through 5.7–6.2 mm
Transformation length: Begins at >14.8 mm, <18.8 mm
Fin development sequence: 1D & P_2, C_1, 2D & A, P_1, C_2
Pigmentation: *Preflexion*—Internally at nape; under hindbrain; internally, posteriorly over center of midbrain after 4 mm; on isthmus; anteriorly on liver & gut; dorsally on gas bladder & hindgut; usually 1 ventrally on hindgut; 5–10 on ventral margin of tail decreasing to 2 by end of stage; 1 under center of notochord tip; heavy along posterior margin of D II; on P_2, heaviest distally on ray 1. *Flexion*—Spreading ventrolaterally on gas bladder & gut; 0–1 (usually 0) on dorsal margin of caudal peduncle by ca. 5.5 mm; along full length of P_2 rays 1–4, heaviest distally on ray 1. *Postflexion*—Externally over midbrain at ca. 6.2 mm & over forebrain at 7.4 mm; on snout by 13.1 mm; 1 at upper end of preopercle at 6.3–6.5 mm, increasing after 10.8 mm; spreading ventrad on gas bladder & gut; usually none ventrally on hindgut after 6.5 mm; 0–1 dorsally on caudal peduncle (usually 0 before 7 mm), increasing after 8 mm; increasing ventrally on caudal peduncle after 8 mm; internally over urostyle by 6.5 mm; proximally on lower C_1; heavy posteriorly on DII; on P_2, heaviest distally on ray 1.
Diagnostic features: Margins of fin spines smooth; D II ca. 130–199% D III length (usually ca. 150–180%); D usually X,13; A III,8; heavy pigment along nearly full length of posterior margin of D II.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–51 48	49–56 52	54–58 56	61–62 62	
BD/BL		28–36 31	33–37 35	35–40 37	35–37 36	
HL/BL		28–33 30	32–37 34	34–39 36	33–36 35	
HW/HL		42–65 51	41–45 43	37–46 41	39–44 41	
SnL/HL		26–37 30	31–36 33	30–37 33	31–33 32	
ED/HL		26–41 32	24–34 30	28–36 31	27–32 29	
P_1L/BL		5–8 7	6–9 8	7–17 11	22	
P_2L/BL		0–27 17	23–41 34	39–53 44	31	
DSL/BL		0–32 15	26–39 34	34–49 41	20–28 24	

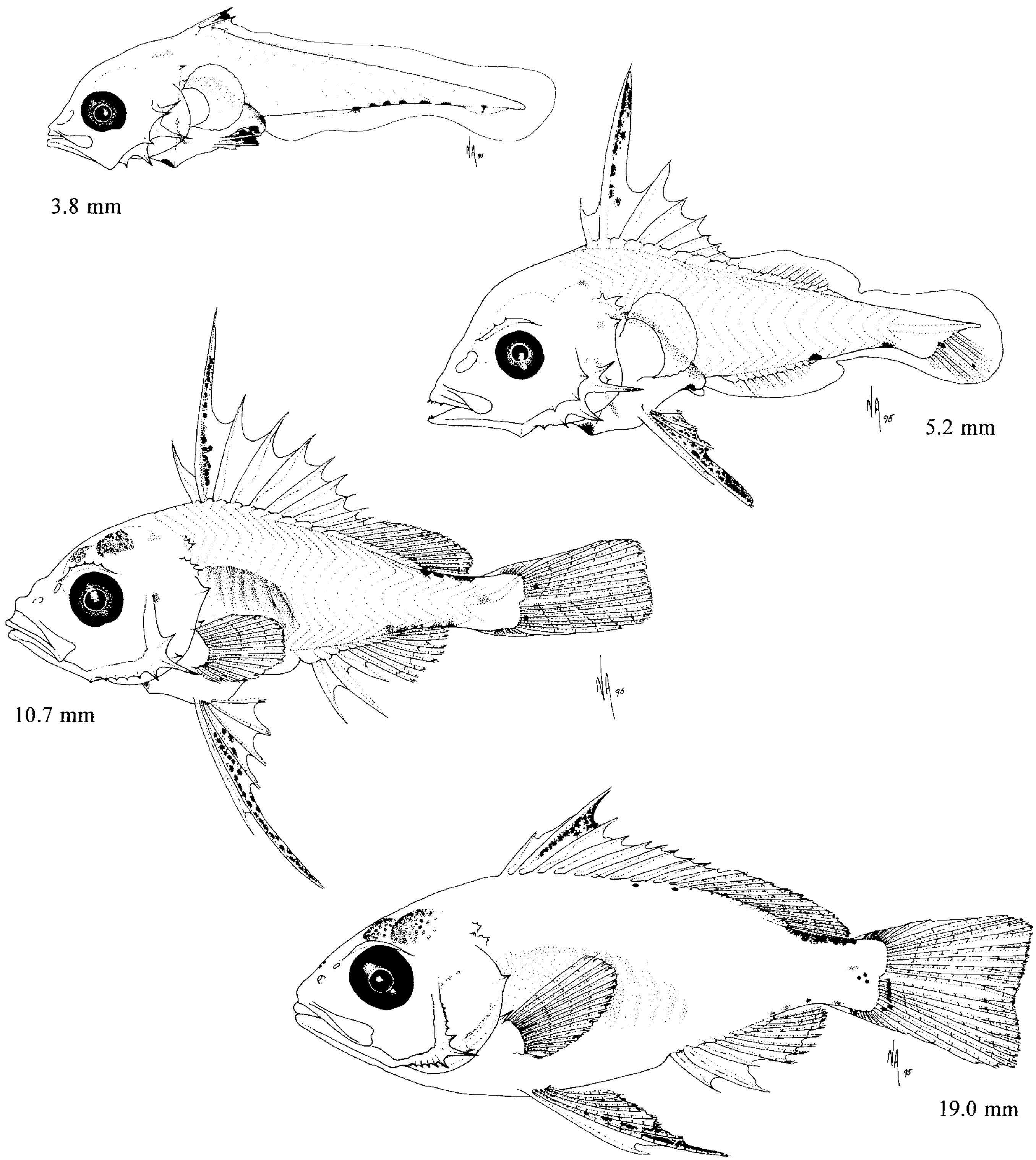

Figure Lutjanidae 5. Preflexion larva, 3.8 mm (CalCOFI 5209, station 144.5G.26); flexion larva, 5.2 mm (CalCOFI 5708, station 121G.55); postflexion larva, 10.7 mm (UCR–ICP—87–105); transformation specimen, 19.0 mm (CalCOFI 5708, station 99G.40; other specimens of similar size have melanophore series along the posterior and posteroventral rim of the orbit).

MALACANTHIDAE: Tilefishes

H. G. MOSER

The family Malacanthidae includes 39 species in eight genera and two subfamilies: Latilinae, the tilefishes, and Malacanthinae, the sand tilefishes (Nelson 1994). Malacanthids are found in tropical to temperate regions throughout the world. Three species in the genus *Caulolatilus* occur in the California Current region (Schneider and Krup 1995b; Allen and Robertson 1994; Table Malacanthidae 1). *Caulolatilus princeps*, the ocean whitefish, is a prominent species of offshore rocky reefs and banks off southern California, Baja California, and the Gulf of California. Its larvae are relatively common in CalCOFI samples taken off central Baja California but have not been taken off California (Moser et al. 1986). *C. affinis*, the Pacific golden-eyed tilefish, is the most common tilefish in the Gulf of California, where it inhabits patch reefs close to shore; it does not occur on the outer coast of Baja California. A third species, *C. hubbsi*, is known principally from Peru and the Galápagos Islands; however, adults have been recorded from the Gulf and California and as far north as southern California (Dooley 1978). Larvae of *C. affinis* or *C. hubbsi* are undescribed.

Malacanthids are medium-sized (typically 30–60 cm), moderately compressed fishes, characterized by long-based dorsal and anal fins with rays of about equal height. Latilines are deeper bodied than malacanthines, generally have fewer dorsal and anal fin rays (D VI–X, 14–27 and A I–II, 11–26 vs. D I–X, 13–60 and A I–II, 12–55), a steeper forehead, and have a ridge of tissue anterior to the dorsal fin (lacking in malacanthids). The pectoral fin is moderately large and falcate, the pelvic fin is thoracic, with I, 5 rays, and the caudal ranges from forked to truncate. The body is covered with small ctenoid scales while those on the head are mostly cycloid. The opercle has single strong (often sharp) opercular spine. Latilines are found on or near rocky reefs deeper than 50 m while malacanthines dwell in burrows or mounds that they construct at depths shallower then 50 m. Some species (e.g., ocean whitefish and the Great northern tilefish of the northwest Atlantic) are harvested commercially and by recreational anglers.

Little is known about spawning in malacanthids. Planktonic eggs of *Lopholatilus chamaeleonticeps* are 1.3–1.4 mm in diameter, have homogeneous amber-tinted yolk, a single oil globule (0.20–0.24 mm in diameter), a moderate perivitelline space, and a reticulated chorion (Fahay 1983). Planktonic eggs of *C. princeps* have not been identified. Latiline larvae hatch at <3.0 mm and have a robust body form with a compact gut and early forming preopercular spination. Preflexion larvae develop numerous spiny ridges on the cranial bones (e.g., frontals, nasals, infraorbitals) and on the posttemporals and supracleithrals. At the beginning of notochord flexion (4–5 mm) patches of spinous scales begin to form on the body and cover the head and body by the end of the postflexion stage at ca. 7 mm (Okiyama 1964; Fahay and Berrien 1981; Fahay 1983; Moser et al. 1986). Early malacanthine larvae have not been described. Postflexion larvae and pelagic juveniles of latilines and malacanthines develop a unique rostral projection (highly ornamented in some malacanthines) formed by the transitory fusion of the nasal bones. Johnson (1984) pointed out that this transitory fusion of the nasal bones is a unique synapomorphy within Percoidei and argued for the presently accepted arrangement of two subfamilies within a single family.

The following description of *C. princeps* is based on Moser et al. (1986). Meristic data were obtained from the literature (Miller and Lea 1972; Dooley 1978) and from counts made during this study.

Table Malacanthidae 1. Meristic characters for the malacanthid species in the California Current vicinity. All have I,5 pelvic fin rays, 9+8 principal caudal fin rays, and 6 branchiostegal rays.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers (total)
Caulolatilus affinis	11–12	15	26–27	VII–IX, 22–25	I–II, 21–24	18–19	11–12+10–11	20–27
C. hubbsi	11	16	27	VIII–X, 23–27	II, 23–26	18–19		21–26
C. princeps	12	15	27	VII–X, 24–27	I–II, 20–26	18–20	13–15+10–13	20–26

MERISTICS

	Range	Mode
Vertebrae:		
Total	27	27
Precaudal	12	12
Caudal	15	15
Fins:		
Dorsal spines	VII–X	IX
Dorsal rays	24–27	25–26
Anal spines	I–II	II
Anal rays	20–26	25
Pelvic	I,5	I,5
Pectoral	18–20	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	13–15	13
Lower	10–13	12
Gill rakers:		
Upper	6–10	
Lower	12–15	
Branchiostegals	6	6

LIFE HISTORY

Range: Vancouver Island, British Columbia to Peru, including Gulf of California & the Galápagos Islands

Habitat: Usually offshore rocky reefs & around islands; 1 – >100 m depth

Spawning season: Summer; in CalCOFI area, larvae most abundant in June–August with a peak in July

ELH pattern: Oviparous; presumably, eggs planktonic; larvae planktonic

LITERATURE

Johnson 1984
Moser 1981
Moser et al. 1986

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.6 mm
Flexion length: ca. 5.5–7.0 mm
Transformation length: Between 8 & 15 mm
Fin development sequence: C_1, P_1 & D & A, P_2, C_2
Pigmentation: *Preflexion*—Gut completely covered; extending dorsad (internally & superficially) to the anterior trunk & anteriad beneath the otic region & brain to the snout; postanal ventral midline series of 9–14 (usually 11–14) extending from 3rd–5th postanal myomere to the caudal fin anlage; by 3.0 mm, on nape, inner & lateral surfaces of P_1 base, preopercular & opercular region, cardiac region, & on the optic & cerebellar brain lobes; late in stage, postanal ventral series begins to coalesce & trunk sheath begins to expand posteriad. *Flexion*—Trunk sheath more than half-way posteriad on tail. *Postflexion*—Trunk sheath to hypural region; remainder of larva covered except jaws & ventral region of head.
Diagnostic features: Stout body form; large head; compactly coiled, heavily pigmented gut; internal pigment bar extending from anterior trunk to snout; early formation of preopercular spines; extensive spiny ridges on frontal, nasal, & other head bones & on posttemporal & supracleithrum; patches of spinous scales form after preflexion stage & cover body by end of postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		39–53 47	51–56 53	59–60 59		56–62 59
BD/BL		26–34 31	37–38 37	41–41 41		29–39 34
HL/BL		29–32 29	33–36 35	39–39 39		29–36 33
HW/HL		69–88 75	59–63 61	58–61 59		48–53 51
SnL/HL		18–32 26	25–28 27	25–30 28		20–27 24
ED/HL		31–51 40	40–42 41	36–39 37		32–38 36
P_1L/BL		7–9 8	12–12 12	14–17 15		16–18 17
P_2L/BL		0–0.9 0.2	0.7–1 0.9	6–9 8		13–14 13

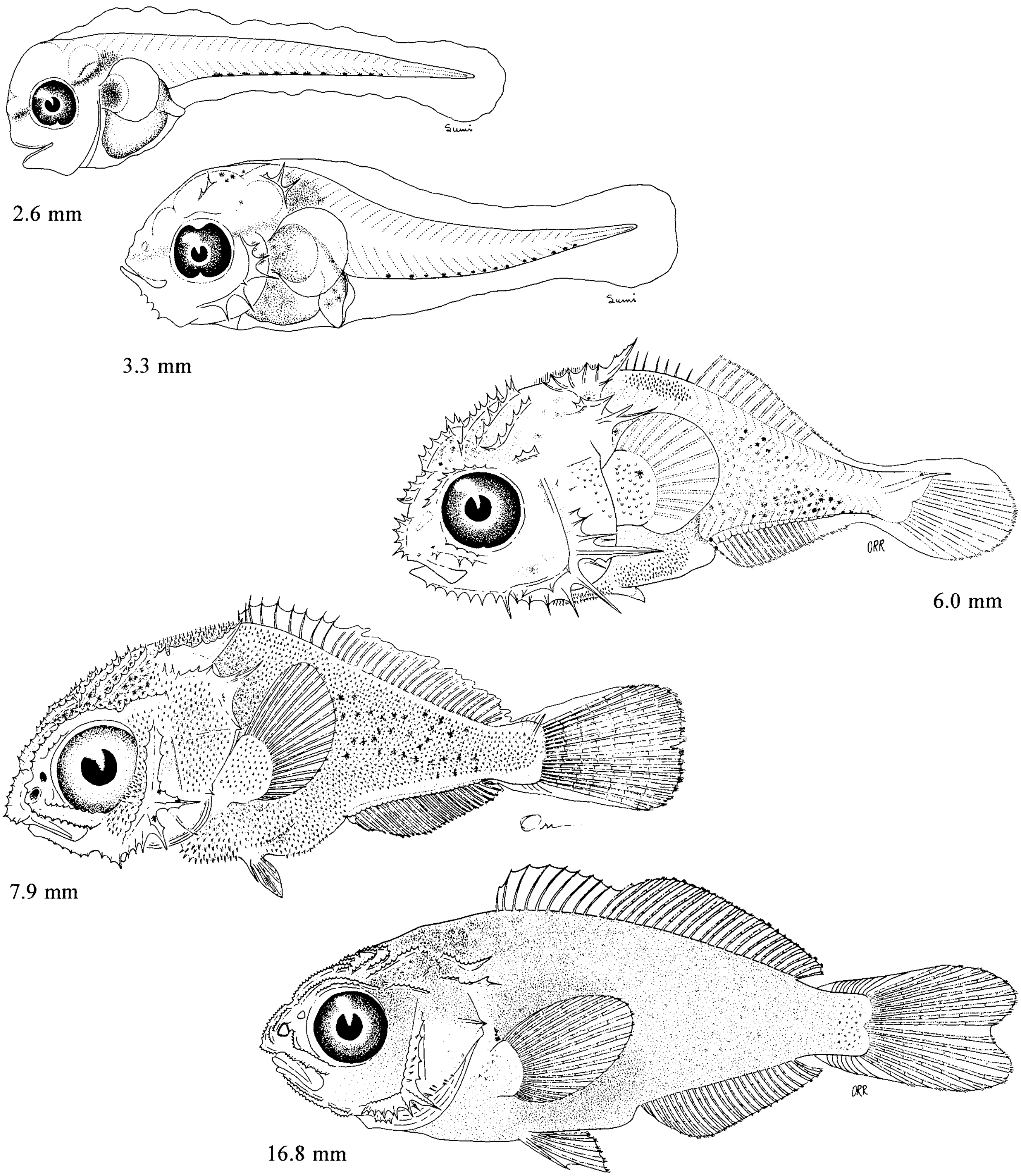

Figure Malacanthidae 1. Preflexion larvae, 2.6 mm, 3.3 mm (Moser et al. 1986); flexion larva, 6.0 mm (Moser 1981); postflexion larva, 7.9 mm; pelagic juvenile, 16.8 mm (Moser et al. 1986).

LOBOTIDAE: Tripletails

W. WATSON

The tripletail genus *Lobotes* presently is thought to consist of a single species, *L. surinamensis*, which occurs worldwide in tropical and subtropical oceans (Heemstra 1986d). In the California Current region, *L. surinamensis* ranges northward to the vicinity of Cabo San Lucas, Baja California Sur. Larval *L. surinamensis* have not been identified in CalCOFI samples, but have been taken during ichthyoplankton surveys off the Pacific coast of Central America.

Adult lobotids are large (to ca. 1 m), moderately deep-bodied and compressed, with a concave forehead, small eye, serrate preopercular margin, and continuous dorsal fin. The rounded caudal fin and rounded posterior lobes of the dorsal and anal fins account for the common name. Adults typically swim near pilings, reefs, and floating objects in bays, estuaries, and along the shallow open coast, and they may be found far offshore sheltering under floating material. Juveniles are well-known leaf mimics. Lobotids are utilized in both sport and some artisanal fisheries.

Spawning, eggs, and yolk-sac larvae have not been described, except that Gudger (1931) described ovarian eggs as spherical and ca. 1 mm in diameter. Tripletail larvae are characterized by a serrate supraoccipital crest and large preopercular spines (Ditty and Shaw 1994). Larvae have a large head (ca. 30–40% BL), moderately long preanal length (ca. 60–70% BL), an increasingly deep body (ca. 25–35% BL before 3 mm, increasing to ca. 50–55% BL by 6 mm), and early development of large, heavily pigmented pelvic fins (rays present by 3 mm, before development of rays in the other fins). Larval pigmentation initially is light and largely restricted to the brain, dorsal surfaces of the gas bladder and gut, and the ventrum. It rapidly increases, so that by the postflexion stage the larvae are nearly completely pigmented.

Larval lobotids are readily recognized by their serrate supraoccipital crest, large preopercular spines, large pigmented pelvic fins, deep body and long preanal length, 24 myomeres (11–13+11–13, usually 12+12), and heavy pigmentation in the postflexion stage. The smallest larvae superficially resemble small holocentrid larvae, but have fewer myomeres, a longer preanal length, a more serrate supraoccipital crest, and lack the rostral spine that characterizes larval holocentrids larger than ca. 2.0–2.5 mm.

The following description is based on detailed observation of 22 larvae (10 preflexion, 2.4–4.1 mm; 4 flexion, 4.8–5.3 mm, 4 postflexion, 5.2–6.9 mm; and 4 transformation, 7.3–8.7 mm) and 4 juveniles (27.8–86.0 mm). These specimens from the Pacific coast of Mexico and Central America may differ slightly from Indo-Pacific and Gulf of Mexico specimens of *L. surinamensis*, primarily in developing somewhat more rapidly (c.f. Ditty and Shaw 1994; Konishi 1988c; also note that the 5.1 mm specimen illustrated in Konishi is not *L. surinamensis*) and in having a somewhat shorter preanal length and shallower body. The larvae of the eastern Pacific *L. surinamensis* are quite similar in appearance and development to larval *Hapalogenys* (c.f. Kinoshita 1988d).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	12	12
Caudal	12	12
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	15–16	15
Anal spines	III	III
Anal rays	10–12	10
Pelvic	I,5	I,5
Pectoral	15–17	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	3–4	4
Lower	3–4	4
Gill rakers:		
Upper	5–7	
Lower	13–15	
Branchiostegals	6	6

LIFE HISTORY

Range: Circumtropical; in eastern Pacific, ranging northward to vicinity of Cabo San Lucas, Baja California Sur

Habitat: Neritic & pelagic; in bays, estuaries, & shallow coastal waters, usually associated with reefs, pilings, floating objects, etc; & offshore in association with floating objects

Spawning season: Summer (Gulf of Mexico & Western North Atlantic)

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ditty & Shaw 1994
Gudger 1931
Hardy 1978b
Johnson 1984
Konishi 1988c
Uchida et al. 1958b

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.4 mm, 3.9 mm (M. T. Vona)
Flexion larva, 5.3 mm (M. T. Vona)
Postflexion larva, 5.9 mm (M. T. Vona)
Transformation specimen, 7.3 mm (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.4 mm
Flexion length: ca. 4.5–5.5 mm
Transformation length: ca. 7.0 mm to >8.7 mm, <27.8 mm
Fin development sequence: P_2, C_1, D & A, P_1, C_2
Pigmentation: *Preflexion–postflexion*—Under hindbrain; encircling hindbrain anteriorly & pair over forebrain by ca. 2.9 mm; on preopercular margin at ca. 3.0 mm; on tips of jaws by ca. 4.9 mm; increasing on head, completely covering it by ca. 5.9 mm; on nape, increasing & spreading caudad; laterally on myosepta between myomeres 8–17 beginning at ca. 4.0 mm, spreading to cover all but caudal peduncle by ca. 5.9 mm; dorsally on gas bladder & gut; along ventral margin of isthmus & gut; on P_1 base by 4.0 mm; heavy on P_2 after 4 mm; on spinous D & A between 5.0–5.9 mm, on soft rays between 5.9–6.9 mm; few along ventral margin of tail. *Transformation*—Heavily pigmented except little or none on end of caudal peduncle & on C rays, P_1 rays, distal 25–50% of D & A soft rays; barred pattern forms.
Diagnostic features: Prominent serrated supraoccipital crest; large preopercular spines; early forming, large, heavily pigmented P_2; myomeres 11–13+11–13=24 (usually 12+12); preanal length ca. 60–70% BL; heavily pigmented in postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		57–64 61	64–69 66	69–79 74	69–74 72	65–67 66
BD/BL		25–40 34	35–43 40	48–54 51	53–54 54	49–54 51
HL/BL		29–36 33	35–36 35	38–44 41	35–40 38	33–36 34
HW/HL		48–71 59	55–64 58	44–60 53	52–66 57	51–66 61
SnL/HL		24–31 27	22–27 25	20–26 23	21–29 25	19–23 21
ED/HL		31–38 33	28–30 29	28–31 29	28–33 30	19–29 23
P_1L/BL		6–9 7	7–8 8	13–15 14	18–21 20	17–19 18
P_2L/BL		0–21 9	17–19 18	21–24 22	19–24 22	27–30 28
PrSL/HL		24–42 34	36–39 37	23–34 29	15–23 19	2–4 3
SoCL/HL		25–44 33	18–24 21	8–14 12	3–7 5	0–0 0

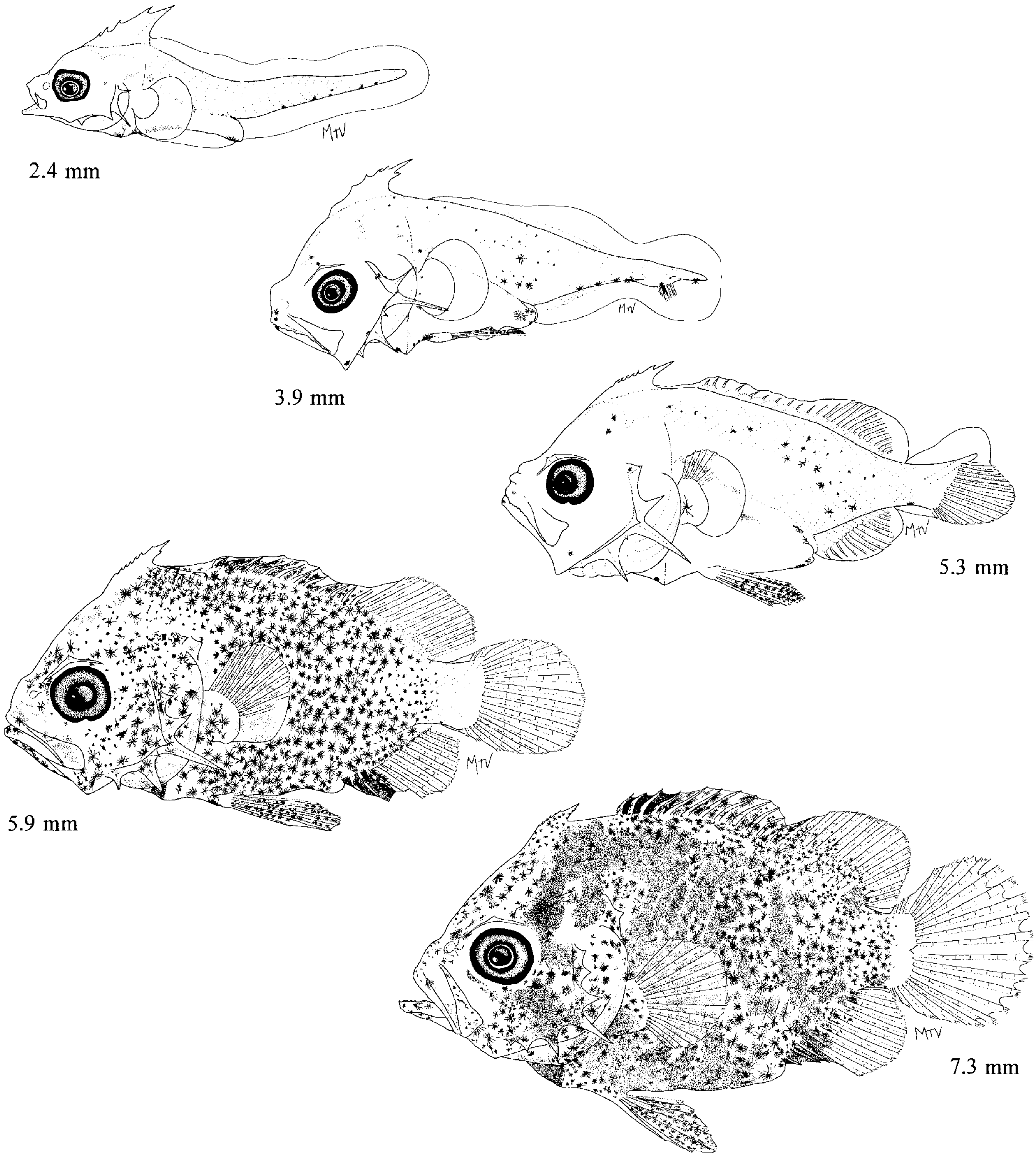

Figure Lobotidae 1. Preflexion larvae, 2.4 mm (IATTC 90041, station T7), 3.9 mm (IATTC 89011, station C1 Grn); flexion larva, 5.3 mm (IATTC 89026, station MSH #2 Grn); postflexion larva, 5.9 mm (IATTC 90034, station ASB #6 Manta); transformation specimen, 7.3 mm (IATTC 90034, station ASB #2 Manta), scales are not shown.

GERREIDAE: Mojarras

W. WATSON

Gerreid taxonomy is somewhat confused, at least at the species level (e.g., de la Cruz-Agüero and Galvan-Magaña 1993). At least seven species occur in the CalCOFI study area, primarily at its the southern end off southern Baja California Sur (Table Gerreidae 1; Cruz-Agüero et al. 1994; Bussing 1995a). Two species, *Eucinostomus argenteus* and *E. currani*, range northward to southern California. Moderate numbers of mojarra larvae have been taken in CalCOFI ichthyoplankton collections, primarily at inshore stations between about Punta Blanca, Baja California, and Cabo San Lazaro, Baja California Sur, during summer and autumn cruises.

Adult mojarras are small to medium-size (most species ca. 15–20 cm, largest to ca. 35 cm) omnivorous residents of warm, shallow, coastal waters and estuaries (some may enter freshwater), where they forage on sand and mud bottoms, among mangroves, etc. Mojarras are compressed, somewhat elongate to oval, with preanal length about two-thirds of body length. The eyes are large, the snout pointed, and the mouth small, terminal, and greatly protrusible. The ventral profile of the head is concave. The continuous dorsal fin usually is broadly notched between its spinous and soft-rayed portions. The short-based anal fin contains three spines and a few soft rays; the second anal spine typically is much stronger than the others. The pectoral fins are long and pointed and the caudal fin is forked. Mojarras are silvery and may be barred or striped. Some species are important in artisanal fisheries.

Gerreids are oviparous, with planktonic eggs and larvae (Johnson 1984). The spherical eggs are 0.6–0.75 mm in diameter with a single oil globule 0.18–0.2 mm in diameter and a segmented yolk (Mito 1963; Rass 1972). Larvae hatch at ca. 1.4 mm with unpigmented eyes, an unformed mouth, and a large yolk sac (Mito 1963). Larvae are characterized throughout development by being moderately deep-bodied to moderately elongate, with a short, coiled gut (in larvae larger than 2 mm, at least), moderate head with short, rounded (in the preflexion stage) to somewhat elongate, pointed (in the postflexion stage) snout, and large eyes. Spination of the head consists only of a few small preopercular spines that develop during the flexion or postflexion stage. Small supracleithral spines may form during the postflexion stage in some species (Leis and Rennis 1983). Larvae initially are oval in cross-section, but become increasingly compressed with development. Larval pigmentation typically is limited to the dorsal surfaces of the head, gas bladder and hindgut, and to the ventral margins of the isthmus, gut and tail through at least the early part of the flexion stage. Melanophores are added along the dorsal and hypural margins during the flexion or postflexion stage.

Although larval gerreids superficially resemble the larvae of many other perciform families, they usually can be distinguished from the others by a combination of morphological characters (primarily the short preanal length, large eyes, pointed snout in the postflexion stage, lack of preopercular spines before late flexion or postflexion and only a few small spines thereafter), meristic characters (24 myomeres, fin ray counts in postflexion specimens), and pigment characters (lateral surfaces of trunk and tail unpigmented through at least notochord flexion, dorsal pigment absent except on head before mid- to late flexion). It is unknown how the larvae of the gerreid species in the CalCOFI study area might be distinguished from one another.

The following description is based on ten preflexion larvae (2.1–3.8 mm), five flexion larvae (4.3–5.2 mm) and ten postflexion larvae (5.6–11.5 mm) of *Eucinostomus* sp(p). All were collected at inshore CalCOFI stations between Punta Baja, Baja California, and Punta San Juanico, Baja California Sur, where *Eucinostomus argenteus*, *E. currani*, and *E. entomelas* occur. The larvae appear to represent a single species, but it is unknown which they are, or if they indeed are all the same species. Meristic counts were obtained from Yañez-Arancibia (1978) and from unpublished data at SWFSC. Ecological information was obtained from Yañez-Arancibia (1978), Allen and Robertson (1994), and Bussing (1995a).

Table Gerreidae 1. Meristic characters for the gerreid species in the CalCOFI study area. All have 9+8 principal caudal fin rays and I,5 pelvic fin rays. Gill raker counts for *Diapterus peruvianus* and *Eucinostomus entomelas* do not include epibranchial (upper) gill rakers.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	GR
Diapterus peruvianus	10	14	24	IX,9–10	III,8	15–16	10+9	12–14
Eucinostomus argenteus	11	13	24	IX,9–10	III,7–8	13–16	10–12+10–11	4–7+7–9
E. currani			24	IX,9–10	III,7–8	15–17		4–7+7–9
E. entomelas	11	13	24	IX,10	III,7	15–16	10–11+10–11	7–9
E. gracilis	10	14	24	IX,10	III,7–8	15	10–11+10–11	5+8
Eugerres axillaris	10	14	24	IX,8–10	III,8		9+7–8	17–22+13–17
Gerres cinereus	10	14	24	IX,10–11	III,6–7	15	8–9+7–8	1+7–9

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	11	11
Caudal	13	13
Fins:		
Dorsal spines	IX	IX
Dorsal rays	9–10	10
Anal spines	III	III
Anal rays	7–8	7
Pelvic	I,5	I,5
Pectoral	13–17	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–12	
Lower	10–11	
Gill rakers:		
Upper	4–7	
Lower	7–9	
Branchiostegals	7–9	8

LIFE HISTORY

Range: *E. argenteus* & *E. currani*, southern California to Peru; *E. entomelas*, Baja California Sur to Peru

Habitat: Over soft bottom in shallow coastal waters, bays & estuaries; *E currani* may enter freshwater

Spawning season: Larvae collected in summer & fall, primarily in August & September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Johnson 1984

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.9 mm, 4.0 mm (H. M. Orr)
Flexion larvae, 4.6 mm (H. M. Orr), 4.8 mm (R. C. Walker)

* All larvae utilized in this description were collected at inshore CalCOFI stations between Punta Baja, Baja California, & Punta San Juanico, Baja California Sur. *Eucinostomus argenteus*, *E. currani*, & *E. entomelas* occur in this area. Although the larvae appear to represent a single species, it is unknown which they are, or if they indeed are a single species. Meristic data above include all three species.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.1 mm
Flexion length: ca. 4.0–5.5 mm
Transformation length:
Fin development sequence: C_1, 2D & A, P_1, 1D & P_2 & C_2
Pigmentation: *Preflexion*—External pair usually present posteriorly over midbrain after 2.4 mm, always present after 3 mm; dorsally on gas bladder & hindgut; anteriorly on gut after 2.4 mm; 1 each anteriorly & posteriorly on ventral margin of gut; 18–20 on ventral margin of tail (ca. 1/myomere), decreasing to 12–13 beginning at postanal myomere 3–5 by end of stage. *Flexion*—Internal pair dorsolaterally on hindbrain after 4.7 mm; 2nd external pair over midbrain at 4.8 mm; 0–1 at upper end of preopercle after 4.5 mm; 1 on isthmus at cleithral symphysis at 4.6 mm; 2 posteriorly on dorsal margin after 4.6 mm; decreasing to 6–8 on ventral margin of tail; 2–4 on hypural margin. *Postflexion*—Increasing over midbrain & internally on mid- & hindbrain; over forebrain at 9.8 mm; at tip of snout by 11.5 mm; increasing on gas bladder & gut; 4 on isthmus by 11.5 mm; series forming along A & 2D bases.
Diagnostic features: Myomeres 24 (5–6 preanal through mid-flexion, increasing to 8–9 in postflexion stage); no spines on head through flexion stage, then few very small preopercular spines in postflexion stage; slender larvae with short, coiled gut; lightly pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–43 41	41–44 42	38–47 42		
BD/BL		21–26 23	23–25 24	21–24 23		
HL/BL		20–26 24	26–29 28	25–31 27		
HW/HL		63–80 69	52–57 55	44–58 52		
SnL/HL		13–29 22	26–31 29	28–32 30		
ED/HL		38–48 42	36–38 37	32–38 36		
P_1L/BL		5–8 6	7–8 7	8–15 11		
P_2L/BL		0–0 0	0–1 0.3	2–12 6		

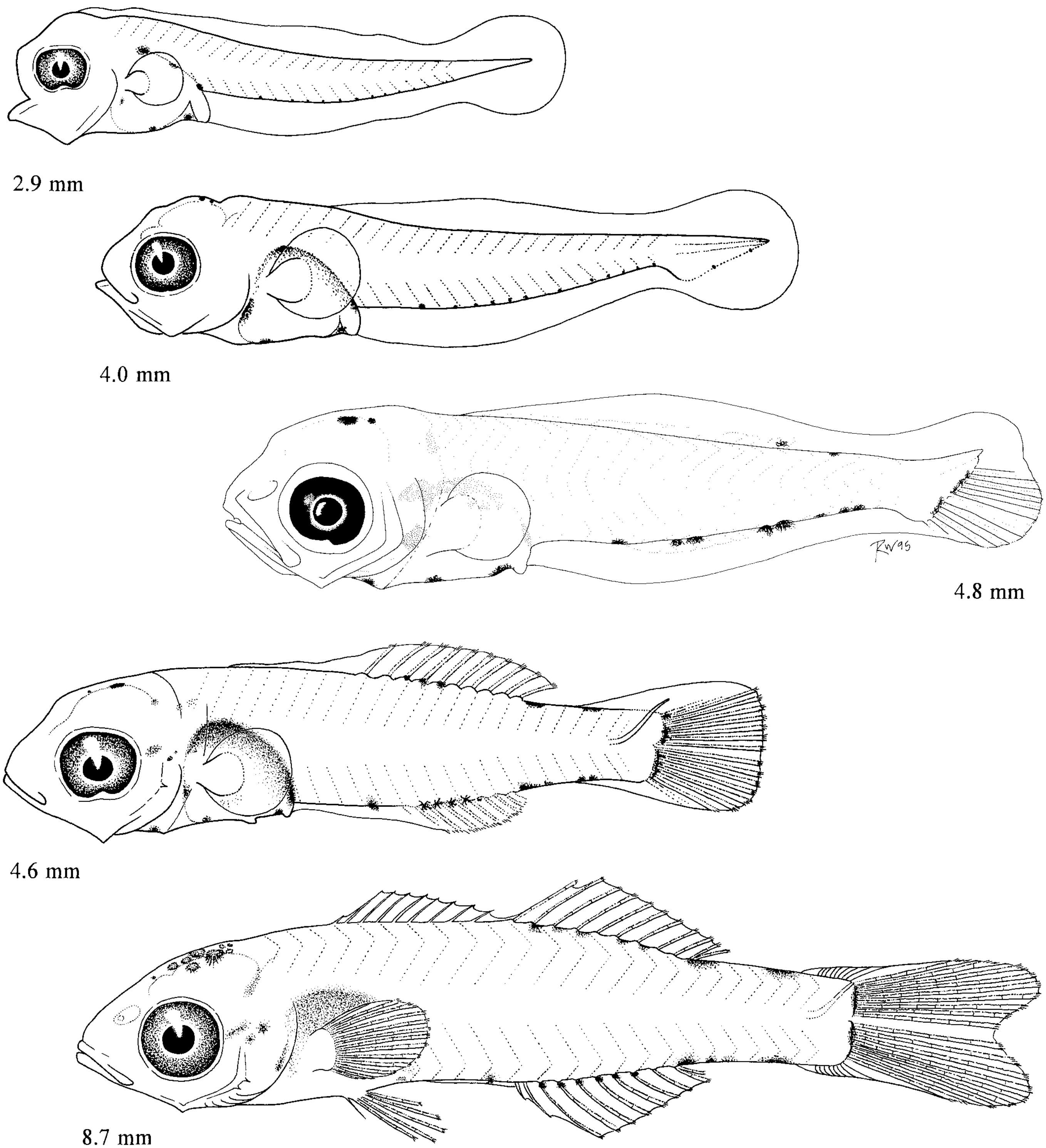

Figure Gerreidae 1. Preflexion larvae, 2.9 mm, 4.0 mm (CalCOFI 6507, station 130.25.5); flexion larvae 4.8 mm (CalCOFI 6008, station 120.45), 4.6 mm (CalCOFI 6608, station 130.30); postflexion larva, 8.7 mm (Johnson 1984).

HAEMULIDAE: Grunts

W. WATSON

Haemulidae contains about 150 species in 17 genera commonly separated into two subfamilies: Haemulinae, composed primarily of New World species, and Plectorhynchinae, composed of Indo-West Pacific and eastern Atlantic species (Johnson 1980; Nelson 1994). At least 12 haemuline species of six genera occur in the CalCOFI study area (Table Haemulidae 1), and several others have been reported to occur near, or perhaps within, the southern part of the study area (e.g., de la Cruz-Agüero 1994; Allen and Robertson 1994; McKay and Schneider 1995). However, reported northern range limits for many of the species differ between literature sources and the study required to determine actual range limits is beyond the scope of this guide. Thus, it should be noted that the species list in Table Haemulidae 1 may be incomplete. Nearly all the eastern Pacific haemulids are primarily tropical and subtropical; only two species, *Anisotremus davidsonii* and *Xenistius californiensis*, normally range northward beyond Baja California Sur (to southern and central California, respectively). Most of the haemulid larvae taken in CalCOFI collections are these last two species.

Haemulids are small to medium-size (generally <1 m), primarily tropical and subtropical fishes that school in shallow coastal waters, typically over reefs and seagrass beds. Haemulids are compressed, often moderately deep-bodied, with a long-based continuous dorsal fin, short-based anal fin, and truncate to indented caudal fin. Some species are quite colorful; barred, striped, and spotted patterns are common. When removed from the water, haemulids make a grunting sound by rubbing their pharyngeal tooth plates together: thus the common name. Some species are highly regarded sport and food fishes and the more colorful species are utilized in the aquarium trade.

Spawning is known for a few species, primarily based on laboratory studies (e.g., Kobayashi and Iwamoto 1984; Potthoff et al. 1984). The planktonic eggs are spherical, ca. 0.7–1.0 mm in diameter, with a single (sometimes 2 or 3) colorless oil globule ca. 0.2 mm in diameter and a narrow perivitelline space (e.g., Hildebrand and Cable 1930; Saksena and Richards 1975; Podosinnikov 1977). The chorion is smooth and unornamented. Larvae hatch at ca. 2–3 mm NL with a large yolk sac, unpigmented eyes, and an unformed mouth. Larvae are somewhat compressed and moderately slender to moderately deep-bodied, with preanal length usually about 50–67% BL. The gas bladder is located above the anterior to middle part of the coiled gut. Larvae typically have series of small to moderate spines along the posterior margins of the inner and outer preopercular shelves, variable numbers of small spines on the other opercular series bones, and often one or more small spines on the supracleithra and posttemporals. Larval *Conodon* develop nasal, frontal, pterotic, and lachrymal spines as well, and in contrast to the other described haemulid larvae, develop spiny scales beginning early in the postflexion stage. Larval pigmentation may be largely restricted to the ventrum (common in the Haemulinae) or may cover much of the body (common in the Plectorhynchinae). Early juvenile haemulines typically display a pattern of two or more midlateral and dorsolateral stripes.

Haemulid larvae resemble the lightly pigmented larvae of many percoid families in the California Current region. In the shallow coastal waters where haemulid larvae occur, larval gerreids, sciaenids, and possibly centropomids are most likely to be confused with them. Centropomids and gerreids have 24 myomeres in contrast to the usual haemulid count of 26. Both have a few small preopercular spines or none, in contrast to the more numerous and larger spines of the haemulids (except *Orthopristis*). Pigment characters may aid in distinguishing the larvae as well (see Gerreidae, this volume, and *Centropomus undecimalis* in Lau and Shafland 1982). Among the lightly pigmented sciaenid larvae, only preflexion stage *Seriphus politus* are likely to be confused with the haemulids. Preflexion *S. politus* are somewhat deeper-bodied with a smaller eye, and have more numerous irregularly spaced melanophores along the ventral margin of the tail than the haemulids (see Sciaenidae, this volume). Among the haemulids, larvae are known only for the four species included here. These four are distinguished from one another by morphometric characters (*Orthopristis reddingi* and *X. californiensis* are more slender than *A. davidsonii* and *Conodon serrifer*), pigment (*C. serrifer* is the most heavily pigmented and *O. reddingi* is least pigmented), and head and pectoral girdle spination (*C. serrifer* is spiniest and *O. reddingi* least spiny).

The following descriptions are based on literature (*A. davidsonii* and *X. californiensis*) and detailed observation of 13 *C. serrifer* and 25 *O. reddingi* (Table Haemulidae 2). Meristic data were obtained from Hong (1977), Watson and Walker (1992), McKay and Schneider (1995), Clothier and Baxter (unpublished manuscript), and counts made during this study. Ecological information was obtained from Hong (1977) Thomson et al. (1979), Eschmeyer et al. (1983), de la Cruz-Agüero et al. (1994), Allen and Robertson (1994), and McKay and Schneider (1995).

Table Haemulidae 1. Meristic characters for the haemulid species that are likely to occur in the CalCOFI study area. All have 10+16 vertebrae, 9+8 principal caudal fin rays, I,5 pelvic fin rays, and 7 branchiostegal rays.

Species	Fin rays				GR
	Dorsal	Anal	P_1	C_2	
Anisotremus davidsonii	XI–XII,14–17	III,8–11	17–19	12–14+11–13	9–12+13–16
A. interruptus	XI–XII,16–18	III,8–10	18–19	12–13+11–13	12+16
A. taeniatus	XII,15–17	III,9–10	17–18	13–14+12–13	21–30 total
Conodon serrifer	XII,12–13	III,7	15–17	12–14+11–13	7+14
Haemulon flaviguttatum	X–XII,15–18	III,9–11	16–19	12–14+13–14	26–31 total
H. maculicauda	XII–XIV,14–17	III,8–11	17–19	12–14+10–14	22–29 total
H. scudderi	XI–XII,14–17	III,7–9	15–19	11–13+11–13	15–21 total
H. sexfasciatum	XI–XII,14–18	III,9–10	15–18	12–13+12	8–9+11–13
Microlepidotus inornatus	XIII–XIV,15–17	III,12–14	18–21	12–13+11–13	8+16–17
Orthopristis cantharinus	XII,15–16	III,12	18–20	13–14+13–14	12+14
O. chalceus	XII–XIII,14–15	III,10–11	18–20	11–12+10–12	19–24 total
O. reddingi	XII–XIII,12–16	III,10–12	17–19	10–13+9–13	9–10+12–13
Xenistius californiensis	XI–XIII,12–14	II–III,11–12	17–19	12–13+11–13	12+26

Table Haemulidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the haemulid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Anisotremus davidsonii	307[a] 0.76–0.88	29[a] 1.7–2.0	L[b]	L[b]	L[b]	L[b]	L[b]
Conodon serrifer	0	0	4 2.6–3.4	3 3.5–3.9	1 6.0	0	5 128.5–139.5
Orthopristis reddingi	0	0	10 2.3–4.6	5 4.9–6.5	5 6.5–12.0	0	5 27.9–31.3
Xenistius californiensis	0	0	L[b]	L[b]	L[b]	L[b]	L[b]

[a] Data provided by G. A. Jordan from an unpublished manuscript by Jordan, G. A., K. B. Iwanaga, P. R. Garrahan, S. V. Williams, and M. L. Matsui. Description of eggs and larvae from the Salton Sea, California: *Anisotremus davidsonii* (Steindachner), (Pisces: Haemulidae), *Bairdiella icistia* (Jordan and Gilbert) and *Cynoscion xanthulus* (Jordan and Gilbert) (Pisces: Sciaenidae). Occidental College, Biology Department, 1600 Campus Road, Los Angeles, CA 90041.

[b] Watson and Walker 1992.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	XI–XII	XI
Dorsal rays	14–17	15–16
Anal spines	III	III
Anal rays	8–11	10
Pelvic	I,5	I,5
Pectoral	17–19	17–18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	12–14	12
Lower	11–13	12
Gill rakers:		
Upper	9–12	
Lower	13–16	
Branchiostegals	7	7

LIFE HISTORY

Range: Santa Cruz Island, California to the Gulf of California

Habitat: Shallow coastal waters, often schooling near kelp & rocky reef habitats

Spawning season: Summer

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

Watson & Walker 1992

* Values calculated from Watson & Walker (1992).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.76–0.88 mm **Yolk:** Homogeneous
No. of OG: 1–15 (usually 1) **Diam. of OG:** 0.15–0.19 mm
Shell surface: Smooth
Pigment: Melanophores on dorsum of embryo beginning shortly after blastopore closure.
Diagnostic features:

LARVAE

Hatching length: 1.7–2.0 mm
Flexion length: 4.2–4.7 mm through 6.0–6.2 mm
Transformation length: 14–15 mm through 19–22 mm
Fin development sequence: C_1, 2D & A, C_2, P_1, 1D, P_2
Pigmentation: *Larvae*—None externally on head except at angular before ca. 8–9 mm, then forming & increasing on dorsum & jaws; on gular & opercular areas beginning at ca. 12 mm; present or absent under hindbrain after ca. 3.3 mm; at anterior margin of forebrain after ca. 6–7 mm; 1–7 on ventral margin between isthmus & anus; on dorsal surface of gas bladder & gut; usually 1 anteriorly at liver; externally, laterally on abdominal area after ca. 8 mm; 10–23 (usually 13–17) on ventral margin of tail; on A base after ca. 4.4 mm; anteriorly on dorsal margin after 12 mm; 0–few on hypural margin & C rays. *Transformation*—Dorsolateral & midlateral stripes; increasing on upper half of body; on 1D & C.
Diagnostic features: Large melanophore on peritoneum anterior to liver; melanophore(s) at anterior margin of forebrain after 6–7 mm; relatively short, compact gut; up to 8 small to moderate spines on posterior preopercular margin; myomeres 7–9+16–19=25–27 (usually 8+18) through flexion stage, 9–12+14–17 (usually 10+16) in postflexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–51 45	37–50 46	39–55 49	55–57 56	54–55 55
BD/BL		19–26 24	23–29 25	20–29 26	30–31 31	29–29 29
HL/BL		22–31 26	28–34 30	24–36 33	35–37 36	32–35 34
HW/HL						
SnL/HL		10–32 25	26–33 29	26–35 30	26–29 28	25–26 25
ED/HL		32–50 38	31–40 35	28–36 31	28–29 29	27–27 27
P_1L/BL						
P_2L/BL						
PrS/HL		0–13 8	6–12 8	3–6 5	1–2 2	1

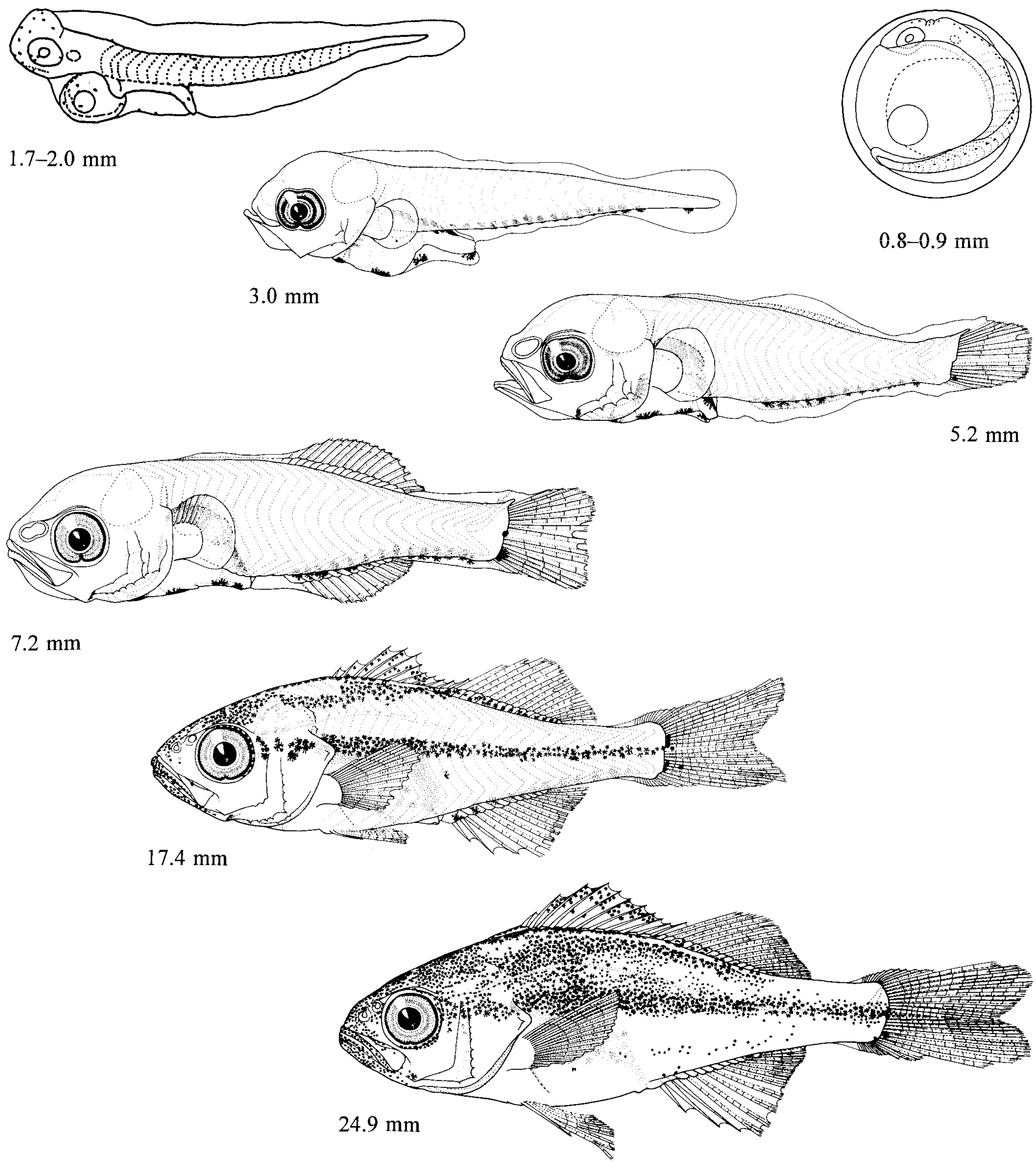

Figure Haemulidae 1. Egg, 0.8–0.9 mm; yolk-sac larva, 1.7–2.0 mm (G.A. Jordan et al., unpublished manuscript); preflexion larva, 3.0 mm; flexion larva, 5.2 mm; postflexion larva, 7.2 mm; transformation specimen, 17.4 mm; early juvenile, 24.9 mm (Watson and Walker 1992). Scales on the transformation and juvenile specimens are not shown.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	XII	XII
Dorsal rays	12–13	12
Anal spines	III	III
Anal rays	7	7
Pelvic	I,5	I,5
Pectoral	15–17	16
Caudal:		
Principal	9–8	9–8
Procurrent:		
Upper	12–14	12
Lower	11–13	12
Gill rakers:		
Upper	7	
Lower	14	
Branchiostegals	7	7

LIFE HISTORY

Range: Bahía San Juanico, Baja California Sur to Peru

Habitat: Nearshore coastal waters

Spawning season: Larvae collected spring–summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.7 mm (N. Arthur)
Flexion larva, 3.9 mm (N. Arthur)
Postflexion larva, 6.0 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.6 mm
Flexion length: ca. 3.5–4 mm
Transformation length: Unknown; >6 mm
Fin development sequence: C_1, 2D & A, 1D & P_1 & P_2 & C_2
Pigmentation: *Preflexion–flexion*—Little dorsally on head; on snout, jaws, opercular area; laterally on midbrain & around hindbrain & anteriorly on notochord; along most myosepta except last 5, extending caudad to all but last 2 myosepta by ca. 3.9 mm; few along ventral margin of tail to last myomere; 0–4 (usually 1) under notochord tip; dorsally on gas bladder; heavy on ventral margin of isthmus & gut; on D & A bases after 3.5 mm; on P_2 base by 3.9 mm; band on anal finfold; 0–few on dorsal finfold after 3.6 mm. *Postflexion*—Uniformly heavy on head & body except end of caudal peduncle; on proximal half of most A rays; little, posteriorly on D; little, proximally on P_2.
Diagnostic features: 6 or more prominent preopercular spines; supraocular, posttemporal, interopercular & subopercular spines form during flexion stage; supracleithral, pterotic, & lachrymal spines added in postflexion stage; spiny scales form during postflexion stage; myomeres 10–12+13–16=25–26 (usually 12+14); heavily pigmented except on end of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		59–67 63	56–60 58	64		62–67 64
BD/BL		25–28 26	26–27 27	32		27–30 28
HL/BL		31–37 33	31–34 33	37		27–28 28
HW/HL		50–67 60	52–55 54	56		56–62 60
SnL/HL		22–24 23	24–27 26	24		23–26 25
ED/HL		31–36 34	29–31 30	29		28–30 29
P_1L/BL		6–8 7	6–7 7	10		23–26 25
P_2L/BL		0–0 0	0–1 0.4	7		18–21 19
PrS/HL		8–16 12	14–17 15	17		9–12 11

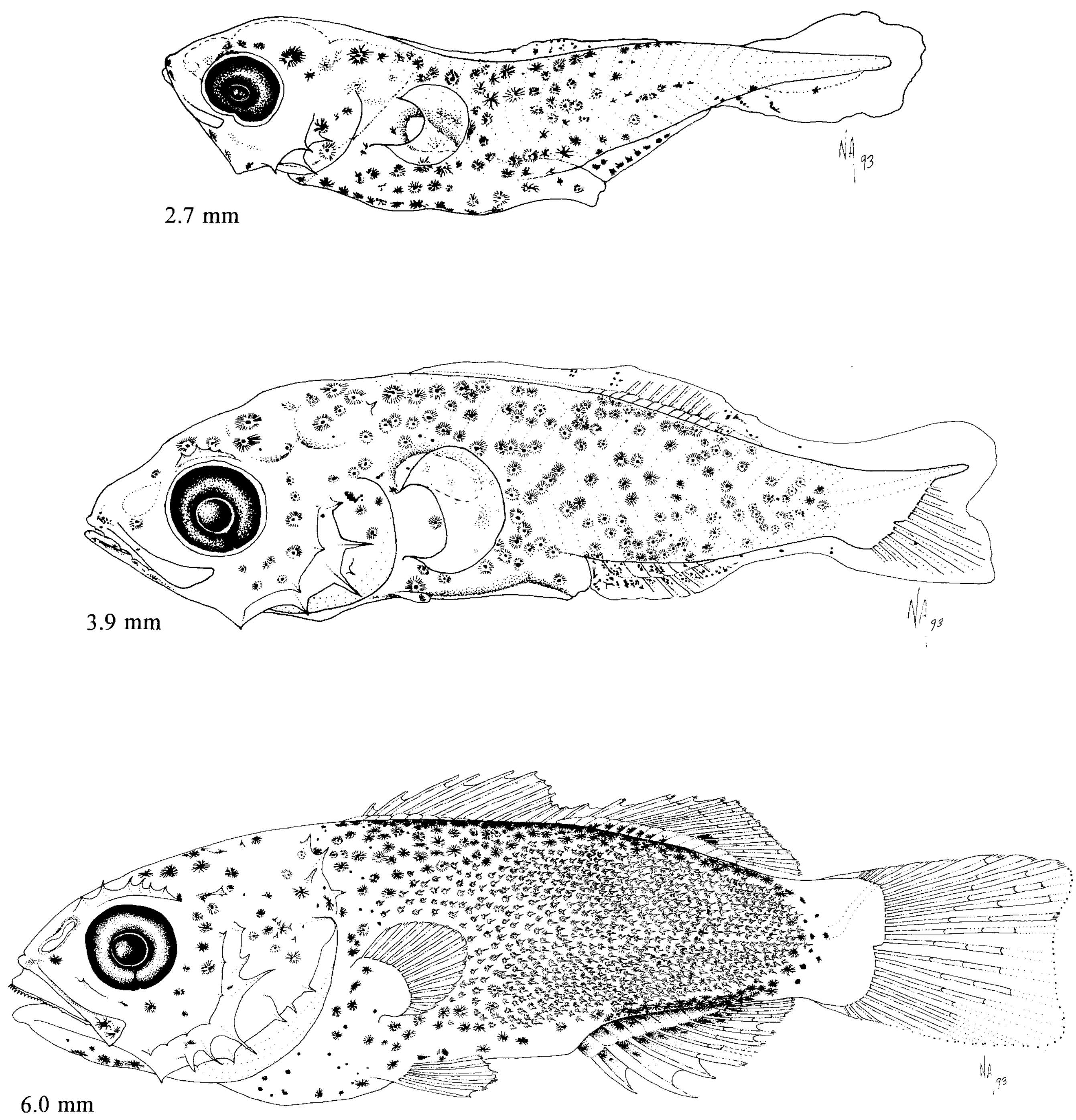

Figure Haemulidae 2. Preflexion larva, 2.7 mm (IATTC 90041, station T–12); flexion larva, 3.9 mm (IATTC 89006, station C2 Red); postflexion larva, 6.0 mm (TO 58–1, station 71).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	12–14	13
Anal spines	II–III	III
Anal rays	11–12	11
Pelvic	I,5	I,5
Pectoral	17–19	17–18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	12–13	12
Lower	11–13	12
Gill rakers:		
Upper	12	
Lower	26	
Branchiostegals	7	7

LIFE HISTORY

Range: Monterey, California to Peru

Habitat: Shallow coastal waters; schools in kelp forests & over rocky reefs

Spawning season: Summer

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

Watson & Walker 1992

* Values calculated from Watson & Walker (1992).

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: 4.3 mm to 5.9–6.2 mm
Transformation length: ca. 15.5–21 mm
Fin development sequence: C_1, 2D & A & C_2, 1D & P_1, P_2
Pigmentation: *Larvae*—On angular at ca. 4–5 mm; at tips of jaws at ca. 8 mm; externally over midbrain beginning ca. 13 mm; over forebrain & on opercular area by ca. 15 mm; under hindbrain; posteriorly on midbrain by ca. 6 mm; dorsally on gas bladder & hindgut; 0–7 on ventral margin from isthmus to hindgut, usually 3–4 in preflexion stage decreasing to 1–2 in postflexion stage; occasionally few externally on lateral surface of abdominal area after 13 mm; 10–25 on ventral margin of tail (usually 13–16); on A base after ca. 4.3 mm; usually 1 on lower hypural margin. *Transformation*—Increasing on upper half of head & body; 2 dorsolateral stripes form; irregular blotches along lateral midline fill in to form midlateral stripe; increasing on spinous D, bands form on soft D & A; few scattered on C.
Diagnostic features: Melanophore(s) under hindbrain present in preflexion stage, on posterior margin of midbrain beginning in flexion stage; relatively elongate & slender; up to 15 small to moderate spines on posterior preopercular margin; myomeres 7–9+17–19=25–27 (usually 8+18) through flexion stage, 10–12+14–16 (usually 10+16) in postflexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		37–47 44	44–52 47	42–56 52	60–61 61	43–61 57
BD/BL		15–25 21	21–25 23	17–25 22	24–26 25	27–28 27
HL/BL		22–28 25	26–32 29	25–34 30	33–35 34	33–36 34
HW/HL						
SnL/HL		13–28 22	21–33 30	17–38 29	25–31 28	22–25 23
ED/HL		32–44 38	29–36 32	27–35 31	30–30 30	28–30 29
P_1L/BL						
P_2L/BL						
PrS/HL		0–16 6	4–11 8	2–7 4	1–1 1	1–2 1

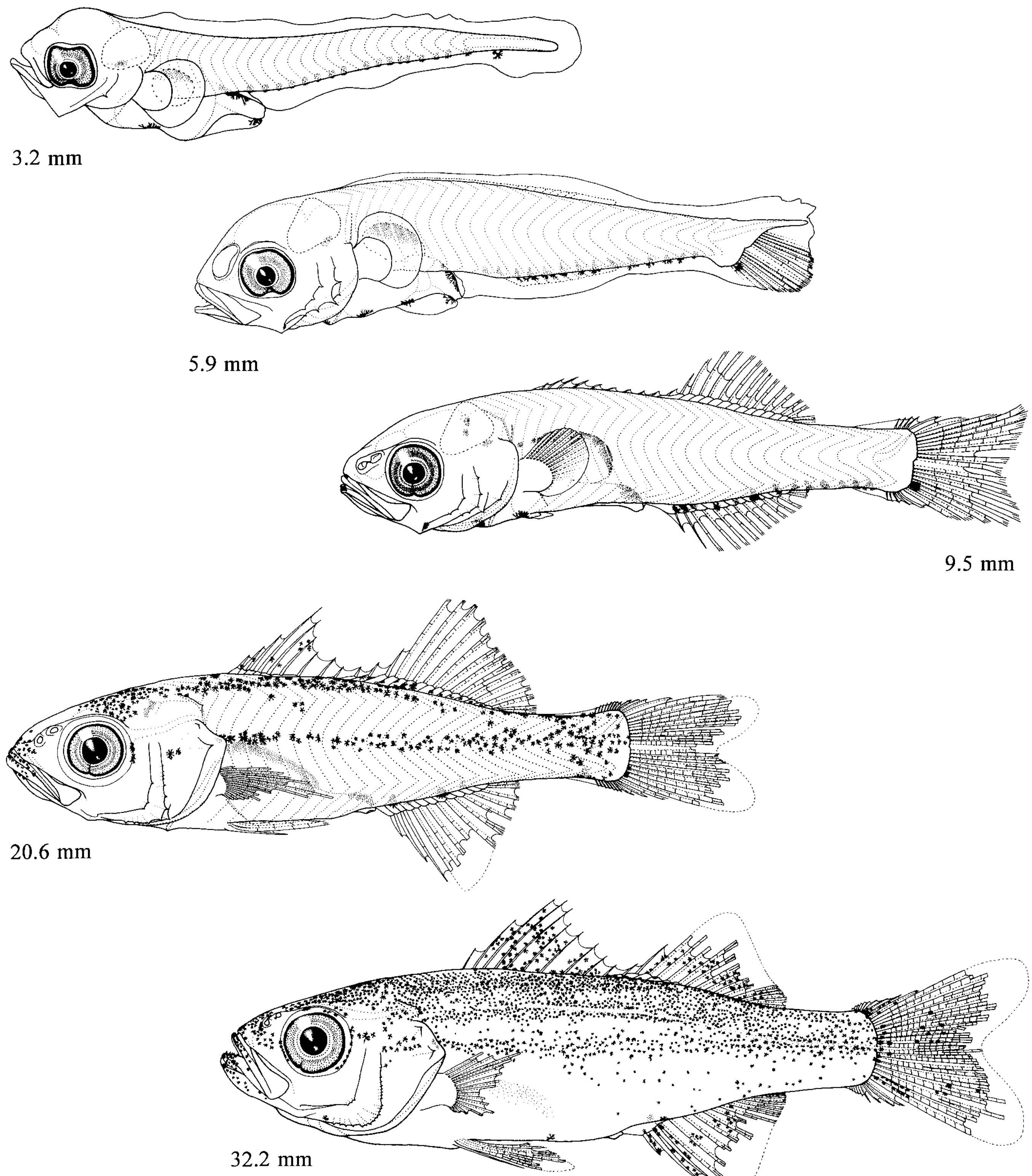

Figure Haemulidae 4. Preflexion larva, 3.2 mm; flexion larva, 5.9 mm; postflexion larva, 9.5 mm; transformation specimen, 20.6 mm; juvenile 32.2 mm (Watson and Walker 1992). Scales on the transformation and juvenile specimens are not shown.

SPARIDAE: Porgies

W. WATSON AND E. M. SANDKNOP

The family Sparidae includes about 100 species in 29 genera (Nelson 1994). Only one of these, *Calamus brachysomus*, the Pacific porgy, occurs in the California Current region. Although the Pacific porgy ranges northward to southern California, its larvae have not been taken in CalCOFI collections north of Punta Eugenia, Baja California Sur.

Adult sparids are small to large (typically <ca. 30 cm, but some species as large as 60–120 cm) near-bottom omnivorous residents of shallow coastal waters, bays, and estuaries. A few species enter brackish or fresh water. Most species occur in warm temperate and tropical regions. Sparids are compressed, usually moderately deep-bodied, with a rounded to steeply oblique forehead, a continuous dorsal fin, and an indented to weakly forked caudal fin. Some species display striped or barred pigment patterns, but most are rather plain, with brownish, reddish, or silvery colors predominating. Many species are important commercial or sport fishes.

Many, perhaps most, sparid species are hermaphroditic (Breder and Rosen 1966; Cody and Bortone 1992). Apparently, all spawn planktonic eggs that are ca. 0.8–1.2 mm in diameter, with a colorless yolk containing a single colorless oil globule ca. 0.1–0.2 mm in diameter (Mito 1963; Breder and Rosen 1966; Johnson 1978; Matus-Nivón et al. 1987; Leis and Trnski 1989). Larvae hatch at a length of ca. 2 mm with a large yolk sac containing the oil globule posteriorly, unpigmented eyes, and an undeveloped mouth and pectoral fins. Pigmentation during the yolk-sac stage typically differs from that of later-stage larvae. Larvae are moderately compressed, with a coiled gut extending to 40–60% of body length. They are moderately slender to deep-bodied. Head and pectoral girdle spination ranges from a few small preopercular spines to many strong spines on the opercular series bones, the cleithra, supracleithra and posttemporals, and the frontals and pterotics (Fahay 1983; Leis and Trnski 1989). Most larvae are lightly pigmented during the preflexion stage, with melanophores largely restricted to the ventrum, the dorsal surfaces of the gas bladder and gut, and, in some species, the dorsal surface of the head. Some species remain lightly pigmented through most of larval development while others develop moderate lateral pigmentation in flexion or early postflexion stages. Barred patterns commonly form by, or during, transformation to the juvenile stage.

Larval sparids resemble the larvae of several percoid families, and in the California Current region larval *C. brachysomus* may be confused with a few other species. During the yolk-sac stage *C. brachysomus* resembles *Paralabrax* (see Serranidae, this volume) and *Genyonemus lineatus* (see Sciaenidae, this volume), but can be distinguished from the former by its posterior oil globule (anterior in *Paralabrax*) and from the latter by having 24 myomeres (25–26 in *G. lineatus*). Normal spawning ranges and seasons of *C. brachysomus* and *G. lineatus* probably do not overlap. As lateral pigmentation begins to form in *C. brachysomus* it may superficially resemble the stromateid, *Peprilus simillimus*, but is easily distinguished by having fewer myomeres and far fewer dorsal and anal fin rays (see Stromateidae, this volume).

The following descriptions are based on the literature (Matus-Nivón et al. 1987, 1989a) and on detailed examination of 16 larvae (6 preflexion, 2.6–3.8 mm; 7 flexion, 4.0–5.8 mm; 3 postflexion, 5.9–6.5 mm) and 4 juveniles (16.7–22.5 mm). Meristic data and ecological information were obtained from the literature (Randall and Caldwell 1966; Thomson et al. 1979; Eschmeyer et al. 1983) and from observations made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	XII–XIII	XII
Dorsal rays	11–13	12
Anal spines	III	III
Anal rays	10–11	10
Pelvic	I,5	I,5
Pectoral	14–16	15
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9	9
Lower	6–7	7
Gill rakers:		
Total	9–12	10–12
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Oceanside, California to Lagunilla, Peru; uncommon north of central Baja California

Habitat: Shallow coastal waters, estuaries, & bays over mixed sand & rock bottom at ca. 1–69 m depth

Spawning season: Larvae collected in summer & fall

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Matus-Nivón et al. 1987, 1989a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.4 mm (R. C. Walker)
Flexion larva, 4.8 mm (R. C. Walker)
Postflexion larva, 5.9 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.99–1.06 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.19 mm
Shell surface: Smooth
Pigment: Yolk & OG unpigmented; melanophores form on late embryo
Diagnostic features: Diameter; OG; segmented yolk

LARVAE

Hatching length: ca. 2.0 mm
Flexion length: 3.1–4.5 mm
Transformation length: ca. 8.5 mm
Fin development sequence: C_1, 2D & A, P_1, 1D, P_2, C_2
Pigmentation: *Yolk-sac*—1 at posterior margin of eye; 3 (large) on dorsal margin at nape, above anus, & at midtail; few on yolk sac & OG; few dorsally along gut; 1 (large) on ventral margin at midtail. *Preflexion*—Few under midbrain & hindbrain; decreasing on dorsum to 0 by 2.8 mm; increasing dorsally on gut; 0–few on gular region; series along ventral margin of gut; increasing on ventral margin of tail (all small); ventrolaterally & along lateral midline near level of hindgut by ca. 3 mm, spreading caudad & cephalad. *Flexion–postflexion*—On opercle & dorsally on head by 4–5 mm, increases on both; increasing on gut; increasing along lateral midline & ventrolaterally, spreading dorsolaterally by 4–5 mm. *Juvenile*—7 bars.
Diagnostic features: Yolk-sac larvae with 3 prominent dorsal & 1 prominent ventral melanophores, posterior OG, myomeres 7–8+16–17=24; later larvae with melanophores along lateral midline & ventrolaterally after ca. 3 mm, dorsolaterally after ca. 4 mm; small preopercular spines by ca. 3 mm, supracleithral spines by ca. 5 mm, & supraoccular spine by ca. 6 mm; myomeres 8–10+14–16=24.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–52 49	49–63 55	60–64 61		61–65 63
BD/BL		24–28 26	24–31 27	28–32 30		38–40 39
HL/BL		23–30 27	27–34 30	32–35 34		33–36 35
HW/HL		45–64 59	57–64 59	36–59 48		37–51 45
SnL/HL		19–27 23	21–28 25	24–26 25		20–28 23
ED/HL		36–48 41	36–40 38	34–40 37		37–42 39
P_1L/BL		5–12 7	6–10 8	8–11 10		22–25 23
P_2L/BL		0–0 0	2–6 4	4–8 6		20–21 21

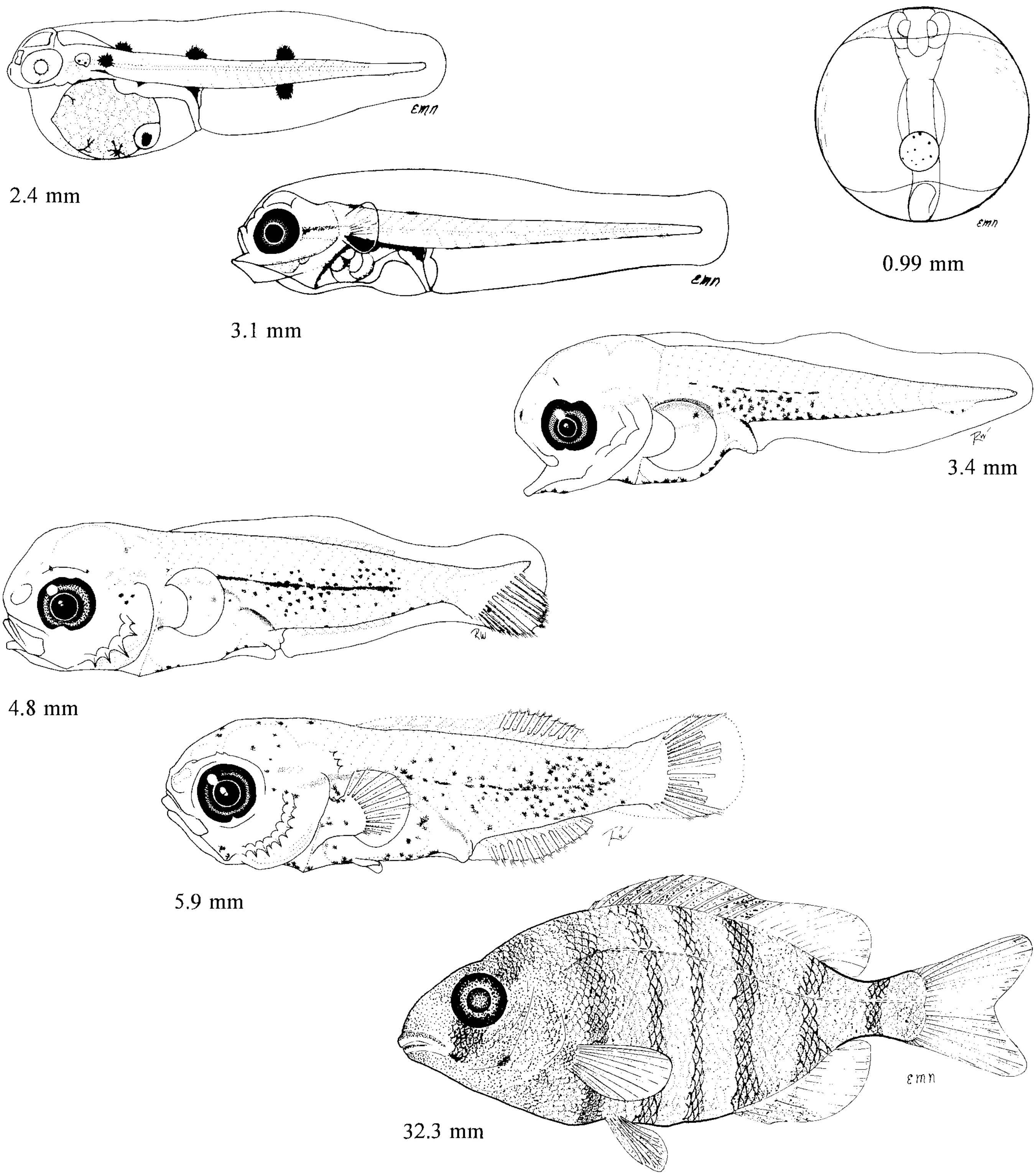

Figure Sparidae 1. Egg, 0.99 mm; yolk-sac larva, 2.4 mm; preflexion larva, 3.1 mm (Matus-Nivón et al. 1987); preflexion larva, 3.4 mm (CalCOFI 5706, station 109G.68); flexion larva, 4.8 mm (CalCOFI 5706, station 109G.68); postflexion larva, 5.9 mm (CalCOFI 5209, station 137.22); juvenile, 32.3 mm (Matus-Nivón et al. 1989a).

SCIAENIDAE: Croakers and drums

H. G. MOSER

Sciaenidae is a large family of about 80 genera and 300 species inhabiting tropical-temperate marine, brackish, and freshwater habitats around the world (Nelson 1994). The family is well represented in the eastern Pacific by >80 species placed in about 23 genera (Allen and Robertson 1994; Chao 1995). A large proportion of this complement is found in tropical waters and the numbers of genera and species decline markedly north of Mazatlán, Mexico (Walker 1960). The decline is even more marked on the outer coast of Baja California from about Bahía Magdalena northwards, where there are about 17 species in 13 genera (Table Sciaenidae 1).

The two most abundant sciaenid species found in CalCOFI ichthyoplankton collections, *Genyonemus lineatus* and *Seriphus politus*, range from about Bahía Magdalena, Baja California Sur, Mexico to north of California; larvae of other species are relatively rare and are restricted to the most shoreward CalCOFI stations. Progress in identification of croaker larvae in the CalCOFI region was greatly enhanced by a rearing program conducted in 1978–1979, during which planktonic eggs were collected in the field, sorted at the laboratory, and carried through to the juvenile stage at the Southwest Fisheries Science Center (Moser et al. 1983)[1]. This method produced complete developmental series of *Cheilotrema saturnum*, *G. lineatus*, *Menticirrhus undulatus*, *Roncador stearnsii*, and *S. politus*. In addition to rearing field-caught eggs, eggs obtained from brood stocks of *Atractoscion nobilis* and *Umbrina roncador* were reared to produce complete ontogenetic series. Descriptions of these seven species are included in this guide. Eggs and larvae of *G. lineatus* and *A. nobilis* have been described previously (Watson 1982; Moser et al. 1983); eggs and larvae of the other species are described for the first time. Larvae of other sciaenids (e.g., *Larimus* sp.) have been identified in CalCOFI samples from the southern part of the survey pattern; however, they are not included in this guide since species identifications are tentative and descriptions of these genera may be found in the literature (e.g., Johnson 1978; Powles 1980; Sinque 1980; Fahay 1983; Ditty and Shaw 1994). Eggs and early larvae of *Cynoscion parvipinnis* have been described from reared series (Ramirez-Sevilla et al. 1986) and a description of later-stage larvae of this species is in preparation (Matus-Nivón, pers. comm.). Descriptions of eggs and larvae of *Bairdiella icistia* and *Cynosion xanthulus* are in preparation (Jordan et al., see Haemulidae Table 2).

Adult sciaenids are moderate to large in size (to nearly 2 m, most <40 cm), compressed to somewhat rounded in cross-section, and elongate to deep-bodied. The mouth ranges from inferior to terminal and is strongly oblique in some taxa in which the mouth is terminal. Most have small teeth arranged in bands and some have strong canine teeth in the upper jaw. The head has cavernous canals associated with the acousticolateralis system and conspicuous pores usually are found on the snout and lower jaw. Some have a single barbel or a group of small barbels on the chin. There is a bony flap on the upper region of the opercle. The dorsal fin is long-based with a deep notch separating the anterior section, with spinous 6–13 rays, from the posterior section consisting of 20–35 soft rays preceded by a single spine; rarely, the two parts of the fin are separate. The anal fin has one or two spines and 6–23 soft rays. The pectoral fin is slightly rounded to falcate and the pelvic fin is thoracic with I,5 rays. The caudal fin has 9+8 principal rays and may be slightly forked, emarginate, rounded, or rhomboid. Scales are ctenoid on the body and usually cycloid on the head; lateral line scales extend onto the caudal fin. The otoliths, primarily the sagittae, are large and thick. The gas bladder is large, highly diverse in form among the various genera, and is supplied by muscles employed in drumming. *Menticirrhus* lacks a gas bladder and does not drum. Most live on sand or mud bottoms in shallow coastal waters and bays and feed on small fishes and bottom invertebrates, primarily crustaceans. Older individuals of some species move to deeper regions of the shelf. About 30 species are restricted to freshwater. They support important commercial and recreational fisheries throughout the world (Chao 1978 1986, 1995; Sasaki 1989; Nelson 1994).

Little is known about spawning which generally occurs from spring to fall in temperate waters. There are numerous reports of sciaenids producing sound at

[1] The following people contributed much time and effort to this program: J. L. Butler, M. S. Busby, E. A. Lynn, E. M. Sandknop, E. G. Stevens, and B. Y. Sumida.

night, coincident with the spawning season, but the role of sound production in spawning and the details of spawning behavior are unknown. Planktonic eggs are small (0.7–1.3 mm, <1.0 mm in most species), round and have homogeneous yolk, a moderate-sized oil globule, and a narrow perivitelline space. Newly hatched yolk-sac larvae are small (1.5–2.5 mm, usually <2.0 mm), at a relatively early stage of development, and usually have distinctive pigment patterns that often undergo marked change during the yolk-sac period. Pigment patterns become relatively stable during preflexion and are helpful in species identification. Larvae can be readily reared; live larvae have complex xanthophore patterns (lost in preserved specimens) which often overlie the melanophore patterns (Moser et al. 1983). In general, sciaenids become epibenthic early in the larval period; presumably this is an adaptation for reducing mortality associated with dispersion from their shallow water habitat (Powles 1981; Schlotterbeck and Connally 1982; Watson 1982; Barnett et al. 1984; Brewer and Kleppel 1986; Jahn and Lavenberg 1986). This loss of vagility may explain the general absence of sciaenids from oceanic islands.

The planktonic eggs of sciaenids are similar to those of many other perciform shorefishes but may be distinguished generally by their small size, fairly large oil globule, and heavy embryonic pigment. In our area, the eggs of *Atractoscion nobilis* (1.2–1.3 mm diameter) are exceptionally large and distinct. We know from rearing experiments that egg diameters of most of the other species overlap but some can be identified by a combination of modal differences in egg and oil globule diameters, embryonic pigmentation, and season of occurrence. Yolk-sac larvae have the oil globule posteriad on the yolk mass and distinctive pigment. Except for the large, highly distinctive yolk-sac larvae of *A. nobilis*, separation of larvae to species is difficult until the pigment pattern is somewhat stabilized at the end of the yolk-sac stage.

Preflexion sciaenid larvae may be recognized by their relatively large, somewhat bulbous head, compact, coiled gut and relatively slender, tapering tail. The robust head, trunk and gut, and slender tail results in a somewhat tadpole-like appearance. Pigmentation ranges from light (e.g., *Genyonemus*) to heavy (e.g., *Atractoscion*) but most species have some pigment on the brain, nape, jaws, gut, gas bladder, and on the postanal ventral midline. Embedded pigment below the brain and in the otic region is present in many species, as are bars on the nape, trunk, or tail. In flexion and postflexion stage larvae, the gut remains compact and the gap between the anus and anal fin origin is characteristically wide. Most species remain robust with a relatively large head, blunt snout, oblique mouth, and retain the tadpole-like appearance of preflexion larvae, although some, e.g., *Menticirrhus* and *Seriphus*, may become somewhat slender. The series of ventral tail melanophores usually coalesces to heavy blotches, as does the pigment above the gut. Many species develop a heavy bar on the trunk (e.g., *Cheilotrema*, *Umbrina*) or tail (e.g., *Menticirrhus*) and some species (e.g., *Atractoscion*) develop a melanistic sheath that covers most of the body. Head spines are well developed in most species but usually only the anterior and posterior preopercular series are prominent. Some of the other spines that may be present are on the opercle, subopercle, interopercle, frontal, infraorbitals, pterotic, sphenotic, posttemporal, and supracleithrum. Ridges (e.g., supraocular, infraorbital, pterotic, posttemporal) often are associated with the these spines (Moser et al. 1983) and, in *Menticirrhus*, patches of minute spines are present on several regions of the head (see description of *M. undulatus*).

Larvae of *Atractoscion* are similar to those of *Stereolepis*, which also is robust and develops a nearly solid pigment sheath on the body, but the gut is longer and straighter in *Stereolepis* and preanal length is relatively greater in preflexion larvae (Sn-A 57% BL vs. 47% BL) (see Polyprionidae in this guide). Polynemid and ephippid larvae are similar to many of the moderately pigmented sciaenid genera; however, their myomere counts differ (24 total myomeres in polynemids and ephippids and usually 25–26 in sciaenids) and, in the preflexion stage, ephippids develop three strong preopercular spines compared with the more numerous but less pronounced preopercular spines in sciaenids. Preopercular spination is poorly developed or lacking in polynemids (see Ephippidae and Polynemidae in this guide). Preflexion stage larvae of some pomacentrids, apogonids, and gerreids may resemble those of sciaenids but they have 24 myomeres (vs. usually 25–26 in sciaenids) and generally a relatively smaller head and smaller, more compact gut (see appropriate sections in this guide for comparison with sciaenids). Haemulids have 26 myomeres and preflexion larvae of some (e.g., *Anisotremus davidsonii*, *Xenistius californiensis*) may be confused with preflexion sciaenids (e.g., *Seriphus politus*). The relatively larger eye and larger, more persistent melanophores in the ventral tail series of the haemulids in combination with a different body shape separates them from sciaenids (see Watson 1982; Haemulidae in this guide).

The following descriptions are based on detailed observations of 90–109 reared specimens of each species and on published information when available (Table Sciaenidae 2). Meristic data were obtained from literature (McPhail 1958; Miller and Lea 1972; Watson 1982; Moser et al. 1983; Walker and Radford 1992; Allen and Robertson 1994; Chao 1995) and from original counts made during this study; ecological information was obtained primarily from these same sources and from Chao (1978, 1986), Powles (1981), and Nelson (1994).

Table Sciaenidae 1. Meristic characters for the sciaenid species in the California Current vicinity. All species have I,5 pelvic fin rays, 9+8 principal caudal fin rays, and 7 branchiostegal rays.

Species	Vertebrae			Fin rays				GR
	PrCV	CV	Total	D	A	P_1	C_2	
Atractoscion nobilis	12–13	12–13	25	IX–X+I,19–23	I–II,8–10	15–18	8–9+7–9	5+11–13
Bairdiella icistia	12	13	25	IX–XI+I,24–29	II,7–9	15–17	9–11+8–10	6–11+15–18
Cheilotrema saturnum	10	15	25	IX–XI+I–II,25–28	II,6–9	17–19	10–12+9–11	6–9+8–14
Cynosion parvipinnis	11–12	11–12	23	VIII–X+I,20–24	II,9–11	16–18	7–9+7–9	2–4+7–9
C. reticulatus	13	12	25	IX–X+I,25–29	II,9–10	16–17	8–9+7–8	2–6+6–8
Elattarchus archidium	11–12	13–14	25	X–XI+I–II,22–28	I–II,7–11	15–18	8–10+7–9	5–8+8–18
Genyonemus lineatus	11–12	14–15	26	XII–XV+I,18–25	II,10–12	17–18	8–10+7–9	9–12+17–21
Larimus pacificus	10–11	14–15	25	X–XI+I,25–28	II,6–8	16–19	6–8+6–7	9–13+16–22
Menticirrhus nasus	10	15	25	X+I,21–23	I,8	19–22	8–9+7–8	4–6+0–6
M. panamensis	10	15	25	IX–X+I,18–22	I,8–9	20–23	7+6	4–5+0–5
M. undulatus	10	15	25	X–XI+I–II,23–27	I–II,7–9	18–20	8–9+6–7	5–8+4–10
Micropogonias ectenes	10	15	25	X+I,23–27	II,7–9	16–19	9–10+8–10	8–9+13–18
Pareques viola	10	15	25	IX+I,40–41	II,7–8	15–17	6–8+7–9	+6
Roncador stearnsii	10	15	25	IX–X+I,21–25	II,7–9	16–18	8–9+8–10	10–14+15–19
Seriphus politus	10	14–15	24–25	VII–IX+I,18–21	II,21–23	16–18	8–11+8–9	7–10+15–17
Umbrina roncador	10	15	25	X–XI+I,24–31	II,6–7	15–20	8–10+5–9	7–9+10–14
U. xanti	10	15	25	X+I,26–32	II,6–7	14–19	8–10+7–9	+12–13

Table Sciaenidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the sciaenid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Juvenile
Atractoscion nobilis	L[a]	L[a]	L[a]	L[a]	L[a]	L[a]
Cheilotrema saturnum	23 0.80–0.86	5 1.5–2.4	9 2.4–4.2	4 4.4–5.5	12 5.5–14.0	6 16.7–26.2
Genyonemus lineatus	L[b], 49 0.79–0.92	L[b], 5 1.8–3.0	L[b], 7 3.0–4.9	L[b], 5 5.3–6.6	L[b], 10 6.5–16.2	L[b], 3 17.2–29.4
Menticirrhus undulatus	4 0.84–0.88	5 1.4–2.6	5 2.6–3.8	3 4.8–5.2	2 5.4–9.6	3 11.5–16.2
Roncador stearnsii	20 0.66–0.76	3 1.9–2.3	6 2.5–4.2	4 5.1–5.8	6 6.6–12.8	4 14.0–23.5
Seriphus politus	25 0.73–0.78	5 1.7–2.5	6 2.6–3.9	4 4.3–5.4	10 6.0–15.0	5 17.2–25.0
Umbrina roncador	85 0.74–0.80	5 1.7–2.2	8 2.2–2.9	4 3.8–4.4	3 6.2–12.7	4 20.7–35.8

[a] Moser et al. 1983 [b] Watson 1982

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	12–13	13
Caudal	12–13	12
Fins:		
Dorsal spines	IX–X+I	X+I
Dorsal rays	19–23	21
Anal spines	I–II	II
Anal rays	8–10	9
Pelvic	I,5	I,5
Pectoral	15–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	9
Lower	7–9	8
Gill rakers:		
Upper	5	
Lower	11–13	
Branchiostegals	7	7

LIFE HISTORY

Range: Juneau, Alaska to Bahía Magdalena, Baja California Sur & Gulf of California

Habitat: Sandy bottom to >100 m depth

Spawning season: Larvae most abundant during May–August in CalCOFI area, with a peak in July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser et al. 1983
Walker et al. 1987

* Calculations from data in Moser et al. (1983).
† Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.24–1.32 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.30–0.36 mm
Shell surface: Smooth
Pigment: Increasing on embryo to form a solid sheath by hatching; on inner surface of OG
Diagnostic features: Large size; large OG located posteriad in yolk sac; pigment on embryo & OG

LARVAE

Hatching length: 2.8 mm
Flexion length: 5.2–6.8 mm
Transformation length: ca. 15.0 mm
Fin development sequence: C_1 & P_1, D & A & P_2, C_2
Pigmentation: *Yolk-sac*—Solid sheath on head & trunk; a bar midway posteriad on tail; dorsal & ventral midline series at tip of tail; some extend into dorsal finfold from trunk; on OG; on preanal finfold; by end of stage, gut covered, on P_1 base, a series on postanal ventral margin but none on dorsal margin. *Preflexion*—On P_1 blade; sheath expands posteriad to midtail by end of stage; accentuated on lateral midline. *Flexion*—On 1D & P_2; heavier on P_1; body sheath expands farther posteriad. *Postflexion*—Heavy on P_1, P_2, & 1D; at 10 mm, a patch forms on hypural region & expands anteriad to meet body sheath by 15 mm; on bases of 2D & A; bars at nape, 1D, 2D, & hypural region; saddle anterior to bar of 2D. *Juvenile*—On 2D, A, & C; 4 additional bars form between initial 5 bars.
Diagnostic features: Larger at hatching & at yolk depletion & stouter than larvae of other sciaenid species in region; heavy body sheath; large, heavily pigment paired fins; distinct barring.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	43–57 49	45–49 47	47–59 51	57–70 64		68–72 70
BD/BL	19–39 27	24–29 26	29–38 33	34–41 36		28–37 32
HL/BL	21–27 24	24–29 27	25–34 30	24–38 36		34–42 37
HW/HL	55–71 65	68–82 74	70–80 74	58–79 67		42–66 53
SnL/HL	13–23 19	18–25 22	22–29 26	21–30 26		19–26 23
ED/HL†	33–49× 31–40 42×36	34–41 37	32–41 36	29–35 31		24–31 28
P_1L/BL	0–5 1	6–6 6	7–12 8	14–28 23		21–28 26
P_2L/BL	0–0 0	0–0 0	2–7 3	10–24 18		16–26 22

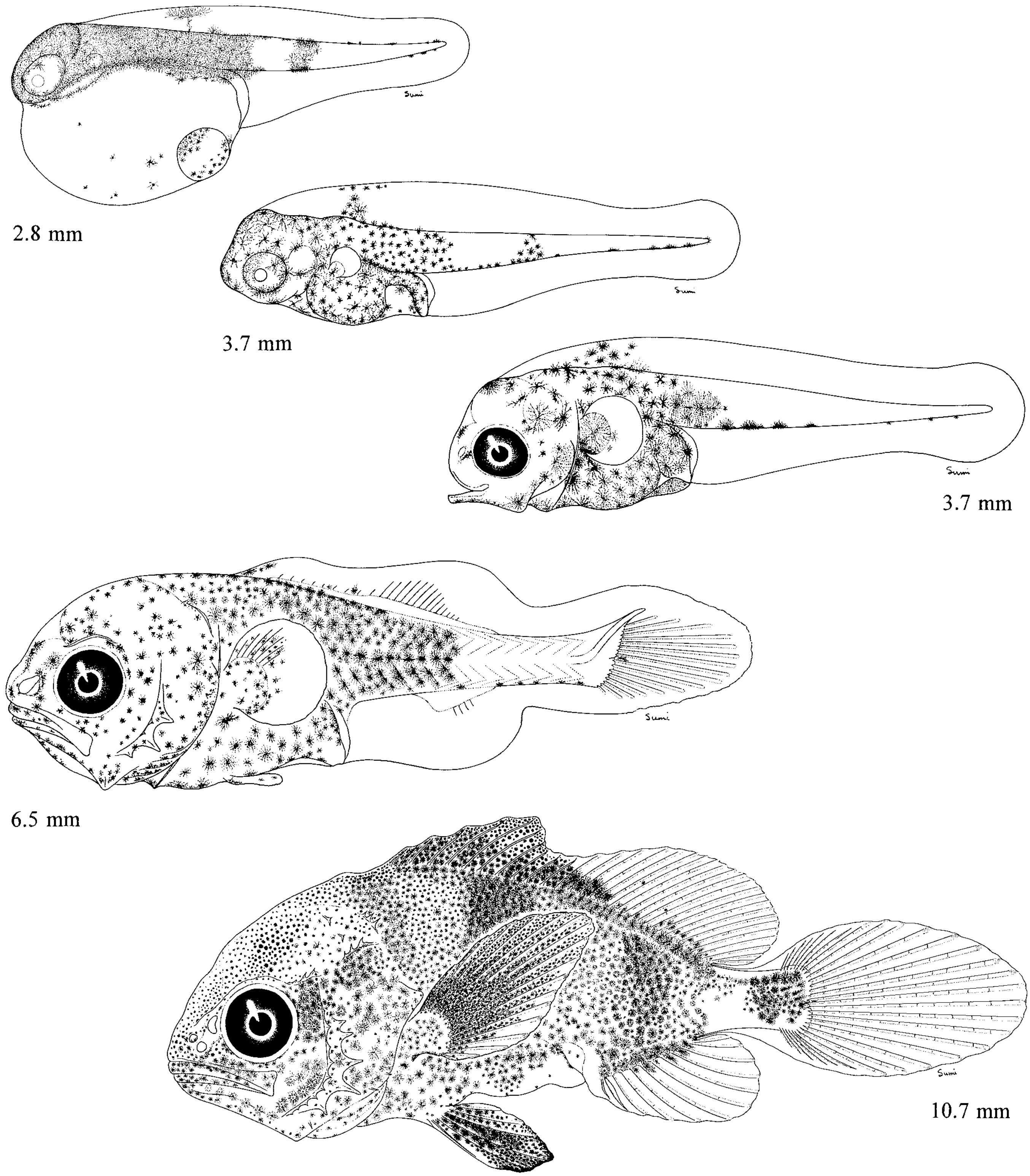

Figure Sciaenidae 1. Yolk-sac larvae, 2.8 mm, 3.7 mm; preflexion larva, 3.7 mm; flexion larva, 6.5 mm; postflexion larva, 10.7 mm (Moser et al. 1983).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	IX–XI+I–II	X+I
Dorsal rays	25–28	26
Anal spines	II	II
Anal rays	6–9	7
Pelvic	I,5	I,5
Pectoral	17–19	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–12	11
Lower	9–11	10
Gill rakers:		
Upper	6–9	
Lower	8–14	
Branchiostegals	7	7

LIFE HISTORY

Range: Point Conception, California to Bahía Magdalena, Baja California Sur & northern Gulf of California

Habitat: Sandy bottom & reefs to >100 m depth

Spawning season: In MEC surveys, larvae occurred in June–September, with peak abundance in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Walker et al. 1987

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.5 mm (B. Sumida MacCall)
Preflexion larvae, 2.4 mm, 2.8 mm (B. Sumida MacCall)
Postflexion larvae, 5.6 mm, 10.8 mm (B. Sumida MacCall)

* Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.76–0.85 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.19–0.26 mm
Shell surface: Smooth
Pigment: Anterior half of mid- to late-stage embryos covered, sparse posteriorly; OG covered
Diagnostic features: Combination of shell & OG diameter & pigmentation (mid- to late-stage)

LARVAE

Hatching length: 1.5 mm
Flexion length: 4.4–5.5 mm
Transformation length: ca. 15.0 mm
Fin development sequence: C_1, 2D & A, 1D & C_2, P_1 & P_2
Pigmentation: *Yolk-sac*—Initially, anterior half covered, series dorsally on tail, sparse on yolk near gut, OG covered; becomes sparse laterally on head; gut becomes covered; concentrates anteriorly on trunk; tuft extends into finfold at midtrunk; series dorsally on tail migrates ventrad, forms evenly spaced series on ventral margin; partial bar forms slightly forward of midtail. *Preflexion*—On head, internally below brain & otic capsule & externally on preopercular & opercular region; laterally on lower jaw (some specimens); bar (superficial & in myosepta) between nape & gut, extending into finfold; on inner & lateral surfaces of P_1 base & on blade; 6–10 on ventral margin of tail. *Flexion*—At tip of lower jaw (some specimens); preopercular bar extends ventrad to angular; opercular patch enlarged; above midbrain (in some). *Postflexion*—Above entire brain; trunk sheath expands posteriad; series on ventral margin of tail coalesces to few (large); at hypural margin; on upper jaw; after ca. 7.0 mm, patch on 1D, patch basally on upper P_1 rays, on P_2 rays, & on 2D & A bases; series on lateral midline of tail. *Juveniles*—Stripe from eye to C on lateral midline; paired stripes on dorsum & 1 between dorsum & lateral midline; additional thinner stripes in larger juveniles.
Diagnostic features: Robust head & body with compact triangular-shaped gut; pigment heavy & characteristic with a narrow bar below nape & a preopercular bar; high 2D ray count 25–28.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	46–60 53	41–46 43	44–51 47	49–63 56		64–66 65
BD/BL	23–47 33	23–36 30	34–36 35	32–39 36		36–39 37
HL/BL	23–31 27	24–31 27	32–33 33	33–37 35		31–38 34
HW/HL	66–76 72	66–78 73	67–83 74	65–83 71		62–72 67
SnL/HL	10–20 15	17–29 24	21–26 23	20–29 24		24–28 26
ED/HL*	42–45× 34–44 44×39	36–43 40	36–38 37	32–38 34		33–39 34
P_1L/BL	0–3 0.5	3–7 6	6–8 7	8–21 14		20–21 21
P_2L/BL	0–0 0	0–0 0	0–2 1	2–18 11		18–20 19

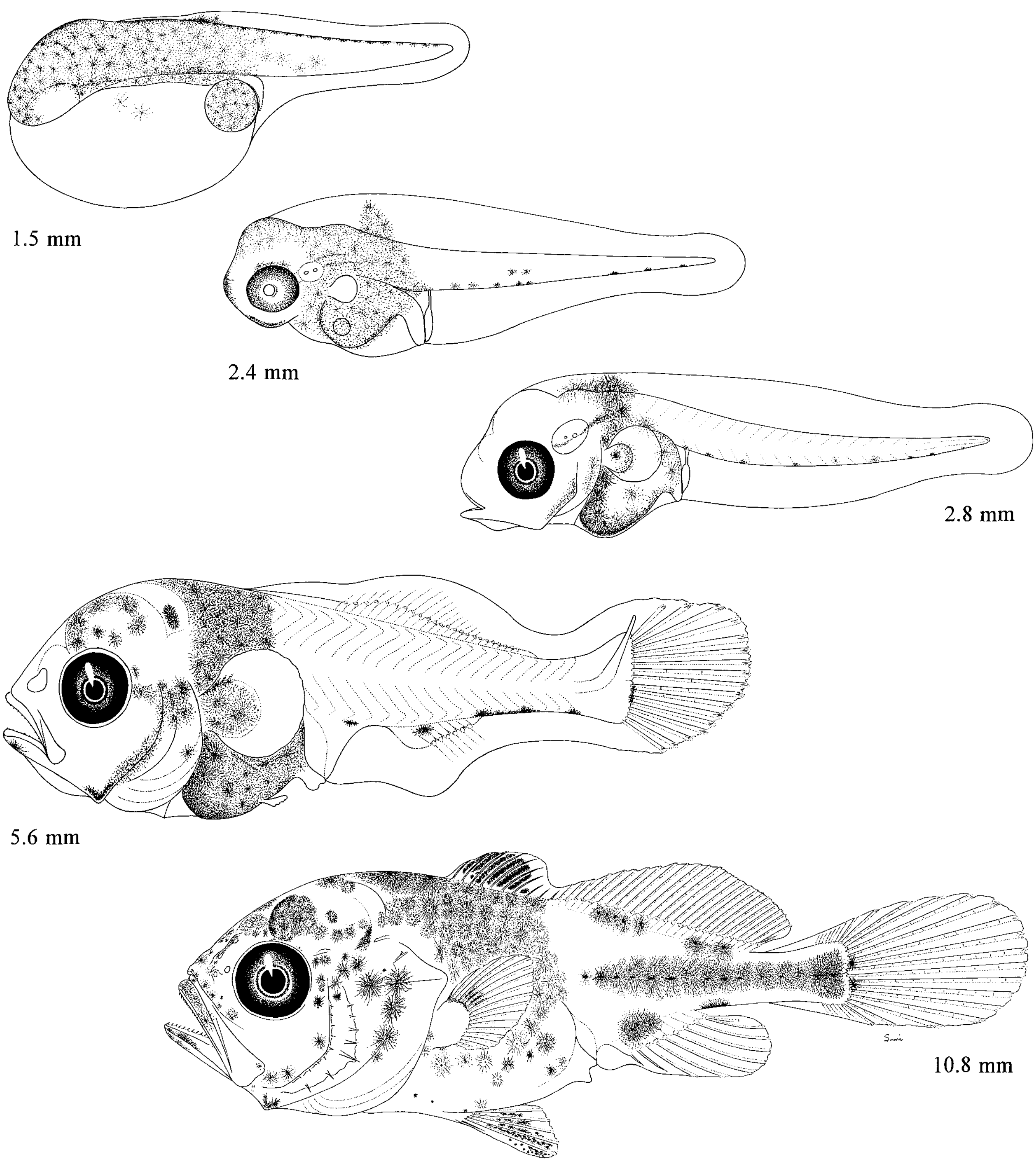

Figure Sciaenidae 2. Yolk-sac larvae, 1.5 mm (May 19, 1978, day 1), 2.4 mm (May 21, 1978, day 3); preflexion larva, 2.8 mm (May 19, 1978, day 7); early postflexion larva, 5.6 mm (June 6, 1978, day 18); late postflexion larva, 10.8 mm (June 29, 1978, day 41). CFRD Ref. Coll., all specimens reared at SWFSC; date of preservation and age listed in parentheses.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11–12	11
Caudal	14–15	15
Fins:		
Dorsal spines	XII–XV+I	XIII+I
Dorsal rays	18–25	22
Anal spines	II	II
Anal rays	10–12	11
Pelvic	I,5	I,5
Pectoral	17–18	18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	9
Lower	7–9	8
Gill rakers:		
Upper	9–12	
Lower	17–21	
Branchiostegals	7	7

LIFE HISTORY

Range: Vancouver Island, British Columbia to Bahía Magdalena, Baja California Sur

Habitat: Soft bottom to 183 m depth, usually <30 m depth

Spawning season: In CalCOFI area, larvae most abundant during December–April, with a peak in March

ELH pattern: Oviparous; planktonic eggs & larvae; larvae may be epibenthic after preflexion stage

LITERATURE

Matarese et al. 1989
Walker et al. 1987
Wang 1981
Watson 1982

* Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.79–0.92 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.19–0.26 mm
Shell surface: Smooth
Pigment: Moderately heavy on head & body in late-stage embryos; scattered on yolk; on distal surface of OG
Diagnostic features: Size; pigmentation on embryo & OG

LARVAE

Hatching length: ca. 1.5–1.8 mm
Flexion length: 5.3–6.6 mm
Transformation length: ca. 17.0 mm
Fin development sequence: C_1, 2D & A, P_1 & 1D & C_2, P_2
Pigmentation: *Yolk-sac*—Many on head condensing to few; ≥1 at nape extending into finfold; migrating from dorsum to gut & yolk sac & forming bars at myomeres 9–10 & 16–18 & series on ventral margin; ≥1 above & below notochord tip. *Preflexion*—None on head except at angular & in otic capsule (most specimens); on nape; above gas bladder; dorsally on hindgut; embedded anterior to gut; on ventral midline of gut; 1 on preanal finfold; 1 in axilla; larger & more widely spaced anteriorly on tail, 1 at midtail largest; 1 mid-dorsally on tail (some specimens). *Flexion*—1 at hypural margin; on tip of lower jaw & central gular region (some specimens); postanal ventral series becoming embedded anteriorly. *Postflexion*—In larvae <9 mm, anteriorly on lower jaw (some specimens), 1 on isthmus (some specimens), & series on each side of A base; in larvae >9 mm, laterally on upper jaw, ventrally & laterally on hindbrain, on opercle, between P_2 bases, on hypural margin, on A & C rays, & on snout. *Juvenile*—Above brain; barred (1 at nape, 2 at 1D, 2 at 2D, & 1 on caudal peduncle).
Diagnostic features: Compared with *Seriphus politus* & *Roncador stearnsii*, dorsal head profile more rounded, gut more saccular & terminal section more elongate, more variation in size & spacing of melanophores in ventral tail series; nape melanophore lacking in *S. politus*; pigment anteriorly on gut & floor of otic capsule not as heavy as in *R. stearnsii*; pigment lacking below foregut (present in *R. stearnsii*); A ray count lower than in *S. politus* & higher than in *R. stearnsii*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	36–56 46	36–41 38	41–48 44	48–57 53		59–63 61
BD/BL	20–34 28	20–23 22	25–31 27	30–34 31		30–32 31
HL/BL	15–26 20	16–24 22	26–32 28	30–37 34		29–32 31
HW/HL	43–80 62	52–65 58	54–61 57	39–57 49		45–58 50
SnL/HL	8–31 18	17–26 22	23–29 25	20–26 23		22–29 26
ED/HL*	43–73× 33–55 53×44	33–48 40	29–33 31	22–32 28		27–31 30
P_1L/BL	0–6 1	5–7 6	5–7 6	7–16 9		18–20 19
P_2L/BL	0–0 0	0–0 0	0–0 0	0–5 4		14–17 16

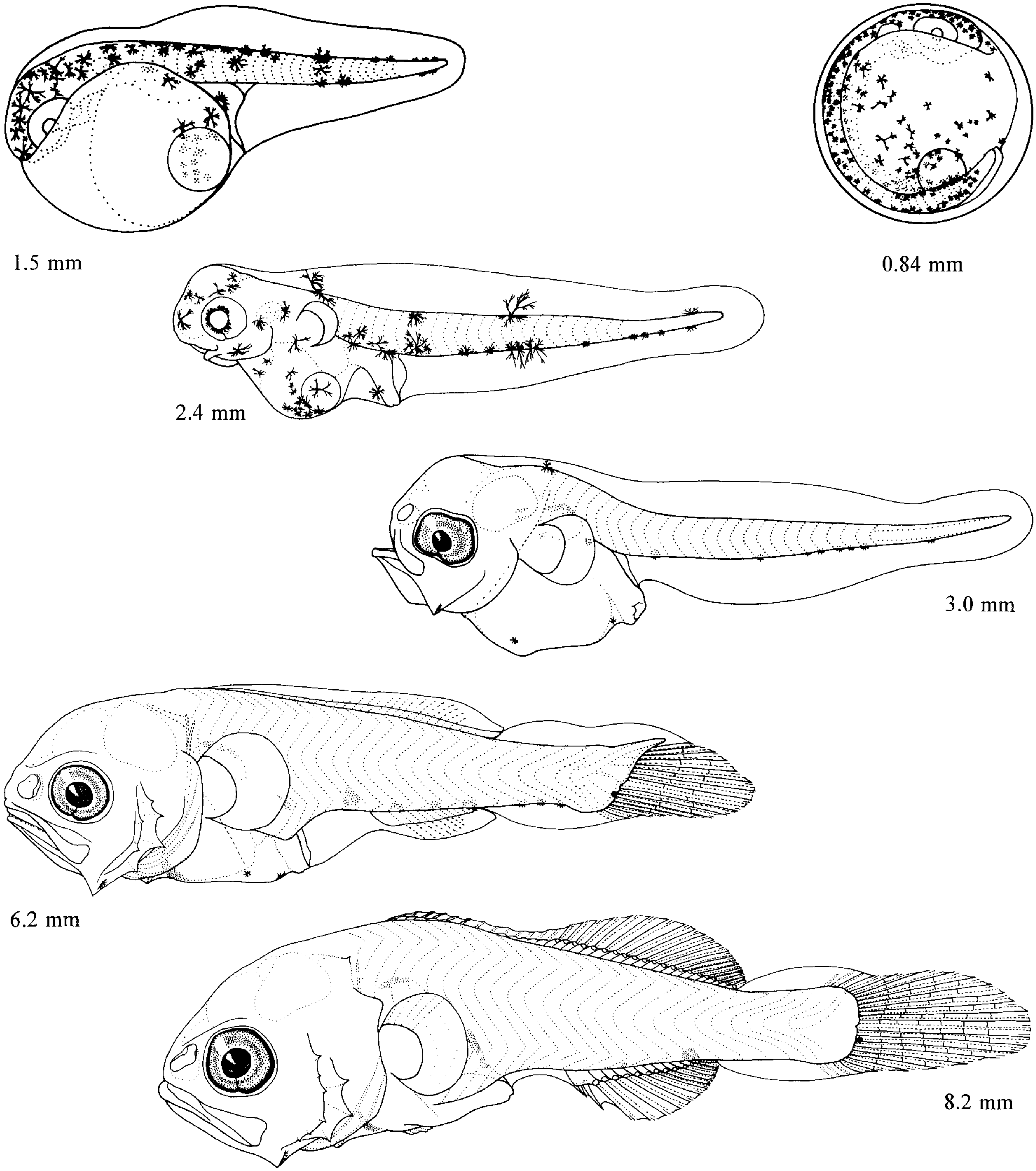

Figure Sciaenidae 3. Egg, 0.84 mm; yolk-sac larvae, 1.5 mm, 2.4 mm; preflexion larva, 3.0 mm; flexion larva, 6.2 mm; postflexion larva, 8.2 mm (Watson 1982).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	X–XI+I–II	X+I
Dorsal rays	23–27	24–25
Anal spines	I–II	II
Anal rays	7–9	8
Pelvic	I,5	I,5
Pectoral	18–20	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	8
Lower	6–7	6
Gill rakers:		
Upper	5–8	
Lower	4–10	
Branchiostegals	7	7

LIFE HISTORY

Range: Point Conception, California to Gulf of California

Habitat: Sandy bottom (usually surf zone) & in bays; to ca. 14 m depth

Spawning season: In MEC surveys, larvae occurred during June–October, with peak abundance in August & September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Walker et al. 1987

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larvae, 1.6 mm, 2.6 mm (B. Sumida MacCall)
Preflexion larva, 2.6 mm (B. Sumida MacCall)
Late flexion larva, 5.2 mm (B. Sumida MacCall)
Postflexion larvae, 5.5 mm, 13.9 mm (B. Sumida MacCall)
Head of 13.9 mm postflexion larva (B. Sumida MacCall)

* Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.80–0.82 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.25–0.26 mm
Shell surface: Smooth
Pigment: Moderately heavy on mid- to late embryos, sparse on posterior one-third of embryo; sparse on OG
Diagnostic features: Large OG; pigment on embryo

LARVAE

Hatching length: ca. 1.4 mm
Flexion length: ca. 4.0–5.2 mm
Transformation length: ca. 10.0 mm
Fin development sequence: C_1, 1D & 2D & A, P_1, P_2, C_2
Pigmentation: *Yolk-sac*—Initially, dispersed over head, trunk, gut, & upper yolk sac with a series dorsally on tail & some on inner surface of OG; subsequently, concentrated on head, in a bar on trunk & gut, in a bar at midtail, & in a sparse series along ventral midline of tail. *Preflexion*—Sparse on brain; on snout; heavy below entire brain & otic capsule; on lower & upper jaw extending to preopercle; on opercle; trunk covered with a few extending into dorsal finfold; gut covered with heavy patch on ventral surface; on inner & lateral surface of P_1 base; heaviest anteriorly in ventral tail series; series on lateral midline anteriorly on tail; trunk sheath & midlateral stripe expand posteriad beyond midpoint of tail by end of stage. *Flexion—postflexion*—Body sheath & midlateral stripe extend to caudal peduncle; somewhat sparse on upper trunk, filling in later; internally above spinal column; heavy on 1D, A, & basally on 2D; patch basally on C & P_2 rays; body covered completely by ca. 11.0 mm, paler ventrally on head & gut.
Diagnostic features: Relatively slender form; heavy pigmentation on head externally & internally below brain & otic capsule; sheath on trunk extending posteriad on tail; stripe at lateral midline; heavy patch ventrally on gut; pigment on 1D & A; unusual head spination.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	42–50 47	39–53 47	55–58 56	61–62 61		59–67 63
BD/BL	22–25 24	22–32 25	25–29 28	26–32 29		26–28 27
HL/BL	19–23 21	21–31 27	31–35 33	30–35 33		28–32 29
HW/HL	70–86 78	60–75 68	60–67 63	63–69 66		63–67 65
SnL/HL	18–23 20	16–28 22	23–33 27	28–29 28		26–33 30
ED/HL*	44–53× 41–49 47×45	36–42 39	33–36 34	32–32 32		28–33 31
P_1L/BL	0–2 0.5	5–7 6	7–9 8	12–17 14		19–23 21
P_2L/BL	0–0 0	0–1 0.2	1–3 2	4–14 9		14–19 16

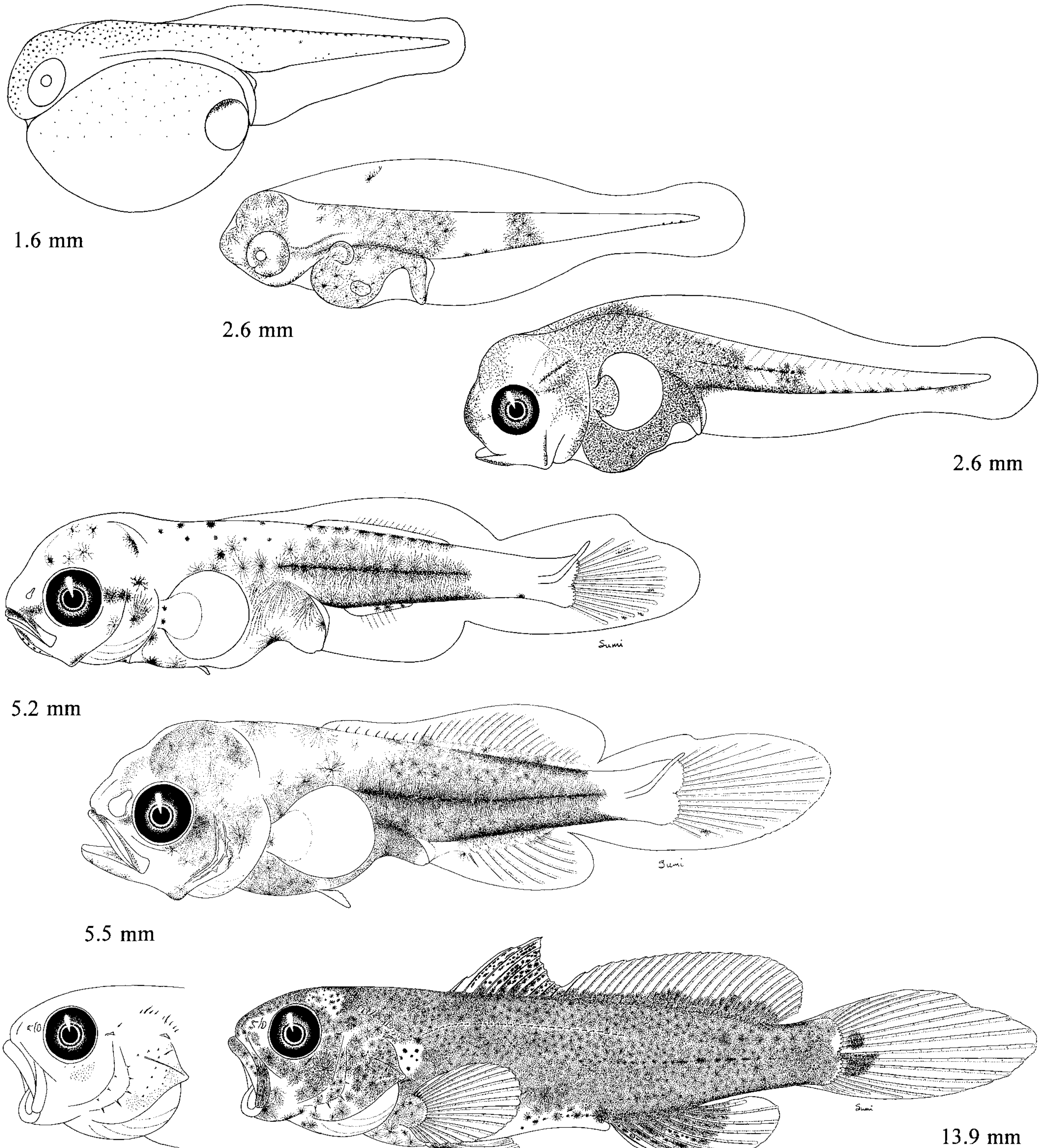

Figure Sciaenidae 4. Yolk-sac larvae, 1.6 mm (July 26, 1978, day 1), 2.6 mm (July 9, 1979, day 4); preflexion larva, 2.6 mm (July 12, 1978, day 6); late flexion larva, 5.2 mm (July 25, 1978, day 19); postflexion larvae, 5.5 mm (July 30, 1978, day 24), 13.9 mm, lateral view and lateral view of head showing spines (July 21, 1978, day 36). CFRD Ref. Coll., all specimens reared at SWFSC; date of preservation and age listed in parentheses.

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	IX–X+I	X+I
Dorsal rays	21–25	22
Anal spines	II	II
Anal rays	7–9	8
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	8–9
Lower	8–10	9
Gill rakers:		
Upper	10–14	
Lower	15–19	
Branchiostegals	7	7

LIFE HISTORY

Range: Point Conception, California to Mazatlán, Sinaloa, Mexico

Habitat: Sandy shores (often in surf zone) & in bays; to 15 m depth

Spawning season: Planktonic eggs collected during June–September (pers. obs.)

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Watson 1982

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larvae, 2.1 mm, 2.3 mm (B. Sumida MacCall)
Preflexion larva, 2.6 mm (B. Sumida MacCall)
Flexion larva, 5.5 mm (B. Sumida MacCall)
Postflexion larvae, 8.3 mm, 11.0 mm (B. Sumida MacCall)

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* Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.66–0.76 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.14–0.16 mm
Shell surface: Smooth
Pigment: Moderately heavy on mid- to late-stage embryos, sparse near tip of tail; on distal surface of OG
Diagnostic features: Small shell & OG diameters; pigment on embryo

LARVAE

Hatching length: <1.9 mm
Flexion length: ca. 5.0–6.0 mm
Transformation length: ca. 13.0 mm
Fin development sequence: C_1, A, 2D, 1D & P_1, C_2, P_2
Pigmentation: *Yolk-sac*—Initially, dispersed over head, sparse on trunk, a series on dorsum of tail with bar at midtail, & several above & below notochord tip; subsequently, concentrates above brain, on snout, nape, beneath hindbrain & otic capsule, & in series along ventral margin of tail with remnant of bar at midtail. *Preflexion*—Initially internally on snout, then lost; on midlateral lower jaw & angular; internally beneath hindbrain & otic capsule; on nape; heavy above gas bladder, embedded anteriorly on gut & on dorsal surface of hindgut; on ventral midline of gut; on preanal finfold; 1 just anterior to cleithral junction; usually 16 – >20 in ventral tail series with 1 enlarged at midtail or slightly posterior to midtail (slightly smaller & more closely spaced in posterior half of series). *Flexion*—Laterally & at tip of upper jaw; 1 on gular membrane; ≥1 on hypural margin; ventral tail series coalescing. *Postflexion*—On postorbital, preopercular, & opercular regions; on mid- & forebrain; back of cerebellum; internally above spinal column; at ca. 8.0 mm, bars begin forming below 1D & 2D; by 11.0 mm bars at nape, 1D, hypural, & 2 at 2D & heavy patch on 1D & on A; by end of stage, on 2D & beginning basally on C rays.
Diagnostic features: Moderately robust with sharply triangular-shaped gut; heavy embedded pigment below otic capsule & brain; heavy pigment above gas bladder & hindgut & embedded anterior to gut; large melanophore on nape; heavy on median fins & bars forming in late postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	38–43 41	36–44 40	43–47 44	50–63 57		59–65 61
BD/BL	19–27 24	17–24 20	26–30 28	33–35 34		31–35 32
HL/BL	21–24 22	21–28 24	26–28 26	27–32 30		31–32 32
HW/HL	68–82 75	60–71 66	69–79 74	66–75 71		59–76 65
SnL/HL	14–17 16	19–28 23	24–29 27	26–33 28		19–29 24
ED/HL*	44–48× 30–40 46×36	27–39 32	26–28 27	24–29 26		27–31 28
P_1L/BL	0–0 0	4–6 5	5–7 6	9–21 14		20–22 21
P_2L/BL	0–0 0	0–0 0	0–1 0.3	1–13 8		18–20 19

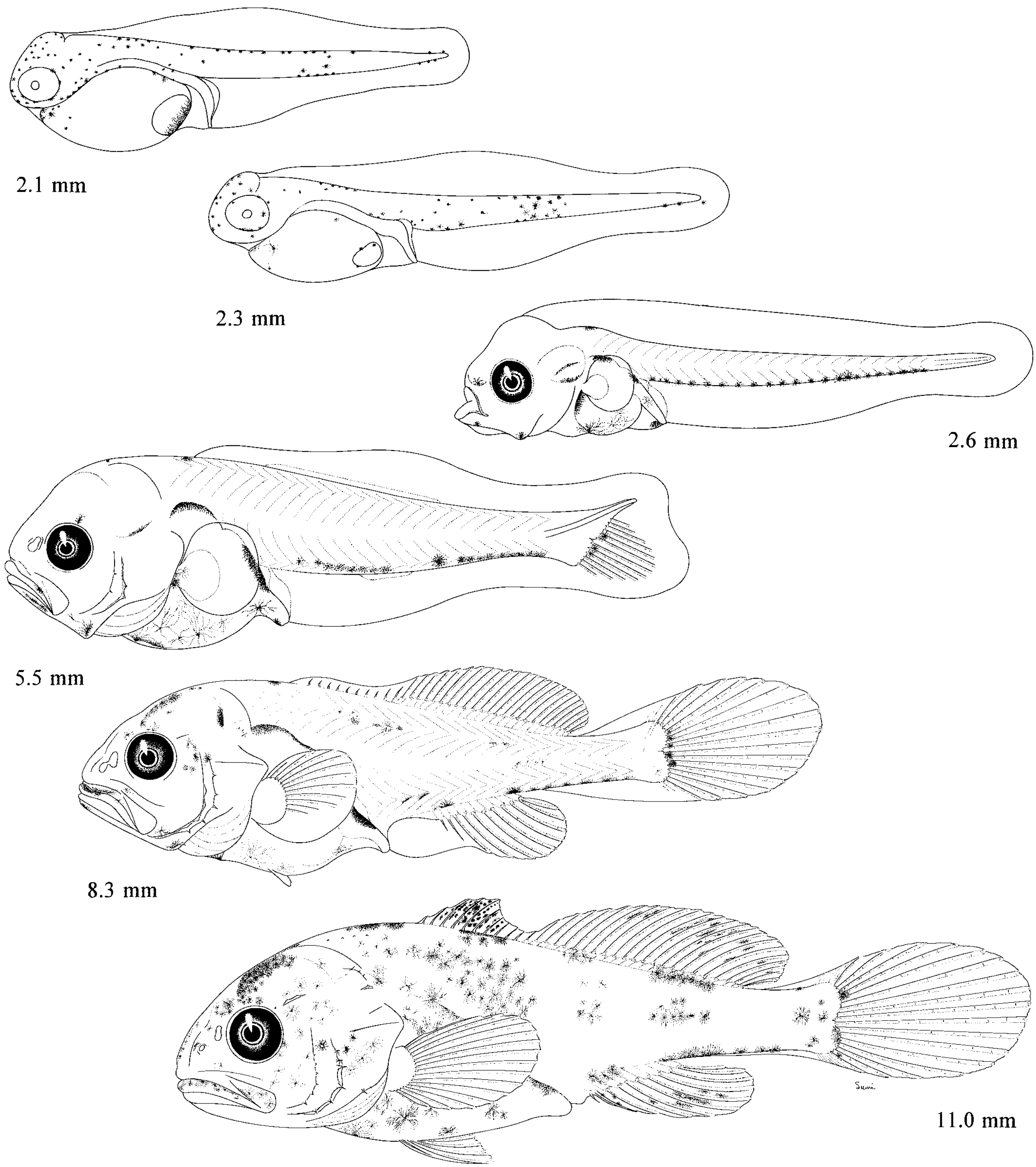

Figure Sciaenidae 5. Yolk-sac larvae, 2.1 mm (August 17, 1979, day 1), 2.3 mm (May 20, 1978, day 2); preflexion larva, 2.6 mm (May 23, 1978, day 8); flexion larva, 5.5 mm (September 15, 1978, day 15); postflexion larvae, 8.3 mm (June 7, 1978, day 19), 11.0 mm (June 12, 1978, day 24). CFRD Ref. Coll., all specimens reared at SWFSC; date of preservation and age listed in parentheses.

MERISTICS

	Range	Mode
Vertebrae:		
Total	24–25	25
Precaudal	10	10
Caudal	14–15	15
Fins:		
Dorsal spines	VII–IX+I	VIII+I
Dorsal rays	18–21	19
Anal spines	II	II
Anal rays	21–23	21–22
Pelvic	I,5	I,5
Pectoral	16–18	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–11	10
Lower	8–9	9
Gill rakers:		
Upper	7–10	
Lower	15–17	
Branchiostegals	7	7

LIFE HISTORY

Range: Yaquina Bay, Oregon to Uncle Sam Bank, Baja California Sur

Habitat: Inshore & in bays; over soft bottom, often around piers; to ca. 50 m depth

Spawning season: Larvae occur from February to October in CalCOFI area, with a peak in May

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Walker et al. 1987
Watson 1982

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.6 mm (R. C. Walker)
Yolk-sac larva, 2.5 mm (B. Sumida MacCall)
Preflexion larva, 2.8 mm (B. Sumida MacCall)
Flexion larva, 6.7 mm (B. Sumida MacCall)
Postflexion larvae, 7.7 mm, 12.6 mm (K. S. Raymond)

* Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.73–0.78 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.18–0.23 mm
Shell surface: Smooth
Pigment: In mid- to late-stage embryos, sparse on back of head & on trunk
Diagnostic features: Shell & OG diameter

LARVAE

Hatching length: ca. 1.6 mm
Flexion length: ca. 4.0–5.4 mm
Transformation length: ca. 16.0 mm
Fin development sequence: C_1, 2D & A, C_2, P_1 & 1D, P_2
Pigmentation: *Yolk-sac*—Initially, sparsely distributed on back of head & dorsally on trunk & a sparse irregular series dorsally on tail; after ventral migration, on lower jaw, angular, beneath hindbrain, sparse on gut & yolk sac, & series on ventral margin of tail. *Preflexion*—Anteriorly on lower jaw (some specimens); on angular; beneath hindbrain; above gas bladder; above hindgut where it diverges ventrad; ventrally on gut; embedded anteriorly on gut; on preanal finfold; ca. 15–20 in ventral tail series, generally uniform in size & evenly spaced, late in stage, more (smaller) in posterior half of ventral tail series (some specimens) & coalescence produces blotches at myomeres 11–13 & 19–21; 1 at hypural margin. *Flexion*—More coalescence in ventral tail series. *Postflexion*—Blotch at A origin & insertion, & 1 between them; 1 at 2D insertion in most larvae >6.0 mm; embedded ventrally at caudal peduncle & hypural region; solid on posterior hypural margin; on upper & lower jaw & median gular region; by ca. 14.0 mm, beginning to form on 1D & distally on 2D, C, & A rays; beginning to form on top of head & on upper body (no bars form).
Diagnostic features: Relatively slender; sparse pigmentation; no nape pigment; vertical streak on angular; large blotch above gas bladder & hindgut; ventral tail series uniform until coalescence; 3 blotches along A base; no tail bars; high A soft-ray count (21–23).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	38–55 45	36–40 38	41–42 42	45–61 55		58–60 59
BD/BL	20–41 28	18–21 19	19–22 21	21–30 27		28–29 29
HL/BL	18–27 22	19–26 21	23–25 24	25–37 33		33–37 34
HW/HL	66–78 73	61–77 68	46–70 58	44–57 50		40–47 43
SnL/HL	13–16 15	14–28 22	25–29 28	23–32 28		27–32 29
ED/HL*	44–52×30–48 48×42	31–41 37	28–35 32	21–26 23		24–29 26
P_1L/BL	0–0 0	0–6 3	5–6 5	4–13 7		12–15 13
P_2L/BL	0–0 0	0–0 0	0–3 0.7	4–11 7		10–13 12

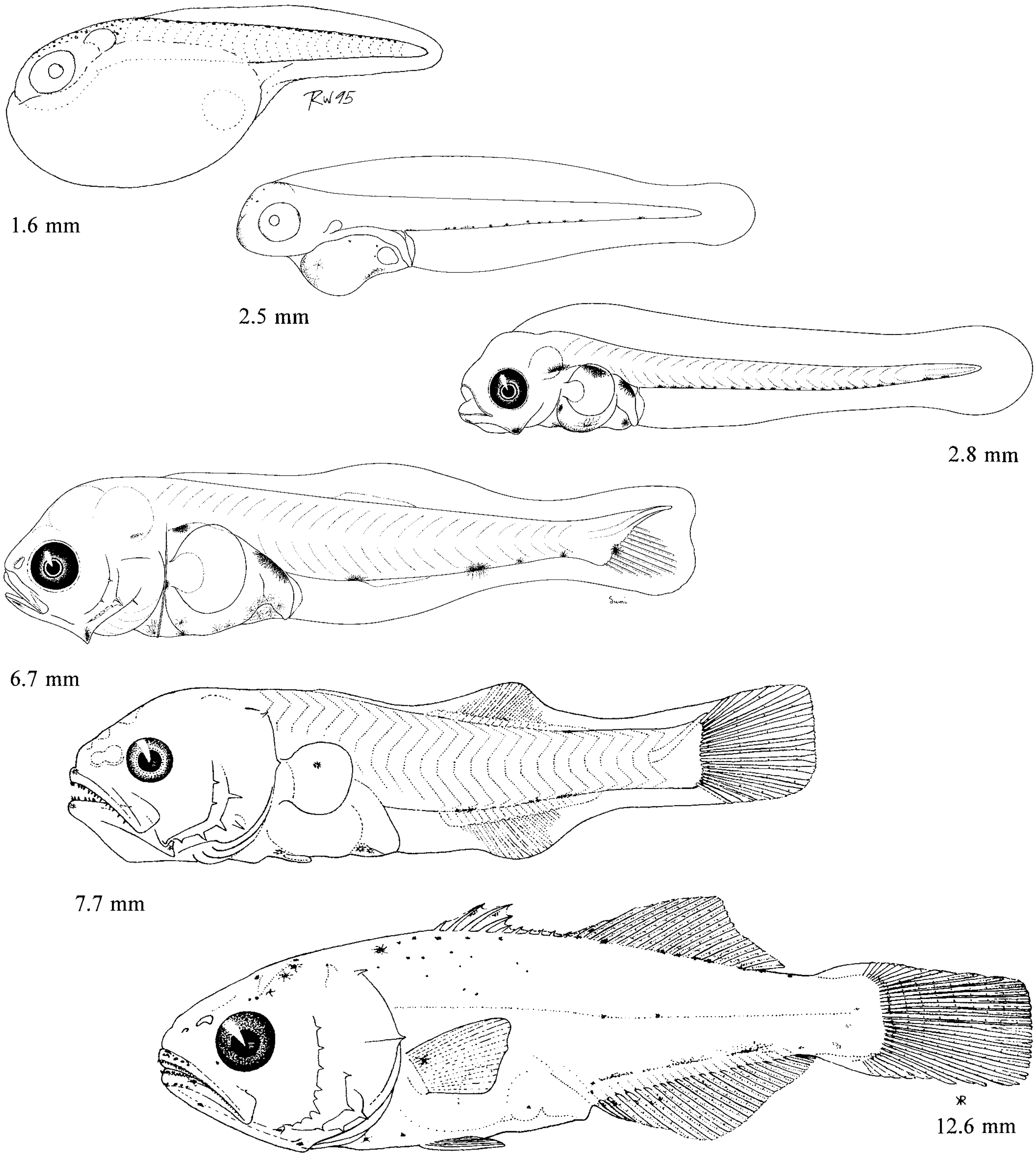

Figure Sciaenidae 6. Yolk-sac larvae, 1.6 mm (March 15, 1979, day 1), 2.5 mm (day 2); preflexion larva, 2.8 mm (August 1, 1978, day 6); flexion larva, 6.7 mm (April 14, 1978, day 49); postflexion larvae, 7.7 mm (June 17, 1968, day 17), 12.6 mm (June 25, 1968, day 26). CFRD Ref. Coll., all specimens reared at SWFSC; date of preservation and age listed in parentheses.

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	X–XI+I	X+I
Dorsal rays	24–31	27
Anal spines	II	II
Anal rays	6–7	7
Pelvic	I,5	I,5
Pectoral	15–20	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	8–9
Lower	5–9	8
Gill rakers:		
Upper	7–9	
Lower	10–14	
Branchiostegals	7	7

LIFE HISTORY

Range: Point Conception, California to Bahía Magdalena, Baja California Sur & the northern Gulf of California

Habitat: Shallow sandy areas & in bays; to ca. 45 m depth

Spawning season: Summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larvae, 1.5 mm, 2.1 mm (B. Sumida MacCall)
Preflexion larva, 2.5 mm (B. Sumida MacCall)
Postflexion larvae, 6.2 mm, 8.9 mm, 12.5 mm (B. Sumida MacCall)

* Eye initially oval, becoming round by preflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.74–0.80 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.18–0.21 mm
Shell surface: Smooth
Pigment: On mid- to late-stage embryos, distributed moderately densely on head, trunk, & tail (sparse at tip); some on yolk sac & OG
Diagnostic features: Shell & OG diameters; pigment

LARVAE

Hatching length: ca. 1.5 mm
Flexion length: ca. 3.2–5.0 mm
Transformation length: ca. 13.0 mm
Fin development sequence: C_1, 2D & A, 1D & P_1 & C_2, P_2
Pigmentation: *Yolk-sac*—Initially, moderately heavy on trunk & tail (except tip), & proximally on OG; after ventral migration, head & gut covered, a bar posteriorly on trunk, 1 or more in finfold above trunk bar, an irregular ventral tail series with a bar at midtail. *Preflexion*—Embedded below brain from hindbrain to snout & in floor of otic capsule; anteriorly on upper & lower jaw; heavy on nape, trunk bar, & gut (heavy patch ventrally on gut); trunk bar moves anteriorly, coalescing with nape patch; on both sides of P_1 base & blade; initially, ca. 16–20 in series on ventral margin of tail with 1 or 2 (large) at midtail (large & more widely spaced anterior to midtail). *Late preflexion–flexion*—Lacking internally on snout & above brain (most specimens); restricted to upper part of P_1 blade; ventral tail series coalescing; 1 or more at hypural margin; at angular. *Postflexion*—By ca. 6.0 mm, above entire brain, postorbital, & opercular region; blotch at A origin, A insertion, & 1 apposing on base of 2D; 1 or more ventrally on caudal peduncle; line at posterior hypural margin; by ca. 9.0 mm, blotch on dorsum at 1D; by ca. 12.0 mm, another blotch anteriorly on 2D, blotches along midlateral trunk & tail, & head covered. *Juveniles*—ca. 10 bars from nape to C.
Diagnostic features: Stout; heavy pigment on head, nape, gut, & bar anteriorly on trunk; no bar on preopercle (present in *Cheilotrema saturnum*); trunk bar does not expand posteriad as in *C. saturnum*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	42–53 47	38–42 40	41–50 46	53–57 55		57–64 61
BD/BL	21–35 27	23–35 28	32–38 34	33–37 36		29–30 30
HL/BL	20–24 22	22–29 25	26–31 29	32–34 33		27–29 28
HW/HL	55–75 66	69–82 74	62–70 66	52–57 56		48–60 53
SnL/HL	17–23 20	20–31 25	26–30 28	24–27 26		24–27 26
ED/HL*	38–51× 30–41 45×35	38–45 42	38–41 40	31–35 33		30–33 31
P_1L/BL	0–2 0.5	4–8 6	5–7 6	10–21 15		16–19 18
P_2L/BL	0–0 0	0–0 0	0–0 0	6–15 11		16–18 17

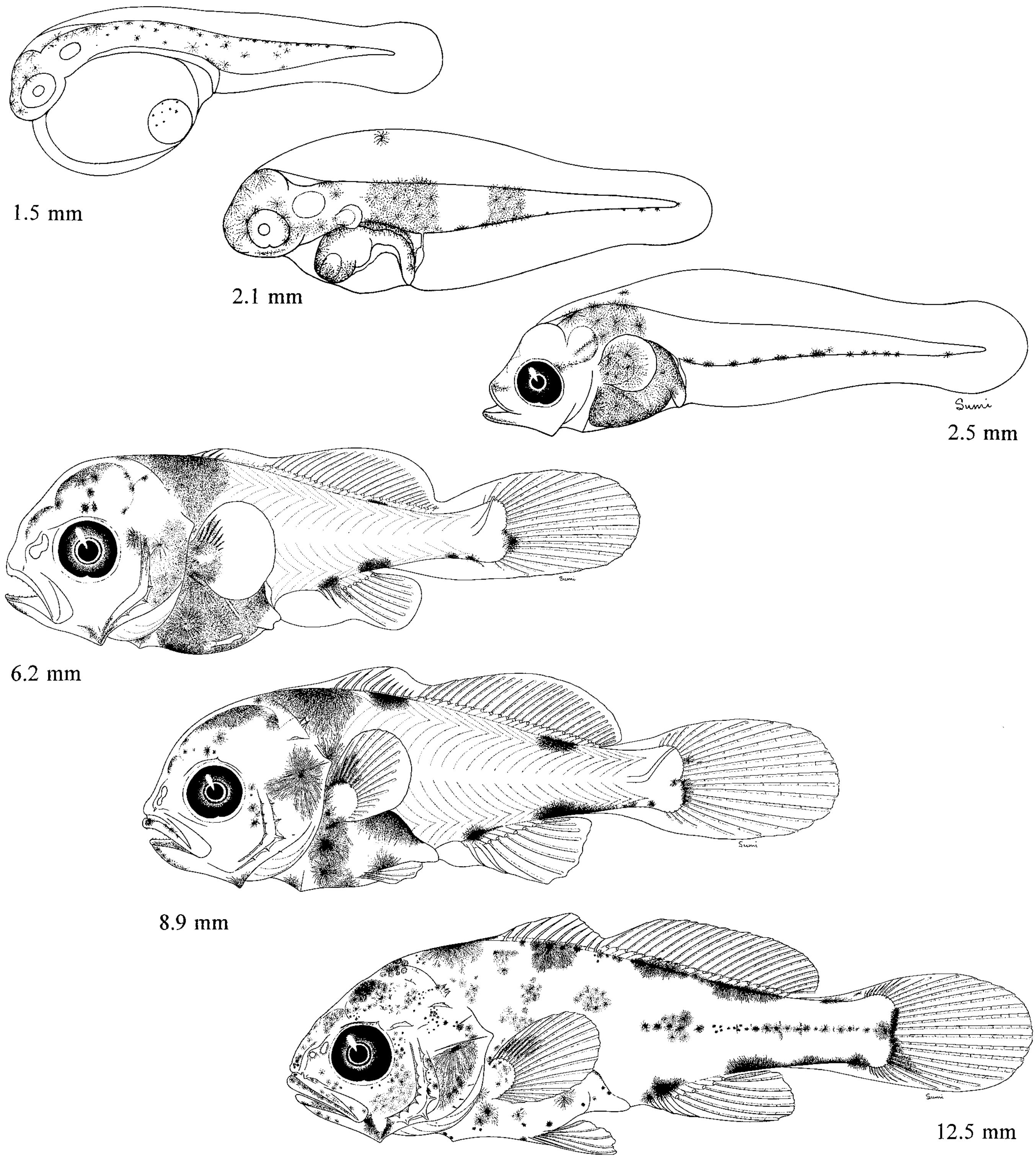

Figure Sciaenidae 7. Yolk-sac larvae, 1.5 mm (September 21, 1979, 36 hours), 2.1 mm (September 22, 1979, 72 hours); preflexion larva, 2.5 mm (May 19, 1978, day 7); early postflexion larva, 6.2 mm (October 12, 1979, day 22); late postflexion larvae, 8.9 mm (October 12, 1979, day 22), 12.5 mm (October 26, 1979, day 26). CFRD Ref. Coll., all specimens reared at SWFSC; date of preservation and age listed in parentheses.

MULLIDAE: Goatfishes

W. WATSON

Mullidae contains about 55 species in six genera (Nelson 1994), two of which occur in the CalCOFI study area (Table Mullidae 1). Both are primarily tropical and subtropical although *Mulloidichthys dentatus* has been recorded as far north as Long Beach, California, and *Pseudupeneus grandisquamis* as far north as San Onofre, California. Their principal ranges are the Gulf of California to Peru (*M. dentatus*) or Chile (*P. grandisquamis*). A few larval mullids have been collected during CalCOFI surveys in September, October and November at inshore stations between about Bahía Asuncion and Cabo San Lazaro, Baja California Sur.

Mullids are medium-size (most species ca. 30–60 cm) residents of warm coastal waters. Many species forage over shallow soft bottoms while others are associated with reefs. All use a pair of long, chemosensory chin barbels to probe the substrate for prey. Mullids are moderately elongate, slightly to moderately compressed, with preanal length just over half of body length. The head is moderately large with a long, rounded snout and moderately small mouth. The spinous and soft-rayed portions of the dorsal fin are short-based and well separated; the short-based anal fin is opposite the second dorsal fin. The caudal fin is forked. The body is covered with large, weakly ctenoid scales. Some mullid species are brightly colored, primarily in shades of red, while others are less strikingly colored in greys, greens, yellows and browns. Some are barred and stripes are common. Pelagic juveniles are blue-green to brown dorsally and silvery below. Many mullid species are highly regarded food fishes.

Mullids are oviparous, spawning spherical planktonic eggs that have a smooth chorion 0.63–0.93 mm in diameter, and that contain a coarsely segmented yolk with a single oil globule 0.15–0.25 mm in diameter (Montalenti 1937; Mito 1963; Marinaro 1971). Larvae ca. 1.6–3.4 mm long hatch with unpigmented eyes and unformed mouth, without pectoral fin buds, and with a large yolk sac containing the oil globule anteriorly (Montalenti 1937; Mito 1963; Marinaro 1971; Schmitt 1983; Johnson 1984). In newly hatched larvae the yolk sac and oil globule extend far forward, well beyond the anterior margin of the head. Larvae are elongate throughout development. The gut initially is a simple, straight tube that extends to about half of body length. It coils and shortens to about one-third of body length by the end of the yolk-sac stage, then gradually lengthens to ca. 50–60% BL during the postflexion and transformation stages. Larvae are moderately compressed and have a moderate head with large eyes and a short, rounded snout that gradually lengthens but remains rounded. Two or three small preopercular spines may form in some species, but more commonly there are no spines on the head or pectoral girdle. The barbels begin to form at the anterior ends of the hypohyals late in the postflexion stage and shift forward during the pelagic juvenile stage, reaching their final position at settlement (Schmitt 1983). The principal caudal rays are the first fin rays to begin forming at the beginning of notochord flexion. About mid-way through flexion, anal and second dorsal fin rays begin to form, either simultaneously, or with the anal rays slightly before the dorsal rays. Dorsal spines form soon after notochord flexion, shortly before to shortly after initial formation of pectoral fin rays. Pelvic fin rays are last to begin forming. The anal fin origin initially is separated by a wide space from the anus, but as the gut lengthens the gap closes. Mullid larvae initially are pigmented primarily on the dorsum and the oil globule, but during the yolk-sac stage most or all of the dorsal pigment migrates to the dorsal surface of the gut and ventral margin of the tail (Montalenti 1937; Mito 1963). Melanophores form dorsally on the head, internally over the notochord, and on the lateral midline of the tail during the preflexion or flexion stage (Montalenti 1937; Uchida et al. 1958b; Miller et al. 1979; Schmitt 1983; Konishi 1988d; this study). Melanophores form on the dorsal margin and increase on all areas during the postflexion stage; late postflexion and transformation specimens are completely pigmented or nearly so, usually darker dorsally, often with a prominent midlateral stripe.

Larval mullids are distinguished by the short preanal length (through notochord flexion), rounded snout, large eyes, none to few small preopercular spines (present from early flexion through mid-postflexion stage in the CalCOFI larvae), 24 myomeres, widely separated dorsal fins (postflexion stage), low dorsal and anal fin-ray counts, and larval pigmentation patterns (especially pigmentation dorsally on the head, internally over the notochord, and on the lateral midline of the tail). In the CalCOFI study area, larval mullids have been confused with atherinids and gerreids, both of which have a short preanal length, more or less rounded snout, large eyes, few small preopercular spines (postflexion stage gerreids) or none (atherinids), and pigmentation patterns that share some elements with the mullid pattern. Atherinid larvae are more elongate than mullid larvae, usually have a shorter preanal length, and have many more myomeres (range 37–54 for species in the CalCOFI area) than the mullids have. Larval gerreids have a somewhat more robust form than larval mullids, develop a somewhat more pointed snout during the postflexion stage, have a continuous dorsal fin, and lack the pigmentation on the lateral midline. It is unknown how larvae of the two mullid species in the CalCOFI study area might be distinguished from one another.

The following description is based on detailed observation of 18 larval (9 preflexion, 2.4–4.2 mm; 4 flexion, 4.2–4.6 mm; 4 postflexion, 4.9–6.6 mm; 1 transformation, 8.7 mm) and five pelagic juvenile (11.1–22.3 mm) mullids. Although these specimens appear to represent a single species, it is unknown which they are or whether they indeed are all one species. Meristic data were obtained from Thomson et al. (1979) and Allen and Robertson (1994) and counts made during this study. Ecological information is from the same literature sources and from Eschmeyer et al. (1983).

Table Mullidae 1. Meristic characters for the mullid species in the California Current vicinity. Both species have 10+14 vertebrae, 8+7 principal caudal fin rays, I,5 pelvic fin rays, and 4 branchiostegal rays.

	Fin rays				
Species	D	A	P_1	C_2	Gill rakers
Mulloidichthys dentatus	VI–VIII+I,8	II,6–7	15–17	8–9+8–9	7–8+19–21
Pseudupeneus grandisquamis	VII–VIII+I,8	I–II,6	16–17	8–9+8–9	6–7+15–18

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VI–VIII	VII (*M. d.*), VIII (*P. g.*)
Dorsal rays	I,8	I,8
Anal spines	I–II	II
Anal rays	6–7	6
Pelvic	I,5	I,5
Pectoral†	15–17	16 (*M. d.*), 17 (*P. g.*)
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	8
Lower	8–9	9
Gill rakers:		
Upper	6–8	
Lower	15–21	
Branchiostegals	4	4

LIFE HISTORY

Range: *M. dentatus*—Long Beach, California to Peru, including Gulf of California & Galápagos Islands; *P. grandisquamis*—Bahía Magdalena & Gulf of California to Chile, one record from San Onofre, California

Habitat: *M. dentatus*—Schools over reefs to ca. 38 m depth; *P. grandisquamis*—Over soft bottom in coastal waters

Spawning season: Mullid larvae collected September–November in CalCOFI study area

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

Hunter 1967

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.0 mm (B. Sumida MacCall)
Flexion larva, 4.5 mm (B. Sumida MacCall)
Postflexion larva, 4.9 mm (B. Sumida MacCall)
Transformation specimen, 8.7 mm (B. Sumida MacCall)

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* *Mulloidichthys dentatus* & *Pseudupeneus grandisquamis* occur in the CalCOFI study area. Larvae described here appear to represent a single species, possibly *M. dentatus* although this identification cannot be confirmed at present. Meristics above include both species.

† Allen & Robertson (1994) give P_1 13–16 for *P. grandisquamis*; however, all specimens of both species examined in this study had 16 or 17 rays, modally 16 for *M. dentatus* & 17 for *P. grandisquamis*.

‡ Eyes oval through postflexion stage, becoming round or nearly so during transformation & pelagic juvenile stages; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.4 mm
Flexion length: 4.2 mm through ca. 4.6–4.9 mm
Transformation length: >6.6 mm, <11.1 mm
Fin development sequence: C_1, 2D & A, 1D & C_2, P_1, P_2
Pigmentation: *Preflexion*—1 posteriorly over midbrain by 2.4 mm & pair over middle of midbrain by 3 mm forming triangular pattern; under hindbrain; on opercle behind mid-eye at ca. 3.3 mm; dorsally on gut; on lateral midline of tail in vicinity of myomeres 18–21; internally over notochord in same area beginning between 3.0–3.3 mm; few on ventral margin of tail, anterior 2–3 widely spaced & disappearing by ca. 3 mm. *Flexion*—Increasing dorsally on head, triangular pattern remains prominent; increasing on opercle; increasing internally on mid- & hindbrain; spreading ventrolaterally on gut; spreading cephalad & caudad over notochord & on lateral midline; ventral tail series becomes double row. *Postflexion*—Increasing on head; on snout & upper jaw by 4.9 mm; externally on nape by 5 mm; dorsally on caudal peduncle between 4.9–5.3 mm, spreading forward; spreading forward on lateral midline & ventral margin. *Transformation*—Covering most of head except light on snout & ventrally; 4 stripes on each side of body (2 dorsally, 1 midlateral, 1 ventral); dorsolaterally on myosepta; few scattered ventrolaterally. *Pelagic juvenile*—Filling in between upper stripes, then down to midlateral stripe; increasing ventrolaterally & on head; completely pigmented except little laterally on abdomen by 18 mm.
Diagnostic features: 24 myomeres; elongate; short preanal length; few, small preopercular spines; 1D & 2D well separated; low D & A counts; dorsal & lateral pigmentation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	PJuv
Sn-A/BL		38–45 42	47–50 49	50–54 52	 58	58–59 58
BD/BL		21–27 23	23–24 24	21–23 22	 21	18–19 18
HL/BL		25–31 28	28–31 30	29–32 31	 30	26–29 27
HW/HL		56–71 61	50–55 53	47–53 49	 41	41–43 42
SnL/HL		18–23 20	19–20 19	20–24 21	 24	22–26 24
ED/HL‡		37–43× 30–38	34–37× 30–31	32–37× 28–32		24–29× 25–28
		39×33	36×31	34×29	29×28	27×27
P_1L/BL		6–9 8	8–10 9	8–10 9	 14	13–15 14
P_2L/BL		0–0 0	0–0 0	2–5 3	 12	12–15 14

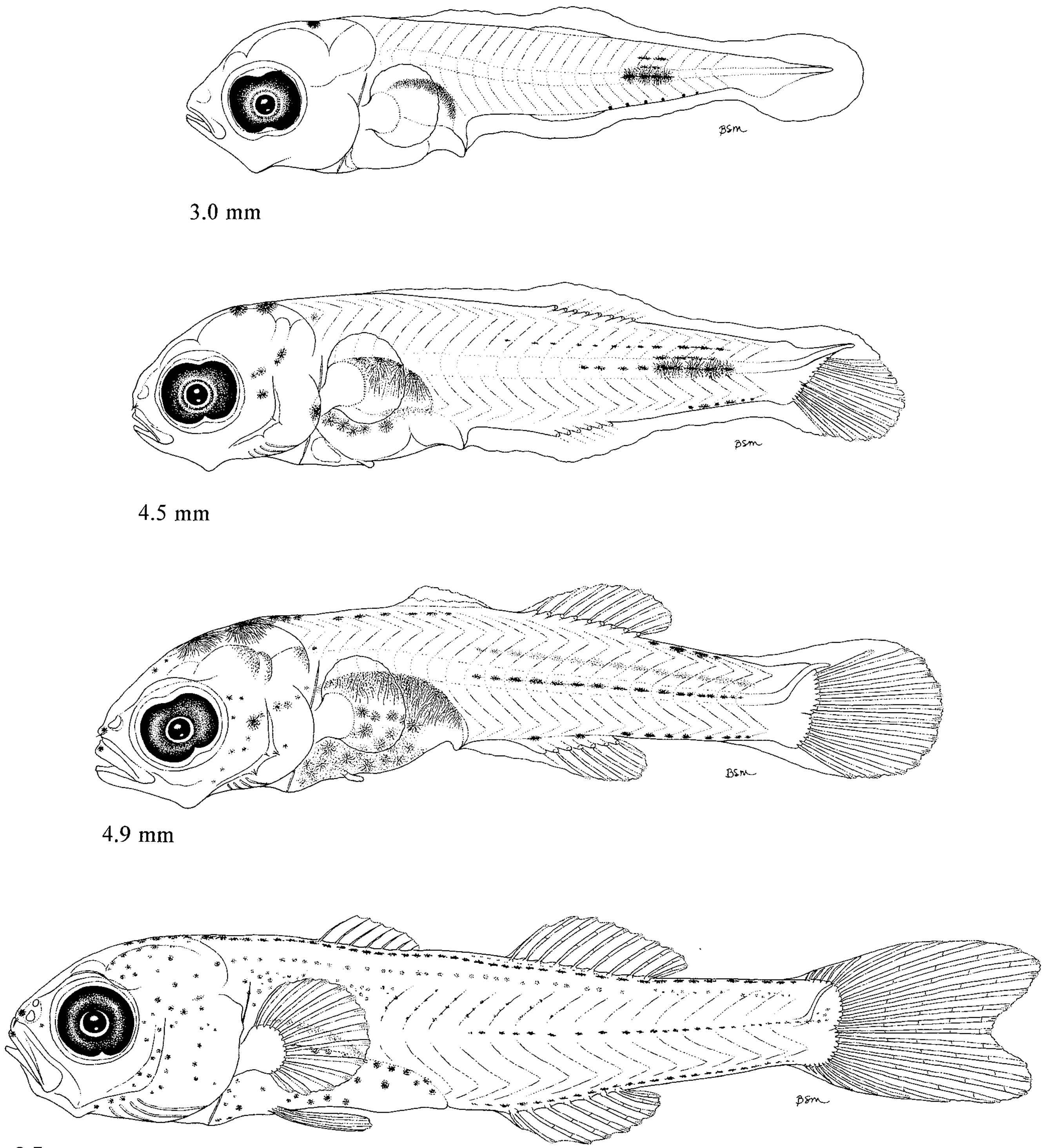

Figure Mullidae 1. Preflexion larva, 3.0 mm (CalCOFI 5210, station 130.30); flexion larva, 4.5 mm (CalCOFI 5810, station 137.23); postflexion larva, 4.9 mm (CalCOFI 5111, station 127.34); transformation specimen, 8.7 mm (CalCOFI 5810, station 133.30).

KYPHOSIDAE: Sea chubs

W. Watson

Kyphosidae contains 15 genera and about 42 species in five subfamilies (Nelson 1994), three of which (Girellinae, Kyphosinae, Scorpidinae) are represented in the California Current vicinity. Some authors consider the girellines, kyphosines, and scorpidines to be separate families (e.g., Hubbs at al. 1979; Johnson 1984, 1993; Johnson and Fritzsche 1989), while others place them all in Kyphosidae (e.g., Jordan and Evermann 1896; Greenwood et al. 1966; Eschmeyer 1990; Nelson 1994) as we do here. All three generally are considered closely related and Johnson and Fritzsche (1989) provided evidence of their monophyly (but monophyly has not been demonstrated for all five subfamilies: Nelson 1994).

Six kyphosid species occur within the CalCOFI study area (Table Kyphosidae 1) and another, *Girella simplicidens* is nearby in the Gulf of California (but uncommon in the lower Gulf: Allen and Robertson 1994). Three species, *Kyphosus analogus*, *K. elegans*, and *Sectator ocyurus* are primarily tropical and subtropical species that are rare north of southern Baja California Sur, while *Girella nigricans*, *Hermosilla azurea*, and *Medialuna californiensis* have more northerly distributions, ranging from central California (*G. nigricans* and *H. azurea*) or British Columbia (*M. californiensis*) to Cabo San Lucas (*H. azurea* and *M. californiensis* occur in the Gulf of California, as well). Larval *G. nigricans* and *M. californiensis* occur in modest numbers in CalCOFI ichthyoplankton samples, primarily during summer at stations between about Point Conception, California, and Punta Eugenia, Baja California Sur. Larval *G. nigricans* are most abundant within about 40 km from shore while *M. californiensis* increase in abundance out to about 280 km from shore. Larval *H. azurea* rarely occur in CalCOFI collections but are fairly common during summer and autumn within about 7 km from shore off southern California (e.g., Walker et al. 1987; Stevens et al. 1989). Larvae of all three species, and especially *H. azurea*, tend to be most abundant in the upper region of the water column (Stevens et al. 1989).

Kyphosids are medium-size to large (most species ca. 40–60 cm, largest to nearly 1 m) residents primarily of coastal waters in all warm seas. They are moderately deep-bodied and compressed with a relatively small head and rounded snout which results in an oval profile. The dorsal fin is long-based and continuous. The short- to long-based anal fin is opposite the soft-rayed portion of the dorsal fin. The caudal fin is emarginate to shallowly forked. Pectoral fins are relatively short and rounded. The body, and often the proximal parts of the median fins are covered with small ctenoid scales. Although there are some brightly colored species, most kyphosids are drably colored in browns or greys; some are striped, others are barred, and at least some *Kyphosus* species can switch between the drab coloration and a white-spotted pattern.

Planktonic larvae have been described for several kyphosid species, but little is known of spawning and eggs. As far as is presently known, the kyphosids are oviparous, spawning planktonic eggs that are spherical, ca. 1.0–1.1 mm in diameter, with a smooth chorion, a homogeneous yolk, and a single oil globule ca. 0.2–0.3 mm in diameter (e.g., Mito 1957, 1963; Watson and Leis 1974; Stevens et al. 1989). Larvae hatch at a length of ca. 2.4–3.0 mm with unpigmented eyes, an unformed mouth, lacking pectoral fin buds, and with a large yolk sac containing the oil globule posteriorly (Orton 1953a; Mito 1957, 1963; Walker and Watson 1983; Stevens et al. 1989). Larvae initially are slender, slightly compressed, and have a straight gut extending to about 40–50% BL. With growth they become deeper-bodied and more compressed. The gut coils during the preflexion stage and preanal length increases during the flexion and/or postflexion stage to ca. 50–60% BL. The head is moderate, initially with a short, rounded snout which lengthens but remains more or less rounded. Small spines form on the preopercular margin late in the preflexion stage or during notochord flexion, and small spines may form on the opercular, subopercular, interopercular, and supracleithral bones as well, depending on the species (e.g., Uchida et al. 1958b; Walker and Watson 1983; Konishi 1988e; Stevens et al. 1989). The principal caudal rays are the first fin rays to begin forming shortly before notochord flexion. Dorsal, anal and pectoral fin rays form during notochord flexion, and pelvic fin rays usually form last, beginning just before or after completion of flexion. Kyphosids are lightly to moderately pigmented initially, but commonly become heavily pigmented on the dorsum (most often with large, discrete melanophores), dorsally on the gas bladder and gut, and along the ventral margin of the tail. Melanophores form on the lateral midline of the tail during the flexion stage in many species and other lateral pigmentation commonly forms on the tail during the flexion or early postflexion stage and subsequently spreads to cover the body. Kyphosids typically are heavily pigmented by the end of larval development.

The distinctive pigmentation along the dorsal and ventral margins, lateral pigmentation in flexion stage and older larvae, 25–27 myomeres, small preopercular spines, and fin ray counts in postflexion stage larvae should preclude confusion of the kyphosids with any other fish larvae in the CalCOFI study area. Some carangid larvae are pigmented like the kyphosids, but are easily distinguished from the kyphosids by their larger preopercular spines, their supraoccipital crest (none in kyphosids), and their longer preanal length during the preflexion stage (>50% BL, usually near 60% vs. <50% BL except ca. 45–60%, usually about 50%, in Kyphosinae). The three kyphosid species commonly collected as larvae in the CalCOFI study area are distinguished by species-specific combinations of pigment patterns and myomere and fin-ray counts. Larval *Kyphosus* (and/or *Sectator*) have been collected occasionally at the southern end of the pattern; these closely resemble *Hermosilla* during the preflexion stage and are difficult to distinguish from it. Fin-ray counts and pigmentation, particularly the lateral pigment on the trunk and tail, readily distinguish the older larvae. It is unknown how larval *Kyphosus* and *Sectator* might be distinguished, except by small meristic differences in later stages (Table Kyphosidae 1).

The following descriptions of *Girella nigricans*, *Hermosilla azurea*, and *Medialuna californiensis* are taken from Stevens et al. (1989). A few larvae used in that study were recategorized as follows: *Girella nigricans*, 2.8 and 3.1 mm larvae changed from preflexion to yolk-sac stage, and 15.8 and 16.5 mm postflexion larvae changed to transformation stage; *Medialuna californiensis*, four juveniles 11.8–13.5 mm reclassified as transformation stage. Larval *Kyphosus* are not described here; see Moore (1962), Miller et al. (1979), Walker and Watson (1983), and Konishi (1988e) for descriptions and illustrations. Meristic data were obtained from Miller and Lea (1972), Thomson et al. (1979), Stevens et al. (1989), Allen and Robertson (1994), and counts made during this study. Ecological information is from the same literature sources.

Table Kyphosidae 1. Meristic characters for the kyphosid species in the California Current vicinity. All have 9+8 principal caudal fin rays and I,5 pelvic fin rays.

	Vertebrae			Fin rays				
Taxon	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers
Girellinae								
Girella nigricans	11	16	27	XII–XIV,12–15	III,10–13	18–20	10–12+9–10	11–14+16–21
Kyphosinae								
Hermosilla azurea	10	15	25	X–XI,11	III,9–10	15–16	9–11+9–10	6–7+11–14
Kyphosus analogus	10	16	26	XI,14	III,13–14	17–19	9–10+8–9	8+16
K. elegans	10	16	26	XI–XII,12–13	III,12	17–19	8–9+7–8	
Sectator ocyurus	10	16	26	XI,14–16	III,13–14	19–20	10–11+9–10	8–10+19–21
Scorpidinae								
Medialuna californiensis	10	15	25	IX–X,22–27	III,17–21	17–20	11–13+10–11	6–8+14–17

MERISTICS

	Range	Mode
Vertebrae:		
Total	27	27
Precaudal	11	11
Caudal	16	16
Fins:		
Dorsal spines	XII–XIV	XIV
Dorsal rays	12–15	13
Anal spines	III	III
Anal rays	10–13	11
Pelvic	I,5	I,5
Pectoral	18–20	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–12	11
Lower	9–10	9–10
Gill rakers:		
Upper	11–14	
Lower	16–21	
Branchiostegals	6–7	6

LIFE HISTORY

Range: San Francisco Bay, California, to Cabo San Lucas, Baja California Sur

Habitat: Coastal waters to ca. 30 m depth, commonly around kelp forests & rocky reefs; pelagic juveniles near surface, often associated with floating material, move inshore to tidepools at ca. 25 mm length & into subtidal zone after ca. 75 mm length

Spawning season: Larvae collected May–December, primarily in June & July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Johnson 1984
Orton 1953a
Stevens et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 3.0 mm
Flexion length: 5.8 mm through 7.9–8.4 mm
Transformation length: 15.7–16.5 mm
Fin development sequence: C_1, 2D & P_1, A & C_2, P_2, 1D
Pigmentation: *Yolk-sac*—Initially few on hindgut, ventrally on first few postanal myomeres, & on yolk sac; increasing & spreading forward on gut & posteriorly on tail; posteriorly on dorsal margin of tail by mid-stage; eyes pigmented by end of stage. *Preflexion*—1 (large) over midbrain & another at nape; increasing over midbrain & over forebrain by ca. 4.5 mm; internally below otic capsule; in roof of mouth by ca. 5 mm; posterior dorsal tail pigment spreading forward along full length of trunk & tail by ca. 4.5 mm; decreasing to 0–1 dorsally on notochord tip; decreasing to 1 ventrally along notochord tip. *Flexion*—Increasing dorsally on head; on opercular area behind mid-eye; on lower jaw; at angular; on isthmus; increasing laterally & ventrally on gut; on lateral midline posteriorly on tail & internally above & below vertebral column in same area, all 3 series spreading forward; at middle of hypural margin, spreading along full length of margin. *Postflexion–transformation*—Increasing generally on head & body. *Pelagic juvenile*—Dark dorsally, lower half silvery; gradually covering 1D & proximal half of 2D; little anteriorly on A.
Diagnostic features: Little or no pigment on notochord tip after yolk absorption; usually an even series on ventral margin of tail beginning at first postanal myomere; no bar on tail; strong midlateral stripe in postflexion through early juvenile stage; 1–2 ventrally on gut; D XII–XIV,12–15 & A III,10–13 (countable by ca. 10 mm); fewer, smaller preopercular spines & shorter preanal length than *Hermosilla* or *Medialuna*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	35–39 37	32–44 38	34–45 39	43–55 49	50–54 52	52–56 54
BD/BL	16–18 17	13–21 18	17–22 20	21–26 24	24–25 24	24–29 27
HL/BL	20–21 20	19–28 22	21–29 26	28–33 30	32–32 32	30–32 31
HW/HL						
SnL/HL	14–25 20	14–27 20	15–27 22	20–24 22	23–24 24	24–26 25
ED/HL	31–43 37	32–58 42	33–47 37	31–36 34	30–31 30	31–33 32
P_1L/BL	7–10 8	5–16 10	6–15 11	14–18 15	17–20 19	18–25 21

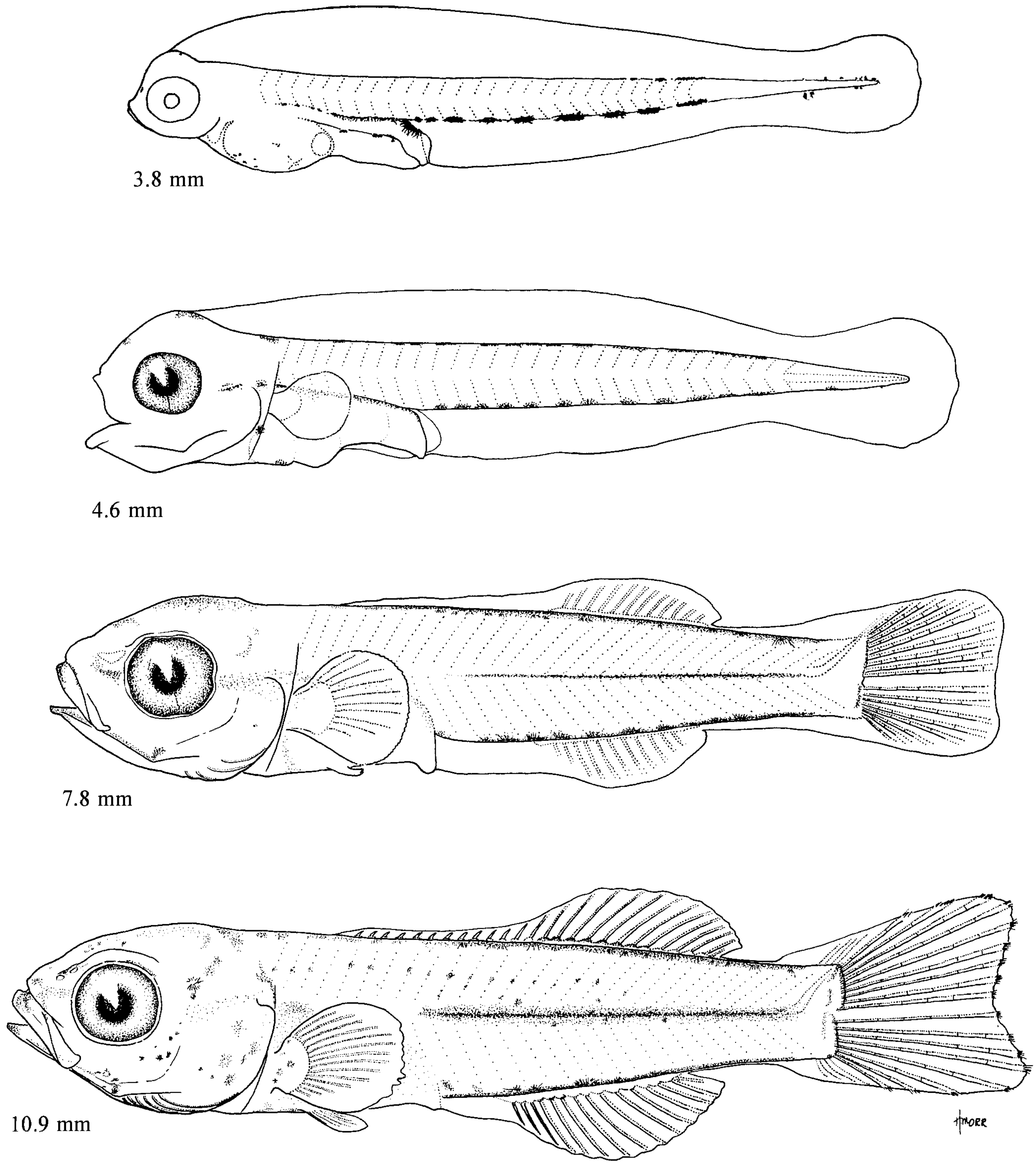

Figure Kyphosidae 1. Yolk-sac larva, 3.8 mm; preflexion larva, 4.6 mm; late flexion larva, 7.8 mm; postflexion larva, 10.9 mm (Stevens et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	X–XI	XI
Dorsal rays	11	11
Anal spines	III	III
Anal rays	9–10	10
Pelvic	I,5	I,5
Pectoral	15–16	15–16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–11	10
Lower	9–10	9–10
Gill rakers:		
Upper	6–7	
Lower	11–14	
Branchiostegals	7	7

LIFE HISTORY

Range: Monterey Bay, California, to Cabo San Lucas, Baja California Sur & throughout Gulf of California

Habitat: Shallow coastal waters to ca. 8 m depth

Spawning season: Larvae collected July–September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Stevens et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: 4.1–4.6 mm through 5.9–6.3 mm
Transformation length: >10.8 mm, <14.3 mm
Fin development sequence: C_1, 2D & A, 1D & P_1 & C_2, P_2
Pigmentation: *Preflexion*—Over midbrain, increasing; in roof of mouth; on tips of jaws beginning between 2.8–3.1 mm; on gular area by 2.8 mm; internally below otic capsule by 2.6 mm; dorsally on hindbrain by 2.8 mm, increasing; series of large, discrete melanophores on dorsal margin of trunk & tail to ca. myomere 20; dorsally on gas bladder & gut, increasing & spreading ventrad; 1–6 on ventral margin of gut; series of large, discrete melanophores on ventral margin of tail to myomere 20–21; 1–4 (small) under notochord tip; posteriorly on lateral midline near end of stage. *Flexion*—Increasing on dorsum, spreading anteriorly onto snout & posteriorly to myomere 21–22; on jaws & gular area; on opercle by 4.4 mm, increasing to cover entire area; increasing on gut; internal series over vertebral column; spreading forward along lateral midline; bar may form proximally on caudal peduncle. *Postflexion*—Increasing on all areas to cover body by end of stage; on 2D except D 1–5 & on A 5–9 or 10 by 7–8 mm; on 1D, A I–III, & proximally on upper P_1 rays by 9.6 mm. *Pelagic juvenile*—Becoming indistinctly barred, then mottled; on P_2.
Diagnostic features: No pigment dorsally & little ventrally on notochord tip; usually an even series on ventral margin of tail beginning at first postanal myomere; bar forms on tail during flexion or early postflexion stage; 1–6 (usually 3–4) ventrally on gut; juvenile mottled; D X–XI,11 & A III,9–10 (countable by 5.5–6.0 mm); more robust form, longer Sn-A distance, smaller size at stage than *Girella* or *Medialuna*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–56 51	49–59 54	56–59 57		56–60 58
BD/BL		18–26 23	21–28 25	25–28 26		29–32 31
HL/BL		22–32 28	26–37 32	29–34 32		30–34 33
HW/HL						
SnL/HL		14–27 22	22–27 25	22–27 24		17–23 20
ED/HL		36–50 40	34–40 37	36–40 39		31–37 34
P_1L/BL		9–14 12	10–15 13	11–21 16		22–28 25

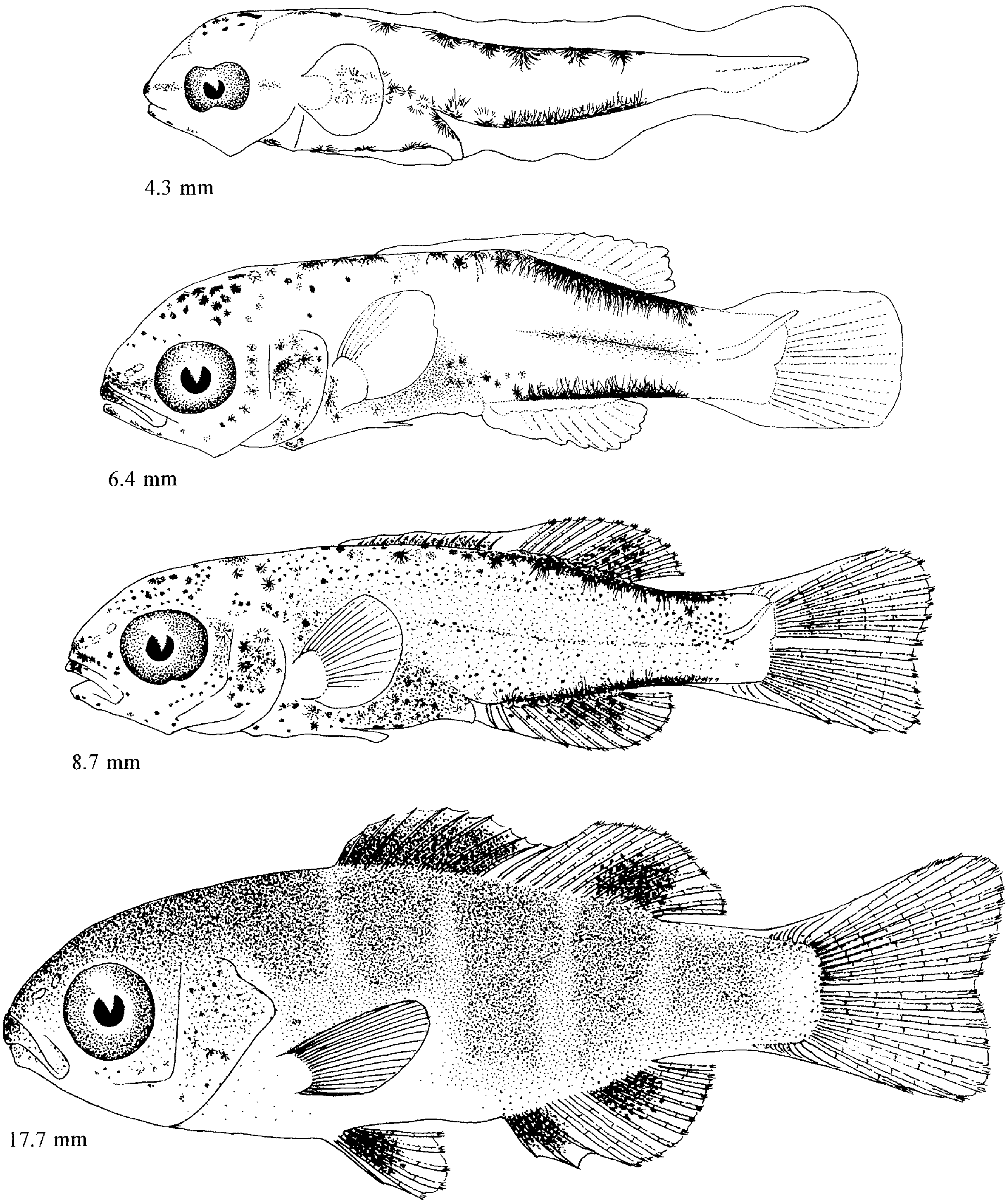

Figure Kyphosidae 2. Preflexion larva, 4.3 mm; postflexion larvae, 6.4 mm, 8.7 mm; pelagic juvenile, 17.7 mm (Stevens et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	IX–X	X
Dorsal rays	22–27	25
Anal spines	III	III
Anal rays	17–21	19
Pelvic	I,5	I,5
Pectoral	17–20	18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	11–13	
Lower	10–11	
Gill rakers:		
Upper	6–8	
Lower	14–17	
Branchiostegals	7	7

LIFE HISTORY

Range: Vancouver Island, British Columbia, to lower Gulf of California

Habitat: Coastal waters to ca. 40 m depth, commonly around rocky reefs & kelp forests; pelagic juveniles near surface, often associated with floating material

Spawning season: Larvae collected April–October with strong July maximum

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Johnson 1984
Stevens et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.20 mm
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.6 mm
Flexion length: 5.8–8.4 mm
Transformation length: ca. 11.8–13.5 mm
Fin development sequence: C_1, 2D & A & P_1 & C_2, 1D, P_2
Pigmentation: *Yolk-sac*—30–40 on dorsal margin between midtrunk & notochord tip, condensing to 18–20 on trunk & tail separated from 5–7 (smaller) on notochord tip; >40 over gut & continuing along ventral margin of tail to notochord tip, those on tail condensing to 16–20 separated from 5–7 (smaller) on notochord tip; forming on gular area & snout as eyes become pigmented. *Preflexion*—Over midbrain, increasing; internally under forebrain; internally below otic capsule; on lower jaw; dorsal margin series continues to condense & disappears from trunk; 1–4 posteriorly on lateral midline of tail by ca. 3.8 mm; ventral tail series continues to condense & disappears from first few postanal myomeres; decreasing on notochord tip. *Flexion*—Increasing dorsally on head; on opercular area behind mideye; spreading ventrad to nearly cover gut; spreading forward along lateral midline & dorso- & ventrolaterally from posterior part of series. *Postflexion*—Increasing on head & gut; dorsal, lateral, & ventral series extend forward; sheath extends forward from caudal peduncle to cover tail & posterior part of trunk by end of stage; on posterior half of 2D. *Transformation*—Increasing on all areas; forming on 1D & posteriorly on A. *Pelagic juvenile*—Body covered; heavy on 1D & all but short anterior section of 2D; heavy on A spines & posterior rays; on P_2 beginning proximally.
Diagnostic features: Usually several melanophores dorsally & ventrally on notochord tip in preflexion stage, decreasing during flexion; usually little or none ventrally on first few postanal myomeres after yolk-sac stage; bar forms on tail during flexion stage; no pigment ventrally on gut; D IX–X,22–27 & A III, 17–21 (countable by ca. 10 mm); longer preopercular spines than *Girella* & *Hermosilla*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–43 40	38–51 44	45–56 51	57–59 58	53–57 55
BD/BL		13–20 17	18–25 22	22–28 24	28–30 29	29–30 29
HL/BL		15–25 21	20–32 27	26–35 30	32–35 34	31–36 33
HW/HL						
SnL/HL		13–27 19	19–27 24	18–22 20	17–22 20	18–22 20
ED/HL		34–51 40	33–48 40	30–40 36	30–34 32	28–34 32
P_1L/BL		7–12 10	10–16 12	13–22 17	20–24 22	21–24 22

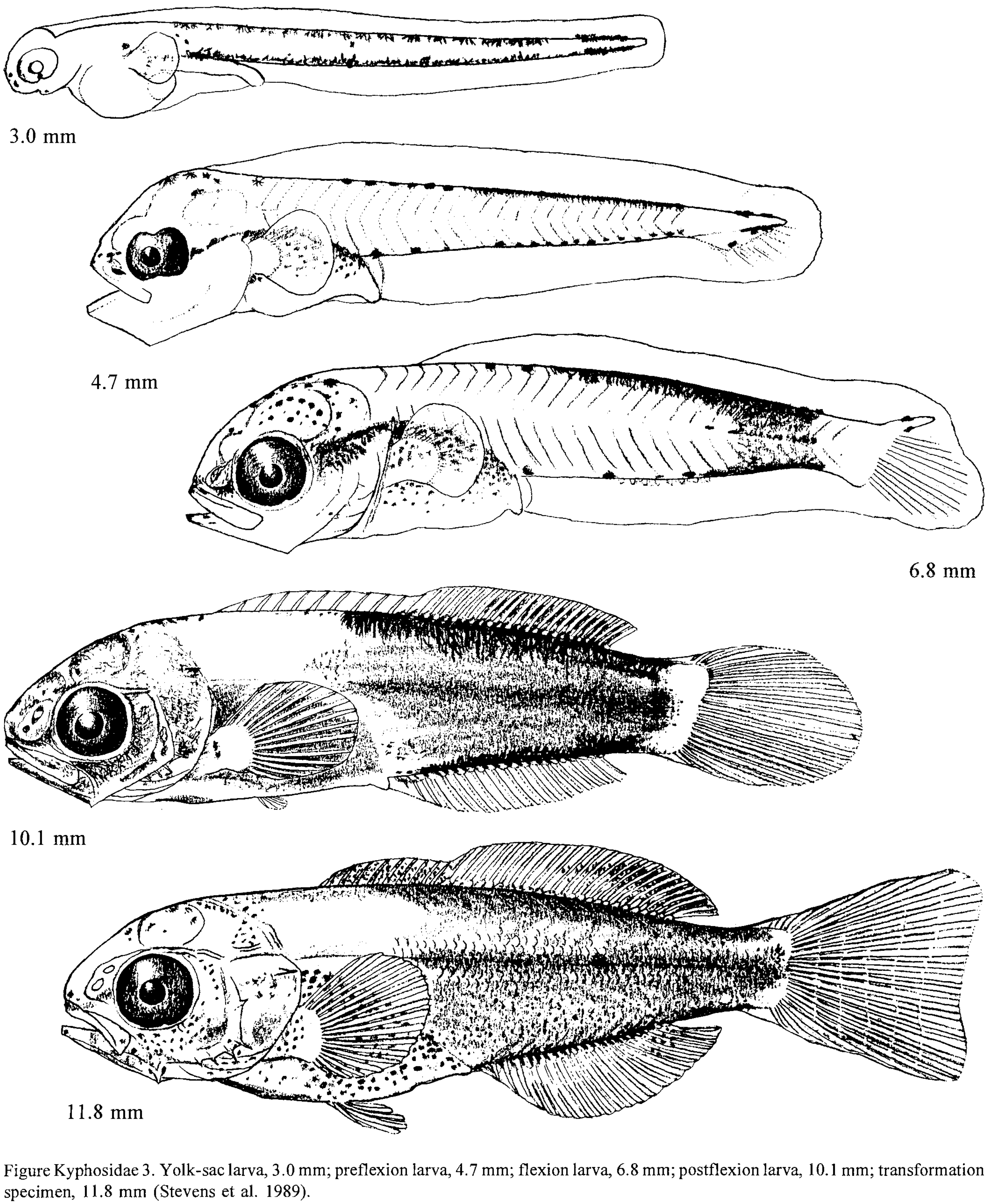

Figure Kyphosidae 3. Yolk-sac larva, 3.0 mm; preflexion larva, 4.7 mm; flexion larva, 6.8 mm; postflexion larva, 10.1 mm; transformation specimen, 11.8 mm (Stevens et al. 1989).

EPHIPPIDAE: Spadefishes

D. A. Ambrose

Ephippidae includes seven genera with about 20 species of fishes (Nelson 1994) which occur in all tropical and some temperate seas. Winterbottom (1993) suggested that spadefishes be included in the suborder Acanthuroidei with the surgeonfishes, instead of in the Percoidei. Only *Chaetodipterus zonatus*, the Pacific spadefish, ranges into the CalCOFI study area to San Diego (Eschmeyer et al. 1983). The Panama spadefish, *Parapsettus panamensis*, also occurs in the Gulf of California and both species range south to Peru. Larval *C. zonatus* are rarely collected in CalCOFI ichthyoplankton tows from off southern Baja California.

Adult spadefishes are deep-bodied and compressed. Most are under 46 cm SL, but some reach 91 cm SL. The mouth is small with vomerine and palatine teeth absent. Gill membranes are attached to the isthmus and a gas bladder is present. A comb-like series of blunt gill rakers are on the first epibranchial (Johnson 1984). Meristics for the family are: V 10+14; D V–IX,18–40; A III,15–18; P_1 I,5; C_1 9+8; C_2 3–7+3–6; Br 6.

Eggs and larvae have been described only for *Chaetodipterus* (e.g., Martínez-Pecero et al. 1990; Ditty et al. 1994a). Eggs are bouyant, spherical, ca. 1 mm in diameter with a single oil globule. Larvae have a robust, deep body which becomes compressed; a small, peak-like, median supraoccipital crest with a single spine dorsally; large preopercular spines, numerous serrated ridges, and other spination on the head. Specialized spinous scales develop during the postflexion stage that eventually transform into the typical adult ctenoid scales. Pigment is initially heaviest anteriorly on the body and spreads posteriad with growth. Notochord flexion and development of median fin rays occur at very small sizes (<5 mm). Larval head spines are more complex and diverse than adult head spines. Juveniles typically display a pattern of dark bands or bars laterally on the body.

The following description of *C. zonatus* is based on detailed examination of 3 preflexion larvae (2.5–3.1 mm), 2 flexion larvae (4.1 and 4.3 mm) and on the literature (Martínez-Pecero et al. 1990). Ecological information was obtained from Eschmeyer et al. (1983) and Allen and Robertson (1994). The 2.8 mm preflexion larva illustrated in Figure Ephippidae 1 was collected in Panama where *Parapsettus panamensis* also occurs. Seven preflexion larvae (2.8–3.3 mm) examined from IATTC collections from Panama had slightly heavier pigment on the pectoral fin base and along the postanal ventral midline of the tail, but otherwise were identical to the preflexion specimens from Baja California. Meristics for *P. panamensis* are D IX,28; A III,24–26; P_1 18 (Allen and Robertson 1994; Schneider 1995).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	18–23	21
Anal spines	II–III	III
Anal rays	16–20	18
Pelvic	I,5	I,5
Pectoral	16–18	17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	5–6	5
Lower	4–5	5
Gill rakers:		
Upper	5–6	
Lower	9–10	
Branchiostegals	6	6

LIFE HISTORY

Range: San Diego to northern Peru, including the Gulf of California

Habitat: Inshore to 46 m depth, usually in small schools

Spawning season:

ELH pattern: Oviparous, eggs & larvae planktonic

LITERATURE

Martínez-Pecero et al. 1990

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.5 mm, 2.8 mm (N. Arthur)
Flexion larva, 4.3 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.99–1.08 mm **Yolk:** Segmented
No. of OG: 1 **Diam. of OG:** ca. 0.13 mm
Shell surface: Smooth, transparent
Pigment: On embryo, yolk & oil globule
Diagnostic features:

LARVAE

Hatching length: 1.8 mm
Flexion length: ca. 3.7 mm
Transformation length: ca. 9–12 mm
Fin development sequence: C, P_1, 2D & A, 1D & P_2
Pigmentation: *Preflexion*—Dorsally on mid- & hindbrain, ventrally on forebrain & anteriorly on gut; scattered dorsally, ventrally & posteriorly on gut; on nape, branchiostegal & gular regions; on angular & P_1 base; ca. 9 along postanal ventral midline of tail. *Flexion*—Scattered across trunk; ventral tail series decreases. *Postflexion*—2 vertical unpigmented areas (over preopercle & over eye); on P_2. *Transformation*—Spreading posteriad over body. *Juvenile*—Heavy over entire body & >50% of D & A.
Diagnostic features: Myomeres 24; in preflexion stage, distinctive melanophores ventrally on forebrain & anteriorly on gut; by ca. 3 mm, a single peak-like spine on supraoccipital crest; large preopercular spines & numerous serrate ridges & other head spines develop; during the postflexion stage, specialized spinous scales begin forming first on head & spread to cover entire body by juvenile stage; body deep, robust, becoming laterally compressed; heavy body pigmentation; head spination greatly reduced by juvenile stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–52 49	51–62 59	59–64 62	56–62 60	51–60 56
BD/BL		28–41 35	38–55 48	57–64 60	57–61 58	54–69 60
HL/BL		22–36 28	37–44 39	38–46 40	37–42 40	32–37 34
HW/HL		53–76 61	66–88 73	60–65 63	50–63 56	46–56 52
SnL/HL		17–22 20	19–25 22	17–25 22	21–28 24	28–37 32
ED/HL		33–51 40	30–37 33	23–39 33	29–38 34	30–34 32
P_1L/BL						
P_2L/BL						

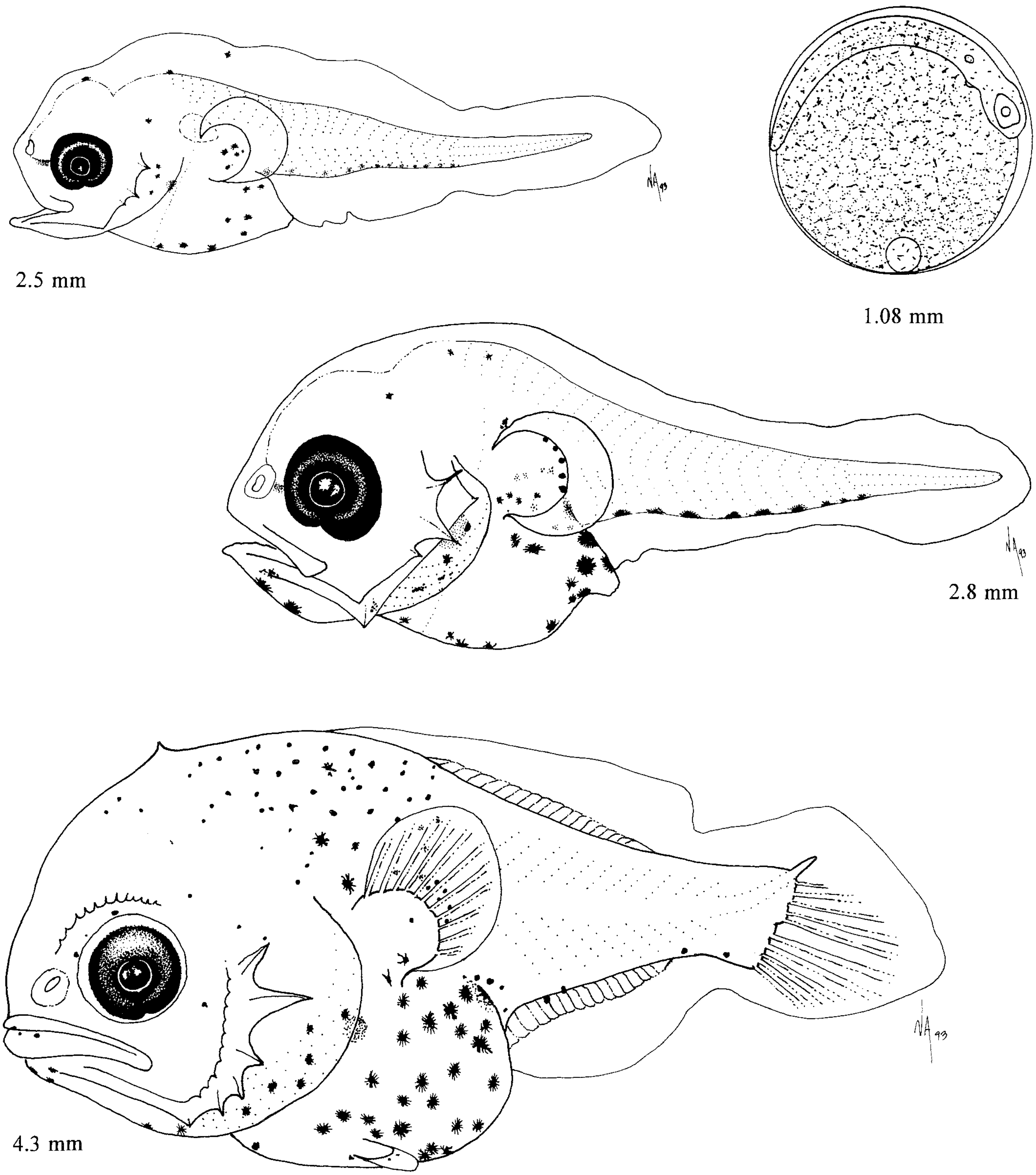

Figure Ephippidae 1. Egg, 1.08 mm (Martínez-Pecero et al. 1990); preflexion larvae, 2.5 mm (CalCOFI 5209, station 137.23), 2.8 mm (IATTC 90027, station T5); flexion larva, 4.3 mm (CalCOFI 5209, station 137.23).

CHAETODONTIDAE: Butterflyfishes

W. WATSON

Four of the 114 butterflyfish species, representing three of the ten genera, may occur in the California Current vicinity (Table Chaetodontidae 1) although only two, *Chaetodon falcifer* and *C. humeralis*, are likely to be encountered in the CalCOFI area. Both species range northward to southern California but, like other chaetodontids, are primarily tropical and subtropical. Small numbers of larvae have been taken in ichthyoplankton collections from the Gulf of California and farther south, but none has been identified in CalCOFI collections.

Adult butterflyfishes are small (most species ca. 15–30 cm) schooling or solitary residents of tropical and subtropical reefs. Most species inhabit water <20 m deep; a few range to as deep as 200 m. Chaetodontids are strongly compressed and ovoid in profile, with a slightly to very produced snout and small terminal mouth, and a truncate or rounded caudal fin. Most are brightly colored, often with striking patterns of bars, stripes, or spots. Many are well known in the aquarium trade.

Spawning is known for a few chaetodontid species (e.g., Colin and Clavijo 1988). The transparent, spherical, planktonic eggs are ca. 0.7–1.0 mm in diameter, have a smooth unornamented chorion, and contain a single oil globule ca. 0.2 mm in diameter (e.g., Burgess 1978; Suzuki et al. 1980; Colin and Clavijo 1988). *Chaetodon nippon* hatches at a length of ca. 1.5 mm, with a large yolk sac containing a posterior oil globule, unpigmented eyes, an unformed mouth, and lacking pectoral fin buds (Suzuki et al. 1980). Preflexion stage chaetodontids initially are slender, with preanal length ca. 60–70% BL, a short rounded snout, and slightly oval to round eyes. Late in the preflexion stage or during notochord flexion the gut coils, body depth increases to ≥50% BL, and the larvae become strongly compressed. A large preopercular spine develops during the preflexion stage. Large bony plates may form on the supracleithral and posttemporal bones, and supraocular, supraoccipital, and additional smaller preopercular spines may form, depending on species (e.g., Leis and Rennis 1983; Leis 1989). The enlarged preopercular spine together with the supracleithral and posttemporal plates characterize the "tholichthys" stage. Larval pigmentation initially is moderate, mainly on the dorsum, ventrum, and gut, but it becomes heavy during the postflexion stage, covering much of the body. Tholichthys-stage individuals may be silvery in life (Leis and Rennis 1983).

Larval butterflyfishes in the California Current vicinity are unlikely to be confused with any others, except very early in the preflexion stage (<2 mm) when they resemble carangids. Once the preopercular spine begins to form (ca. 2 mm), its broad shape distinguishes the chaetodontids from the carangids, which develop much thinner, pointed, and more numerous preopercular spines (see Carangidae, this volume). It is unknown how young larvae of the chaetodontid species might be distinguished from one another but postflexion stage and older specimens usually can be identified by a combination of dorsal, anal, and pectoral fin ray counts (Table Chaetodontidae 1).

The following description of *Chaetodon humeralis* is based on detailed observation of 10 preflexion stage larvae (1.9–4.0 mm), single flexion (4.0 mm) and postflexion stage (6.2 mm) larvae, 9 tholichthys (6.7–27.3 mm), and a juvenile (29.5 mm) specimen. Larvae of the other species were unavailable. The tholichthys stage of *Forcipiger* was illustrated by Kendall and Goldsborough (1911) and a photograph was shown by Randall (1961). Meristic data were obtained from Hubbs and Rechnitzer (1958), Thomson et al. (1979), and counts made during this study. Ecological information was obtained from Thomson et al. (1979) and Eschmeyer et al. (1983).

Table Chaetodontidae 1. Meristic characters for the chaetodontid fishes in the California Current region. All have 24 vertebrae, 9+8 caudal fin rays, I,5 pelvic fin rays, and 7 branchiostegal rays.

Species	Fin rays				Gill rakers
	D	A	P_1	C_2	
Chaetodon falcifer	XIII,20–21	III,14–16	14–15	4+3	4–5+11
C. humeralis	XI–XIII,18–21	III,14–17	15–17	3–4+3	0
Forcipiger flavissimus	XI–XII,21–25	III,17–18	14–16		12–16 total
Johnrandallia nigrirostris	XII,23–25	III,18–19	16–17	3+3	

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	XI–XIII	XIII
Dorsal rays	18–21	19
Anal spines	III	III
Anal rays	14–17	16
Pelvic	I,5	I,5
Pectoral	15–17	16–17
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	3–4	3
Lower	3	3
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	7	7

LIFE HISTORY

Range: San Diego, California to Peru & Galápagos Islands

Habitat: Coastal waters, from tidepools to ca. 55 m depth (usually < ca. 15 m), usually over reefs or sandy bottom near reefs

Spawning season: Larvae collected primarily in August & September

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.7 mm (N. Arthur)
Flexion larva, 4.0 mm (N. Arthur)
"Tholichthys," 6.7 mm, 27.0 mm (N. Arthur)

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* All specimens included probably are *C. humeralis*, but only the postflexion & older specimens could be unequivocally identified as *C. humeralis*.
† Tholichthys stage.
‡ Eye is oval, becoming round by postflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <1.9 mm
Flexion length: 4 mm to <6.2 mm
Transformation length†: ca. 6.5–27.3 mm
Fin development sequence: C_1, D & A & P_1 & C_2, P_2
Pigmentation: *Preflexion–postflexion*—Heavy on dorsum from midbrain to myomere 15–17, extending caudad to myomere 22–23 by 4 mm, & spreading ventrad to cover most of upper half by ca. 6.2 mm; at tips of jaws; on sides of maxillaries; on preopercle; on gular area; on branchiostegal membranes & isthmus; externally on abdomen; on ventral margin of tail to postanal myomere 5–6, spreading caudad to postanal myomere 10 by 4 mm & dorsad to cover most of lower half by ca. 6.2 mm; 0–3 under notochord tip; series on lateral midline beginning at ca. 4 mm; internally under midbrain, on hindbrain, over gut & gas bladder; 0–few on anterior half of anal finfold. *Tholichthys*—Completely covered except none on P_1, A, C, or soft-rayed portion of D.
Diagnostic features: Large, broad, rounded preopercular spine; broad posttemporal plate present by 4 mm, supracleithral plate by 6 mm; myomeres 24 (usually 11–12+12–13); D soft rays usually 19–20 (present by 6 mm); heavy pigment on dorsum, ventrum, & gut; bar on caudal peduncle by 4 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr†	Juv
Sn-A/BL		60–70			69–73	
		65	64	72	70	63
BD/BL		24–40			59–67	
		30	39	57	65	65
HL/BL		25–35			39–48	
		31	36	47	44	37
HW/HL		47–67			49–69	
		53	46	54	55	54
SnL/HL		19–24			21–28	
		22	23	23	25	28
ED/HL‡		33–43× 30–35			31–39	
		37×33	37×34	34	35	37
P_1L/BL		6–9			23–29	
		7	9	15	27	28
P_2L/BL		0–0			17–34	
		0	0	13	29	30
PrS/HL		4–44			9–57	
		22	42	57	27	18

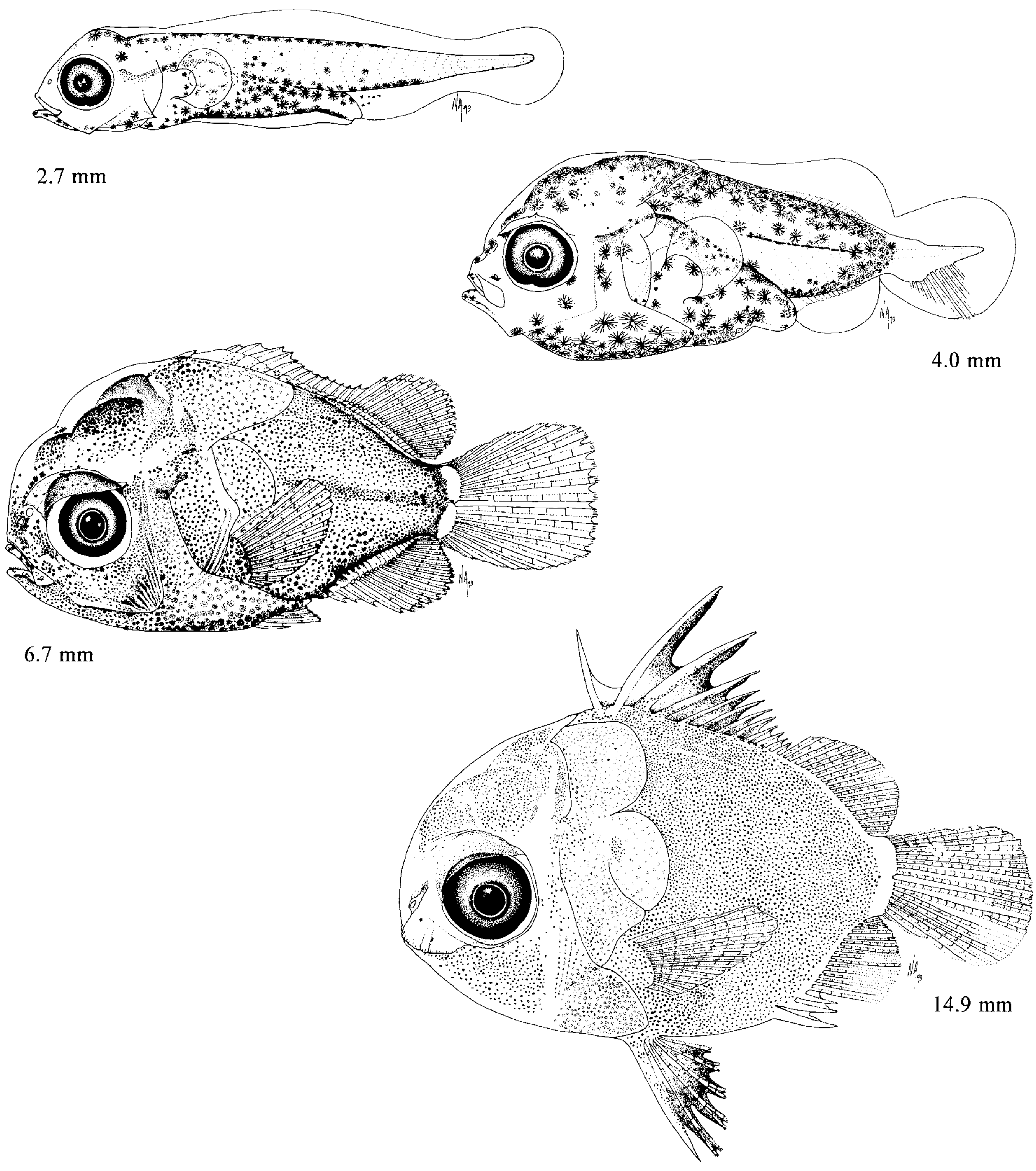


Figure Chaetodontidae 1. Preflexion larva, 2.7 mm (IATTC 90028, station MSL1 Red); early flexion larva, 4.0 mm (IATTC 90031, station MSH2 #2 Grn); "tholichthys" stage specimens, 6.7 mm (SIO 73–264), 14.9 mm (TO 58–1, station 75). Scales on the "tholichthys" specimens are not shown.

POMACENTRIDAE: Damselfishes

W. WATSON

The pomacentrids traditionally were considered percoid fishes (e.g., Greenwood et al. 1966; Nelson 1984) until Kaufmann and Liem (1982) transferred them (together with the cichlids and embiotocids) to Labroidei, based on similarities in pharyngeal anatomy. This placement has become widely, but not universally accepted. Richards and Leis (1984) argued that early life history characters provide little, if any, support for placement of the pomacentrids, cichlids and embiotocids in Labroidei and Eschmeyer (1990) retained all three in Percoidei. In this volume we follow Eschmeyer in retaining the pomacentrids in Percoidei. Pomacentridae contains about 321 species in 28 genera (Allen 1991); at least eight species in six genera occur in the CalCOFI study area (Table Pomacentridae 1) and another six species occur at, or near the southern limit of the study area (Allen and Robertson 1994; Schneider and Krupp 1995c). Two species, *Hypsypops rubicundus* and *Chromis punctipinnis* range northward to California. *Azurina hirundo* and *Stegastes leucorus* occur at Isla de Guadalupe within the CalCOFI study area (*A. hirundo* also is known from Rocas Alijos); *Abudefduf declivifrons*, *A. troschelii*, *C. alta* and *S. rectifraenum* occur off Baja Calfornia Sur in the study area. Larval *C. punctipinnis* are common in summer ichthyoplankton samples; larval *H. rubicundus* are less common, although small preflexion-stage larvae may be quite abundant at times. Among the others only larvae of *S. rectifraenum* and *A. troschelii* are common in CalCOFI samples.

Adult pomacentrids typically are small (≤30 cm), deep-bodied, compressed fishes. All are associated with rocky and coral substrates, or with kelp. Pomacentrids may be solitary and territorial (e.g., *Hypsypops*), or may "school" (e.g., *Chromis*).

Pomacentrids are oviparous with oval, attached, demersal eggs. The eggs, typically ca. 1–2 mm long and containing 1–2 small oil globules, are attached by adhesive filaments from their basal poles to the nest substrate, which is prepared by the male (or both) parent(s). The male (or both parents) tends the nest during incubation, which ranges from 4–5 days to 2–3 weeks.

The planktonic larvae hatch with pigmented eyes, a functional mouth, and a small yolk sac. Preflexion stage larvae are characterized by a short preanal length (usually ≤40% BL), coiled gut, and pigment usually only on the ventral margin of the tail, on the gut, and dorsally on the head. Typically, the body becomes rather deep (>40% BL) during larval development, the gut lengthens to ca. 50% BL, and series of small spines form along the margins of one or more of the opercular series of bones. Myomere counts are 25–27 (usually 26); preanal myomere counts commonly are about 6 for preflexion stage larvae and 10–11 for postflexion stage larvae.

Among fish larvae in the CalCOFI study area, the pomacentrids are most likely to be confused with nomeids of the genus *Cubiceps* (preflexion stage only), and preflexion stage *Chromis punctipinnis* are likely to be confused with *Scomber japonicus*. In both cases, the pomacentrids have fewer myomeres (25–27, usually 26) than the others (all with ≥30). Older larvae are readily recognizable as pomacentrids and should not be confused with the larvae of any other family in the area.

Early life histories are poorly documented for the eastern Pacific pomacentrids. Since courtship and nesting behavior are readily observable and nests are relatively easily collected, the eggs have been documented for some species, but larval descriptions generally are lacking. The following species accounts are based primarily on detailed examinations of larvae and juveniles of *C. punctipinnis* (42 specimens), *S. rectifraenum* (33), *H. rubicundus* (26), and *A. troschelii* (26) (Table Pomacentridae 2). The primary sources for adult meristic (Table Pomacentridae 1), distribution, and habitat data are Miller and Lea (1972), Thompson et al. (1979), Greenfield and Woods (1980), Eschmeyer et al. (1983), Allen and Robertson (1994), and Baxter and Clothier (unpublished manuscript). Additional meristic data were collected during the present study.

Table Pomacentridae 1. Meristic characters for the pomacentrid species likely to be encountered along the Pacific coast of California and Baja California. All have 26 vertebrae, 9+8 principal caudal fin rays, and I,5 pelvic fin rays. Gill raker counts for *Abudefduf declivifrons*, *Azurina hirundo*, *Chromis punctipinnis*, and *Stegastes leucorus* do not include epibranchial (upper) gill rakers.

	Fin rays				
Species	D	A	P_1	C_2	GR
Abudefduf declivifrons	XIII,12–13	II,10	19–20	4+4	16
A. troschelii	XII–XIII,12–13	II,11–12	19–20	3–4+3–4	23–33
Azurina hirundo	XII,10–12	II,11–12	20–21	4–5+4–5	25–27
Chromis alta	XIII,12–14	II,12–13	19–21	4+4	7–9+20–24
C. punctipinnis	XII–XIII,10–13	II,10–12	20–22	4–5+4–5	25–27
Hypsypops rubicundus	XI–XIII,15–17	II,12–15	23–24	3–4+3–4	3+12
Stegastes leucorus	XII,14–16	II,12–14	20–22	4+4	10–12
S. rectifraenum	XII,13–15	II,12–13	19–21	4+3–4	9–12+9–11

Table Pomacentridae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the pomacentrid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Abudefduf troschelii	0	2	9	5	4	1	5
		2.2–2.4	2.5–3.8	3.4–3.7	3.7–5.0	5.3	10.3–11.9
Chromis punctipinnis	L[a]	5	9	5	10	9	4
		2.7–3.4	3.2–4.8	5.1–5.6	5.3–7.4	6.6–12.8	13.4–23.7
Hypsypops rubicundus	10	6	10	1	2	1	6
		2.9–3.5	3.0–4.7	3.9	6.2–6.4	7.2	9.0–17.3
Stegastes rectifraenum	0	0	10	6	7	5	5
			2.1–3.5	2.9–4.0	3.6–4.5	4.6–5.4	5.8–13.0

[a] Turner and Ebert 1962

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XII–XIII	XIII
Dorsal rays	12–13	13
Anal spines	II	II
Anal rays	11–12	12
Pelvic	I,5	I,5
Pectoral	19–20	19–20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	3–4	4
Lower	3–4	4
Gill rakers:		
Total	23–33	
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Bahia San Juanico, Baja California Sur to Peru, & throughout Gulf of California

Habitat: Nearshore, usually near reefs; juveniles common in tidepools

Spawning season: Summer

ELH pattern: Oviparous; demersal eggs attached in nest prepared & guarded by male; planktonic larvae

LITERATURE

Thomson et al. 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.2 mm (B. Sumida MacCall)
Preflexion larva, 2.5 mm (B. Sumida MacCall)
Flexion larva, 3.5 mm (B. Sumida MacCall)
Transformation specimen, 5.3 mm (B. Sumida MacCall)

* Eye horizontally elongate at hatching, becoming round by transformation stage; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment: Yolk orange to pink
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 3.5 mm
Transformation length: ca. 5 mm through <10 mm
Fin development sequence: P_2, 1D & C_1, 2D & A, C_2, P_1
Pigmentation: *Yolk-sac*—Usually 3 in longitudinal series on nape; under hindbrain; on otic capsule; heavy on gas bladder, anteriorly & ventrally on gut; series on ventral margin of tail. *Preflexion*—Increasing on brain & gut; under opercle, spreading ventrad & onto branchiostegal membrane; on P_2; migrating internally on tail. *Flexion–postflexion*—Laterally on trunk, spreading ventrad & caudad except little externally on abdominal area; on 1D by 3.5 mm. *Juvenile*—Only distal parts of D & A rays, end of caudal peduncle, & C lack pigment.
Diagnostic features: P_2 develops at end of yolk-sac stage; 1D develops in preflexion stage before 2D or A; longitudinal series of nape melanophores; roughly uniform body pigment propagates caudad, except little or no external pigment laterally on abdominal area in larvae; barred after ca. 20 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	36–37 36	37–48 43	50–57 54	57–62 60	 61	62–67 64
BD/BL	24–28 26	24–36 31	37–42 39	41–42 42	 44	44–49 46
HL/BL	26–27 27	25–35 31	34–40 38	38–41 40	 44	37–40 38
HW/HL	62–64 63	57–73 66	58–64 62	59–60 59	 53	55–70 62
SnL/HL	20–24 22	20–33 28	25–40 29	25–28 26	 29	21–27 25
ED/HL*	42–48× 36–36	35–49× 33–41	36–43× 32–41	37–42× 36–37		35–40
	45×36	41×35	39×37	39×37	36	37
P_1L/BL	5–6 6	5–11 8	8–9 8	8–11 10	 11	21–23 22
P_2L/BL	0–0.2 0.1	2–13 7	16–25 20	21–28 23	 27	24–27 25

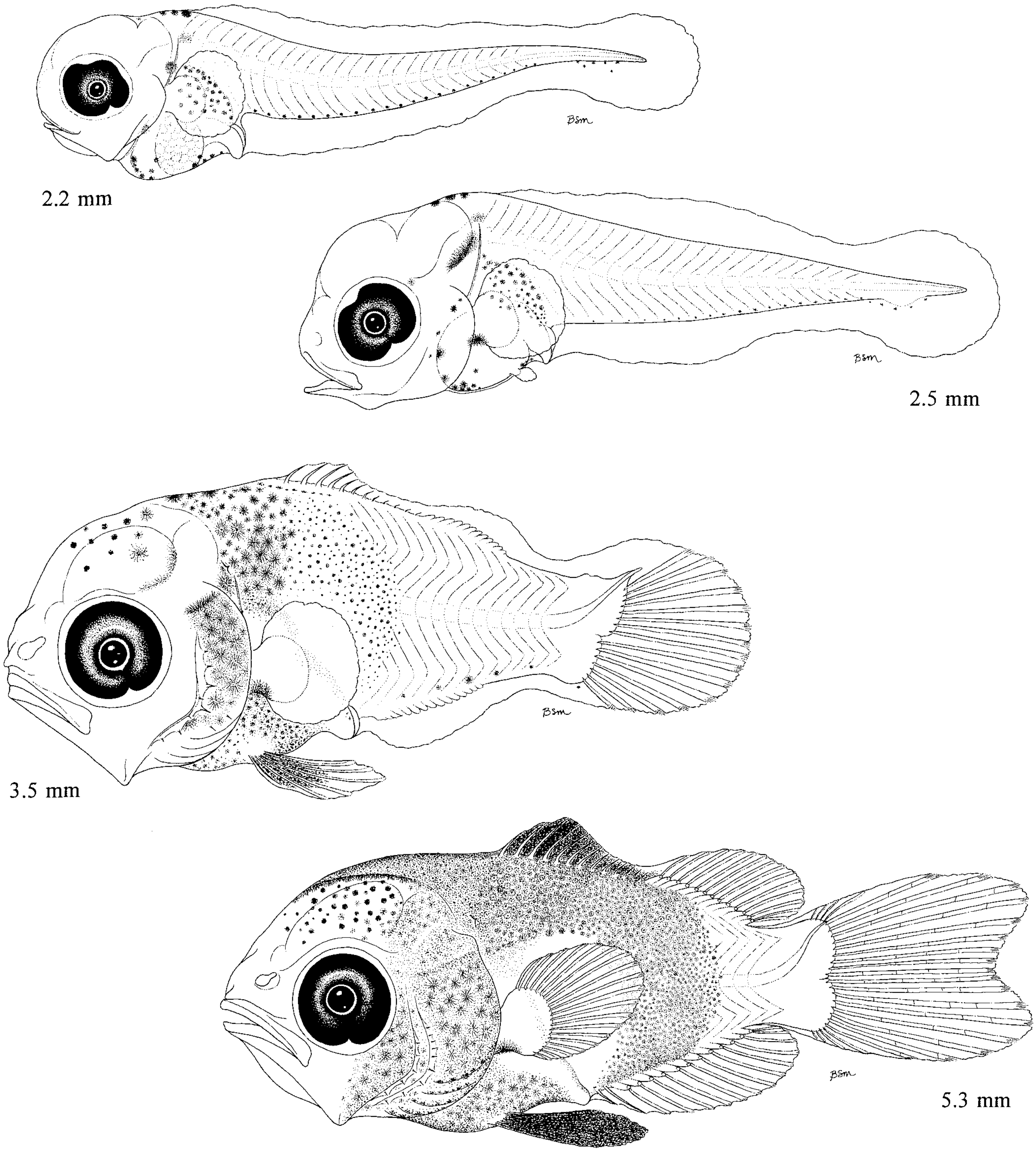


Figure Pomacentridae 1. Yolk-sac larva, 2.2 mm (CalCOFI 5708, station 111G.30); preflexion larva, 2.5 mm (CalCOFI 5708, station 154G.15); flexion larva, 3.5 mm (CalCOFI 5209, station 154G.12); transformation specimen, 5.3 mm, scales forming along lateral line not shown (CalCOFI 5209, station 137G.23).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XII–XIII	XIII
Dorsal rays	10–13	11–12
Anal spines	II	II
Anal rays	10–12	11
Pelvic	I,5	I,5
Pectoral	20–22	20–21
Caudal:		
Principal	17	17
Procurrent:	4–5	5
Upper	4–5	5
Lower		
Gill rakers:		
Upper		
Lower	25–27	
Branchiostegals	6	6

LIFE HISTORY

Range: Monterey, California to Isla de Guadalupe & Punta San Pablo, Baja California Sur; larvae may occur to at least Punta San Juanico, Baja California Sur

Habitat: Kelp beds, pilings, & rocky areas along open coast, surface to ca. 40 m depth

Spawning season: Summer

ELH pattern: Oviparous; demersal eggs attached under ledges or in small caves to nest sites prepared & guarded by males; planktonic larvae

LITERATURE

Ahlstrom 1965
Limbaugh 1964
Turner & Ebert 1962

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.4 mm (B. Sumida MacCall)

* Eye horizontally elongate at hatching, becoming round during transformation stage; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.1–1.3 × 0.6–0.7 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:**
Shell surface: Unsculptured; cluster of ca. 7 adhesive filaments at basal pole
Pigment: Yolk initially pink, becoming whitish; late embryo with larval pigmentation
Diagnostic features: Chorion oval, attached to substrate by cord composed of adhesive filaments

LARVAE

Hatching length: ca. 2.7–3.1 mm
Flexion length: ca. 5–7 mm
Transformation length: ca. 7–13 mm
Fin development sequence: C_1, P_1 & A & 2D, P_2 & C_2, 1D
Pigmentation: *Yolk-sac*—Pair over forebrain, moderate to heavy on gut, except may be none ventrally; series on ventral margin of most of tail. *Preflexion*—On mid- & hindbrain by 3.1–3.3 mm; on opercle by 4 mm; none on forebrain & none ventrally on gut by 4 mm; fewer on ventral margin of tail; by 4.4 mm, 1–3 each in vicinity of myomeres 15–20 on dorsal margin, lateral midline, & ventral margin. *Flexion–juvenile*—Increasing on each pigmented area; bar on tail by 6 mm; upper half mostly pigmented by 13.4 mm.
Diagnostic features: Pigment usually light to absent ventrally on gut; none on P_1 blade; dorsal, lateral, & ventral pigment posteriorly on tail by late preflexion stage, becoming a bar in flexion stage; relatively slender (BD usually ≤33% BL).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	31–39 33	36–43 40	45–49 47	50–56 53	54–58 56	47–58 55
BD/BL	16–29 20	21–26 24	27–30 29	29–34 32	32–34 33	26–35 32
HL/BL	18–21 19	19–29 26	33–36 34	35–40 37	35–42 38	28–35 32
HW/HL	63–72 68	56–76 65	56–68 62	45–63 57	48–60 55	49–64 55
SnL/HL	22–24 22	26–33 30	30–36 32	28–35 33	28–38 34	28–33 31
ED/HL*	44–50× 37–42 47×40	39–53× 31–43 43×37	36–39× 32–38 37×35	36–41× 33–39 38×36	32–39× 30–38 35×35	33–36 35
P_1L/BL	4–5 5	4–7 6	6–7 7	6–9 8	8–14 11	17–21 19
P_2L/BL	0 0	0 0	1–3 2	3–10 6	10–18 14	18–24 20

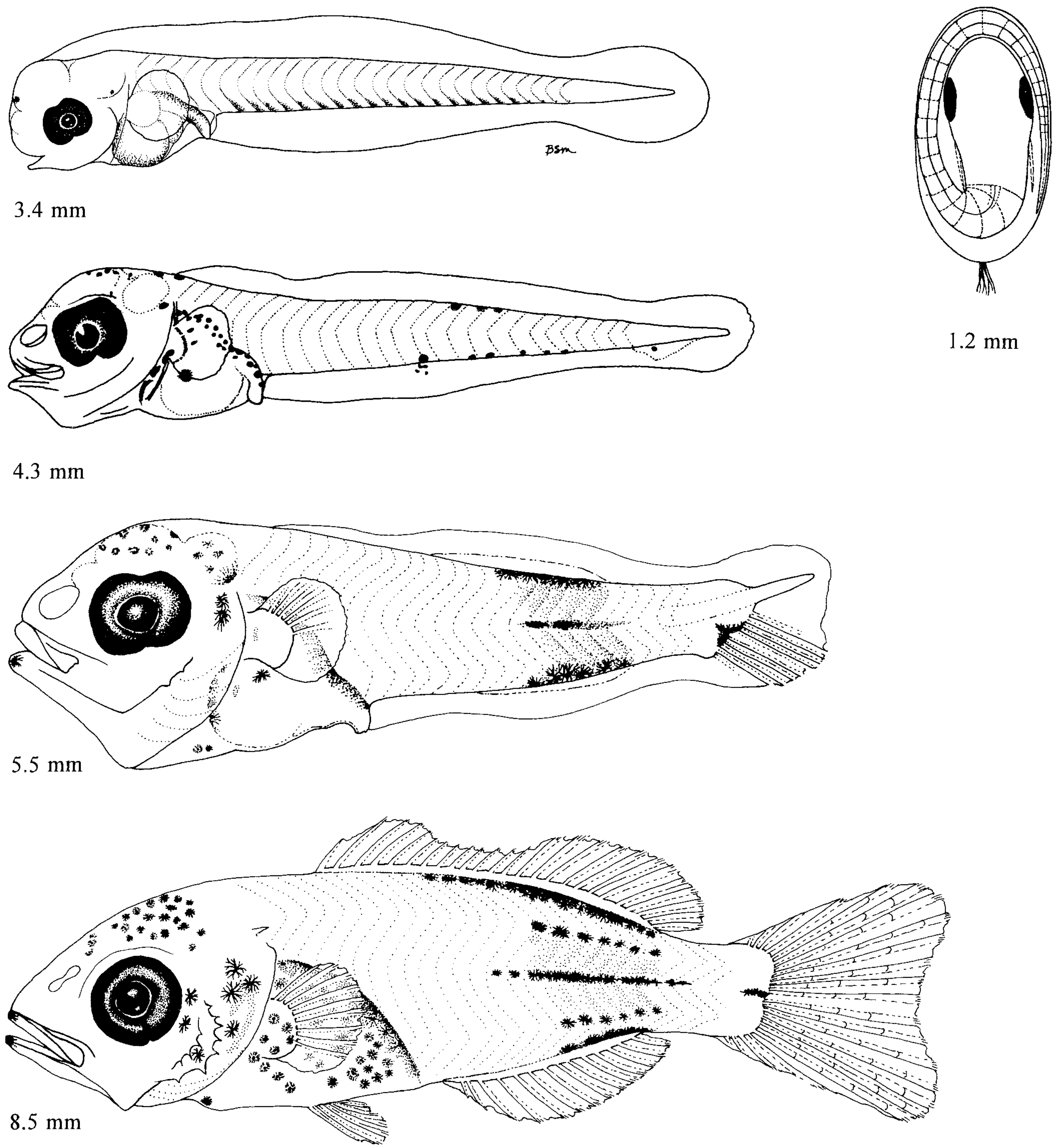


Figure Pomacentridae 2. Egg, ca. 1.2 mm long (Turner and Ebert 1962); newly hatched larva, 3.4 mm (CalCOFI 6608, station 110.32); preflexion larva, 4.3 mm (modified from Ahlstrom 1965); flexion larva, 5.5 mm (CalCOFI 5008, station 87.60); postflexion larva, 8.5 mm (modified from Ahlstrom 1965).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	15–17	16–17
Anal spines	II	II
Anal rays	12–15	14
Pelvic	I, 5	I, 5
Pectoral	23–24	23
Caudal:		
Principal	17	17
Procurrent:		
Upper	3–4	4
Lower	3–4	4
Gill rakers:		
Upper	3	3
Lower	12	12
Branchiostegals	6	6

LIFE HISTORY

Range: Monterey, California to Isla de Guadalupe & to Bahía Magdalena, Baja California Sur

Habitat: Rocky bottom along coast, intertidal to ca. 30 m depth; shelters in crevices & caves in reefs

Spawning season: Spring & summer

ELH pattern: Oviparous; demersal eggs attached in nest prepared & guarded by male; planktonic larvae, apparently primarily neustonic

LITERATURE

Limbaugh 1964

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.8 × 1.3 mm (B. Sumida MacCall)
Yolk-sac larva, 3.3 mm (B. Sumida MacCall)
Preflexion larva, 4.7 mm (B. Sumida MacCall)
Flexion larva, 3.9 mm (B. Sumida MacCall)
Postflexion larva, 6.2 mm (B. Sumida MacCall)
Juvenile, 14.1 mm (B. Sumida MacCall)

* The single flexion stage specimen available appears to be shrunken, thus proportions relative to body length probably are too large.
† Eye horizontally elongate at hatching, becoming round by transformation stage; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.2–1.3 × 0.7–0.8 mm **Yolk:** Homogeneous; 0.5–0.8 × 0.5 mm diam.
No. of OG: None **Diam. of OG:**
Shell surface: Unsculptured; cluster of adhesive filaments at basal pole
Pigment: Yolk initially orange-yellow, becoming green-grey; late stage embryos have larval pigment pattern
Diagnostic features: Chorion oval, attached to substrate by adhesive filaments at basal pole

LARVAE

Hatching length: 2.9–3.5 mm
Flexion length: 3.9–4.7 mm through <6.2 mm
Transformation length: ca. 7–9 mm
Fin development sequence: C_1, P_1, 2D & A, 1D & P_2 & C_2
Pigmentation: *Yolk-sac*—Heavy on gut & P_1 base; pair over forebrain; few over mid- & hindbrain; few to many on ventral margin of tail, except often none at myomeres 6–9 & 14–17; 1–2 (large) on dorsal & ventral margins at myomeres ca. 18–20. *Preflexion–postflexion*—Increasing on & over brain & on branchiostegal membrane; on P_1 blade by ca. 4 mm; tail pigment internal by ca. 4 mm; on posterior lateral surface of tail late in flexion stage. *Transformation*—Increasing on P_1; increasing anterolaterally & dorsally; bar posteriorly on tail.
Diagnostic features: Heavy gut pigment, especially ventrally in preflexion stage; P_1 pigment; large dorsal & ventral melanophores on tail, becoming internal by 4 mm; body deep after preflexion stage (usually ≥40% BL).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F*	PoF	Tr	Juv
Sn-A/BL	32–37	34–43		55–56		49–61
	34	38	52	55	56	56
BD/BL	20–28	23–31		40–40		46–53
	22	28	37	40	45	49
HL/BL	19–24	23–33		38–41		36–43
	21	27	45	39	41	40
HW/HL	63–71	57–100		68–72		66–71
	67	74	68	70	69	68
SnL/HL	24–29	24–36		29–33		21–29
	26	29	33	31	31	25
ED/HL†	43–50× 39–43	38–48× 34–41		41–42× 38–41		36–59
	46×40	44×39	36×32	41×40	38	40
P_1L/BL	3–4	6–10		15–18		24–28
	3	8	18	16	18	26
P_2L/BL	0	0		7–9		19–31
	0	0	0	8	17	27

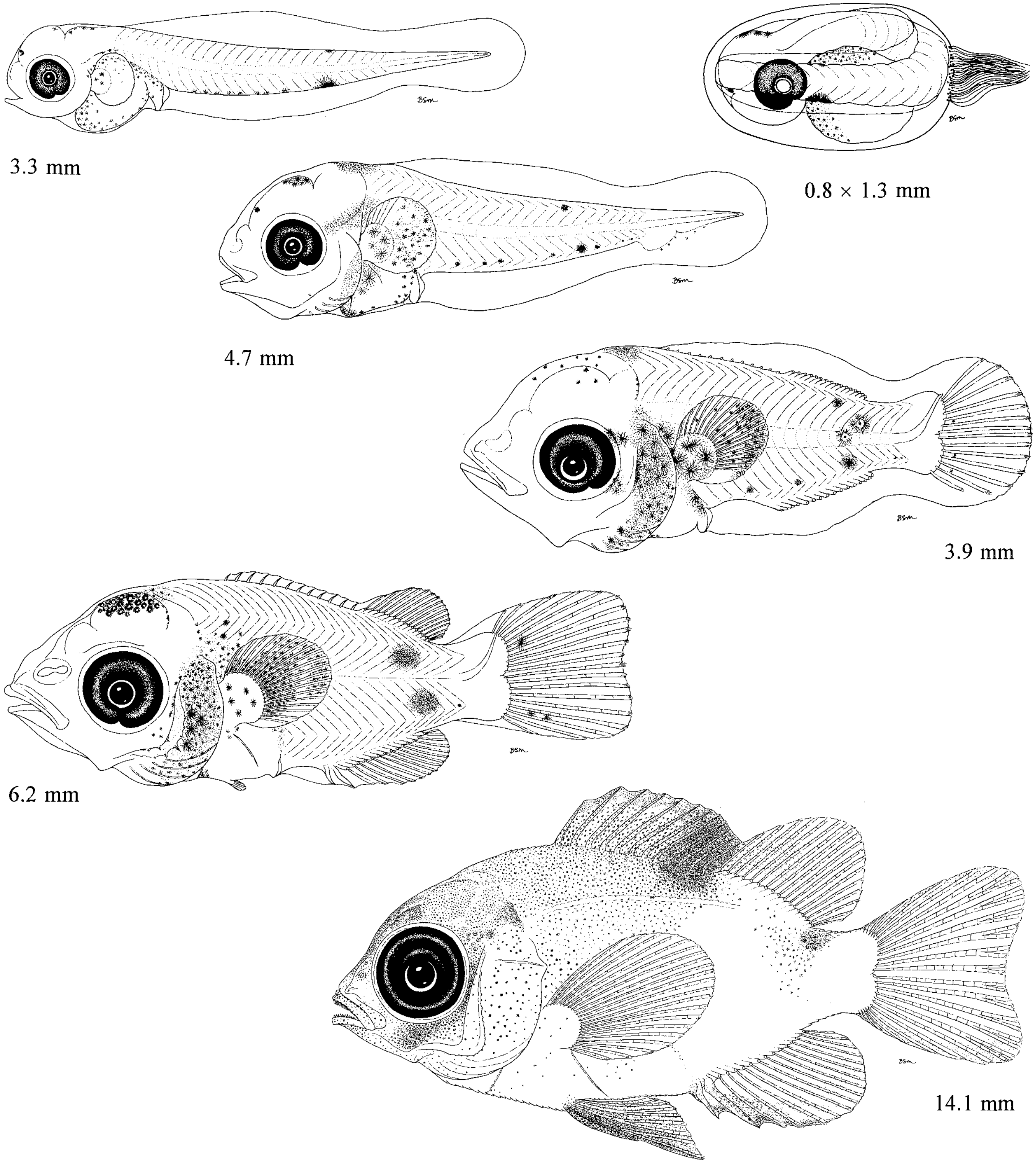


Figure Pomacentridae 3. Egg, 0.8 × 1.3 mm; newly hatched larva, 3.3 mm (CFRD Ref. Coll., North Coronado Island, August 6, 1965); preflexion larva, 4.7 mm (CalCOFI 5408, station 110.60); late flexion larva, 3.9 mm, specimen slightly shrunken (CalCOFI 6907, station 123.42); postflexion larva, 6.2 mm (CalCOFI 6307, station 107.45); juvenile, 14.1 mm, scales not shown (CFRD Ref. Coll., collected near La Jolla, California, September 1955).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11–12	12
Caudal	14–15	14
Fins:		
Dorsal spines	XII	XII
Dorsal rays	13–15	15
Anal spines	II	II
Anal rays	12–13	13
Pelvic	I,5	I,5
Pectoral	19–21	20
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	4	4
Lower	3–4	4
Gill rakers:		
Upper	9–12	
Lower	9–11	
Branchiostegals	6	6

LIFE HISTORY

Range: Bahía San Juanico, Baja California Sur through Gulf of California

Habitat: Shallow reef areas

Spawning season: Late spring through summer

ELH pattern: Oviparous; demersal eggs attached on nest (rock surface) tended by male parent; planktonic larvae

LITERATURE

Thomson et al. 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.4 mm (B. Sumida MacCall)
Flexion larva, 3.8 mm (B. Sumida MacCall)
Postflexion larva, 4.0 mm (B. Sumida MacCall)
Transformation specimen, 4.8 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: < ca. 2.2 mm
Flexion length: 2.9–3.5 through 3.6–4.0 mm
Transformation length: ca. 4.5–5.4 mm
Fin development sequence: C_1, 2D & A & P_1, C_2 & 1D, P_2
Pigmentation: *Preflexion*—Patch (1–6) on nape; under mid- & hindbrain; on gas bladder; on upper, anterior, & anteroventral areas of gut; series on ventral margin of tail; on upper margin of P_1. *Flexion–postflexion*—Increasing on mid- & hindbrain; medially on upper part of opercle; on cleithrum; increasing on gut; decreasing on ventral margin of tail; 1–2 internally on epaxial region at midtail; present or absent internally on hypaxial region near midtail; 1–3 on A. *Juvenile*—Laterally on trunk above gut, expanding caudad; completely pigmented by ca. 8 mm.
Diagnostic features: Dense pigment anteroventrally on gut & on distal margin of upper P_1; internal epaxial pigment near midtail after preflexion stage; small larvae, early transformation (ca. 5 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	33–43 39	42–49 46	48–53 51	54–57 55	57–64 61	
BD/BL	26–35 31	34–41 37	38–45 41	44–47 46	46–49 48	
HL/BL	24–34 30	31–41 37	37–43 40	39–41 40	33–41 38	
HW/HL	64–79 71	59–74 67	61–70 65	62–73 68	66–77 73	
SnL/HL	23–36 32	32–39 35	30–38 34	30–35 33	21–35 26	
ED/HL	36–52× 30–41 41×36	32–37× 32–37 36×35	34–41× 34–40 36×37	36–41× 37–41 38×39	35–42× 35–42 38×37	
P_1L/BL	5–9 7	8–11 9	10–14 12	14–19 17	19–30 26	
P_2L/BL	0 0	0–1 1	2–12 5	10–16 14	17–34 26	

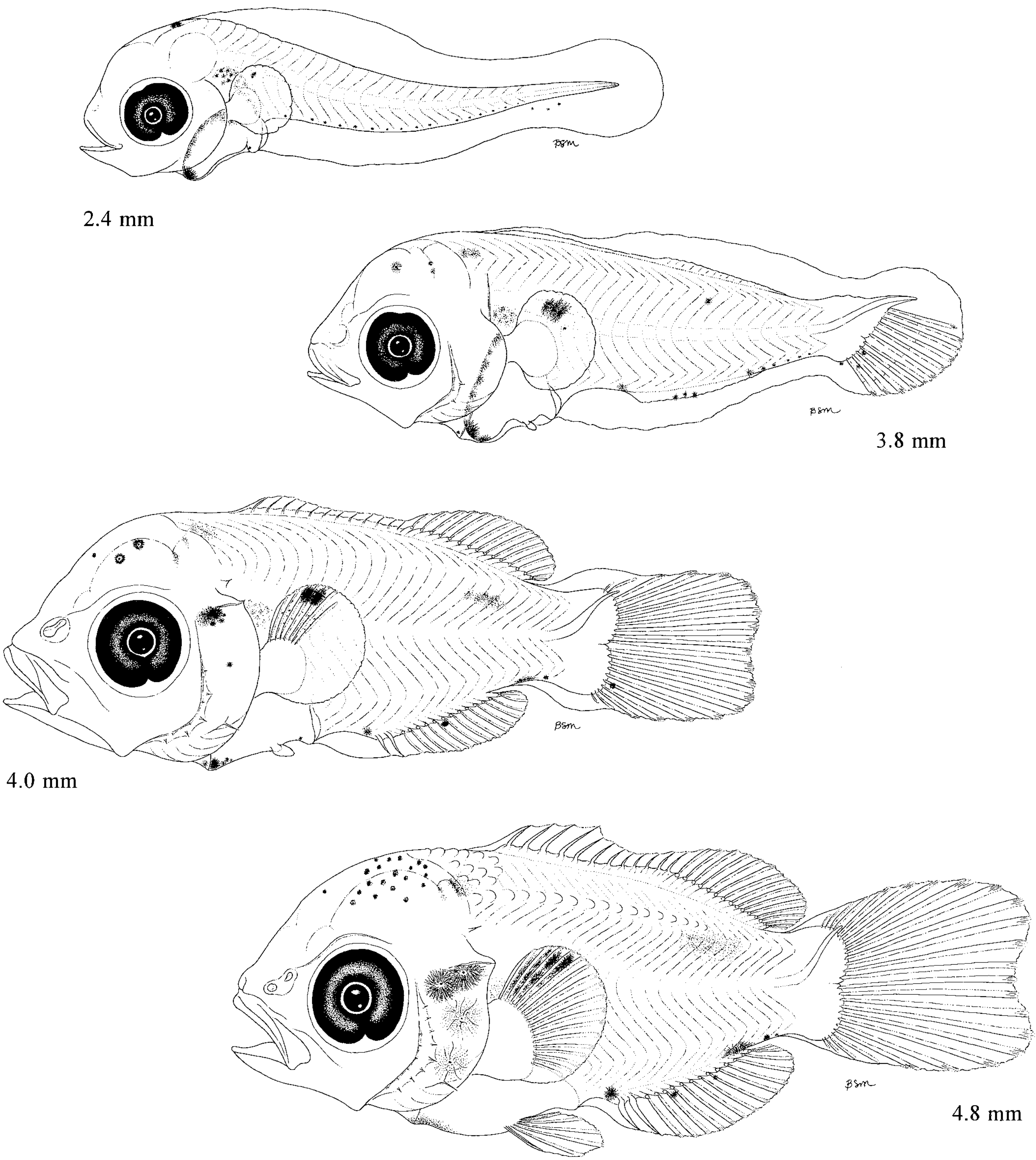


Figure Pomacentridae 4. Preflexion larva, 2.4 mm (CalCOFI 5708, station 133G.27); flexion larva, 3.8 mm (CalCOFI 5706, station 147G.32); postflexion larva, 4.0 mm (CalCOFI 5209, station 130G.31); transformation specimen, 4.8 mm (CalCOFI 5209, station 131.5G.33).

CIRRHITIDAE: Hawkfishes

W. WATSON

Cirrhitidae contains about 32 species in nine genera (Nelson 1994); three species in three genera occur at the southern end of the CalCOFI study area (Table Cirrhitidae 1). All three are primarily tropical and subtropical but range northward to the southern tip of Baja California Sur and into the central or northern Gulf of California (Bussing and Lavenberg 1995a). Larvae have not been collected in CalCOFI ichthyoplankton samples from the Pacific coast of Baja California, but have been taken in ichthyoplankton collections from the Gulf of California and farther south.

Most hawkfishes are small (<ca. 20 cm) epibenthic ambush predators that reside on shallow tropical and subtropical coral or rocky reefs. Most are moderately deep-bodied and compressed, and all have a continuous, notched dorsal fin containing ten spines with cirri on the fin membranes near their tips, a short anal fin (III, 5–7), and 14 pectoral fin rays. The unbranched lower pectoral rays, which are longer and thicker than the others, are used as supports when the fish is perched on the reef. Hawkfishes commonly are brightly colored and strikingly marked with bars or spots; many species are important in the aquarium trade, and some of the larger species are utilized in artisanal fisheries.

Hawkfishes are oviparous, with planktonic eggs and larvae (e.g., Leis and Rennis 1983; Tanaka and Suzuki 1991; Tanaka 1994, 1995). The eggs are spherical, 0.7–0.9 mm in diameter, with a smooth chorion, homogeneous, transparent yolk, and a single oil globule ca. 0.1–0.2 mm in diameter (Tanaka and Suzuki 1991; Tanaka 1994, 1995). Larvae ca. 1.4–2.3 mm long hatch with unpigmented eyes and a large yolk sac containing the oil globule anteriorly (extending beyond the anterior margin of the head in newly hatched larvae). Neither the pectoral fins nor the mouth have formed at hatching. Larval hawkfishes are elongate, with a straight gut ca. half to two-thirds of body length and a prominent gas bladder that inflates in the preflexion stage. The snout initially is short and rounded but becomes elongate and pointed by mid-way through the preflexion stage and a mandibular barbel forms during preflexion and persists until late in the postflexion stage. Melanophores are largely limited to the dorsum at hatching, but migrate ventrally during the yolk-sac stage and subsequently occur mainly on the dorsal surfaces of the gut and gas bladder and on the ventrum from the tip of the barbel to near the last myomere, except that they usually are absent ventrally on the posterior half (or more) of the intestine. One or more pigment patches may form on the dorsum, and, during the postflexion stage, these may spread ventrolaterally to form bars. Melanophores in the patches and bars are primarily myoseptal. Barred patterns are common in juveniles. Laboratory-reared larval *Cirrhitichthys*, *Cyprinocirrhites*, and *Neocirrhites* become nearly completely pigmented during the preflexion stage (Tanaka 1994, 1995).

Larval cirrhitids are unlikely to be confused with the larvae of any other family once the mandibular barbel has formed (by ca. 3 mm); younger larvae superficially resemble some young gobiids and labrids. Among the known CalCOFI area goby larvae, only *Coryphopterus nicholsii* <3 mm has a pigment pattern like the hawkfish pattern (see Gobiidae, this volume). However, these small gobiids have a distinctly shorter preanal length (Sn-A 45–48% BL versus 58–65% for the cirrhitids). Among the labrids, only *Semicossyphus pulcher* ca. 3–5 mm resemble cirrhitids; larval *S. pulcher* usually do not have melanophores distributed continuously along the entire ventral margin of the tail (see Labridae, this volume), and they have 28 myomeres (cirrhitids have 26). It is unknown how larvae of the three hawkfish species might be distinguished from one another, except that dorsal fin-ray counts may aid in separating postflexion stage specimens: although ranges overlap (Table Cirrhitidae 1), modal counts are 11 for *Cirrhites rivulatus*, 12 for *Cirrhitichthys oxycephalus*, and 13 for *Oxycirrhites typus*.

The following description is based on detailed observation of 14 larvae (1 yolk-sac, 1.6 mm; 10 preflexion, 1.8–4.1 mm; 2 flexion, 3.9–5.1 mm; 1 postflexion, 5.2 mm) that appear to represent a single species, possibly *C. oxycephalus*, and on five juvenile *C. oxycephalus*, 20.1–28.1 mm. Meristic data were obtained from Randall (1963) and from counts made during this study. Ecological information was obtained from Randall (1963), Thomson et al. (1979), and Bussing and Lavenberg (1995a).

Table Cirrhitidae 1. Meristic characters for the cirrhitid fishes in the California Current region. All have 10+16 vertebrae, 14 pectoral fin rays, I,5 pelvic fin rays, 8+7 principal caudal fin rays, and 6 branchiostegal rays.

	Fin rays			
Species	D	A	C_2	Gill rakers
Cirrhites rivulatus	X,11–12	III,6	11–13+10–12	5–7+11–13
Cirrhitichthys oxycephalus	X,12–13	III,6	12–13+10–12	3–5+10–12
Oxycirrhites typus	X,13	III,7	10–12+10–11	5+12–13

Cirrhitidae*

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	
Precaudal	10	
Caudal	16	
Fins:		
Dorsal spines	X	
Dorsal rays	11–13	
Anal spines	III	
Anal rays	6–7	
Pelvic	I,5	
Pectoral	14	
Caudal:		
Principal	8+7	
Procurrent:		
Upper	10–13	
Lower	10–12	
Gill rakers:		
Upper	3–7	
Lower	10–13	
Branchiostegals	6	

LIFE HISTORY

Range: *Cirrhites rivulatus*—Gulf of California & Cabo San Lucas to Colombia; *Cirrhitichthys oxycephalus*—Gulf of California & Cabo San Lucas to Colombia & throughout tropical Indo-Pacific; *Oxycirrhites typus*—Cabo San Lucas vicinity & central Gulf of California to Colombia & tropical Indo-Pacific

Habitat: Epibenthic on rocky & coral reefs; *Cirrhites rivulatus* & *Cirrhitichthys oxycephalus* on shallow reefs, *Oxycirrhites typus* on deep reefs

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.6 mm (N. Arthur)
Preflexion larva, 2.8 mm (N. Arthur)
Flexion larva, 5.1 mm (R. C. Walker)
Postflexion larva, 5.2 mm (N. Arthur)
Juvenile, 20.4 mm (N. Arthur)

* Three species occur at the southern end of the CalCOFI area: *Cirrhites rivulatus*, *Cirrhitichthys oxycephalus*, & *Oxycirrhites typus*. Larvae described here appear to represent a single species, possibly *C. oxycephalus* although they differ considerably in pigmentation from the laboratory-reared preflexion stage specimens shown by Tanaka (1994); juveniles are *C. oxycephalus*. Meristics represent all three species.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 1.6 mm
Flexion length: ca. 4–5 mm
Transformation length: <20 mm
Fin development sequence: C_1, 2D & A, 1D & C_2, P_1 & P_2
Pigmentation: *Yolk-sac*—Ventrally on snout; posteriorly on dorsal margin of tail; heavy dorsally on gut, continuing on ventral margin of tail; little anteriorly along ventral margin of gut. *Preflexion–postflexion*—1 over midbrain at ca. 3.9 mm, increasing to 4 over mid- & hindbrain by 5.1 mm; row along gular membrane extending onto barbel by 2.9 mm; internally under hindbrain & in floor of otic capsule by 3.9 mm; 2nd dorsal patch added at middle of tail by 2.8 mm & 3rd at ca. postanal myomeres 1–3 by 3.4 mm; few scattered on D & A beginning at ca. 3.9 mm; little on caudal finfold after ca. 3.4 mm; internally in middle of tail by 3.9 mm. *Juvenile*—7–8 indistinct bars; light on all fins except bars continue onto D.

Diagnostic features: Moderately elongate & slender; long, acute snout; mandibular barbel; moderately long gut; prominent gas bladder; myomeres 10–13+13–16=26; pigment mainly on barbel & gular region, & dorsally on gas bladder & gut, continuing ventrally along tail; prominent myoseptal dorsal patches on tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		54–71	61–64			58–61
	60	62	62	62		59
BD/BL		12–16	13–14			28–31
	10	14	14	15		30
HL/BL		21–29	25–30			27–32
	21	25	27	30		30
HW/HL		35–58	29–35			48–60
	53	41	32	32		55
SnL/HL		18–35	34–35			21–29
	21	29	35	33		26
ED/HL		26–34	24–24			29–33
	44	29	24	21		32
P_1L/BL		5–7	5–6			33–36
	0	6	6	6		34
P_2L/BL		0–0	0–0			18–22
	0	0	0	0		21
BbL/HL		0–8	8–9			0–0
	0	3	9	10		0

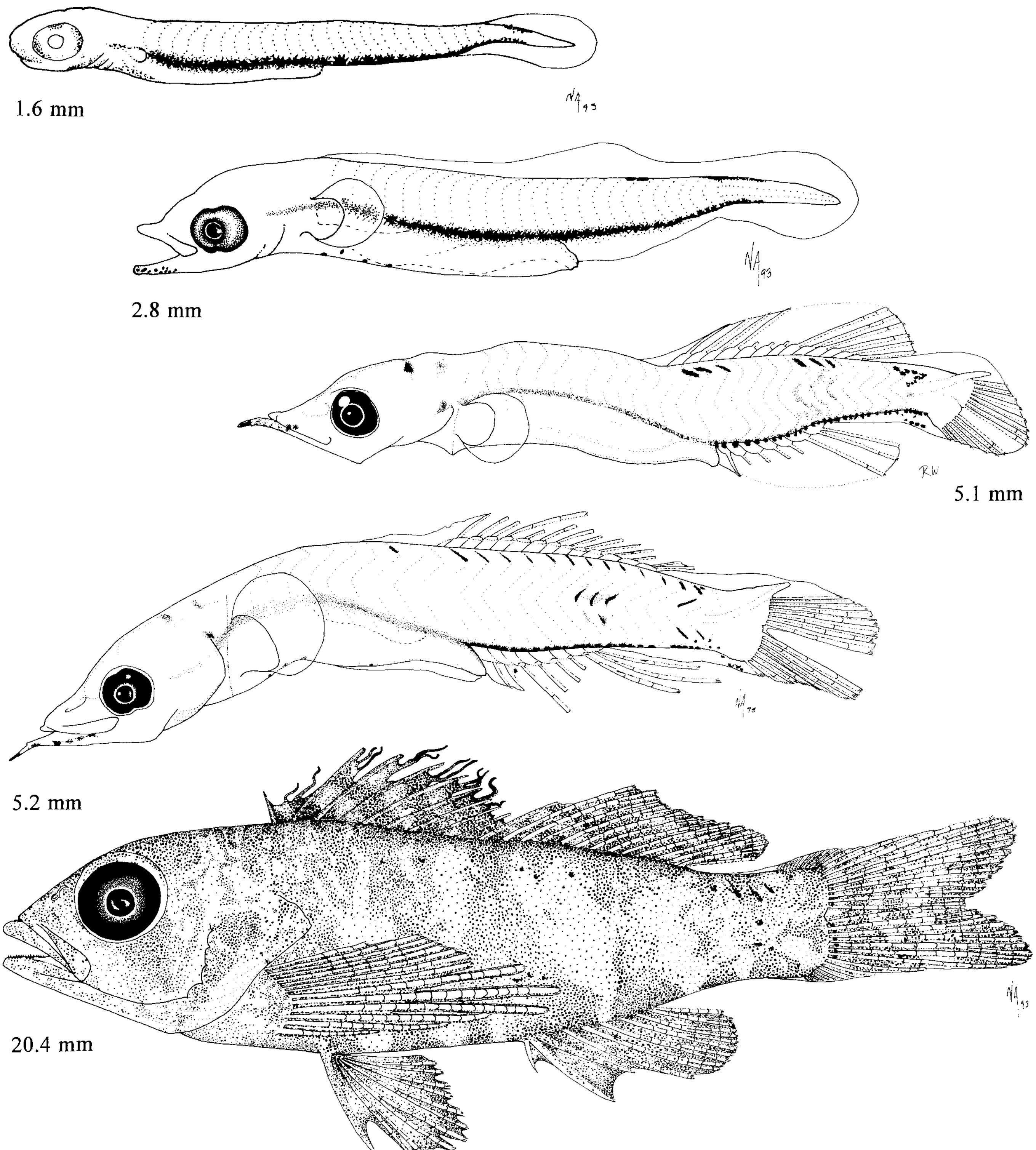


Figure Cirrhitidae 1. Yolk-sac larva, 1.6 mm (IATTC 90041, station T–12); preflexion larva, 2.8 mm (IATTC 90018, station AAB1 #2 Grn); flexion larva, 5.1 mm (IATTC 90028, station MAB #1 Grn); early postflexion larva, 5.2 mm (IATTC 90018, station AAB1 #2 Red); juvenile *Cirrhitichthys oxycephalus*, 20.4 mm (SIO 65–345). Scales are not shown on the juvenile specimen.

OPISTOGNATHIDAE: Jawfishes

W. WATSON

Two opistognathid species, *Opistognathus punctatus* and *O. rhomaleus* (Table Opistognathidae 1) are known to occur in the CalCOFI area: *O. puntatus* ranges northward to Bahía Ballenas (R. H. Rosenblatt, Scripps Institution of Oceanography, pers. comm., July 1995) and *O. rhomaleus* ranges to Bahía Magdalena along the Pacific coast of Baja California Sur. Only a few larval jawfishes have been identified in nearshore CalCOFI ichthyoplankton samples from the outer coast of Baja California Sur south of Cabo San Lazaro, but they are relatively common in collections from the Gulf of California.

Adult jawfishes are epibenthic or demersal burrowing residents of shallow (typically ca. 10–30 m) sand and sand-rubble bottom. Many species occur in colonies. They are small to medium-size (ca. 9–60 cm), elongate fishes with large heads, very large mouths, large eyes, and a short snout. The dorsal fin is continuous and unnotched, the caudal fin is rounded, and the pelvic fins are thoracic, with the outer two rays unbranched and thicker than the others. Most species are cryptically colored and marked with various patterns of spots, bars, and stripes.

Opistognathids spawn small (ca. 0.8–0.9 mm), round to oval eggs that are attached to one another via filaments to form egg masses which are orally brooded by the male parent (Bohlke and Chaplin 1957; Leong 1967; Colin 1972; Colin and Arneson 1978; Thresher 1984). Larval *O. aurifrons* hatch at ca. 3 mm with functional mouth, pigmented eyes, and little yolk (Thresher 1984). Opistognathid larvae have a large head with large mouth, a short, compact, coiled gut, and prominent gas bladder. Leis and Trnski (1989) described Australian jawfish larvae with an inconspicuous gas bladder, and with an initially uncoiled gut. Larvae become more robust as they develop and, during the postflexion stage the snout begins to shorten. A few small preopercular spines form in the preflexion stage, and a small subopercular spine may form during the postflexion stage. Larvae are lightly pigmented, with melanophores primarily on the gas bladder, gut, and ventral margin of the tail. Eastern Pacific and western Atlantic *Opistognathus* larvae typically have moderately to heavily pigmented branchiostegal membranes throughout development, in contrast to Australian larvae which lack this pigment (Leis and Trnski 1989).

Opistognathid larvae in the CalCOFI area are unlikely to be confused with those of any other family, except during the preflexion stage when they resemble the similarly pigmented larvae of *Apogon guadalupensis* and *A. retrosella* (see Apogonidae, this volume). The opistognathids have larger eyes, larger mouth with maxillary extending past mid-eye (versus not extending past the anterior margin of the eye in the apogonids), and a higher myomere count (25–30 versus 24). Larval *O. punctatus* and *O. rhomaleus* are separable during the postflexion stage by dorsal and anal fin ray counts (Table Opistognathidae 1), and by the somewhat more extensive pigmentation on the head and ventral margin of the tail in *O. punctatus*. It is unknown how smaller larvae might be distinguished, except that *O. rhomaleus* has fewer myomeres (Table Opistognathidae 1).

The following description is based on examination of 26 larvae (10 preflexion, 2.7–4.2 mm; 6 flexion, 4.3–5.0 mm; 10 postflexion, 5.0–8.3 mm) of *Opistognathus* sp. from the Gulf of California and Bahía Magdalena, and on 5 juvenile *O. rhomaleus*, 37.1–43.0 mm. The larvae appear to represent a single species; postflexion specimens have fin ray counts consistent with *O. rhomaleus*. However, myomere counts (usually 25–26) are lower than would be expected for either *O. rhomaleus* or *O. punctatus* (28–30), even for the Bahía Magdalena specimens, where only these two species have been recorded. Meristic data were obtained from Thomson et al. (1979), unpublished data provided by Dr. R. H. Rosenblatt (Scripps Institution of Oceanography, pers. comm., July 1995), and counts made during this study.

Table Opistognathidae 1. Meristic characters for the jawfish species in the CalCOFI study area. Both species have 8+8 principal caudal fin rays, I,5 pelvic fin rays, and 6 branchiostegal rays.

Species	Vertebrae			Fin rays				Gill rakers
	PrCV	CV	Total	D	A	P_1	C_2	
Opistognathus punctatus	10	20	30	XI,17	III,17	19–21	3–4+3–4	13–17+28–34
O. rhomaleus	10	18	28	X–XI,12–14	II,13	20–21	4–5+3–4	9–11+19–22

MERISTICS†

	Range	Mode
Vertebrae:		
Total	28	28
Precaudal	10	10
Caudal	18	18
Fins:		
Dorsal spines	X–XI	XI
Dorsal rays	12–14	13
Anal spines	II	II
Anal rays	13	13
Pelvic	I,5	I,5
Pectoral	20–21	20
Caudal:		
Principal	8+8	8+8
Procurrent:		
Upper	4–5	4
Lower	3–4	4
Gill rakers:		
Upper	9–11	10
Lower	19–22	20
Branchiostegals	6	6

LIFE HISTORY

Range†: Gulf of California to Islas de Revillagigedo, & to Bahía Magdalena on the Pacific coast of Baja California Sur

Habitat: Burrows located in sand bottom in shallow coastal waters

Spawning season: Larvae collected June–October, primarily June–August

ELH pattern†: Oviparous; eggs attached to one another via intertwining filaments, egg mass orally brooded by male parent; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Eggs, 0.8–0.9 mm (N. Arthur)
Preflexion larva, 2.8 mm (M. T. Vona)
Flexion larva, 4.6 mm (M. T. Vona)
Postflexion larva, 7.2 mm (M. T. Vona)

* Two species, *Opistognathus punctatus* & *O. rhomaleus* occur in the CalCOFI study area. Meristic characters of the larvae described here do not entirely match those of either species, but are most like *O. rhomaleus*.

† *Opistognathus rhomaleus*.

EARLY LIFE HISTORY DESCRIPTION

EGGS†

Shell diam.: 0.8–0.9 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.2 mm
Shell surface: Smooth, cluster of 5–7 long filaments attached at basal pole
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.7 mm
Flexion length: ca. 4.3–5.0 mm
Transformation length: >8.3 mm, <37.1 mm
Fin development sequence: C_1, P_1, 2D & A, 1D & P_2, C_2
Pigmentation: *Larvae*—Peppering on snout, premaxillary, & dentary after ca. 8 mm; pair posteriorly over midbrain by 5–6 mm, increasing to 3 or more after 8 mm; 1 at nape at ca. 3 mm, becoming internal by 5 mm; moderate to heavy on branchiostegal membrane; medially on upper part of opercle at ca. 3.7 mm; 1 ventrally on gut near anus; usually 1 ventrally on anterior part of gut; 1–4 (usually 2) along ventral margin of tail, becoming internal by 5 mm; heavy dorsally on gut & gas bladder; few on some A rays and/or bases after 7 mm. *Juvenile*†—Head spotted, 7–8 bars between nape & hypural margin; intense black blotch on branchiostegal membrane; all fins pigmented.

Diagnostic features: Large head with large mouth; short compact gut & prominent gas bladder; myomeres 25–26 (usually 9–10+16); heavy pigment on branchiostegal membrane & on dorsal surfaces of gas bladder & gut, little pigment elsewhere.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv†
Sn-A/BL		44–54 48	47–57 50	52–56 54		53–54 53
BD/BL		23–30 27	27–34 29	29–32 31		21–23 22
HL/BL		28–36 31	33–42 35	33–39 36		32–34 33
HW/HL		55–74 62	58–67 62	63–78 69		54–61 57
SnL/HL		25–36 29	27–31 29	15–30 25		9–12 11
ED/HL		30–38 35	29–34 31	26–36 31		22–25 24
P_1L/BL		6–8 7	7–10 8	8–17 12		16–17 17
P_2L/BL		0–0 0	0–5 2	4–21 12		19–22 20

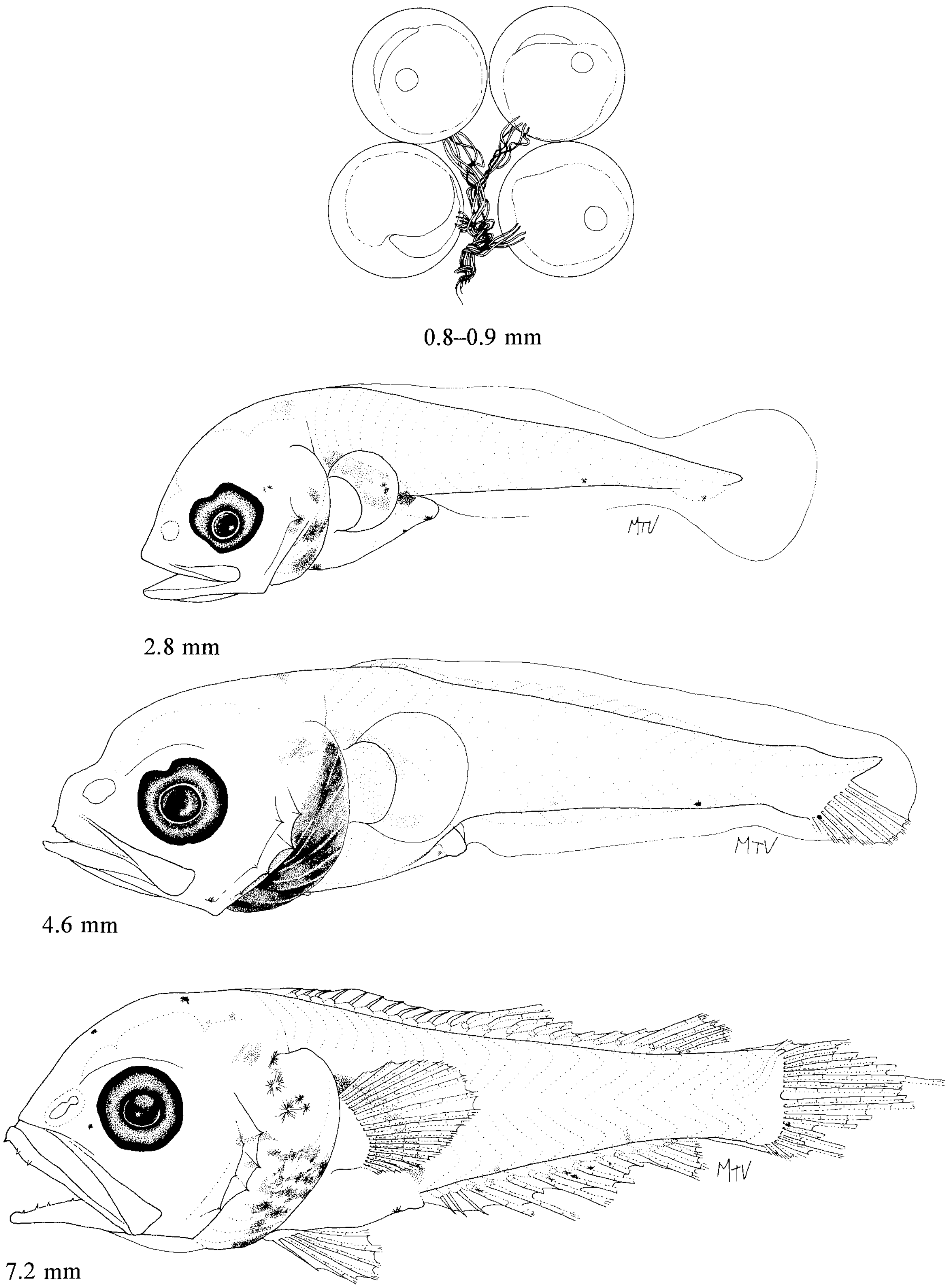


Figure Opistognathidae 1. *Opistognathus rhomaleus* eggs, 0.8–0.9 mm (SIO 75–598); *Opistognathus* sp.—preflexion larvae, 2.8 mm; flexion larva, 4.6 mm (CalCOFI 5706, station 127G.90); postflexion larva, 7.2 mm (CalCOFI 5706, station 103G.10).

HOWELLIDAE: Pelagic basslets

E. M. SANDKNOP AND W. WATSON

The taxonomic status of the pelagic basslets is uncertain. They have been placed in Apogonidae (e.g., Norman 1966), Percichthyidae (e.g., Fraser 1972; Hubbs et al. 1979), Acropomatidae (e.g., Heemstra 1986c), and considered *incertae sedis* (e.g., Johnson 1984; Eschmeyer 1990). Roberts (1993) recognized them as their own family, Howellidae, and although Nelson (1994) provisionally retained them in Acropomatidae, he expressed the reservation that perhaps they should indeed be placed in their own family. A *Howella* species has been reported from the California Current vicinity (Fedoryako 1976; Hubbs et al. 1979) and another (*H. pammelas*) is nearby in the eastern tropical Pacific (Heller and Snodgrass 1903). The identity of the California Current *Howella* species is not enirely clear. In Fedoryako's (1976) revisionary study, *H. sherborni* was reported as the only species in the California Current, whereas other authors (e.g., Fitch and Lavenberg 1968; Hubbs et al. 1979; Eschmeyer et al. 1983) have reported only *H. brodiei* from the area. Fedoryako (1976) separated the two species primarily on the basis of presence or absence of teeth on the vomer and palatines and on opercular spine morphology. Examination of several specimens of each species indicates considerable variation in the complexity of the upper opercular spines. Furthermore, specimens from the California Current smaller than 40–45 mm have simple opercular spines, and also apparently lack vomerine teeth (both characters are those of *H. brodiei*: Ogilby 1898), while larger specimens have variably complex opercular spines (complexity apparently usually increases with increasing body size) and most have one or more small vomerine teeth (characters are those of *H. sherborni*: Fedoryako 1976). The vomerine teeth are blunt, nearly embedded in tissue, and easily overlooked in many of the larger specimens. Palatine teeth were not visible in any of the California Current specimens; they either are lacking or are minute and embedded in tissue. Since the apparent ontogenetic variation and perhaps specimen-to-specimen variability in key characters are as large as the differences between species, a reevaluation of these species, including reexamination of the type specimens, is suggested.

Larval *H. brodiei/sherborni* occur in modest numbers in CalCOFI collections, primarily during summer at stations >300 n mi from shore. Modest numbers of *H. pammelas* were taken in the eastern tropical Pacific during the EASTROPAC surveys (Ahlstrom 1971, 1972b). In addition, a few postflexion stage larvae and juveniles of *Bathysphyraenops simplex* have been taken far from shore on extended CalCOFI surveys and in the EASTROPAC surveys.

Howellids are small (8–10 cm) mesopelagic residents of tropical and warm temperate oceans. At least one species migrates vertically to near the surface at night (Fitch and Lavenberg 1968). *Howella* is moderately compressed and somewhat elongate, with preanal length about 60% of body length. The head is moderately large, with large eyes, large mouth, and spiny opercular series bones. The pectoral fin is very long, extending to the anal fin origin. The two short-based dorsal fins are well separated. The short-based anal fin is below the second dorsal fin. The caudal peduncle is long and the caudal fin forked. Pelagic basslets are brown to black.

Planktonic eggs have been reported (Johnson 1984) and planktonic larvae are known, but larval size and developmental stage at hatching are unknown. Larval *H. pammelas* as small as 1.4 mm have pigmented eyes, an open mouth, and no yolk although an oil globule remains. Larvae initially are somewhat elongate, oval in cross-section, with preanal length just over half of body length. With growth they become moderately deep-bodied and compressed, with preanal length near 60% of body length. The gut begins as a simple straight tube but loops during the preflexion stage. The eyes and mouth are moderately large throughout larval development. Preopercular spines form during the preflexion stage; one or more of those along the posterior margin become moderately elongate. Posttemporal, opercular, subopercular, and interopercular spines are added during the flexion and postflexion stages. Larval pigmentation initially is light to moderate, with melanophores primarily dorsally on the gut, on the head, and dorsally on, or surrounding, the anterior part of the tail. Depending on species, pigmentation increases slowly to rapidly with postflexion larvae ranging from moderately pigmented on the head, gut, and tail to nearly completely pigmented. In addition to the melanophores, live larval *H. brodiei/sherborni* have yellow chromatophores in the same areas on the gut and tail, and a translucent pale orange caudal peduncle and fin.

Larval morphology, meristic characters (Table Howellidae 1), the distinctive pigment patterns, and the offshore location of the larvae should preclude confusion of *Howella* with the larvae of other families in the CalCOFI study area. Larval pigmentation likewise provides the means to distinguish *H. brodiei/sherborni* from *H. pammelas*.

Species descriptions are based on detailed examination of 22–28 specimens of each species (Table Howellidae 2). Meristic data were obtained from Fedoryako (1976) and counts made during this study, and ecological information is from Fedoryako (1976) and Fitch and Lavenberg (1968).

Table Howellidae 1. Meristic characters for the howellid species in the California Current vicinity. All species have 9+8 principle caudal fin rays, I,5 pelvic fin rays, and 7 branchiostegal rays.

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	P_1	C_2
Bathysphyraenops simplex	10	16	26	VIII+I,9	III,7	13–16	8+8
Howella pammelas	10	16	26	VIII+I,9–10	III,7	13–15	9+8
Howella sp.	10	16	26	VIII+I,9	III,7	13–15	9–10+9–10

Table Howellidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the *Howella* species descriptions.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Howella pammelas	4 1.4–1.7	7 2.3–3.6	5 3.4–4.1	5 4.2–5.4	7 5.8–8.8	0
Howella sp.	1 1.9	6 2.6–3.7	5 4.1–5.4	4 5.1–7.9	2 6.5–9.3	4 13.8–25.7

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	9–10	9
Anal spines	III	III
Anal rays	7	7
Pelvic	I,5	I,5
Pectoral	13–15	14
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9	9
Lower	8	8
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Poorly known, at least eastern tropical Pacific; larvae range between about 15° N & 17° S, primarily 0°–9° N in eastern Pacific

Habitat: Mesopelagic

Spawning season: Larvae collected July–December with August–September peak

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 1.8 mm, 2.4 mm (B. Sumida MacCall)
Flexion larva, 3.4 mm (B. Sumida MacCall)
Postflexion larva, 4.2 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 1.4 mm
Flexion length: 3.4–3.6 mm through 4.1 mm
Transformation length: ca. 5.8–8.8 mm
Fin development sequence: A & C_1, 2D, P_2, 1D & P_1 & C_2
Pigmentation: *Yolk-sac through preflexion*—0–1 on forebrain; heavy band under hindbrain; over full length of gut & onto ventral margin of first 1–2 postanal myomeres; at tips of both jaws & on gular area by 2.3 mm; posteriorly on midbrain and/or anteriorly on hindbrain by 2.4 mm; in roof of mouth by 2.7 mm; dorsal patch in vicinity of postanal myomeres 4–6; internally over & under notochord from level of mid-gut to midtail by 2.3 mm; extending along most of length of notochord by 3.3 mm; series along lateral midline beginning above hindgut before 2.3 mm & spreading caudad & cephalad, on myosepta in same area by 2.4–2.7 mm; on cleithra & ventrally on gut by 2.3 mm. *Flexion–postflexion*—Increasing on head, gut, laterally on trunk & tail to completely cover body by 3.8 mm, except none on fins or end of caudal peduncle; lighter on snout & lower part of head; on P_2 by 3.9–4.2 mm.
Diagnostic features: Pigmentation; relatively deep body; small size at flexion & transformation stages.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	56–65 61	56–65 58	57–68 62	63–67 65	63–69 65	
BD/BL	21–23 22	21–30 26	25–37 33	34–40 38	34–37 35	
HL/BL	17–30 22	26–33 29	32–41 36	30–38 35	35–41 37	
HW/HL	52–80 66	41–67 50	33–50 42	41–58 47	37–44 41	
SnL/HL	13–30 20	19–48 31	28–31 29	28–31 30	27–36 30	
ED/HL	38–44 42	31–40 35	29–33 31	28–33 31	25–29 27	
P_1L/BL	0–8 2	6–8 7	7–9 8	9–10 10	8–14 11	
P_2L/BL	0–0 0	0–3 0.4	6–10 8	10–14 11	13–18 16	

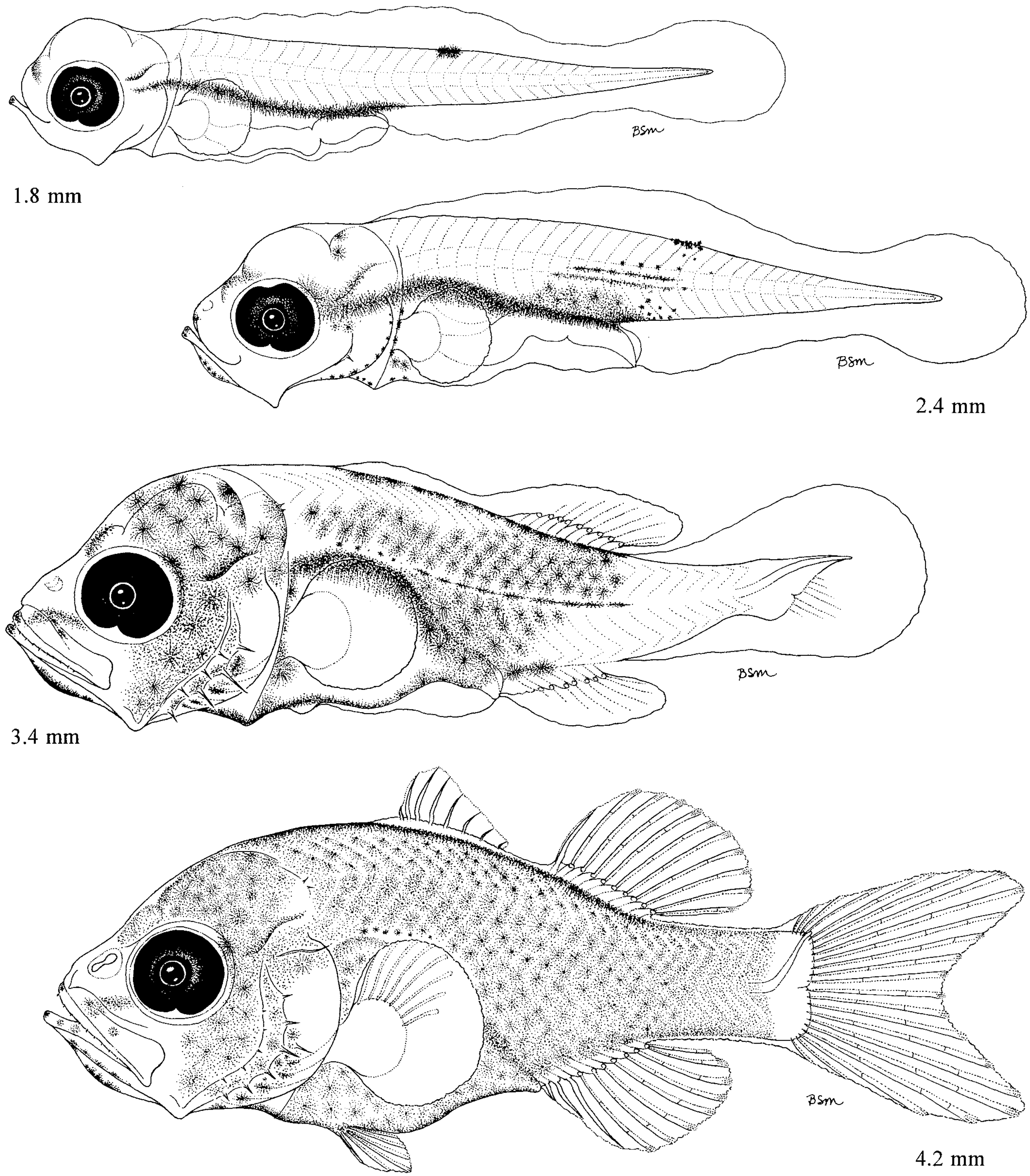


Figure Howellidae 1. Preflexion larvae, 1.8 mm (EASTROPAC, station 20.051); 2.4 mm (EASTROPAC, station 20.048); flexion larva, 3.4 mm (EASTROPAC, station 20.051); postflexion larva, 4.2 mm (EASTROPAC, station 30.235).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	9	9
Anal spines	III	III
Anal rays	7	7
Pelvic	I,5	I,5
Pectoral	13–15	14
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–10	
Lower	9–10	
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	7

LIFE HISTORY

Range: Cosmopolitan; between 60° N & 50° S

Habitat: Mesopelagic (ca. 300–1,850 m depth) during the day, migrating into the epipelagic zone (as shallow as 30 m depth) at night

Spawning season: Larvae collected throughout the year with July–September peak in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.2 mm (B. Sumida MacCall)
Flexion larva, 4.6 mm (B. Sumida MacCall)
Postflexion larva, 7.9 mm (B. Sumida MacCall)
Transformation specimen, 9.3 mm (B. Sumida MacCall)

* All larvae included here appear to represent a single species, which should be *H. brodiei* or *H. sherborni*.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <1.9 mm
Flexion length: 4.1 mm through 4.8–5.4 mm
Transformation length: 6.5–8 mm through ca. 10 mm
Fin development sequence: C_1 & 2D & A, 1D & P_2, P_1, C_2
Pigmentation: *Yolk-sac through preflexion*—Initially on roof of mouth, under hindbrain & on pharyngobranchial area, dorsally on most of gut, ventrally on first few postanal myomeres; at tip of upper jaw by 2.1 mm & lower jaw by 2.6 mm; over midbrain & laterally on hindbrain by 2.6 mm; present or absent over forebrain; band across mid-opercle by 2.7 mm; on gular area by 2.7 mm; on cleithra by 2.7 mm; spreading ventrad on gas bladder & gut after 2.1 mm; series on lateral midline & internally over notochord in vicinity of myomeres 6–8 through 16–18 by 2.1 mm, & internally below notochord & on hypaxial myosepta in same area by 2.6 mm; dorsal patch in vicinity of myomeres 12–14 through 16–18 by 2.1 mm & on epaxial myosepta in same area at 3.2–3.6 mm. *Flexion–postflexion*—Increasing dorsally on head & laterally on trunk & tail; in nostrils by 4.4 mm; along 1D base by 4.8 mm & 2D base by 6.2 mm, extending onto caudal peduncle. *Transformation–juvenile*—Increasing on all areas, by 13 mm, fully pigmented except little or none on fins.
Diagnostic features: Pigmentation; relatively slender.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		59–67	59–68	63–67	61–62	52–63
	60	62	63	64	61	59
BD/BL		19–28	22–30	28–31	29–30	24–29
	21	23	26	29	29	26
HL/BL		26–33	31–36	33–36	30–36	33–36
	26	29	34	35	33	35
HW/HL		37–47	32–39	28–41	38–38	29–34
	52	41	36	35	38	31
SnL/HL		21–33	32–34	31–34	31–33	23–32
		27	33	33	32	28
ED/HL		30–39	24–30	26–32	28–35	23–26
	44	35	28	29	31	24
P_1L/BL		7–10	6–10	8–11		15–22
	10	8	8	9	9	18
P_2L/BL		0–0	0–4	8–12	11–14	11–18
	0	0	1	10	12	15

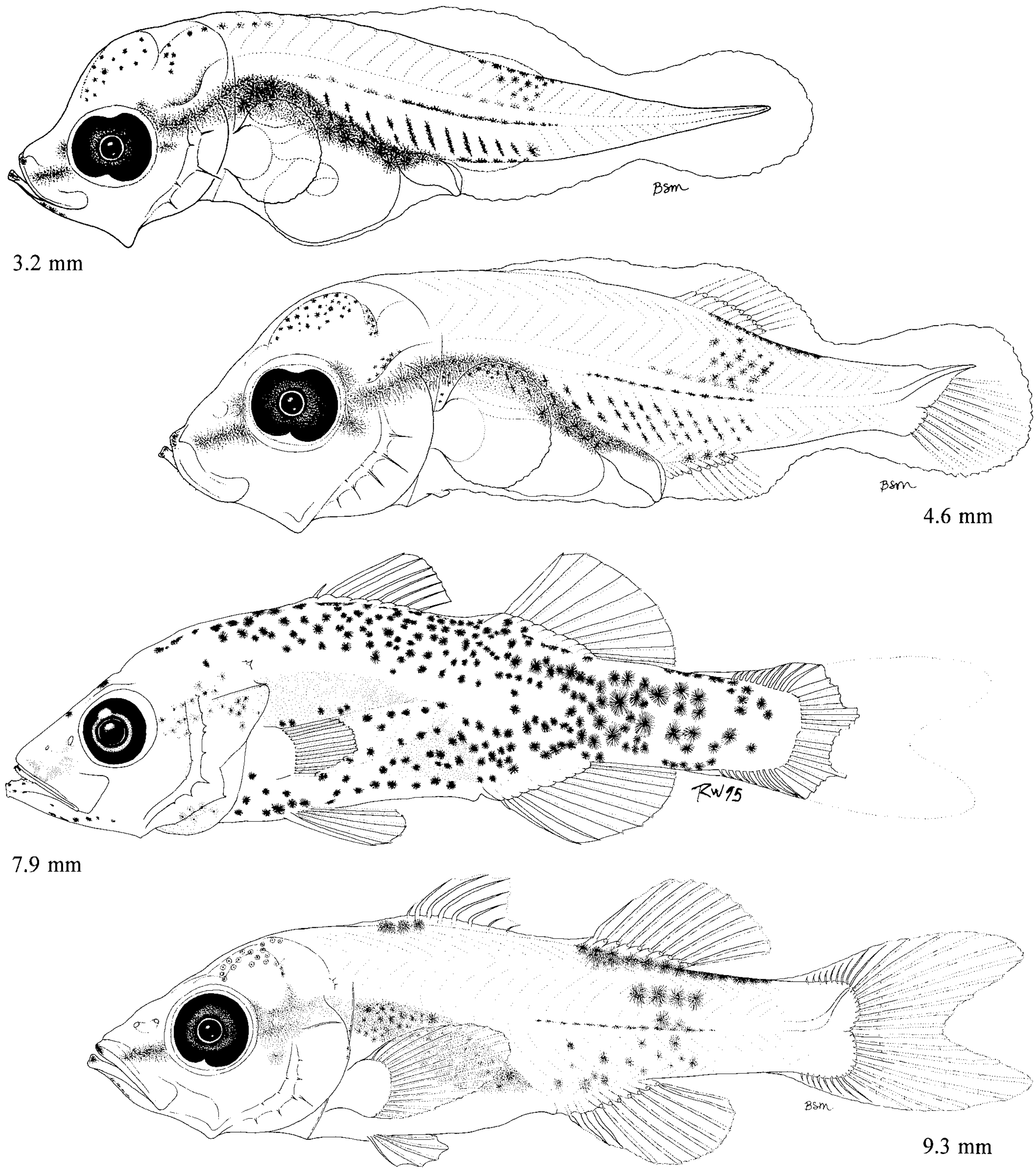


Figure Howellidae 2. Preflexion larva, 3.2 mm (CalCOFI 8810, station 93.3.100); flexion larva, 4.6 mm (FRONTS 85, station 2, MOCNESS); postflexion larva, 7.9 mm (CalCOFI 8810, station 76.7.100); transformation specimen, 9.3 mm (CalCOFI 8904, station 93.3.110.0).

MUGILIDAE: Mullets

E. M. SANDKNOP AND W. WATSON

Although mugilid monophyly has long been accepted, the phylogenetic position of the family is not settled. Traditionally, the mugilids usually were placed in a perciform suborder, Mugiloidei, near the polynemids and sphyraenids (or including them in some classifications). Stiassny (1990, 1993) suggested that mugilid affinities are with the atherinomorph fishes rather than with the percomorphs, while Parenti (1993) discounted an atherinomorph relationship. Johnson and Patterson (1993) argued on the basis of several shared characters that the mugilomorphs, atherinomorphs, gasterosteiforms, synbranchiforms, and elassomatids are related and erected a new percomorph group—Smegmamorpha—to contain them. Nelson (1994) acknowledged Johnson and Patterson's (1993) arrangement, but placed the mugilids in their own prepercomorph series and order near the atherinomorphs. Because the phylogenetic position of the mugilids is unresolved, in this volume we prefer to follow tradition and Eschmeyer (1990) in placing them in their own perciform suborder, Mugiloidei, near the polynemids (with which they probably are not closely related).

Mugilidae contains perhaps 80 species in about 17 genera (Nelson 1994). Eight species in four genera occur in the eastern Pacific (Ebeling 1961); four of these species in three genera have been reported to occur in the CalCOFI study area (Harrison 1995). By far the most widely distributed is *Mugil cephalus*, which ranges from San Francisco Bay, California, to Chile and worldwide in warm seas. *M. curema* ranges from Bahía Magdalena, Baja California Sur and throughout the Gulf of California to Chile in the eastern Pacific (and ranges widely in warm waters of the Atlantic, as well), while *Chaenomugil proboscideus* ranges from the Cabo San Lucas vicinity and lower Gulf to Panama. *Agonostomus monticola* occurs in fresh and brackish waters from the vicinities of Bahía Magdalena and the Gulf of California to Colombia. Small numbers of mugilid larvae—presumably *M. cephalus* although none could be identified to species with certainty—have been collected between Bahía Sebastián Viscaíno and Cabo San Lucas during CalCOFI surveys, primarily at stations between about 37 and 92 km from shore during summer and autumn.

Mullets are small to large (ca. 16–90 cm) benthic grazers that school in warm coastal marine and brackish waters. Some are freshwater residents as adults. Mullets are moderately elongate and compressed, with preanal length about two-thirds of body length. The small head tapers to a small to medium size mouth. Teeth are small or lacking. The pharyngeal bones and gill arches are modified to form the pharyngobranchial organ, used in filter feeding (Harrison and Howe 1991). The eyes typically are partially covered with adipose eyelids. There are two widely separated, short-based dorsal fins; the short-based anal fin is below the second dorsal. Pectoral fins are high on the sides and pelvic fins are abdominal (but anteriorly on the abdominal area). The caudal fin is emarginate or forked. The body is covered with cycloid, crenate, or ctenoid scales (Roberts 1993). Mullets typically are countershaded, with shades of brown, green, blue or grey dorsally and silvery or white below. Striped patterns are common. Mugilidae contains several species that are important in commercial and subsistence fisheries, and some that are cultured in ponds.

Mullets are oviparous, with planktonic eggs and larvae (e.g., de Sylva 1984a). Eggs are spherical, with a smooth to weakly striated chorion 0.6–1.3 mm in diameter, a narrow perivitelline space, a homogeneous yolk, and a single oil globule (or several, coalescing to one) ca. 0.3–0.5 mm in diameter (e.g., Martin and Drewry 1978; Brownell 1979; de Sylva 1984a; Ikeda and Mito 1988). Larvae hatch at a length of ca. 1.8–3.4 mm with unpigmented eyes, lacking a mouth or pectoral fin buds, and with a large yolk sac containing the oil globule posteriorly (e.g., Sanzo 1936; Anderson 1957; Brownell 1979; Ikeda and Mito 1988). Larvae initially are moderately elongate, with a straight gut extending to about 60% BL. The gut coils near the end of the yolk sac stage or early in the preflexion stage, and preanal length increases to about two-thirds of body length. The head is moderate, with large, slightly oval to round eyes and a rounded snout. There are no spines on the head or pectoral girdle, except that some species may develop weak infraorbital serrations (Leis and Trnski 1989). Principal caudal rays are the first fin rays to begin forming, late in the preflexion stage.

These are followed by the soft rays of the dorsal and anal fins, which begin forming simultaneously during notochord flexion. Addition of rays is anterior to posterior in both fins. Pectoral rays are next to begin forming, near the end of the flexion stage or early in the postflexion stage; addition of rays is ventrad. Pelvic fin buds form shortly before or during notochord flexion, and rays begin to form late in the flexion stage or early in the postflexion stage, about concurrently with formation of the spines of the first dorsal fin. Mullet larvae are moderately to heavily pigmented initially, with melanophores primarily on the dorsum and ventrum, or covering nearly the entire body. Larvae subsequently become (or remain) heavily pigmented, often with denser pigmentation on the dorsum, in a midlateral stripe, and on the ventral margin of the tail. Late larvae may become silvery laterally and ventrally and the pelagic juveniles of some species are bright silver on the flanks and ventrum. This silvery pelagic juvenile stage is sometimes referred to as the "querimana" stage.

Mullet eggs closely resemble the spherical planktonic eggs spawned by numerous coastal marine fishes and it is doubtful that they can be distinguished with certainty from similar eggs routinely encountered in plankton samples. Mullet eggs have a larger oil globule relative to the egg diameter than many species with otherwise similar eggs, and at least some *M. cephalus* eggs have fine striations on the chorion which may aid in identification. Mullet larvae are more distinctive. Key characters are the robust body, abdominal pelvic fins (visible by, or during notochord flexion), widely separated, short-based dorsal fins (apparent by the end of notochord flexion, or soon thereafter), lack of spines on the opercular series bones and pectoral girdle, and heavy pigmentation. Mullets are unlikely to be confused with any other fish larvae in the CalCOFI study area.

The following description of *Mugil cephalus* is based on examination of 28 eggs and 20 larvae and pelagic juveniles (1 yolk-sac, 2.2 mm; 7 preflexion, 2.4–3.8 mm; 3 flexion, 4.3–4.4 mm; 4 postflexion, 4.5–6.1 mm; 2 transformation, 9.6 and 10.3 mm; 3 pelagic juveniles, 14.2–22.8 mm) collected during CalCOFI surveys. All presumably are *M. cephalus*, although species identifications could not be made with certainty. Larvae described here are consistent with the numerous literature descriptions of larval *M. cephalus* (e.g., Sanzo 1936; Anderson 1958; Dekhnik 1973; Senou and Kinoshita 1988; Leis and Trnski 1989). Eggs and larvae of *Mugil curema* from the western Atlantic were described and illustrated by Anderson (1957) and those illustrations are shown also in Martin and Drewry (1978) and de Sylva (1984a). Since no eggs or larvae of *M. curema* have been identified in CalCOFI collections, that species is not described here. Refer to the literature cited above for illustrations and descriptions.

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	11–12	12
Caudal	12–13	12
Fins:		
Dorsal spines	IV+I	IV+I
Dorsal rays	7–8	8
Anal spines	III	III
Anal rays	6–8	8
Pelvic	I,5	I,5
Pectoral	14–18	16
Caudal:		
Principal	7–8+7	8+7
Procurrent:		
Upper	7–9	8
Lower	7–10	9
Gill rakers:		
Upper	24–36	
Lower	50–76	
Branchiostegals	6	6

LIFE HISTORY

Range: Circumglobal in warm seas; in the eastern Pacific from San Francisco Bay, California to Chile.

Habitat: Schools in coastal waters including bays and estuaries, may enter fresh water

Spawning season: Larvae collected in all months except February; highest abundance & frequency of occurrence in late summer & autumn with August peak, low November–July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Leis and Trnski 1989
Martin and Drewry 1978 & references cited therein
Senou and Kinoshita 1988

* Modal counts of meristic characters are given for eastern North Pacific *M. cephalus*; descriptions of eggs and larvae refer to specimens collected during CalCOFI surveys.

† Eyes initially oval, becoming round by the postflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.74–0.82 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.28 mm
Shell surface: Fine, weak striations
Pigment: On OG; on dorsal & ventral margins of advanced embryo, dorsolaterally on body; on dorsal midline, divided into two bands, joining at midbrain
Diagnostic features: Shell & OG diameter; pale amber chorion; shell surface

LARVAE

Hatching length: ca. 2.2 mm
Flexion length: 3.9–4.4 mm
Transformation length: 7.5–12.0 mm
Fin development sequence: C_1, 2D & A, P_1 & C_2, 1D & P_2
Pigmentation: *Late yolk-sac*—Anteriorly on both jaws; ventral to mid- & hindbrain; in otic capsule; heavy on dorsum from midbrain to myomere 18; light dorsolaterally on trunk & tail to myomere 18; series on lateral midline to myomere 18; heavy dorsally, lighter ventrally on gut; series on ventral margin of tail to myomere 18, extending up onto sides of tail; few on notochord tip, dorsally & ventrally. *Preflexion*—Increasing on all areas, becoming generally covered by ca. 3.3 mm except last 4 myomeres unpigmented & lower half of head lightly pigmented. *Flexion*—Gradually spreading caudad, only last 1–2 myomeres & hypural area unpigmented by end of stage; few on C by 4.4 mm; pigmentation remains denser on dorsal & ventral margins & lateral midline. *Postflexion*—Uniformly covered by 5.2 mm, except none on distal margin of P_1 base & blade, D, A, & hypural area; little on C; on D & A bases & covering hypural area by 6 mm. *Transformation*—Spreading from hypural area onto proximal part of C; becoming silvery, beginning ventrolaterally on abdominal area, by 8 mm.
Diagnostic features: Heavily pigmented throughout development; no spines on head or pectoral girdle; robust form.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	PJuv
Sn-A/BL		61–71	66–79	68–73	64–68	66–67
	57	66	73	71	66	66
BD/BL		29–35	28–36	28–31	26–26	23–26
	25	32	32	30	26	24
HL/BL		27–32	28–36	32–36	27–29	28–30
	29	30	33	34	28	29
HW/HL		40–69	55–61	55–61	63–65	46–56
	53	53	59	58	64	52
SnL/HL		16–22	21–27	20–24	24–29	20–28
	28	21	23	22	27	24
ED/HL†		36–43× 33–38	35–42× 30–39	33–39	24–35	27–34
	36×31	39×34	38×34	36	30	31
P_1L/BL		4–7	6–9	8–12		16–16
	6	6	8	9	18	16
P_2L/BL		0–0.3	1–5	6–13	15–15	15–15
	0	0.04	3	8	15	15

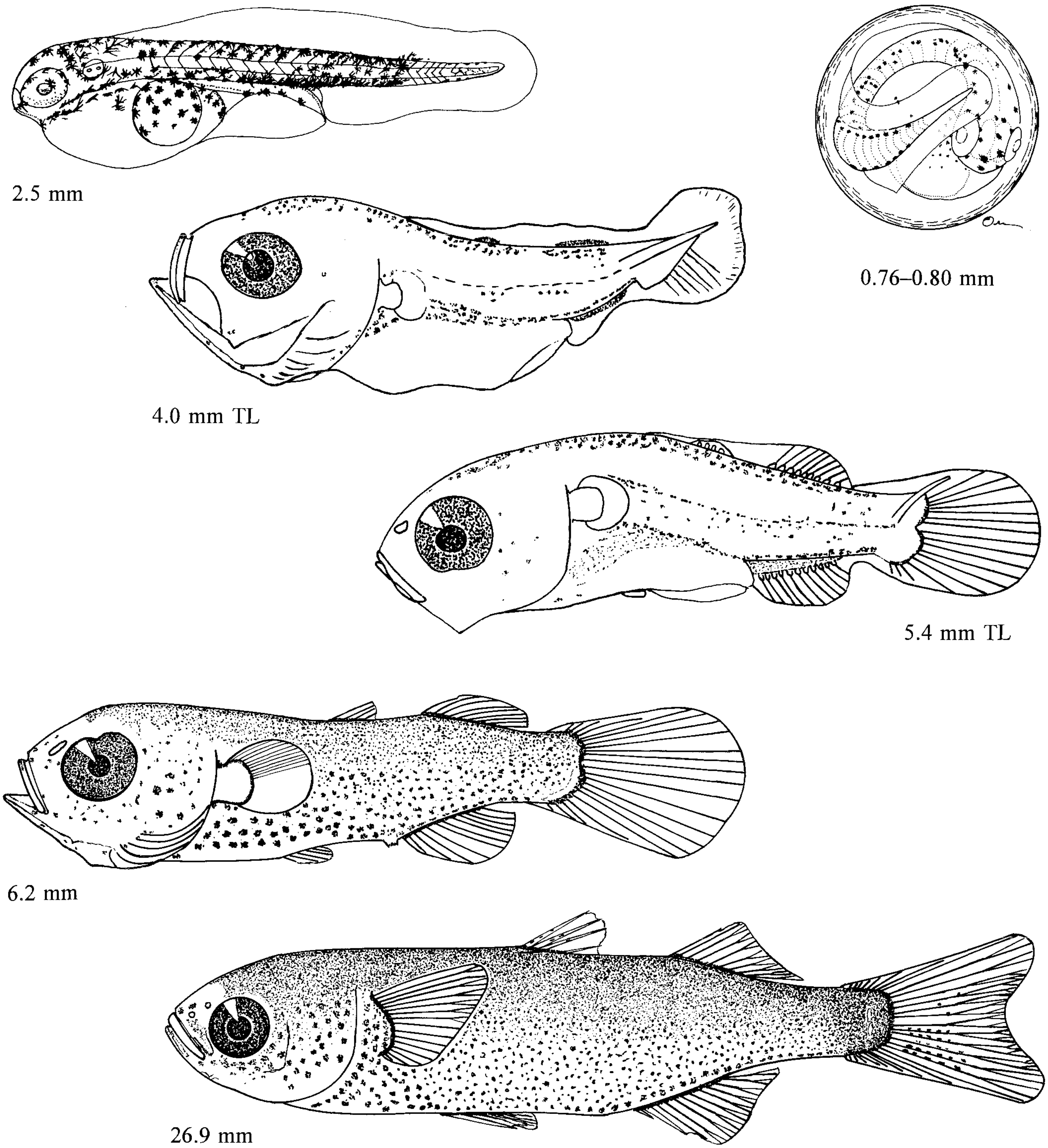


Figure Mugilidae 1. Egg, 0.76–0.80 mm (Matarese and Sandknop 1984); yolk-sac larva, 2.5 mm (Sanzo 1936; reproduced from figure redrawn in Martin and Drewry 1978); late preflexion larva, 4.0 mm TL; late flexion larva, 5.4 mm TL; postflexion larva, 6.2 mm TL; pelagic juvenile, 26.9 mm SL (Anderson 1958).

POLYNEMIDAE: Threadfins

E. M. SANDKNOP AND W. WATSON

Jordan and Evermann (1896) placed the polynemids in their own suborder, Rhegnopteri, of uncertain affinity but possibly related to Sciaenidae or Mugilidae. In recent years most workers have continued to place the polynemids in their own suborder, Polynemoidei, thought to be most closely related to the Mugiloidei and Sphyraenoidei (e.g., Greenwood et al. 1966; Nelson 1984; Eschmeyer 1990). DeSylva (1984c) noted differences between the polynemids and the other two suborders and Johnson (1986) discounted the supposed close relationship of the three suborders while placing the sphyraenids in the Scombroidei. Johnson (1993) expressed the opinion that assignment of the polynemids to a separate suborder is unwarranted and suggested, on the basis of a shared unique interdigitation of the metapteryoid and quadrate, and the general close resemblance of their larvae, that sciaenids and polynemids may be sister groups that should be united in a superfamily, Polynemoidea. Nelson (1994) placed the polynemids in the Percoidei and noted the possible sister group relationship with sciaenids. Here, because the systematic position of the polynemids is not yet resolved, we follow Eschmeyer (1990) in treating them as their own suborder.

Polynemidae consists of about 33 species in seven genera of tropical and subtropical fishes (Nelson 1994). Two *Polydactylus* species occur in the CalCOFI study area: *P. approximans*, the blue bobo, ranges from Peru to Monterey, California, while the yellow bobo, *P. opercularis*, ranges from Peru to Los Angeles, California. Both species are rare north of the central Baja California peninsula. A few polynemid larvae, mostly *P. approximans*, have been collected during CalCOFI surveys, primarily from June through October at inshore stations between ca. Punta Abreojos and Cabo San Lazaro, Baja California Sur. Larvae of both species are relatively common in ichthyoplankton collections made to the south of the CalCOFI study area.

Polynemids are medium-size to large (commonly ≤50 cm; largest species to ca. 2 m) fishes that forage for benthic animals on soft bottom in warm coastal waters and estuaries. Pelagic juveniles may range far from shore. Polynemids are somewhat elongate and compressed with preanal length ca. 50–60% BL. The snout is bluntly conical, the mouth inferior, and the eyes, with adipose eyelids, are anterior. There are two well separated dorsal fins, the first composed of spines and the second containing a spine and several soft rays. The anal fin is opposite the second dorsal fin. The caudal fin is forked. The most striking polynemid feature is the pectoral fin, which is divided into an upper "normal" section and a lower section of elongate, free rays. When foraging, polynemids extend these free rays in a fan-like arrangement with the ray tips in contact with the bottom. Polynemids are variously pigmented, blue-grey or yellow to brown dorsally and lighter ventrally, sometimes with narrow stripes, and often with dusky, black, or yellow to orange fins. Pelagic juveniles may be countershaded with a bluish dorsum and silvery white ventrum, or strongly marked with broad bars. Polynemids are important food fishes in some areas; they are utilized in both commercial and recreational fisheries.

Polynemids are oviparous; at least one *Polydactylus* species is a protandrous hermaphrodite (Santerre and May 1977; May et al. 1979). The planktonic eggs are transparent and spherical, 0.72–0.99 mm in diameter, with a smooth chorion and single oil globule 0.27–0.37 mm in diameter (Kowtal 1972; May et al. 1979). Larvae ca. 1.5–2.0 mm long hatch with unpigmented eyes, unformed mouth, and a large yolk sac (Sarojini and Malhotra 1952; Kowtal 1972). Yolk absorption is completed at a larval length of about 3 mm (Kowtal 1972; Santerre and May 1977). Polynemid larvae are moderately deep-bodied and compressed, with a coiled gut that extends to ca. 45–65% BL. The gas bladder is prominent through at least notochord flexion, but becomes obscured by the increasing abdominal pigmentation during the postflexion stage. The head is large, with moderate to large eyes and a rounded snout. The characteristic adult snout shape is first discernable during the postflexion stage as a low, rounded protuberance, becoming conical during the transformation or juvenile stage. A few, very small preopercular spines form during notochord flexion in some species (Leis and Trnski 1989); there is none in the eastern Pacific species. Principal caudal fin rays are the first fin rays to begin developing, late in the preflexion stage. Simultaneous development of anal and second dorsal rays begins early in the flexion stage. Pectoral rays and the spines of the first dorsal fin begin forming slightly later during notochord flexion and, at the end of the stage, pelvic and procurrent caudal rays begin to form. Pectoral rays are added from top to bottom and, in the eastern Pacific species, all or nearly all are forming before the lower group of rays detaches from the upper lobe of the fin and begins to shift anteroventrally during the postflexion stage. These lower rays are thicker than the upper rays before detachment, and become longer after detachment. The fin membrane disappears from the lower lobe of the pectoral fin during detachment. Larval polynemids are lightly to moderately pigmented through the beginning of notochord flexion, with melanophores primarily dorsally on the head, on the gas bladder, anteriorly, dorsally, and ventrally on the gut, and on the ventral margin of the tail. A melanophore commonly is present at the posterior margin of the articular or over the angular bone. During the flexion and postflexion stages pigmentation may remain light (e.g., Leis and Trnski 1989), or it may become moderate to heavy (Aboussouan 1966; Leis and Trnski 1989; this study). The terminal section of the intestine commonly is conspicuously unpigmented (except for a ventral melanophore or two in some species) throughout larval development.

Preflexion stage polynemids superficially resemble those of several perciform families in the California Current vicinity, but are readily distinguished from most by several characters. Key among these are the robust body, the large head, the lack of spines on the head and pectoral girdle, and the pigment pattern. Young larvae of some sciaenid species share the robust form, have a moderately large head, and are pigmented much like the polynemids. However, the sciaenids develop preopercular spines during the preflexion stage (and other spines later), and typically have 25–26 myomeres vs. 24 for the two *Polydactylus* species. Early in the flexion stage it becomes obvious that polynemids will have well separated dorsal fins—a key character—and during the postflexion stage the distinctive pectoral fin morphology becomes apparent. Larvae of the two *Polydactylus* species usually can be distinguished from one another by the pigment characters given in the following descriptions. The number of free pectoral rays, countable by 8 mm, also distinguishes the two species (5–6 in *P. approximans*; 8–9 in *P. opercularis*).

The following descriptions are based on detailed examinations of 36 *P. approximans* and 43 *P. opercularis* (Table Polynemidae 1). Meristic data were obtained from Meek and Hildebrand (1923), Miller and Lea (1972), Allen and Robertson (1994), and counts made during this study. Ecological information is from Eschmeyer et al. (1973) and Allen and Robertson (1994).

Table Polynemidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the *Polydactylus* species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Polydactylus approximans	0	0	6	8	13	3	6
			3.1–4.2	3.8–5.2	4.8–13.3	15.2–17.5	20.0–30.5
P. opercularis	0	0	10	13	10	6	4
			2.9–4.0	4.0–7.2	6.0–14.2	15.0–20.8	25.8–36.7

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	12–14	12
Anal spines	III	III
Anal rays	13–15	14
Pelvic	I,5	I,5
Pectoral*	15+5–6	15+6
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	12–14	13
Lower	12–13	12–13
Gill rakers:†		
Upper	11–16	
Lower	15–19	
Branchiostegals	7	7

LIFE HISTORY

Range: Monterey Bay, California to Peru, including Gulf of California & Galápagos Islands

Habitat: Adults: inshore waters over sand-mud bottom, near river mouths or along sandy beaches; pelagic juveniles often found far offshore

Spawning seasou: Throughout the year; in CalCOFI area, larvae occur primarily from July through December

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.3 mm (M. T. Vona)
Flexion larva, 5.0 mm (M. T. Vona)
Postflexion larvae, 5.4 mm, 8.7 mm (M. T. Vona)

* P_1 consists of separate upper & lower portions; counts are given as upper rays + lower free rays.
† Miller & Lea (1972) give gill raker counts of 11–16+16–19, while Allen & Robertson (1994) give 11–12+15–16.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.1 mm
Flexion length: ca. 3.8–4.2 mm through 4.8–5.2 mm
Transformation length: ca. 15.2–17.5 mm
Fin development sequence: C_1, 2D & A, 1D & P_1, P_2, C_2
Pigmentation: *Preflexion*—Externally over midbrain by 3.6 mm; internally posteriorly over hindbrain; under hindbrain by 3.5 mm; anterolaterally on hindbrain by 3.6 mm; 1 at center of upper jaw by 3.5 mm; 0–1 on gular area; 1 on angular; pair at cleithral symphysis; dorsally on gas bladder, extending onto hindgut; anteriorly on liver; 3–4 ventrally on gut; 1 externally behind P_1 base by 3.5 mm; series ventrally on tail, initially ca. 1 per myomere externally, becoming internal & decreasing in number beginning anteriorly; few on ventral finfold. *Flexion*—0–2 over forebrain; increasing over midbrain; spreading from hindbrain over vertebral column to level of 2D insertion by end of stage; on upper preopercle; distally on opercle by 4.1 mm; 0–4 on isthmus; increasing on gas bladder & gut; on lateral midline at level of 2D & A insertion & internally under vertebral column in same area by 4.1 mm. *Postflexion*—Increasing on all areas to cover body except last third of caudal peduncle by 7.8 mm; sparse on snout & ventrally on head & gut; none on P_1 blade, P_2, D, A. *Transformation*—Increasing on all areas & covering caudal peduncle.
Diagnostic features: Compared with *P. opercularis*, more pigment on ventral finfold, more external lateral pigment on trunk & tail during flexion & postflexion stages, less on gular area & ventrally on gut during preflexion stage; 5–6 free P_1 rays (countable by 8 mm); A origin below 2D origin.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–55 51	53–61 56	59–65 62	60–60 60	56–62 57
BD/BL		31–37 34	32–40 36	30–38 34	27–30 28	25–29 26
HL/BL		30–36 33	33–36 35	33–40 36	33–34 33	31–36 33
HW/HL		62–72 68	63–72 68	52–70 59	45–56 51	48–54 50
SnL/HL		19–26 23	18–24 22	16–25 20	20–23 21	19–25 22
ED/HL		32–36 34	32–36 34	30–36 33	30–32 31	26–29 27
P_1L/BL		5–8 7	6–10 8	8–21 15	20–25 22	17–21 19
P_2L/BL		0–3 0.5	3–7 5	7–18 11	16–19 17	16–18 17

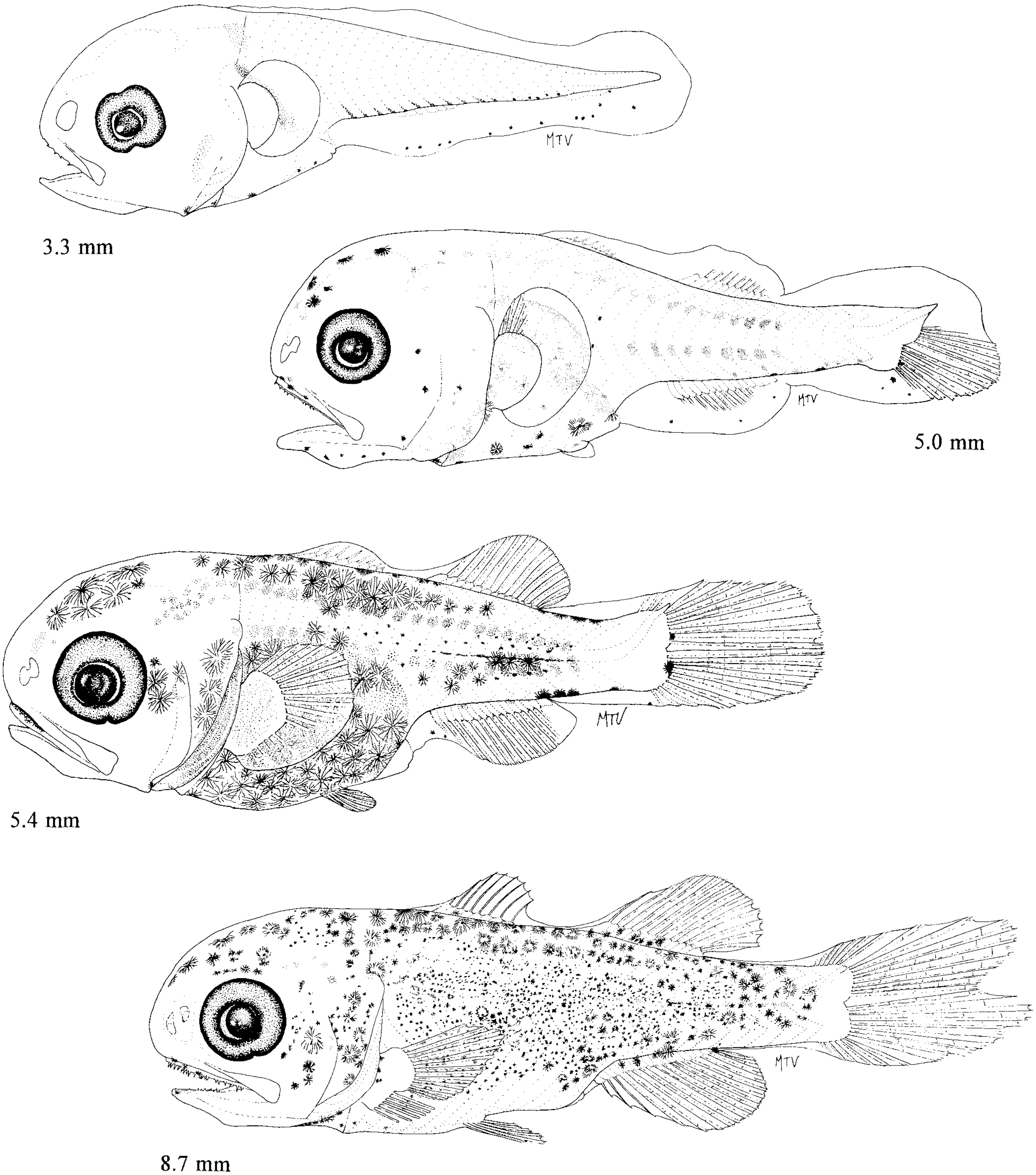


Figure Polynemidae 1. Preflexion larva, 3.3 mm (TO 58–1, station 71); flexion larva, 5.0 mm (CalCOFI 5706, station 151G.100); postflexion larvae, 5.4 mm (IATTC Mazatlán Project 5–14–5), 8.7 mm (CalCOFI 5706, station 139G.85).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	10	10
Caudal	14	14
Fins:		
Dorsal spines	VIII+I	VIII+I
Dorsal rays	11–13	12
Anal spines	III	III
Anal rays	12–14	14
Pelvic	I,5	I,5
Pectoral*	15+8–9	15+9
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	12–13	13
Lower	11–13	12–13
Gill rakers:		
Upper	16–17	
Lower	18–21	
Branchiostegals	7	7

LIFE HISTORY

Range: Los Angeles Harbor, California, to Peru, including Gulf of California

Habitat: Adults near shore over soft bottoms along open coast, in bays & estuaries; pelagic juveniles range far offshore

Spawning season: Throughout the year

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.3 mm (M. T. Vona)
Flexion larva, 6.3 mm (R. C. Walker)
Postflexion larva, 8.3 mm (M. T. Vona)

* P_1 consists of separate upper & lower portions; counts are given as upper rays + lower free rays.

EARLY LIFE HISTORY DESCRIPTION

EGGS

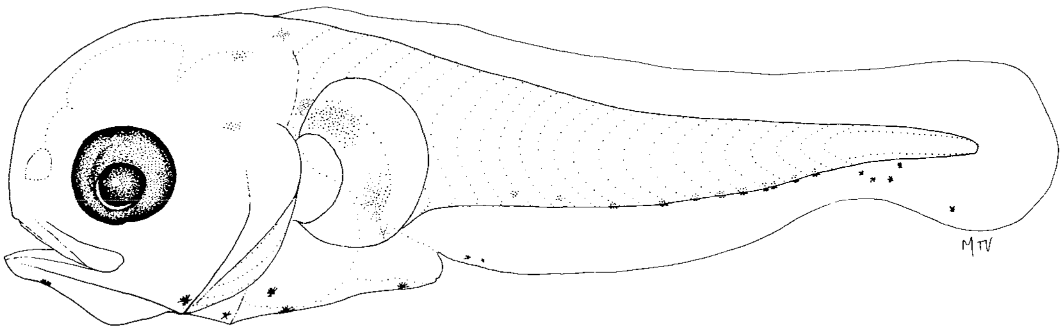
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

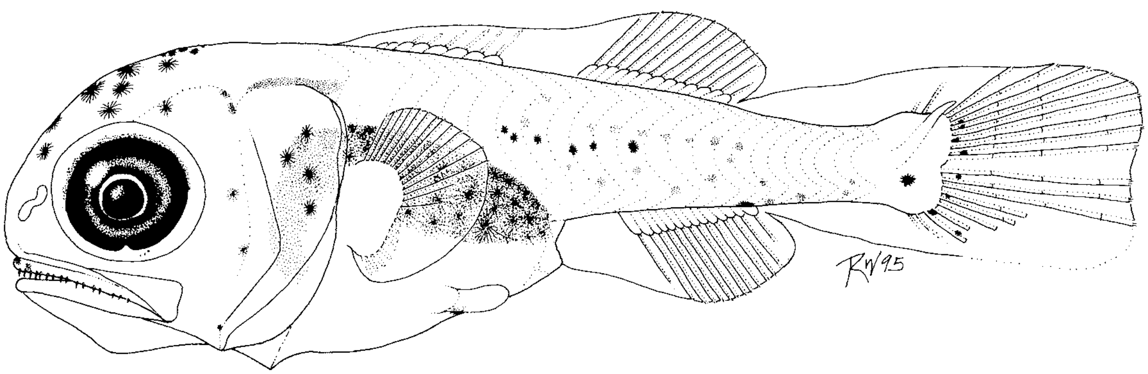
Hatching length: <2.9 mm
Flexion length: ca. 4.0 mm through 6.0–7.2 mm
Transformation length: ca. 15.0–20.8 mm
Fin development sequence: C_1 & 2D & A, P_1, 1D, P_2, C_2
Pigmentation: *Preflexion*—Few over midbrain, gradually increasing; 0–3 over forebrain after 3.4 mm; internally at nape, spreading to cover hindbrain & extending over notochord to myomere 3–8 by 4 mm; 1 at center of upper jaw by 4 mm; 0–2 on preopercle; 1 on gular area, increasing; 1 at angular; 1–2 on isthmus, increasing; pair at cleithral symphysis; anteriorly on liver; dorsally on gas bladder & upper end of hindgut; 3–many ventrally on gut; ca. 1 per myomere on ventral margin of tail, becoming internal beginning anteriorly & decreasing in number; few under notochord tip & on caudal finfold. *Flexion*—Increasing on head & gut except decreasing ventrally on gut after 5 mm; internally along lateral midline of trunk & externally in same area by 5.1 mm; 1 at A insertion; few scattered on C rays. *Postflexion*—Increasing on all areas & spreading caudad laterally; little or none on snout & lower jaw; in narrow band dorsolaterally & ventrolaterally on trunk & tail; on end of caudal peduncle. *Transformation*—Completely pigmented except none on P_1, P_2 & A; light on D & C; little on gut, lower jaw, & posterior margins of caudal peduncle.
Diagnostic features: Compared with *P. approximans*, less pigment on ventral finfold (usually little or none), less external lateral pigment on trunk & tail during flexion & postflexion stages, more pigment on gular area & ventrally on gut during preflexion stage; 8–9 free P_1 rays (countable by 8 mm); A origin below 2D ray 3 or 4.

MORPHOMETRICS (range & mean in %)

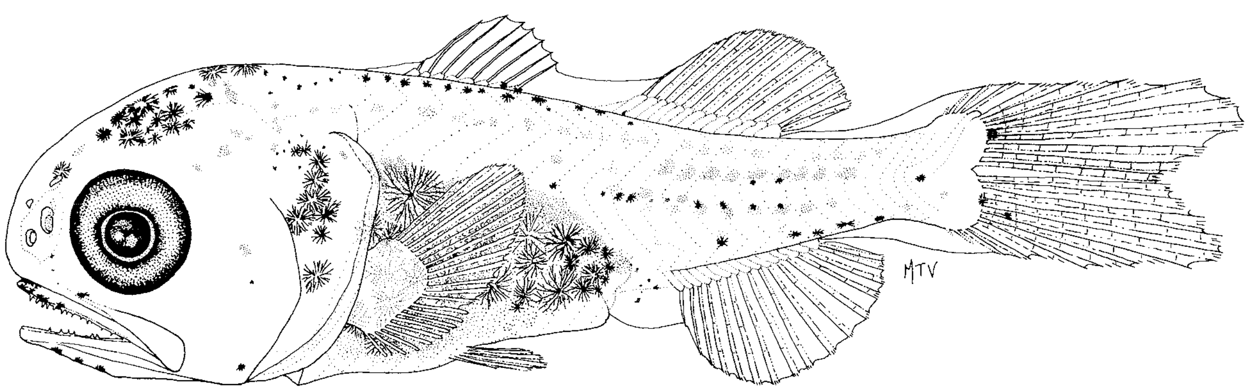
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–51 48	55–63 58	58–65 62	58–64 62	56–62 59
BD/BL		29–34 32	31–37 33	26–31 29	25–27 26	23–24 23
HL/BL		29–35 32	32–39 36	35–39 37	34–36 35	30–33 32
HW/HL		49–70 61	52–75 60	42–68 55	45–52 48	38–47 44
SnL/HL		19–28 22	19–25 21	17–23 20	19–22 21	20–36 24
ED/HL		32–36 34	30–41 34	25–36 31	23–31 28	24–28 25
P_1L/BL		5–10 7	8–13 10	12–18 15	16–25 19	17–19 18
P_2L/BL		0–0 0	4–7 6	8–14 10	12–18 14	14–16 15



3.3 mm



6.3 mm



8.3 mm

Figure Polynemidae 2. Preflexion larva, 3.3 mm; late flexion larva, 6.3 mm (TO 58–1, station 69); postflexion larva, 8.3 mm (IATTC Mazatlán Project 5–14–5).

LABROIDEI

W. WATSON

In most classifications through the early 1980s the labroid fishes (variously classified as an order, a perciform suborder, and a percoid superfamily) were considered to be the Labridae, Scaridae, and Odacidae (e.g., Greenwood et al. 1966; Norman 1966; Gosline 1971; Nelson 1984). Based on various synapomorphies involving the pharyngeal apparatus, Kaufman and Liem (1982) and Stiassny and Jensen (1987) defined an expanded suborder that subsumed these three families in the Labridae, and included the Cichlidae, Embiotocidae, and Pomacentridae as well. Monophyly of this larger suborder is widely accepted, but some authors have expressed reservations. For example, Richards and Leis (1984) argued that while early life history characters show a close relationship among the labrids, scarids and odacids (but enough differences to support retention of three separate families), they do not support monophyly of the larger suborder. Johnson (1993) noted that the expanded Labroidei might be monophyletic, but expressed skepticism because none of the defining characters is unique to it and there apparently are not other characters supporting monophyly. Nelson (1994) provisionally accepted the larger suborder but retained the labrids, scarids and odacids as separate families. Bellwood (1994) likewise accepted Kaufman and Liem's (1982) classification, except that he rejected fusion of the labrids, scarids and odacids. In this volume we follow Eschmeyer (1990) in restricting the Labroidei to the three traditional labroid families and in retaining the others in Percoidei.

Labroidei is represented in the California Current vicinity by the families Labridae and Scaridae. The labrids have been subdivided into several subfamilies and tribes by various workers (e.g., Norman 1966; Araga 1984; Yamakawa 1984; Webb 1990), but as noted by Nelson (1994) monophyly has been demonstrated for only one tribe, Cheilinini (Westneat 1993). Bellwood (1994) stated that the labrids apparently are paraphyletic and in need of revision. The scarids commonly are separated into two subfamilies, Sparisomatinae and Scarinae (e.g., Schultz 1958, 1969; Eschmeyer 1990; Nelson 1994), but Bellwood (1994) provided evidence that the sparisomatines are paraphyletic and rejected the subfamilial division, while arguing that monophyly of the family as a whole is strongly supported by a number of synapomophies. Interestingly, larval sparisomatines appear to be rather distinct from larval scarines on the basis of small, but clear differences in morphology and pigmentation (see Scaridae, this volume; Leis and Rennis 1983; Richards and Leis 1984; Kojima 1988b). Nevertheless, subfamilial or tribal level divisions are made for neither labrids nor scarids in this volume.

Families included: Labridae
Scaridae

LABRIDAE: Wrasses

W. WATSON

Labridae presently is thought to contain about 60 genera and 500 species (Nelson 1994). At least 14 species in eight genera occur in the CalCOFI study area along the Pacific coast between central California and the southern tip of Baja California (Table Labridae 1), and additional species that have not been reported from the study area occur nearby in the Gulf of California (Thomson et al. 1979; Abitia-Cárdenas et al. 1994; Allen and Robertson 1994; Gomon 1995). Only three species range northward as far as southern California (*Halichoeres semicinctus*) or central California (*Oxyjulis californica* and *Semicossyphus pulcher*). The larvae of these three species occur more or less commonly in CalCOFI ichthyoplankton samples, primarily during summer and autumn. Larvae of *H. dispilus*, *Thalassoma* sp(p.), and *Xyrichtys* spp. have been taken in CalCOFI samples off southern Baja California and from the Gulf of California, as well as from other ichthyoplankton surveys farther south. Larvae of the remaining species have not been identified in CalCOFI collections.

Labridae is a large, primarily tropical, family of fishes that vary greatly in size, shape, and color. Adult body sizes range from <10 cm to ca. 3 m, and shapes range from cylindrical to deep-bodied and slab-sided. Wrasses in this study area typically are smaller than 30–40 cm (*Bodianus diplotaenia* reaches ca. 75 cm and *S. pulcher* ca. 1 m) and are moderately to strongly compressed (*O. californica* is cigar-shaped). Many labrid species are brightly colored; some are well known in the aquarium trade. Wrasses typically are associated with shallow reefs, kelp forests, etc., where they may be planktivores, omnivorous benthic pickers, predators on epibenthic invertebrates and fishes, or cleaners. Complex social hierarchies have been documented for many species. Protogynous hermaphroditism is common.

Spawning and early life histories have been documented for many labrid species (e.g., Richards and Leis 1984). All are oviparous and most spawn small, spherical, planktonic eggs. The eggs typically are slightly less than 1 mm in diameter (range ca. 0.5–1.1 mm) with a smooth chorion, narrow perivitelline space, unsegmented colorless yolk, and single oil globule typically ca. 0.1–0.2 mm in diameter. The oil globule often is colorless, but in some species is orange-pink to red-brown, at least during early development. Larvae hatch at a length of ca. 1.5–3 mm with unpigmented eyes, a large yolk sac with anterior oil globule that initially extends beyond the anterior margin of the head, and they lack a functional mouth. Preanal length commonly is about half of body length, but may be nearly three-quarters of body length in some (e.g., *Xyrichtys*). As the gut coils (usually during the flexion stage) preanal length decreases to around half of body length for those species that initially have a long preanal length, but it changes little for the others. Larval labrids range from moderately elongate and slender to moderately deep-bodied. Some have a rather long and pointed snout while others have a shorter, more rounded snout. The mouth is small. Eye shape ranges from round to distinctly oval. Head spination is rare in the family and is absent in the species from the CalCOFI study area. Larval labrids are compressed and all in the CalCOFI study area have between 24 and 29 myomeres. Pigmentation may be moderate, mainly on the dorsum in newly hatched larvae, but by the end of yolk absorption, melanophores typically are absent to sparse, particularly in the tropical species (yellow, orange, or red pigment is common in live larvae). After yolk absorption, melanophores typically are limited mainly to the swimbladder, gut, and tail. For additional description of larval labrids, refer to Russell (1976), Leis and Rennis (1983), Richards and Leis (1984), and references cited in those publications.

Larval labrids usually are readily recognizable on the bases of body shape, preanal length, myomere count, lack of spines on the head, fin ray counts in postflexion stage specimens, and typically sparse pigmentation. Larval scarids resemble labrids in most of these characters and are the larvae in the California Current vicinity that are most likely to be confused with the labrids. Larval scarids typically have a series of evenly spaced melanophores along the ventral margin of the tail, while such pigment is absent in labrid species of the CalCOFI vicinity. The intestine is rugose in larval scarids, but not in the CalCOFI area labrids. Scarids have 13 principal caudal fin rays while labrids have 14–15 (usually 14). The collection site may be useful as well: larval scarids have not been collected north of about Punta Abreojos, Baja California Sur. Larvae of some myctophid species superficially resemble labrids during the preflexion stage but are readily distinguished from the labrids by myomere counts (≥30 in the myctophids vs. ≤29 in the labrids) and gut rugosity (rugose in myctophids, not in labrids).

Identification of five of the seven labrid genera from the CalCOFI study area is relatively simple using the following descriptions, but identification of all species presently is not possible. Characters that would allow separation of larval *Thalassoma lucasanum* from *T. grammaticum*, and of the three *Xyrichtys* species through the flexion stage are unknown. On the basis of a few postflexion specimens it appears that *Halichoeres dispilus* (Figure Labridae 1) may be separable from *H. semicinctus* by a lack of pigment on the swimbladder and hindgut (present in *H. semicinctus*). Larval *Bodianus diplotaenia* and *H. notospilus* are unknown.

The following descriptions are based on detailed examinations of larvae and juveniles of at least six species and on published literature (Table Labridae 2). Late larvae of *Halichoeres dispilus* are shown in Figure Labridae 1, but are not described separately because of insufficient material. Identification of *H. dispilus* is based on unpublished work by Herbert C. Perkins. Perkins' unpublished work on larval *H. semicinctus*, *O. californica* and *S. pulcher* aided in completing those species' descriptions. The primary sources for meristic and adult distribution and habitat data were Miller and Lea (1972), Thompson et al. (1979), Eschmeyer et al. (1983), Bussing (1985), Gomon (1995), and Clothier and Baxter (unpublished manuscript). Additional counts were taken during this study. Randall (1995) demonstrated that eastern Pacific records of *T. lutescens* reported by other authors refer to *T. grammaticum*.

Table Labridae 1. Selected meristic characters for labrid species in the CalCOFI study area. All species have I,5 pelvic fin rays, 7+7 principal caudal fin rays, and 6 branchiostegal rays.

Species	Vertebrae			Fin rays				GR
	PrCV	CV	Total	D	A	P_1	C_2	
Bodianus diplotaenia	11	17	28	XI–XII,9–11	III,11–13	17	8–10+8–9	6–8+10–14
Decodon melasma	11	17–18	28–29	XI–XII,9–10	III,9–10	14–18	9–10+8–10	5–7+9–12
Halichoeres dispilus	9	16	25	IX,11	III, 11–12	12–13	5–7+5–7	6+7
H. nicholsi	9	16	25	IX,11	III,12	13	6–7+6	
H. notospilus	9	15–16	24–25	IX,11	III,11–12	13	6+5–6	
H. semicinctus	9	17	26	IX,11–12	III,12–13	12–13	6+6–7	5–8+11–13
Oxyjulis californica	10–11	15–17	26–27	IX–X,13	III,13	12–15	6–7+6	6–7+12–16
Polylepion cruentum	11	17	28	XI,11	III,11–12	17–21	9–11+9–11	5–8+10–12
Semicossyphus pulcher	11–12	16–17	28	XI–XII,10–11	III,10–12	17–19	9–10+9–10	
Thalassoma grammaticum	10	15	25	VIII,12–13	III,11	15–16	6+6	20–24 total
T. lucasanum	10	15	25	VIII,12–14	III,11–12	14–15	5–6+5–6	
Xyrichtys mundiceps	9	16	25	IX,12	III,11–12	11–12	4–6+4–5	6–8+15
X. pavo	8	16	24	II+VII,12–13	III,12–13	12–13	4–5+4	6+6
X. taeniourus	9	16	25	II+VII,12	III,12	13	4+3–4	

Table Labridae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the labrid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Halichoeres semicinctus	0	5 1.5–2.2	10 2.6–4.8	6 5.1–5.7	10 6.2–12.9	0	5 21.9–34.0
Oxyjulis californica	L[a]	5 2.1–3.2	10 2.6–6.4	5 6.4–7.7	10 7.8–21.0	0	5 18.6–31.0
Semicossyphus pulcher	0	5 2.7–3.3	10 3.3–6.2	5 5.4–6.6	6 6.4–8.3	0	2 15.6–19.2
Thalassoma sp(p).	0	0	1 3.1	1 4.1	10 4.0–12.6	4 11.4–11.8	5 11.9–15.3
Xyrichtys mundiceps	0	0			10 5.1–18.8	0	4 25.7–30.2
X. pavo	0	0			4 8.5–12.2	0	1 14.1
Xyrichtys sp(p).	0	0	7 2.6–4.1	5 4.2–4.7	0	0	0

[a] Bolin 1930

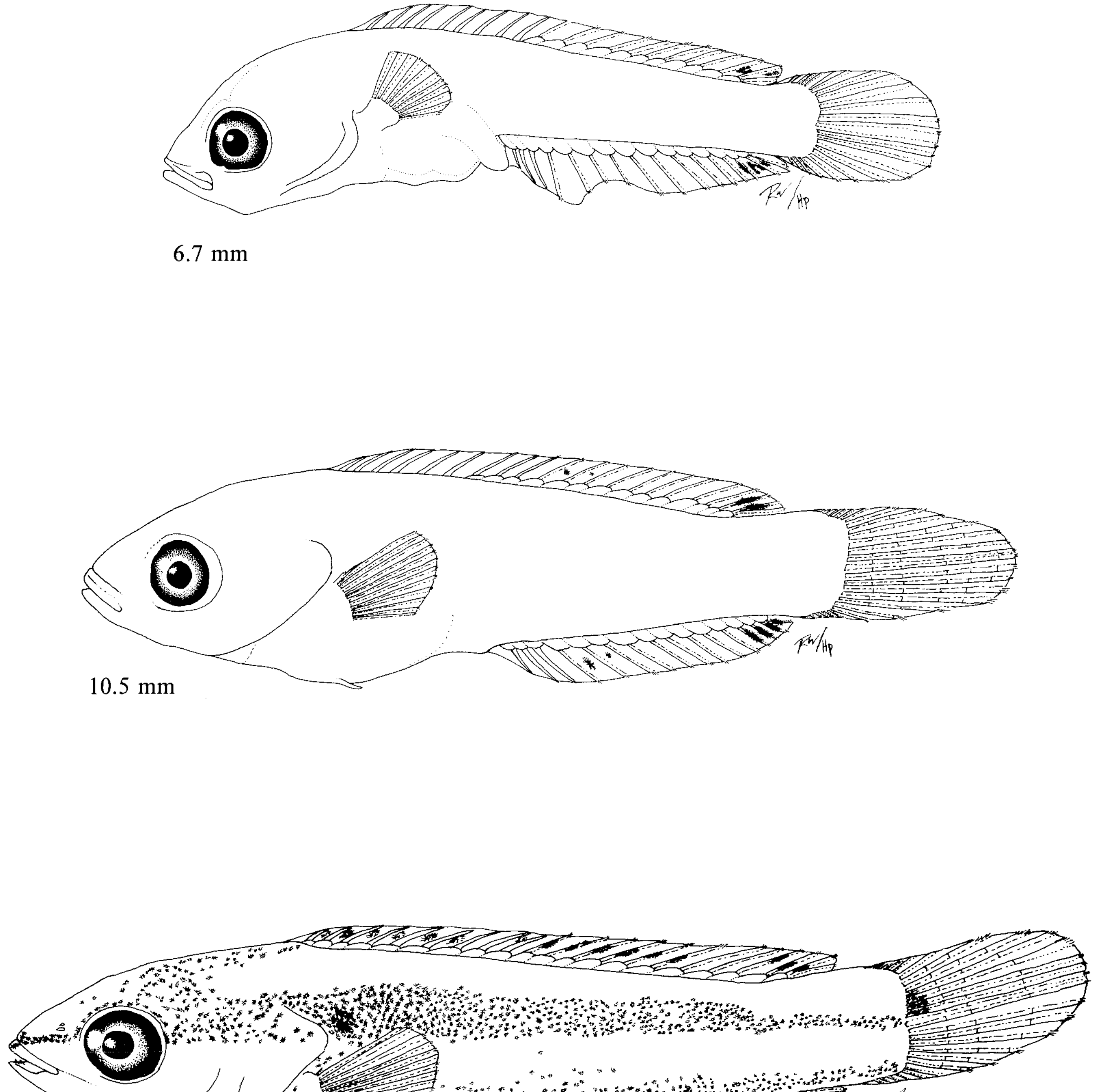


Figure Labridae 1. Chameleon wrasse, *Halichoeres dispilus*: postflexion larvae, 6.7 mm, 10.5 mm; juvenile, 16.6 mm. All illustrations are redrawn by R. C. Walker from unpublished work of Herbert C. Perkins, who did not show myomeres or scales on his original drawings.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	9	9
Caudal	17	17
Fins:		
Dorsal spines	IX	IX
Dorsal rays	11–12	12
Anal spines	III	III
Anal rays	12–13	12
Pelvic	I,5	I,5
Pectoral	12–13	13
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	6	6
Lower	6–7	6
Gill rakers:		
Upper	5–8	7–8
Lower	11–13	12–13
Branchiostegals	6	6

LIFE HISTORY

Range: California & Baja California south from Point Conception; uncommon south of Isla de Guadalupe; in Gulf of California

Habitat: Water column over & adjacent to shallow (<ca. 25 m depth) rocky reefs & in tidepools; buries in sand at night

Spawning season: Summer to early fall

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.2 mm (B. Sumida MacCall)
Preflexion larva, 4.0 mm (B. Sumida MacCall)
Flexion larva, 5.4 mm (B. Sumida MacCall)
Postflexion larva, 9.4 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 1.5–2 mm
Flexion length: ca. 5–6 mm
Transformation length: >13 mm, <21 mm
Fin development sequence: C_1, 2D & A, C_2, 1D & P_1, P_2
Pigmentation: *Larvae*—0–few on snout, none after 2 mm; few along midgut, condensing to single posterior area by 2.5 mm, extending onto ventrum by 5 mm; 1 on cleithrum by 5.5 mm; 1 on ventral margin at ca. myomere 21–22, extends onto A rays 11–12 by ca. 6 mm; 1 on dorsal margin at ca. myomere 12–13, moves onto finfold by 2.5 mm, & on D rays 1–2 in postflexion stage; blotch at D rays 11–12 by 6.6 mm, 1 on nape by 8.7 mm; over midbrain by 12.9 mm. *Juvenile*—Upper half dark; 1–2 prominent blotches on posterior half of D.
Diagnostic features: Preanal myomeres 9–11 (usually 10), 26 total myomeres; gut coiled posteriorly after ca. 4 mm; pigment on cleithrum, posteriorly on midgut, & on ventral margin of tail at ca. myomeres 21–22; on dorsal finfold at ca. myomeres 12–13; pigment on D rays 11–12, rarely extending onto body.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	49–53	50–57	54–57	52–59		52–55
	51	53	55	55		54
BD/BL	10–13	11–16	18–21	19–23		20–25
	11	13	19	21		22
HL/BL	18–21	19–23	26–27	27–30		25–31
	19	21	27	28		27
HW/HL	50–71	44–57	44–49	37–47		47–51
	60	51	47	41		49
SnL/HL	15–21	11–25	23–26	24–31		26–29
	19	18	24	28		28
ED/HL	43–57	28–47	27–31	24–29		28–32
	48	33	29	26		30
P_1L/BL	0–2	5–7	6–8	8–13		15–18
	1	6	7	11		17
P_2L/BL	0–0	0–0	0–0	0.1–2		10–12
	0	0	0	1		11

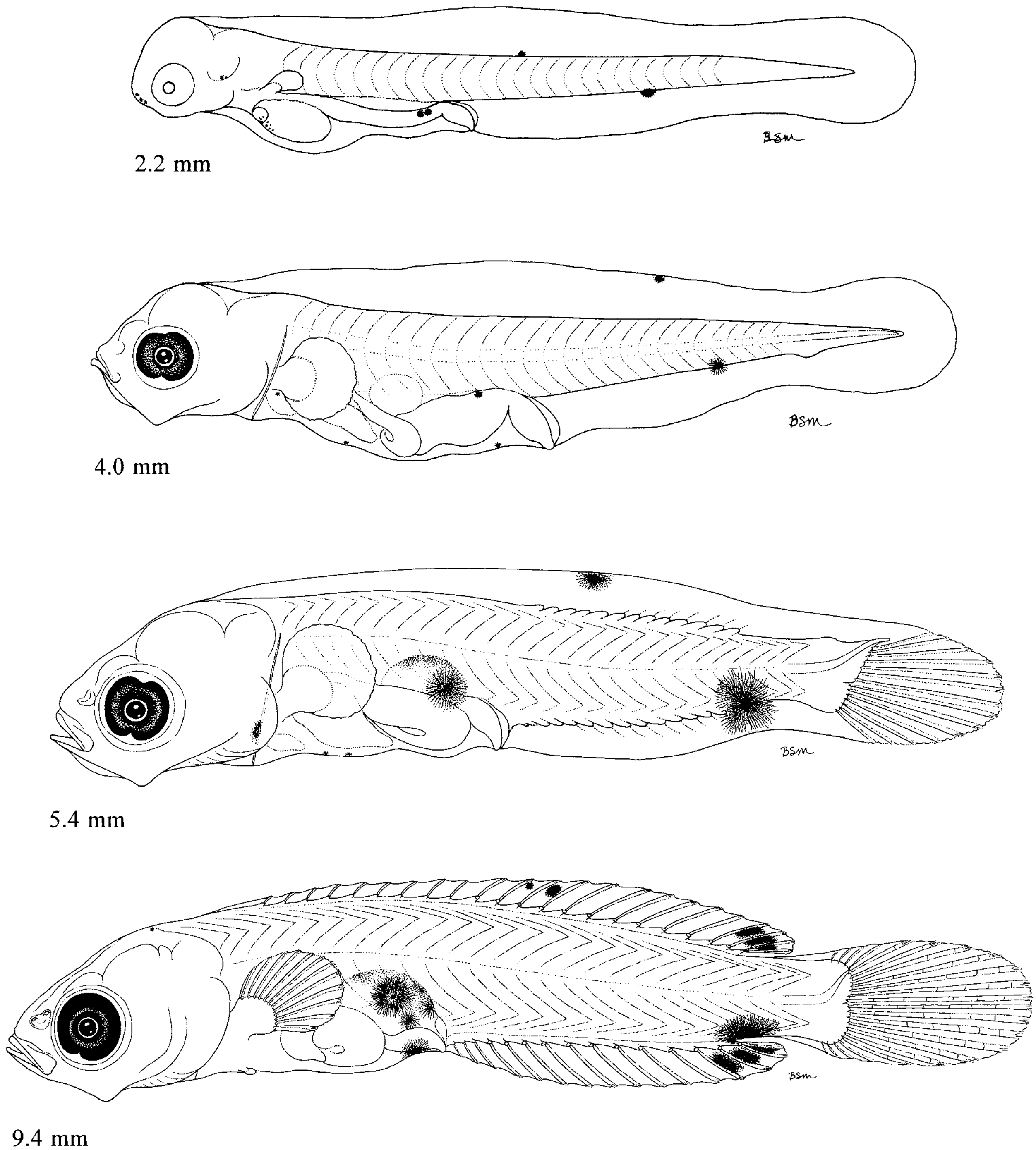


Figure Labridae 2. Yolk-sac larva, 2.2 mm (CalCOFI 6507, station 120.24); preflexion larva, 4.0 mm (CalCOFI 6410, station 137.21); flexion larva, 5.4 mm (CalCOFI 6608, station 120.55); postflexion larva, 9.4 mm (CalCOFI 5708, station 127.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	26
Precaudal	10–11	10
Caudal	15–17	16
Fins:		
Dorsal spines	IX–X	IX
Dorsal rays	13	13
Anal spines	III	III
Anal rays	13	13
Pelvic	I,5	I,5
Pectoral	12–15	13
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	6–7	6
Lower	6	6
Gill rakers:		
Upper	6–7	6
Lower	12–16	
Branchiostegals	6	6

LIFE HISTORY

Range: Sausalito, California, to Isla Cedros, Baja California

Habitat: Over rocky bottom & around kelp & other macrophyte beds; surface to ca. 73 m depth

Spawning season: Late spring–fall (ca. May–October), peak July–September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Bolin 1930
Orton 1953a

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.1 mm (B. Sumida MacCall)
Preflexion larva, 3.2 mm (B. Sumida MacCall)
Flexion larva, 7.7 mm (B. Sumida MacCall)
Postflexion larva, 10.7 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

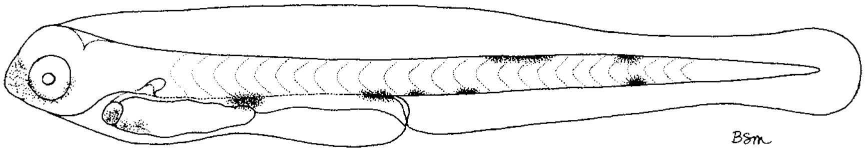
Shell diam.: 0.74–0.79 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.15 mm
Shell surface: Smooth
Pigment: OG orange-pink, becoming colorless by blastopore closure; later embryo with dorsal & OG melanophores, bar on tail before hatching
Diagnostic features: Shell diameter; OG color early, & location near head in late-stage eggs; embryonic pigmentation

LARVAE

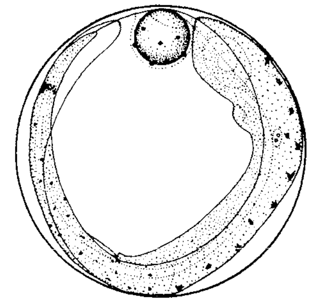
Hatching length: ca. 2 mm
Flexion length: ca. 6.4–7.7 mm
Transformation length: ca. 19–22 mm
Fin development sequence: C_1, 2D & A, C_2, 1D, P_1, P_2
Pigmentation: *Yolk-sac*—Irregular dorsolateral series, migrating ventrad, condensing into patches on hindgut & at ca. myomeres 21–23. *Preflexion–postflexion*—Dorsal & ventral margin blotches or bar across tail at myomeres 21–23, extending onto last D & A rays in postflexion stage; posteriorly over midgut/anterior hindgut & on ventral surface by 6 mm; ring around gut by flexion stage; 1 at nape, 1 over midbrain by 8.2–10.7 mm. *Juvenile*—Upper half darker; 2 prominent blotches on C base.
Diagnostic features: Preanal myomeres 10–11 (usually 10), 25–27 (usually 26) total myomeres; prominent dorsal & ventral melanophores or bar on tail at ca. myomeres 21–23, extending onto last D & A rays in postflexion stage; pigment band posteriorly around midgut; no cleithral pigment.

MORPHOMETRICS (range & mean in %)

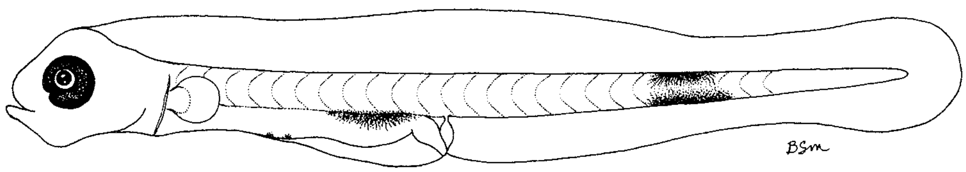
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	49–58 52	49–55 52	52–54 53	51–62 55		53–63 57
BD/BL	9–22 12	9–13 11	11–13 12	14–20 17		20–22 20
HL/BL	17–19 18	16–22 19	19–23 21	24–31 26		24–31 28
HW/HL	44–55 49	44–61 52	41–51 47	39–45 41		39–49 46
SnL/HL	8–15 13	14–24 18	21–22 21	23–33 27		23–32 29
ED/HL	33–50 39	30–39 34	30–33 32	27–32 29		28–34 30
P_1L/BL	0–1 0.5	4–6 5	3–6 5	5–14 9		14–17 16
P_2L/BL	0–0 0	0–0 0	0–0 0	0–5 1		8–10 9



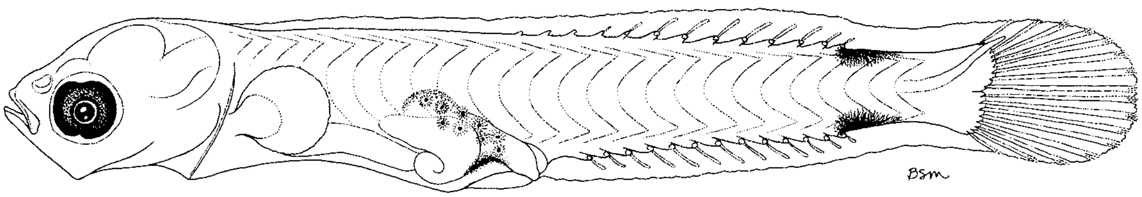
3.1 mm



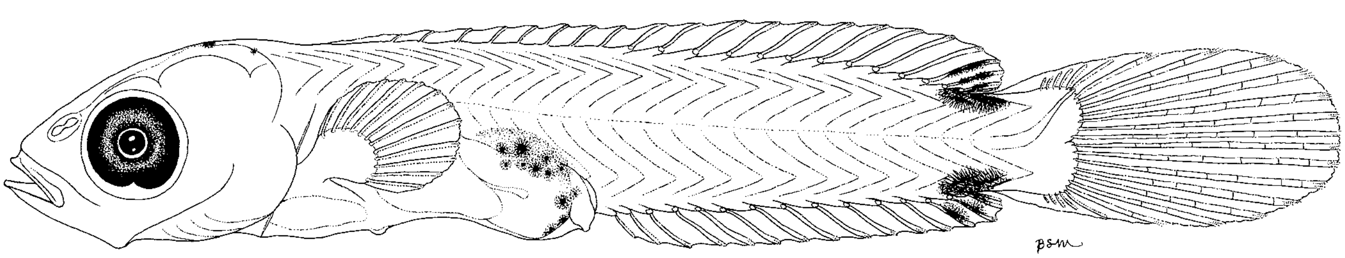
0.74–0.79 mm



3.2 mm



7.7 mm



10.7 mm

Figure Labridae 3. Egg, near hatching (Bolin 1930); yolk-sac larva, 3.1 mm (CFRD Ref. Coll., reared at SWFSC, 1 day after hatching, May 15, 1978); preflexion larva, 3.2 mm (CFRD Ref. Coll., reared at SWFSC, day 5, May 17, 1978); flexion larva, 7.7 mm (CalCOFI 5106, station 97.32); postflexion larva, 10.7 mm (CalCOFI 8407, station 76.7.55).

MERISTICS

	Range	Mode
Vertebrae:		
Total	28	28
Precaudal	11–12	12
Caudal	16–17	16
Fins:		
Dorsal spines	XI–XII	XII
Dorsal rays	10–11	10
Anal spines	III	III
Anal rays	10–12	12
Pelvic	I,5	I,5
Pectoral	17–19	18
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	9–10	9–10
Lower	9–10	9–10
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Monterey, California, to Cabo San Lucas, Baja California Sur, & Gulf of California

Habitat: Over rocky bottom & in kelp forests; surface to ca. 55 m depth

Spawning season: Late spring to early fall, peak July–September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Orton 1953a

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.3 mm (B. Sumida MacCall)
Preflexion larva, 4.7 mm (B. Sumida MacCall)
Flexion larva, 6.1 mm (B. Sumida MacCall)
Postflexion larva, 8.2 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

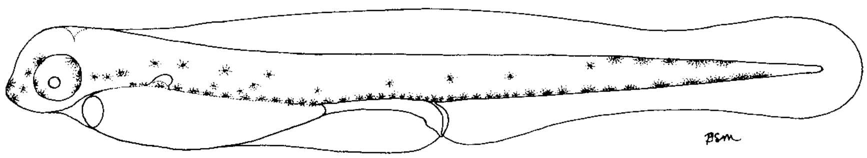
Shell diam.: 0.80 mm
Yolk: Homogeneous
No. of OG: 1
Diam. of OG: 0.17 mm
Shell surface: Smooth
Pigment:
Diagnostic features:

LARVAE

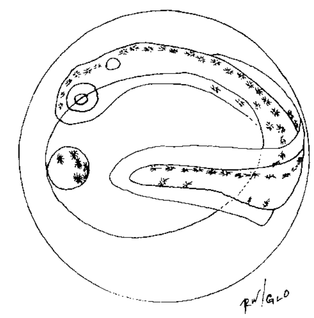
Hatching length: ca. 2.5 mm
Flexion length: 5.4–6.2 mm through 6.4–6.6 mm
Transformation length: >8.3 mm, <15.6 mm
Fin development sequence: C_1, C_2, 2D & A, 1D & P_1 & P_2
Pigmentation: *Yolk-sac*—0–few (small) dorsally, on first few postanal myomeres; usually 2 (large) posteriorly, on dorsal margin of tail; 1–2 ventrally on snout; series over gut & onto ventral margin of tail to myomere 15–20; under notochord tip. *Preflexion–postflexion*—Series along ventral margin of tail at ca. myomeres 12–20 & 26–28, posterior few move onto caudal peduncle by 6.8 mm; 2 to few on dorsal margin at ca. myomeres 20–26; 0–1 on isthmus; 0–1 on ventral margin of gut. *Juvenile*—Prominent blotches on D (usually 2), A (usually 1), C (1–3), & most of P_2.
Diagnostic features: Preanal myomeres 11–12 (usually 11), 28 total myomeres; tail with discontinuous ventral melanophore series, dorsal pigment over gap in ventral series; melanophore series from posterior margin of eye to end of gut; prominent fin blotches in juvenile.

MORPHOMETRICS (range & mean in %)

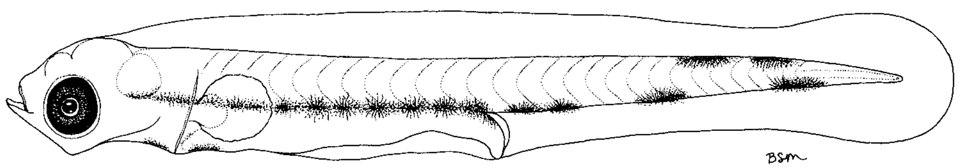
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	50–60 55	55–61 57	58–61 59	60–63 61		60–61 61
BD/BL	9–24 16	10–15 12	15–19 17	20–21 21		28–31 30
HL/BL	14–19 17	16–24 20	24–28 26	30–32 31		34–36 35
HW/HL	38–67 53	36–58 49	43–45 44	40–45 43		53–57 55
SnL/HL	8–18 12	15–23 19	20–26 23	24–26 25		27–28 27
ED/HL	36–46 43	24–39 31	21–26 24	23–28 25		34–35 34
P_1L/BL	0–3 1	2–5 4	5–6 5	6–8 8		19–20 19
P_2L/BL	0–0 0	0–0 0	0–0 0	0–1 1		15–16 15



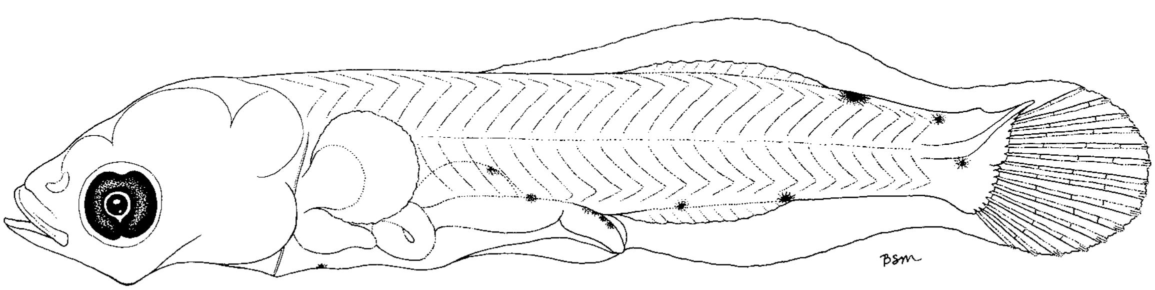
3.3 mm



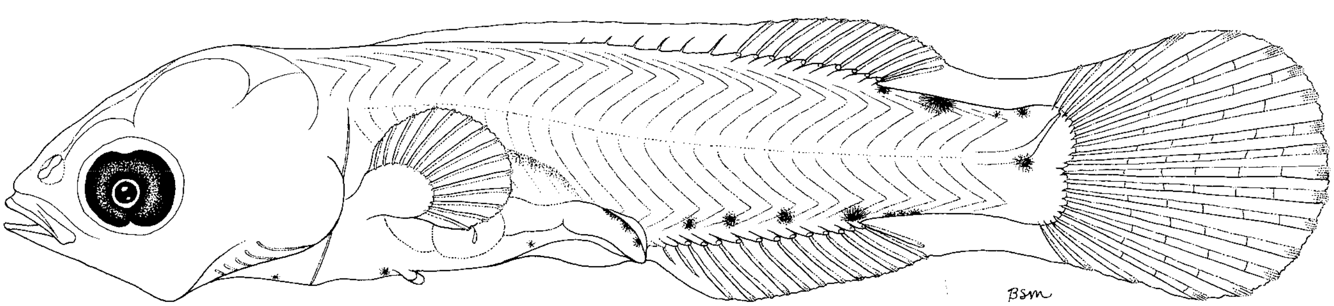
ca. 0.80 mm



4.7 mm



6.1 mm



8.2 mm

Figure Labridae 4. Egg, near hatching, redrawn and modified by R. C. Walker from Orton (1953a); yolk-sac larva, 3.3 mm (CFRD Ref. Coll., reared at SWFSC from eggs collected off Mission Beach, San Diego, California, June 23, 1978); preflexion larva, 4.7 mm (CFRD Ref. Coll., reared at SWFSC from eggs collected off Tourmaline Canyon, California, August 16, 1978); flexion larva, 6.1 mm (CalCOFI 5109, station 123.37); postflexion larva, 8.2 mm (CalCOFI 8407, station 82.46).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10	10
Caudal	15	15
Fins:		
Dorsal spines	VIII	VIII
Dorsal rays	12–14	13
Anal spines	III	III
Anal rays	11–12	11
Pelvic	I,5	I,5
Pectoral	14–16	
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	5–6	
Lower	5–6	
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: In CalCOFI area, Gulf of California to Cabo San Lucas; *T. lucasanum* ranges north to Bahía Magdalena, Baja California Sur

Habitat: Over reefs near shore

Spawning season: Larvae collected in summer & fall

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.1 mm (B. Sumida MacCall)
Flexion larva, 4.1 mm (B. Sumida MacCall)
Postflexion larva, 5.0 mm (B. Sumida MacCall)

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* Two species in CalCOFI area: *T. lucasanum* & *T. grammaticum.* Most (perhaps all) larvae examined probably are *T. lucasanum.*

† *Thalassoma lucasanum.*

‡ Eye is parallelogram-shaped to oval; horizonal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 4 mm
Transformation length: ca. 11–13 mm
Fin development sequence: C_1, D & A & C_2, P_1, P_2
Pigmentation: *Larvae*—No melanophores. *Transformation*—Upper half becomes heavily pigmented; stripe along distal half; most of dorsal fin covered.
Diagnostic features: Somewhat narrow eye subtended by crescent-shaped choroid tissue; relatively long, pointed snout; looped gut in postflexion stage; preanal myomeres 10–13 (usually 10–11), 25–26 total myomeres; dorsal spines VIII; melanophores lacking throughout larval stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr†	Juv†
Sn-A/BL				51–63	54–56	53–60
		63	66	56	55	57
BD/BL				24–32	25–28	26–28
		22	23	29	26	27
HL/BL				30–35	31–33	29–35
		28	29	31	32	31
HW/HL				28–43	42–54	42–49
		43	34	37	46	45
SnL/HL				25–33	21–26	21–24
		20	31	29	24	23
ED/HL‡				20–24×	27–28×	28×31
				20–26	26–28	27–30
		23×24	22×21	22×24	28×27	30×29
P_1L/BL				8–19	19–21	19–21
		8	7	14	20	20
P_2L/BL				0–2	4–7	7–10
		0	0	1	6	9
CL/HL				1–4	0–0	0–0
		4	5	3	0	0

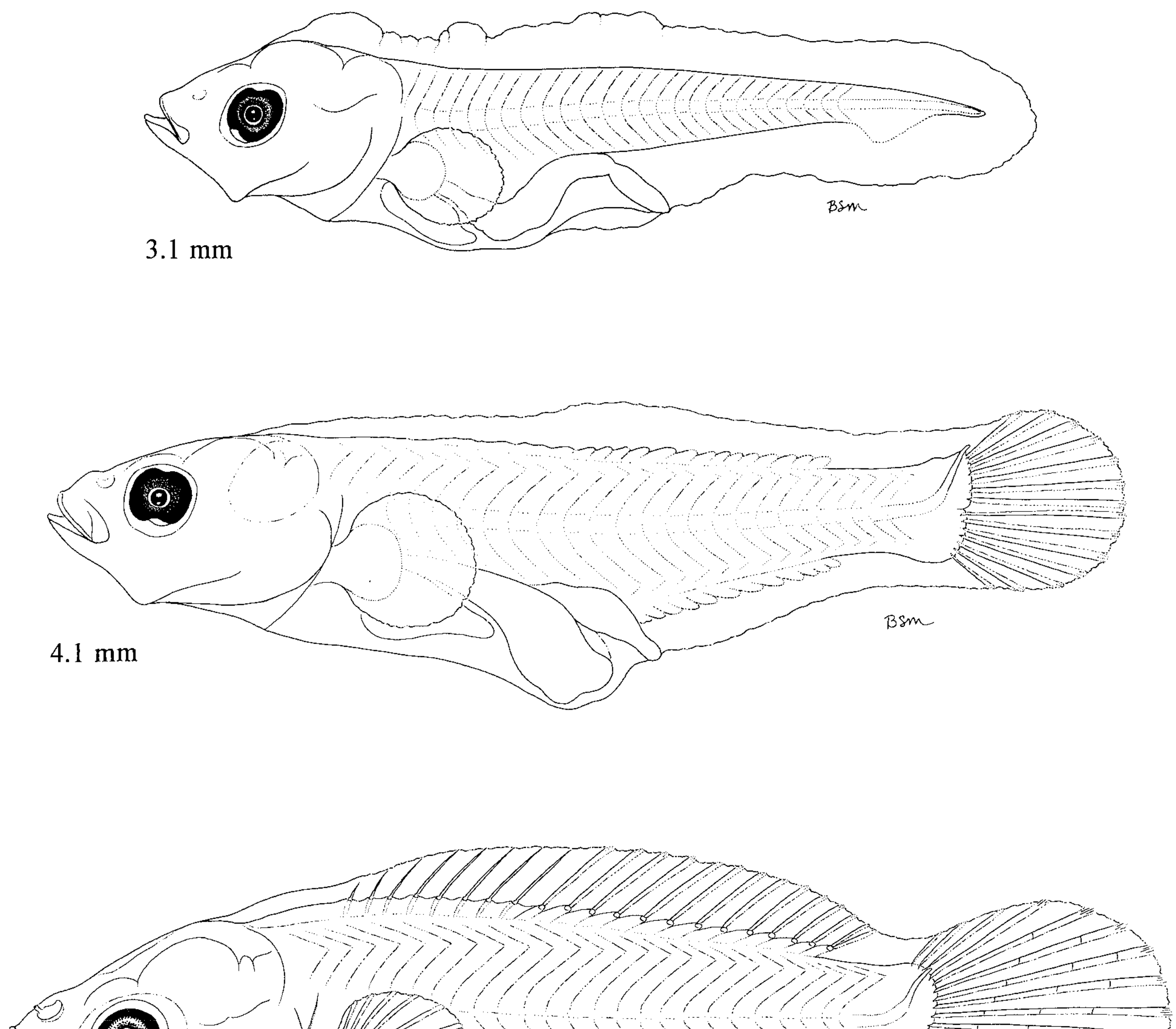

Figure Labridae 5. Preflexion larva, 3.1 mm (CalCOFI 5708, station 151G.37); flexion larva, 4.1 mm (CalCOFI 7210, station 157.15); postflexion larva, 5.0 mm (CalCOFI 7210, station 157G.13).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	9	9
Caudal	16	16
Fins:		
Dorsal spines	IX	IX
Dorsal rays	12	12
Anal spines	III	III
Anal rays	11–12	12
Pelvic	I,5	I,5
Pectoral	11–12	12
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	4–6	4–5
Lower	4–5	4
Gill rakers:		
Upper	6–8	
Lower	15	15
Branchiostegals	6	6

LIFE HISTORY

Range: Southern end of Baja California Sur, primarily Cabo San Lucas area

Habitat: Over sandy bottom in shallow water

Spawning season: Larvae collected in spring and summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.6 mm (B. Sumida MacCall)
Flexion larva, 4.7 mm (B. Sumida MacCall)
Postflexion larvae, 5.9 mm, 9.0 mm (B. Sumida MacCall)

* Three species in CalCOFI area: *X. mundiceps*, *X. pavo*, & *X. taeniourus*; all postflexion stage larvae & juveniles here are *X. mundiceps* (preflexion & flexion probably are *X. mundiceps* as well). Many authors use the synonym *Hemipteronotus* for this genus.

† Eye is vertically elongate; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.6 mm
Flexion length: ca. 4–5 mm
Transformation length: >18.8 mm, <25.7 mm
Fin development sequence: C_1, A, D & P_1 & C_2, P_2
Pigmentation: No melanophores during larval development.
Diagnostic features: Vertically elongate eye with conical choroid tissue; gut long & straight in larvae up to ca. 5 to 5.5 mm, very short & coiled by ca. 6 mm; compressed body; no melanophores; preanal myomeres 7–14 (usually 14 through ca. 4.1 mm, 11 to ca. 5.5 mm, & 9 thereafter), 24–26 (usually 25) total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		67–71 69	65–69 67	40–60 46		45–47 46
BD/BL		15–18 17	17–20 18	20–25 22		26–27 26
HL/BL		23–25 24	24–27 26	21–29 25		25–27 26
HW/HL		39–52 43	25–41 35	27–38 34		42–44 43
SnL/HL		14–26 20	21–28 24	23–38 31		29–33 31
ED/HL†		23–30× 25–31	19–22× 21–26	16–25× 19–28		24–27× 24–26
		25×27	21×23	20×23		25×25
P_1L/BL		3–6 5	6–9 7	8–19 14		19–20 19
P_2L/BL		0–0 0	0–0 0	0–2 1		10–11 11
CL/HL		0–6 2	4–7 5	4–8 6		0–0 0

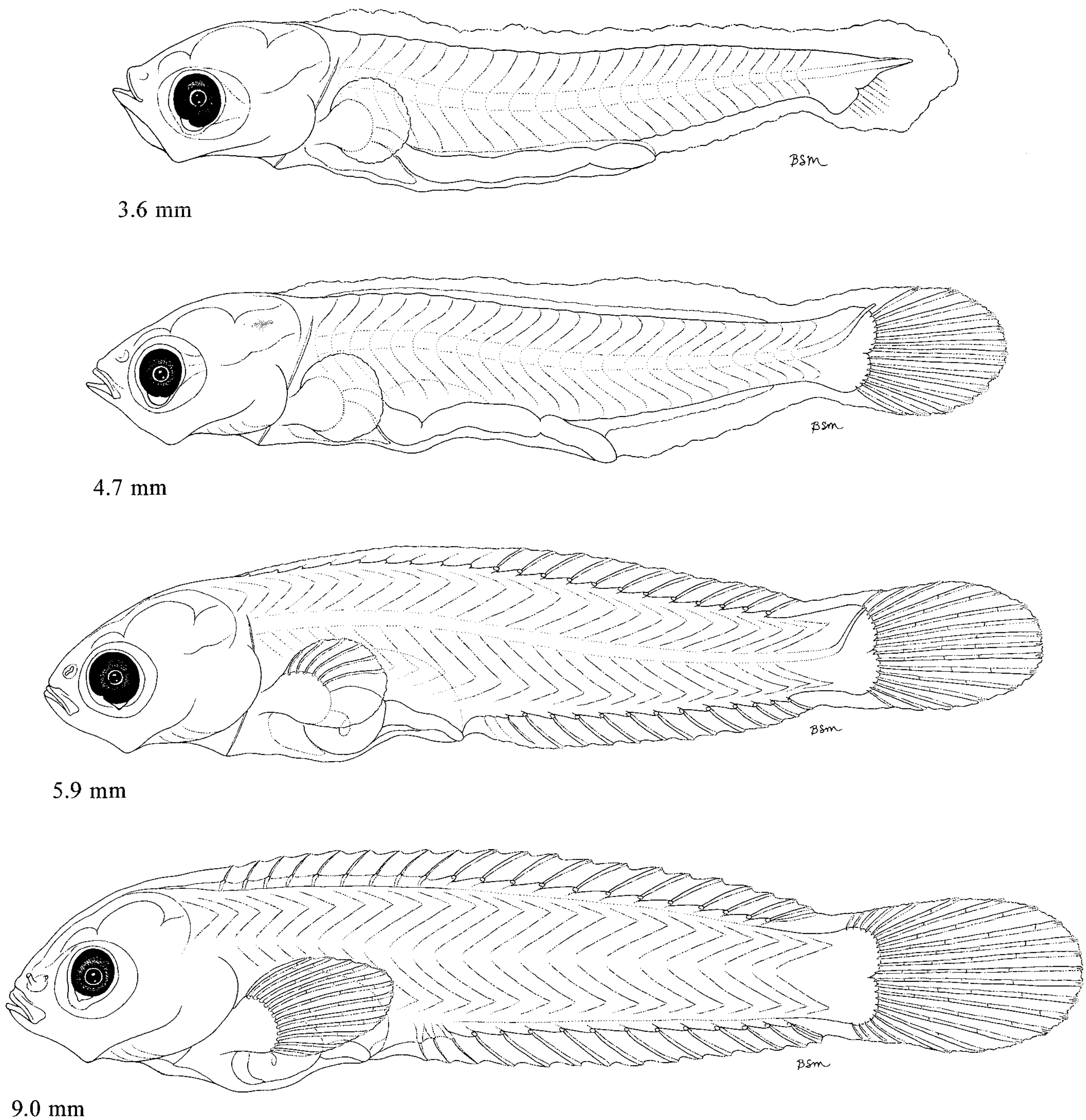

Figure Labridae 6. Late preflexion larva, 3.6 mm (CalCOFI 5708, station 157G.70); late flexion larva, 4.7 mm (CalCOFI 5708, station 151G.55); postflexion larva, 5.9 mm (CalCOFI 5708, station 157G.115); postflexion larva, 9.0 mm (CalCOFI 5708, station 153.20). Three smaller specimens probably are *X. mundiceps*, although larval *Xyrichtys* smaller than ca. 6 mm presently cannot be unequivocally identified to species in our area.

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	8	8
Caudal	16	16
Fins:		
Dorsal spines	II+VII	II+VII
Dorsal rays	12–13	12
Anal spines	III	III
Anal rays	12–13	12
Pelvic	I,5	I,5
Pectoral	12–13	12
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	4–5	5
Lower	4	4
Gill rakers:		
Upper	6	6
Lower	6	6
Branchiostegals	6	6

LIFE HISTORY

Range: Tropical Indo-Pacific to eastern Pacific; in eastern Pacific from lower Gulf of California & Cabo San Lucas region to Panama and Galápagos Islands

Habitat: Over sandy bottom near reefs in shallow water

Spawning season: Larvae collected in spring and summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 10.0 mm (B. Sumida MacCall)

* Eye is vertically elongate; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <8.5 mm
Transformation length: >12.2 mm, <14.1 mm
Fin development sequence:
Pigmentation: No melanophores in larval stage.
Diagnostic features: Vertically elongate eye with conical choroid tissue in larvae; first two dorsal spines originate over nape, well separated from rest of fin in postflexion stage; short gut; no melanophores in larvae; preanal myomeres 8–10 (in postflexion stage), 24–25 total myomeres.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				49–52 51		51
BD/BL				22–25 24		32
HL/BL				25–27 26		29
HW/HL				30–35 32		43
SnL/HL				26–31 29		28
ED/HL*				17–19× 19–22 18×21		28×25
P_1L/BL				12–14 13		18
P_2L/BL				0.4–2 1		13
CL/HL				5–7 7		0

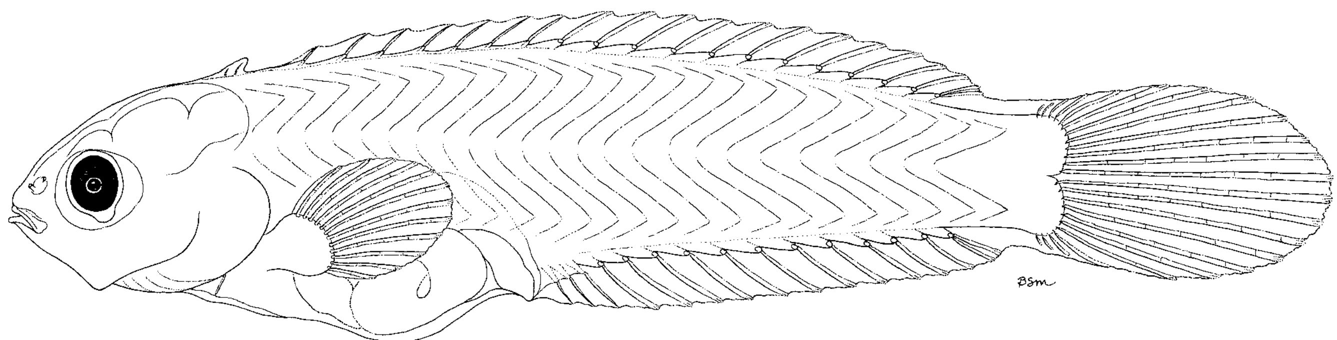

Figure Labridae 7. Postflexion larva, 10.0 mm (CalCOFI 5706, station 149G.34).

SCARIDAE: Parrotfishes

W. WATSON

Scaridae contains about 60 species in ten genera (Bellwood 1994). Five species of two genera reach the CalCOFI study area (Table Scaridae 1) and another, *Calatomus spindens*, has been seen nearby in the Gulf of California at Bahía de Palmas, Baja California Sur (Rosenblatt and Hobson 1969). *Nicholsina denticulata* and *Scarus perrico* range to Bahía Magdalena and Bahía Almejas, respectively, on the outer coast of Baja California Sur, while *S. compressus*, *S. ghobban*, and *S. rubroviolaceus* enter the CalCOFI study area in the vicinity of Cabo San Lucas (Rosenblatt and Hobson 1969). All five are distributed primarily in the Gulf of California and/or to the south of the CalCOFI study area (Rosenblatt and Hobson 1969; Thomson et al. 1979; Allen and Robertson 1994). A few larval scarids have been taken during CalCOFI ichthyoplankton surveys at inshore stations primarily south of Cabo San Lazaro, although a larval *N. denticulata* was collected from the vicinity of Punta Abreojos and a larval *Scarus* sp. from the vicinity of Punta San Juanico, Baja California Sur. Larvae of both genera occur more commonly in ichthyoplankton collections from the Gulf of California and the Pacific coast of mainland Mexico and Central America.

Scarids are small to large (ca. 10–120 cm, commonly ca. 30–50 cm) herbivorous residents of coral and rocky reefs and seagrass beds in tropical and subtropical coastal marine waters. The role of scarids in reef ecosystems has been the subject of much research interest (e.g., Hiatt and Strassburg 1960; Brock 1979; Bellwood and Choat 1990). Scarids are moderately elongate to moderately deep-bodied and compressed, with preanal length a little more than half of body length. The head is moderately large and the snout rounded or blunt in most species; terminal males of some species develop a fatty hump on the head. The teeth are fused to form a parrot-like beak in many species and the pharyngeal bones and teeth are strongly developed and modified to form a pharyngeal mill, used to grind rock, coral fragments and sand to facilitate digestion of the included algae. Scarids have a continuous dorsal fin containing nine spines and ten rays, three spines and nine rays in the anal fin, and 13 principal rays in the rounded to indented caudal fin. The body is covered with large cycloid scales. Females and immature males commonly are drably pigmented in browns to reddish-browns or greys, while terminal males often are vividly colored in bright blues and greens, with violet, red, orange, and yellow highlights. Scarids commonly are utilized in local fisheries in tropical areas.

Most scarids are protogynous hermaphrodites and as far as is known all have planktonic eggs and larvae (e.g., Leis and Rennis 1983; Richards and Leis 1984). Eggs are spherical, 0.6–1.1 mm in diameter, or spindle-shaped, 1.3–3.0 mm long and 0.5–0.6 mm wide, with a smooth chorion, homogeneous yolk, and single oil globule (none in *Hipposcarus*) 0.10–0.15 mm in diameter (Cipria 1939; Winn and Bardach 1960; Mito 1962; Randall and Randall 1963; Watson and Leis 1974; Leis and Rennis 1983; Colin and Bell 1991). Larvae hatch at ca. 1.6–2.4 mm with unpigmented eyes, an unformed mouth, unformed pectoral fin buds, and a large yolk sac with the oil globule anteriorly placed (Cipria 1939; Mito 1962; Randall and Randall 1963; Leis and Rennis 1983). Scarid larvae are elongate and moderately compressed, with preanal length about 50–60% BL. The gut initially is a simple straight tube; the intestine (except the terminal section) becomes rugose by the end of the yolk-sac stage, the gut folds anteriorly during notochord flexion, and it coils during the postflexion stage. The prominent gas bladder is located above the middle of the gut initially, but shifts posteriorly to near the end of the gut during the postflexion stage. The head is small to moderate, initially with a short, rounded snout which elongates, and with oval eyes (vertically elongate, becoming nearly round late in the postflexion stage or during the transformation stage) which may have a small mass of choroid tissue ventrally. There are no spines on the head or pectoral girdle. The principal caudal rays are the first fin rays to begin forming, by the beginning of notochord flexion. By mid-flexion dorsal soft rays begin to form, either just before or concurrently with the soft rays of the anal fin. Addition of rays in both fins is anteriad. Dorsal and anal fin spines form after the soft rays; addition of dorsal spines is anteriad. Pectoral fin rays begin to form about concurrently with the dorsal spines (addition is ventrad) and pelvic fin rays form last. Newly hatched scarids are pigmented primarily on the dorsum, but also may have a little pigment on the finfold, ventrum, and oil globule (Cipria 1939; Mito 1962; Randall and Randall 1963). The dorsal melanophores migrate to the ventrum and those on the finfold are lost (or also move to the ventrum) before the end of the yolk-sac stage. Larval pigmentation subsequently is light and changes little. There always are melanophores on the terminal section of the intestine and along the ventral margin of the tail, and there may be melanophores on the dorsal margin of the tail, on the pectoral fin base and/or axil, and on the gas bladder.

The elongate form, rugose gut, and oval eyes (sometimes with choroid tissue) of larval scarids result in a myctophid-like appearance before the median fins form; however, the scarids are easily distinguished from myctophids by their lower myomere count (24–26, usually 25 for scarids vs. 29–46, usually >30 for myctophids). Scarids also superficially resemble eleotrids and some gobiids in the CalCOFI study area before their unpaired fins form. The gut is rugose in scarids but not in the eleotrids or gobiids, and it is folded anteriorly in flexion stage scarids and posteriorly in eleotrids, but not folded in gobiids. The eyes are vertically elongated in scarids and eleotrids, but round or horizontally elongated in gobiids. Eleotrids and gobiids usually have ≥26 myomeres. Once the dorsal and anal fins have formed, larval scarids cannot be confused with myctophids, eleotrids, or gobiids. Larval scarids look like larval labrids throughout development, but can be distinguished by the gut rugosity (absent in the CalCOFI area labrids), larval pigmentation (especially the melanophore series along the ventral margin of the tail which the labrids lack; *Semicossyphus pulcher* does have ventral tail pigment, but it is not the even melanophore series that typifies scarids), and by principal caudal fin ray counts (7+6 in scarids, 7+7 in the CalCOFI area labrids). Larvae of the two scarid types collected in the CalCOFI study area are most easily distinguished by pigmentation on the dorsal margin of the tail, which is present in *Scarus* but absent in *Nicholsina*.

The following descriptions are based on examination of 13 *Nicholsina denticulata* (10 postflexion stage, 4.8–11.1 mm, 1 transformation stage, 12.9 mm, and 2 juveniles 19.5 and 20.2 mm) and 7 *Scarus* sp(p). (3 flexion stage, 3.7–4.7 mm; 4 postflexion stage, 4.2–7.8 mm). The *Scarus* sp(p). larvae may be a single type which should be *S. perrico* based on the collection of a flexion stage specimen near Punta San Juanico, somewhat north of the reported range of *S. perrico* but far to the north of the reported ranges for the other *Scarus* species. However, because it is unknown how, or even if, larvae of the *Scarus* species in the CalCOFI area differ, and because four of the seven larvae utilized in the description were collected in the Gulf of California where all four *Scarus* species occur (Table Scaridae 1), the larvae are not attributed to any species. Meristic data were obtained from Schultz (1958, 1969), Rosenblatt and Hobson (1969), and counts made during this study. Ecological information is from Rosenblatt and Hobson (1969), Thomson et al. (1979) and Allen and Robertson (1994).

Table Scaridae 1. Meristic characters and approximate geographic ranges for the scarid species in the California Current vicinity. All have 25 vertebrae, IX,10 dorsal fin rays, III,9 anal fin rays, 7+6 principal caudal fin rays, I,5 pelvic fin rays, and 5 branchiostegal rays. BCS = Baja California Sur; Gulf = Gulf of California.

Species	Fin rays P_1	Fin rays C_2	Gill rakers	Geographic range
Nicholsina denticulata	13–14	6–8+6–7	11–13	Bahía Magdalena, BCS & Gulf to Peru & offshore islands
Scarus compressus	14–15	8+7	42–57	Lower Gulf to Ecuador & Galápagos Islands
S. ghobban	14–17	5–7+5–6	42–57	Lower Gulf to Ecuador & Galápagos Islands, tropical Indo-Pacific, Red Sea
S. perrico	14–16	5–7+5–7	38–45	Bahía Almejas, BCS & lower Gulf to Peru & Galápagos Islands
S. rubroviolaceus	14–16	6–7+6	50–64	Lower Gulf to Costa Rica, Galápagos Islands & other offshore islands, tropical Indo-Pacific

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	9	9
Caudal	16	16
Fins:		
Dorsal spines	IX	IX
Dorsal rays	10	10
Anal spines	III	III
Anal rays	9	9
Pelvic	I,5	I,5
Pectoral	13–14	13
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–8	8
Lower	6–7	7
Gill rakers:		
Total	11–13	
Branchiostegals	5	5

LIFE HISTORY

Range: Bahía Magdalena, Baja California Sur, & throughout Gulf of California to Peru, Galápagos Islands, & other offshore islands

Habitat: Over algae-covered reefs, strongly associated with *Sargassum*

Spawning season: Postflexion stage larvae collected August through February

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 7.9 mm (B. Sumida MacCall)
Transformation specimen, 12.9 mm (R. C. Walker)
Juvenile, 21.2 mm (R. C. Walker)

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* Eye oval, initially vertically elongate, then broadening & becoming slightly horizontally elongate in the transformation stage. Horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <4.8 mm
Transformation length: ca. 12 mm through <19 mm
Fin development sequence: C_1, 2D & A & C_2, 1D & P_1, P_2
Pigmentation: *Postflexion*—Heavy dorsally on gas bladder, continuing onto dorsum of terminal section of intestine; 1 (usually large) at each A fin ray base beginning at A 2–4; 0–2 internally near ventral margin of caudal peduncle. *Transformation*—Larval pigment absent by 12.9 mm, except little on terminal section of intestine; sprinkling on dorsum, becoming sparser posteriorly; little on snout & below eye; on A base & few proximally on fin; on P_1; little, proximally on C. *Juvenile*—Nearly completely pigmented, lighter ventrally on head & gut; mottled or indistinctly barred pattern.
Diagnostic features: No pigment on dorsal margin of tail before transformation; pigment on dorsum of terminal section of intestine (vs. dorsolaterally in *Scarus*); eye large compared with *Scarus*; P_1 13–14.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				49–53 51	62	59–60 59
BD/BL				17–24 20	32	32–34 33
HL/BL				22–28 25	36	35–37 36
HW/HL				34–49 45	55	54–59 57
SnL/HL				21–31 26	23	28–28 28
ED/HL				24–31× 27–34 26×31	32×30	29–31× 28–28 30×28
P_1L/BL				8–14 11	16	15–16 16
P_2L/BL				0–5 1	11	14–14 14

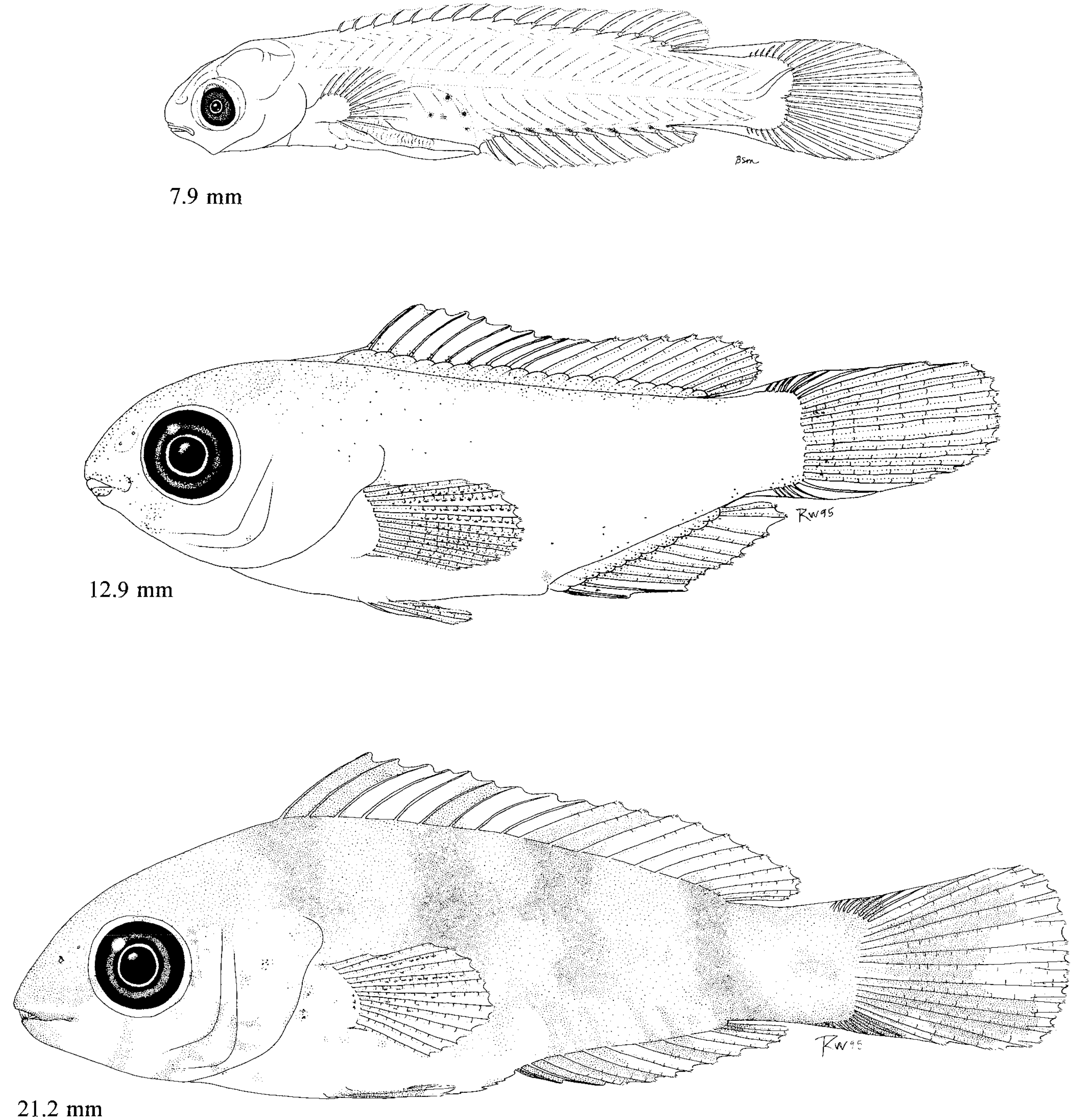

Figure Scaridae 1. Postflexion larva, 7.9 mm (CalCOFI 5301, station 150.30); transformation specimen, 12.9 mm, scales forming but not shown (SIO 62–25); juvenile, 21.2 mm, scales not shown (SIO 62–25).

MERISTICS

	Range	Mode
Vertebrae:		
Total	25	25
Precaudal	10–11	
Caudal	14–15	
Fins:		
Dorsal spines	IX	IX
Dorsal rays	10	10
Anal spines	III	III
Anal rays	9	9
Pelvic	I,5	I,5
Pectoral	14–17	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	5–8	
Lower	5–7	
Gill rakers:		
Total	38–64	
Branchiostegals	5	5

LIFE HISTORY

Range: *S. compressus*—Bahía Concepcíon, Baja California Sur to Ecuador & Galápagos Is.; *S. ghobban*—Punta Pulpito, Baja California Sur, to Ecuador & Galápagos Is., Indo-Pacific, Red Sea; *S. perrico*—Bahía Almejas & Punta Mangles, Baja California Sur to Peru & Galápagos & Cocos Is.; *S. rubroviolaceus*—Loreto, Baja California Sur to Panama, offshore islands, & Galápagos Is., & Indo-Pacific

Habitat: Coastal waters over rocky & coral reefs

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 3.7 mm (W. Watson)
Postflexion larvae, 4.2 mm, 7.8 mm (W. Watson)

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* Larvae described here may be a single species, possibly *S. perrico* based on the collection of a specimen in the vicinity of Bahía San Juanico, Baja California Sur. However, *S. compressus*, *S. ghobban*, and *S. rubroviolaceus* also occur in the study area. Meristics above encompass all four species.

† Eyes oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <3.7 mm through ca. 4.2–4.7 mm
Transformation length: >7.8 mm
Fin development sequence: C_1, 2D, A, C_2, 1D & P_1, P_2
Pigmentation: *Flexion*—Dorsally on gas bladder; 1–2 (usually 1) dorsolaterally along each side of terminal section of intestine; few to many in double row dorsally on tail beginning at myomere 12–13, becoming single row after myomere 20–23 & continuing to near notochord tip; ca. 1/myomere on ventral margin of tail beginning at postanal myomere 1–3, becoming shallowly internal; 0–3 on hypurals. *Postflexion*—Gas bladder & hindgut pigment become continuous; decreasing dorsally on tail & becoming restricted to caudal peduncle; 0–several proximally on C.
Diagnostic features: Melanophores on dorsal margin of tail; dorsolateral melanophore(s) on each side of terminal section of intestine (vs. dorsal in *Nicholsina*); small eyes (compared with *Nicholsina*); P_1 usually 14–15.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			52–57 55	54–56 55		
BD/BL			14–17 16	19–21 20		
HL/BL			22–26 25	25–27 26		
HW/HL			47–50 49	49–50 50		
SnL/HL			15–20 17	24–31 27		
ED/HL†			21–23× 27–32 23×29	19–21× 27–28 20×28		
P_1L/BL			4–7 5	5–8 7		
P_2L/BL			0–0 0	0–0.3 0.1		

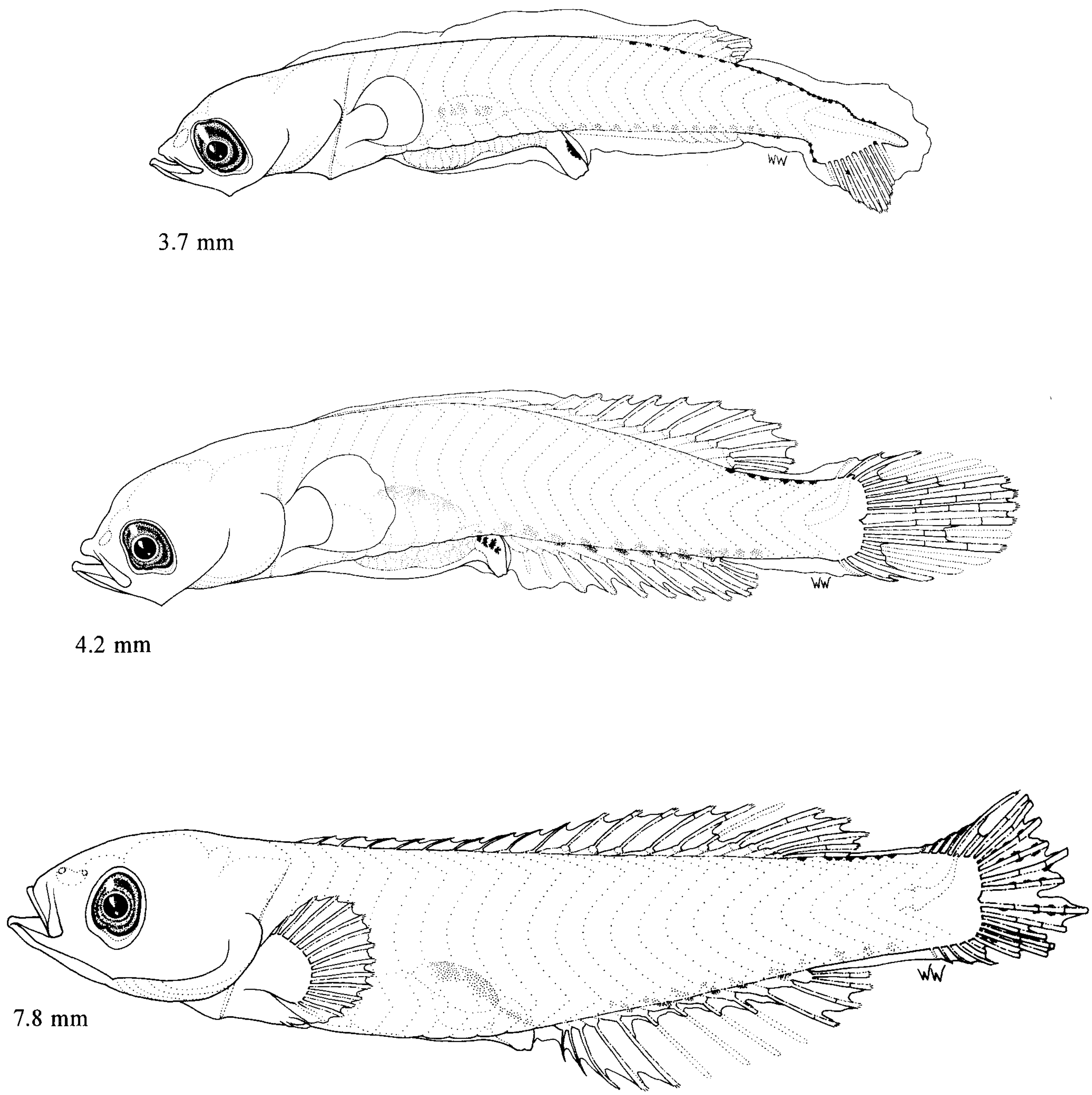


Figure Scaridae 2. Early flexion larva, 3.7 mm (IATTC 89006, station D1 Red); early postflexion larva, 4.2 mm (CalCOFI 5708, station 151G.37); later postflexion larva, 7.8 mm (CalCOFI 5706, station 157.25).

ZOAROIDEI

W. Watson

The perciform suborder Zoarcoidei contains nine families and about 318 species of temperate to boreal, primarily North Pacific demersal fishes (Nelson 1994). The zoarcoids, often referred to as the "northern blennioids," at various times have been placed in the perciform suborders Blennioidei (e.g., Gosline 1968) and Trachinoidei (Bathymasteridae: Greenwood et al. 1966), and in a gadiform suborder, Zoarcoidei (Zoarcidae: Greenwood et al. 1966). Gosline (1968) recognized the superfamily Zoarceoidae within the Blennioidei, including all the fishes now called zoarcoids except the monotypic Scytalinidae. The zoarcoids were excluded from the Blennioidei by Springer and Freihofer (1976) and subsequently were treated as the presently constituted perciform suborder by Nelson (1984). The suborder is not well diagnosed; the only common characters are a single nostril on each side of the head and the lack of a basisphenoid (Springer 1993; Nelson 1994).

Most zoarcoid fishes are oviparous (*Zoarces* is viviparous), with demersal egg masses and parental care. Eggs typically are large (>1 mm) and incubation periods are long (ca. 14–120 days). Larvae may be quite large and are well developed at hatching, with pigmented eyes and open mouth, and in some species with fin rays developing or even fully formed (e.g., Anderson 1984; Matarese et al. 1984b, 1989). Larvae are elongate, moderately to strongly compressed, usually with preanal length not more than half of body length (up to 67% BL in pholids). There are no spines on the head or pectoral girdle. Larval pigmentation commonly is light, occurring primarily on the gut, on the head in some species, and along the ventrum. Some species are moderately to heavily pigmented on the dorsum and/or laterally, as well (e.g., Anderson 1984; Matarese et al. 1984b). Development is direct, without specialized stages, although anarhichadids, cryptacanthodids, and zaprorids may have an extended pelagic juvenile stage (e.g., Matarese et al. 1984b; Marliave 1987).

At least 52 species representing eight of the nine zoarcoid families occur in the CalCOFI study area. However, fewer than ten species, representing four families, have been recognized as larvae in CalCOFI ichthyoplankton collections. The other four families, Cryptacanthodidae, Scytalinidae, Zaproridae, and Zoarcidae are not included here, except that example illustrations of larvae of all but the scytalinids (whose larvae are unknown) are shown in Figure Zoarcoidei 1. Refer to Anderson (1984) and Matarese et al. (1984b, 1989) for further descriptions and additional references.

Families included: Bathymasteridae
Stichaeidae
Pholidae
Anarhichadidae

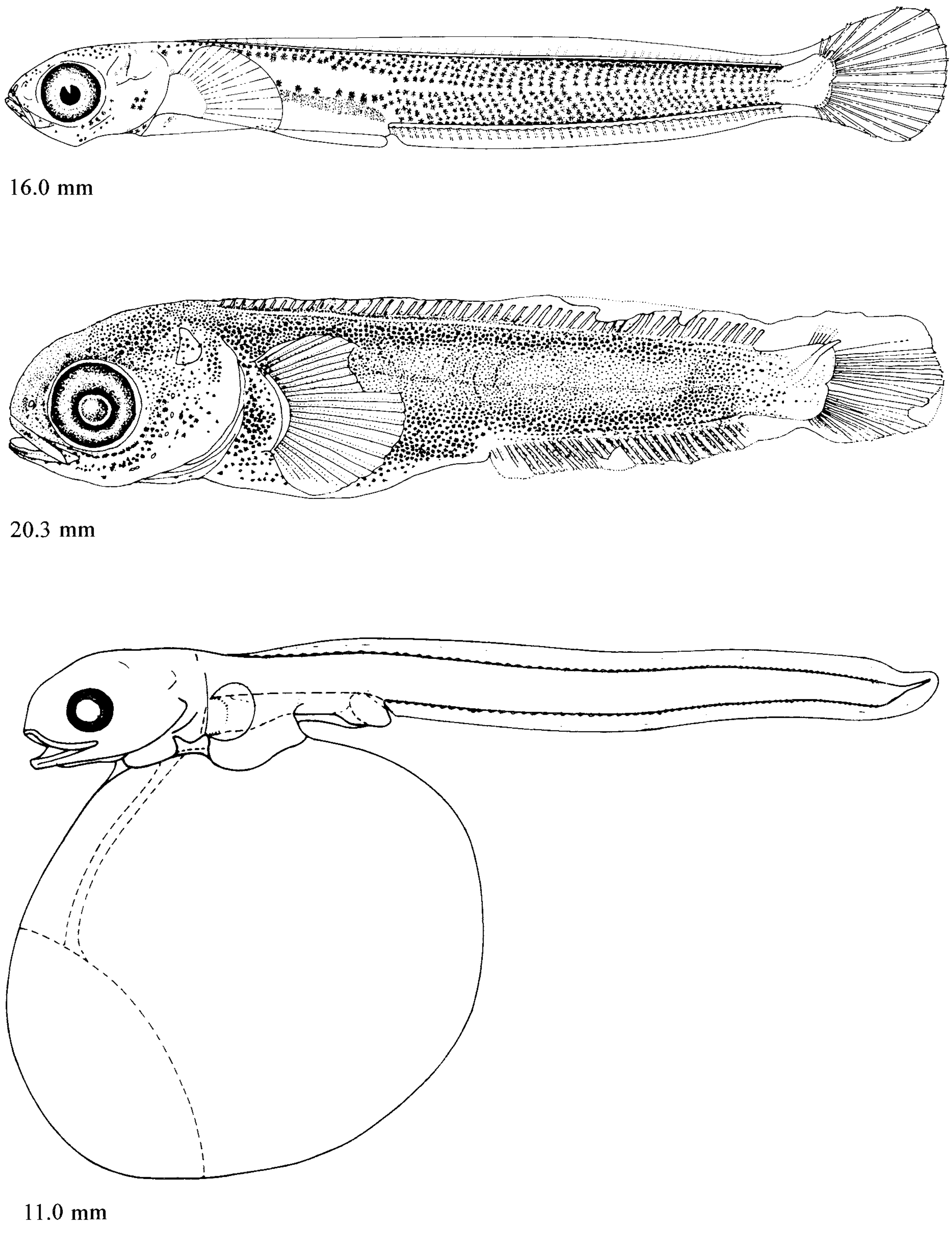


Figure Zoarcoidei 1. Top: *Cryptacanthoides aleutensis*, family Cryptacanthodidae, 16.0 mm (Matarese et al. 1984b); middle: *Zaprora silenus*, family Zaproridae, 20.3 mm (Haryu and Nishiyama 1981); bottom: *Bothrocara* sp., family Zoarcidae, 11.0 mm (Kendall et al. 1983).

BATHYMASTERIDAE: Ronquils

W. Watson

Bathymasteridae contains about seven species in three genera (Matarese 1990; Nelson 1994). Although as many as five species have been reported from California (Hubbs et al. 1979), probably only three species occur in the CalCOFI study area (Eschmeyer et al. 1983; Matarese 1990). Larval ronquils rarely occur in CalCOFI ichthyoplankton samples, except those of a *Rathbunella* species, which have been taken in modest numbers at stations over the continental shelf between about Monterey Bay, California, and Bahía Sebastián Vizcaíno, Baja California.

Ronquils are small (ca. 15–30 cm) benthic residents of sandy and rocky bottom from the intertidal zone to nearly 200 m depth (primarily subtidal to ca. 100 m) in the cool waters of the North Pacific Ocean. Ronquils are elongate and moderately compressed, with preanal length slightly less than half of body length. The long dorsal fin is composed mostly of segmented rays. The thoracic pelvic fin consists of a spine and five segmented rays, and the rounded caudal fin usually contains 7+7 principal rays. Pigmentation, which is sexually dimorphic and varies with maturity, ranges from browns to blues, with yellow to red highlights in some species, and usually with bars and/or spots.

Ronquils are oviparous (Matarese et al. 1984b). *Ronquilus jordani* spawns amber colored, demersal eggs 0.9–1.1 mm in diameter, each containing a single oil globule, that are incubated by the male parent (Breder and Rosen 1966; Fitch and Lavenberg 1975; Matarese et al. 1989). Larvae 5.5–6 mm long hatch with pigmented eyes (Matarese et al. 1984b). Bathymasterid larvae are elongate, with preanal length usually ca. 35–45% BL. The initially straight gut coils during the flexion stage (*Rathbunella*, at least). The head initially is rounded but becomes less so (bluntly pointed in some species) as the snout elongates. The eye is moderate to large. There are no spines on the head or pectoral girdle. Larval pigmentation is light to moderate. Melanophores are present dorsally on the gut and along the ventrum and may be present, depending on species and developmental stage, on the dorsum, on the lateral surfaces of the tail, and internally over the notochord.

Larval bathymasterids resemble larval stichaeids, labrisomids, and clinids. In the CalCOFI area the bathymasterid species have fewer myomeres (Table Bathymasteridae 1) than the stichaeids (Table Stichaeidae 1) and more than the labrisomids except *Cryptotrema corallinum* (Table Labrisomidae 1). The clinids typically have a slightly longer preanal length (usually ≥45% BL) than the bathymasterids have (usually <45%), and *Heterostichus rostratus* has more myomeres (54–59 versus 47–51). Older postflexion stage larvae are easily distinguished by the composition of the dorsal fin: bathymasterids have far fewer spines than segmented rays, clinids and labrisomids have more spines than segmented rays, and most stichaeids have only spines. Larval *Rathbunella* are pigmented much like larval *Ronquilus jordani* and have similar myomere counts, but lack the hypaxial pigment on the tail and the melanophores along the dorsal margin of the tail (in the postflexion stage) that are typical of *R. jordani* (Matarese et al. 1989). The *Rathbunella* species differ slightly from one another in meristic characters; it is unknown whether the larvae also differ in other characters.

The following description is based on examination of 25 larval *Rathbunella* (10 preflexion, 4.0–9.0 mm; 7 flexion, 8.3–10.9 mm; 8 postflexion, 10.2–15.9 mm) that appear to represent a single species whose meristic characters and geographic range are most consistent with *R. alleni*. Larval *Ronquilus jordani* have not been identified in CalCOFI samples and are not described, but are shown in Figure Bathymasteridae 1. Refer to Matarese et al. (1989) for additional information. Meristic data are from Matarese (1990) and counts made during this study.

Table Bathymasteridae 1. Meristic characters for the ronquil species in the CalCOFI study area. All bathymasterids have I,5 pelvic fin rays and 6 branchiostegal rays.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_1	C_2
Rathbunella alleni	12–14	33–37	48–50	V–VI,37–39	II,31	16–18	7+7	6–7+4–5
R. hypoplecta	13–14	35–37	50–51	VI,40	II,31–32	17–19	7+6–7	6–7+5
Ronquilus jordani	13–15	34–37	49–50	I–II,42–45	I–II,32–33	17–19	7+7	6+5

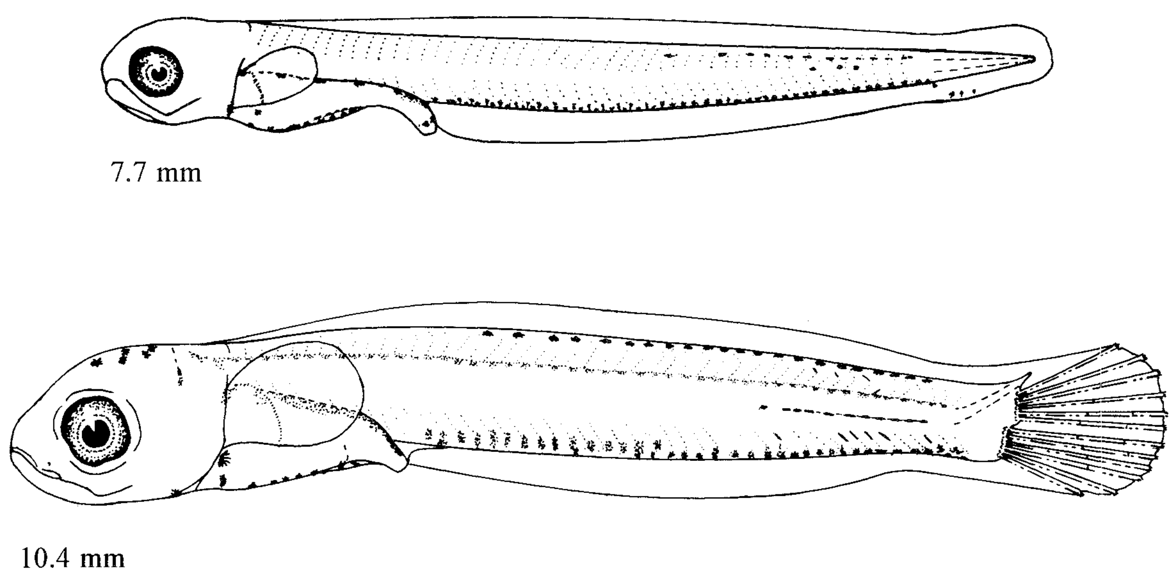


Figure Bathymasteridae 1. *Ronquilus jordani*: preflexion larva, 7.7 mm; early postflexion larva, 10.4 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	48–50	49
Precaudal	12–14	13
Caudal	33–37	35–36
Fins:		
Dorsal spines	V–VI	V–VI
Dorsal rays	37–39	38
Anal spines	II	II
Anal rays	31	31
Pelvic	I,5	I,5
Pectoral	16–18	16–17
Caudal:		
Principal	7+7	7+7
Procurrent:		
Upper	6–7	7
Lower	4–5	5
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Central California to northern Baja California

Habitat: On sandy & rocky bottom at ca. 6–90 m depth along the open coast

Spawning season: Larvae collected in all months except December, with most larvae taken January–May & in July

ELH pattern: Oviparous; demersal eggs brooded by parent; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.4 mm (N. Arthur)
Flexion larva, 10.8 mm (N. Arthur)
Postflexion larva, 12.5 mm (N. Arthur)

* Meristic characters and collection locations for the larvae described here are most consistent with *R. alleni*. Adult meristic, range, & habitat data are given for *R. alleni*.

EARLY LIFE HISTORY DESCRIPTION

EGGS

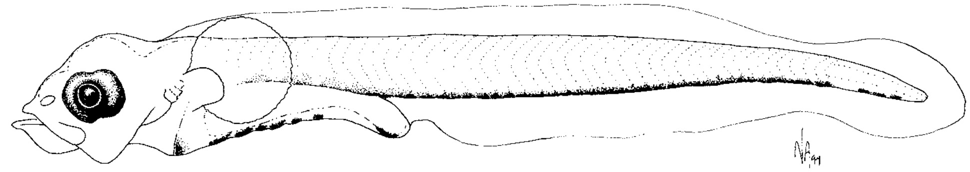
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

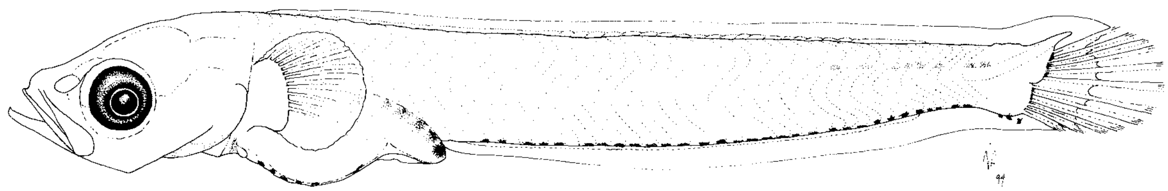
Hatching length: <4 mm
Flexion length: 8.3–9.0 mm through 10.2–10.9 mm
Transformation length: >15.9 mm
Fin development sequence: P_1, C_1, D & A, C_2, P_2
Pigmentation: None on head; 0–3 on dorsal margin in vicinity of postanal myomeres 20–26, becoming internal by ca. 9 mm & no longer visible after ca. 10 mm; 2 or more internally above notochord in posterior half of tail beginning at ca. 8 mm; 2 ventrolateral pairs anteriorly on gut, converging anteriorly to form V by 6 mm, then condensing to 1 at anterior margin of liver by ca. 9 mm; 3–6 on ventral margin of midgut; 0–1 ventrally near anus; 5–8 each in 2 dorsolateral rows on gut, last 1–3 externally on end of hindgut; 40–45 on ventral margin of tail (beginning at first postanal myomere), decreasing to 30–35 (beginning at postanal myomere 3–4) by 8 mm; 3–8 under notochord tip or along hypural margin.
Diagnostic features: Myomeres 11–14+34–37=47–51 (usually 13–14+35–36=48–49); no pigment on dorsum (except often 1–3 posteriorly on tail before ca. 9 mm) or laterally on tail to at least 15.9 mm.

MORPHOMETRICS (range & mean in %)

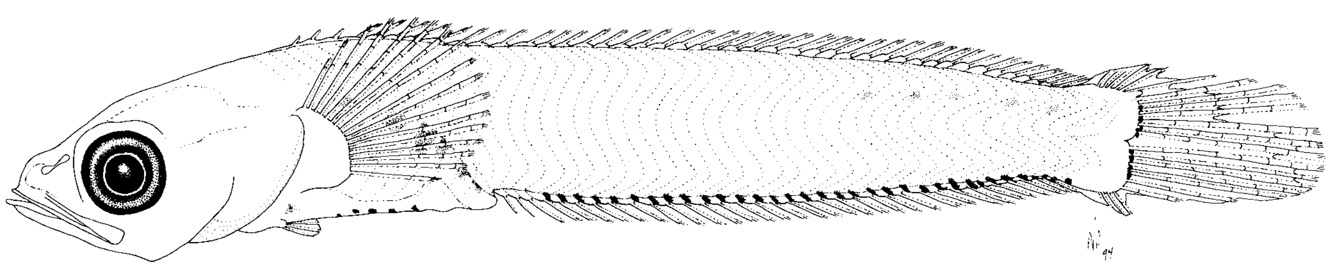
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–47 43	39–43 41	42–44 43		
BD/BL		12–15 13	12–15 13	14–16 15		
HL/BL		18–22 20	11–23 19	23–26 24		
HW/HL		49–66 57	47–53 51	41–50 45		
SnL/HL		15–30 24	24–32 28	22–30 26		
ED/HL		29–40 34	28–31 29	24–29 27		
P_1L/BL		4–7 6	5–7 6	8–15 11		
P_2L/BL		0–0 0	0–0 0	0–4 1		



5.4 mm



10.8 mm



12.5 mm

Figure Bathymasteridae 2. Preflexion larva, 5.4 mm (CalCOFI 6604, station 97.30); flexion larva, 10.8 mm (CalCOFI 7503, station 110.32.4); postflexion larva, 12.5 mm (MEC I110, station LE–M).

STICHAEIDAE: Pricklebacks

W. Watson

Stichaeidae contains about 65 species in perhaps as many as 36 genera (Nelson 1994); at least 17 species occur in the CalCOFI study area (Table Stichaeidae 1; Eschmeyer et al. 1983; Follett and Anderson 1990). Although most are distributed northward from central or northern California, a few range to southern California or Baja California. Larval stichaeids rarely occur in CalCOFI ichthyoplankton collections: only a few specimens of *Plectobranchus evides*, *Anoplarchus* spp., and *Chirolophis* (?) sp(p). have been identified, primarily from inshore stations.

Pricklebacks are small (most species <25 cm, largest to ca. 75 cm), demersal inhabitants of soft and rocky bottom and seaweed habitats from the intertidal zone to the upper continental slope. Stichaeids are elongate and compressed, with preanal length ca. 40–50% BL. They have a relatively small head with small eyes and a small mouth. The long, low dorsal fin is composed entirely of spines in most species, and both the dorsal and anal fins typically are confluent with the small, rounded caudal fin. Pelvic fins are lacking in a few species and are reduced and thoracic in the others. Pigmentation is cryptic, ranging from grey to rosy; shades of brown with darker bars or mottling is common.

Stichaeids spawn adhesive spherical eggs, 1.3–2.5 mm in diameter, each containing one or more oil globules, that are attached to one another to form a small egg mass that is brooded by a parent (e.g., Fujita and Uchida 1959; Shiogaki and Dotsu 1972a; Shiogaki 1981, 1982; Matarese et al. 1989). Larvae ca. 8–12 mm long hatch with pigmented eyes, open mouth, and small yolk sac (e.g., Shiogaki and Dotsu 1972a; Shiogaki 1981, 1982). Larvae are elongate and compressed with preanal length ca. 40–50% BL. The head is relatively small; eyes range from moderate to large. There are no spines on the head or pectoral girdle. Larval pigmentation typically is light, occurring primarily on the dorsal surfaces of the head and/or gut, internally along the notochord, and on the ventrum. Larval *P. evides* differ from the typical pattern in that their melanophores are grouped into blotches along the gut and laterally on the tail.

Larval stichaeids resemble larvae of many of the zoarcoid and blennioid families. They can be distinguished from most bathymasterid, pholid, and blennioid species by myomere counts: most pholids have more myomeres (>80) than most stichaeid species (most in the 60–80 range), while bathymasterids and most blennioid species have fewer (<60). Larval stichaeids have preanal length ca. 40–50% BL; pholids have a longer preanal length (>50%), while bathymasterids and blennioids (except blenniids and clinids) have a shorter preanal length (<40–45% for most species). Only pholids and most of the stichaeids have the dorsal fin composed solely of spines (present by early postflexion stage); most pholids have >80 spines while most stichaeids have <80. Larval *P. evides* superficially resemble larvae of the bythitid *Brosmophycis marginata*, but have fewer myomeres (57–61 versus 63–65), fewer pigment patches along the dorsal and ventral margins, and much different fin ray counts (see Bythitidae, this volume).

Since most of the larval stichaeids collected during CalCOFI surveys are *Plectobranchus evides*, only that species is described here, based on literature (Matarese et al. 1989) and on detailed examination of 9 preflexion (7.4–13.0 mm), 2 flexion (13.6, 18.5 mm) and 3 postflexion (19.1–27.3 mm) stage larvae. Refer to Matarese et al. (1989) for descriptions and illustrations of other species. Meristic data given in Table Stichaeidae 1 were obtained from Miller and Lea (1972), Matarese et al. (1989), A. C. Matarese (NMFS, Alaska Fisheries Science Center, pers. comm., August 1995), and from counts made during this study.

Table Stichaeidae 1. Meristic characters for the stichaeid species in the CalCOFI study area.

Species	Vertebrae			Fin rays						
	PrCV	CV	Total	D	A	P_1	P_2	C_1	C_2	GR
Allolumpenus hypochromus				XLIV–XLIX	I,31	12	I,3			
Anoplarchus insignis	17–19	44–49	62–68	LVII–LXIV	I,40–46	9–10	0	6–7+ 6–7	3–4+ 2–3	
A. purpurescens	17–19	40–46	58–64	LIV–LX	I–II,35–41	9–10	0	6–7+ 6–7	3–4+ 3–4	3–5+ 5–10
Cebedichthys violaceus	23–25	40–47	65–71	XXII–XXV, 40–43	I–II,39–42	10–11	0	7+7	4–5+ 2–3	3–4+ 6–10
Chirolophis decoratus			65–67	LXI–LXIII	I,44–51	14–15	I,4			
C. nugator	14–15	43–44	55–59	LII–LV	I,37–42	13–14	I,4	6+7	5–6+ 3–4	
Ernogrammus walkeri	16–17	36–38	53–55	XLVII–LII	II,31–34	15–17	I,3	7+7	3–4+4	1–3+ 5–10
Esselenia carli	15–16	49–54	65–70	XXXVIII–XLIII, 19–23	II,44–49	11–12	0	7–8+ 5–7	2–5+ 2–4	
E. laurae			60–62	XXXVIII–XLIII, 14–18	II,41–44	12	I	7+7	3–5+ 2–3	
Kasatkia sp.			68	LXI–LXIV	II,39–40		0–I			
Lumpenus sagitta	26–29	46–54	75–82	LXIV–LXXIV	I,45–52	15–17	I,3–4	6+7	6–7+ 4–6	
Phytichthys chirus	24–25	50–52	75–76	LXIX–LXXVIII	II–III,40–50	15	0	6+7		
Plagiogrammus hopkinsii	12	32–33	43–45	XXXVII–XLI	II,26–29	14	I,4	7+6	4+4	
Plectobranchus evides	20	39–40	59–60	LIV–LVII	II–III,34–36	14–15	I,3	7+6–7	4+3–4	
Poroclinus rothrocki	19–20	47–48	65–68	LVII–LXVII	III,40–44	13–15	I,3	7+6	5–6+4	
Xiphister atropurpureus	22–24	51–56	73–80	LXV–LXXII	I,49–55	11–12	0	6+6–7	5–6+ 3–4	2–3+ 6–10
X. mucosus	29–31	44–53	73–83	LXXI–LXXVIII	I,46–50	12	0	6+6–7	5+3–4	

MERISTICS

	Range	Mode
Vertebrae:		
Total	59–60	59–60
Precaudal	20	20
Caudal	39–40	39–40
Fins:		
Dorsal spines	LIV–LVII	LIV–LV
Dorsal rays	0	0
Anal spines	II–III	II
Anal rays	34–36	34–35
Pelvic	I,3	I,3
Pectoral	14–15	14–15
Caudal:		
Principal	7+6–7	7+6
Procurrent:		
Upper	4	4
Lower	3–4	4
Gill rakers:		
Upper		
Lower		
Branchiostegals	5–6	5

LIFE HISTORY

Range: Central British Columbia to San Diego, California

Habitat: Soft bottom, 84–274 m depth

Spawning season: Larvae collected in winter & spring, primarily February–April

ELH pattern: Oviparous; brooded, demersal eggs; planktonic larvae

LITERATURE

Matarese et al. 1989

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* P_1 intact in only one specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS
- **Shell diam.:**
- **Yolk:**
- **No. of OG:**
- **Diam. of OG:**
- **Shell surface:**
- **Pigment:**
- **Diagnostic features:**

LARVAE
- **Hatching length:** <7.4 mm
- **Flexion length:** ca. 13–19 mm
- **Transformation length:** >31 mm
- **Fin development sequence:** C_1, P_1, D & A & C_2
- **Pigmentation:** *Preflexion–postflexion*—Little, externally on snout after ca. 27 mm; 0–1 near angular; internally posteriorly on midbrain & on hindbrain after 27 mm; dorsally & dorsolaterally on gut in 3 blotches, last blotch sometimes encircles end of hindgut; 3 pigmented areas on tail, anterior area is ventrolateral, middle area is ventrolateral or encircles tail, becoming primarily midlateral during flexion stage, & posterior area encircles notochord tip; all three become primarily internal during flexion & early postflexion stages.
- **Diagnostic features:** Pigmented in 6 distinct blotches or bars, 3 along gut & 3 on tail; myomeres 19–23+37–40=57–61 (usually 21–22+38–39=60–61.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–53 50	48–50 49	47–51 49		
BD/BL		8–11 10	8–9 8	8–8 8		
HL/BL		16–20 18	17–18 17	20–20 20		
HW/HL		39–52 45	41–51 46	29–41 34		
SnL/HL		16–24 21	28–29 28	23–31 28		
ED/HL		22–31 26	21–23 22	18–20 19		
P_1L/BL		3–5 4	5*	8–9 9		
P_2L/BL		0–0 0	0–0 0	1–3 2		

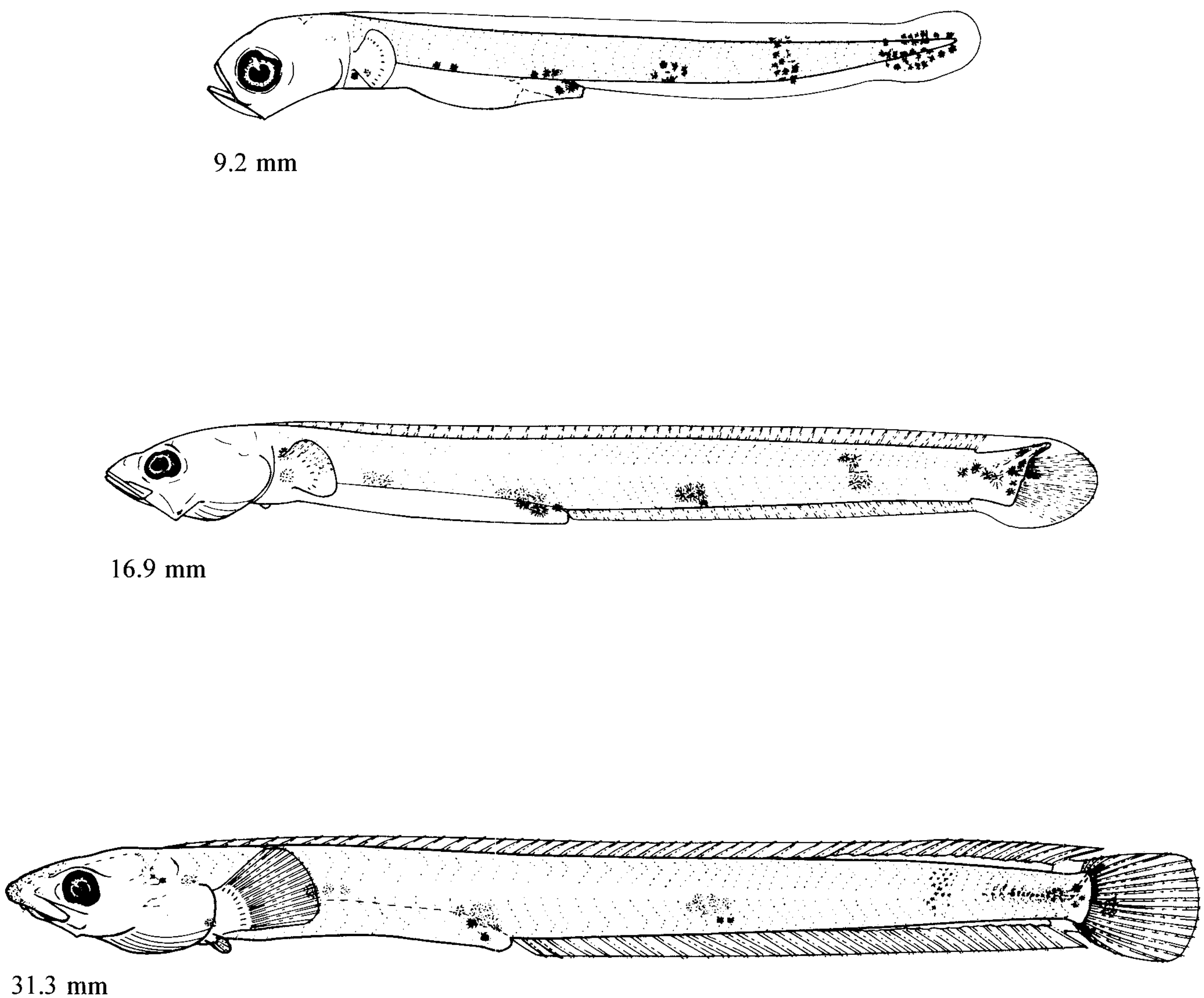


Figure Stichaeidae 1. Preflexion larva, 9.2 mm; flexion larva, 16.9 mm; postflexion larva, 31.3 mm (Matarese et al. 1989).

PHOLIDAE: Gunnels

W. WATSON

Pholidae contains about 14 species in four genera (Nelson 1994); seven species occur in the CalCOFI study area (Table Pholidae 1). The four *Pholis* species range northward from central or northern California, *Apodichthys flavidus* reaches southern California, and *Ulvicola sanctaerosae* and *Xererpes fucorum* range as far south as central Baja California (Eschmeyer et al. 1983). Only a few larval *Pholis* sp(p). have been taken during CalCOFI ichthyoplankton surveys, all from stations north of Point Conception, California.

Pholids are small (most species <30 cm) eel-like denizens of intertidal and shallow subtidal rocky bottom, kelp forests, and other macroalgal habitats. They are strongly compressed, with preanal length ca. 45–65% BL, and have a small head with small eyes. The long, low dorsal fin is composed entirely of spines and both the dorsal and anal fins are confluent with the small, rounded caudal fin. Pelvic fins are reduced or absent; *U. sanctaerosae* larger than ca. 75 mm lack pectoral fins as well. Gunnels typically are cryptically colored in yellows, greens, browns and reds, often with spotted or barred patterns.

Pholids spawn adhesive eggs 1.4–3.0 mm in diameter, each containing a single oil globule, that are attached to a nest substrate and brooded by the parents (Breder and Rosen 1966; Marliave 1975; Matarese et al. 1989). Newly hatched larvae are large and well developed, with pigmented eyes, open mouth, and little yolk (e.g., Tokuya and Amaoka 1980). Larvae are elongate, moderately to strongly compressed, with preanal length ca. 60–67% BL. There are no spines on the head or pectoral girdle. Larval pigmentation occurs primarily on the dorsal surface of the gut and along the ventrum; some species have melanophores on the dorsal surface of the head and/or internally over the notochord. Development is direct, without a distinctive transformation stage.

Larval gunnels in the CalCOFI study area superficially resemble the larvae of some stichaeids and bathymasterids, but have a longer preanal length (>50% BL for the pholids versus ≤50% BL for the others) and more myomeres (>80 for the pholids versus <60 for the bathymasterids and <80 for most of the stichaeids). It is unknown how larvae of most of the pholid species might be distinguished from one another, except by meristic characters (Table Pholidae 1). Larval *A. flavidus* and *X. fucorum* have large, relatively widely spaced melanophores dorsolaterally along the gut, while *Pholis* sp(p). and *U. sanctaerosae* have smaller, often more closely spaced, gut melanophores (Matarese et al. 1989; this volume). Larval *A. flavidus* can be distinguished from *X. fucorum* by its higher fin ray and postanal myomere counts (e.g., Table Pholidae 1) and by having more internal pigment along the notochord and less external pigment on the ventral margin of the gut (see Matarese et al. 1989). Meristic characters usually should distinguish larval *Pholis* sp(p). from *U. sanctaerosae* as well; in addition, *Pholis* sp(p). lack notochord pigment, at least during flexion and early postflexion stages (Matarese et al. 1989), while *U. sanctaerosae* always has this pigment.

The following descriptions are based on detailed observation of 25 *U. sanctaerosae* and 26 *X. fucorum* (Table Pholidae 2). *Pholis* sp(p). and *A. flavidus* are not described here; see Matarese et al. (1989) and Wang (1981) and references cited therein. Meristic data were obtained from the literature (Rosenblatt 1964; Matarese et al. 1989) and from counts made during this study. Ecological information was obtained from Eschmeyer et al. (1983).

Table Pholidae 1. Meristic characters for the pholid species in the CalCOFI study area. All have 5 branchiostegal rays.

Species	Vertebrae			Fin rays						
	PrCV	CV	Total	D	A	P_1	P_2	C_1	C_2	GR
Apodichthys flavidus	48–55	42–51	96–101	XC–XCIV	I,36–42	14	0	7+7	7+4	3+10–13
Pholis clemensi	37–39	57–59	94–98	LXXXVII–XCI	II,48–53	11–14	I,I			11 total
P. laeta	40–42	43–45	81–89	LXXIV–LXXXI	II,32–39	11–12	I,1	7+7	6+3	
P. ornata	42–43	42	80–87	LXXIV–LXXX	II,34–38	11–12	I,1	6–7+7	6+3–4	
P. schultzi	42–44	46–51	88–93	LXXX–LXXXIX	II,40–44	11–12	I,1–2	7–8+7	5–6+ 2–3	1–2+ 7–10
Ulvicola sanctaerosae	47–55	50–56	99–108	XCIII–XCVIII	I,40–48	0	0	6+5–6	5–8+ 3–5	
Xererpes fucorum	50–54	35–40	84–93	LXXXII–LXXXVII	I,29–38	12	0	6–7+7	8–9+ 5–6	1–2+ 6–9

Table Pholidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the pholid species descriptions.

Species	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Ulvicola sanctaerosae	0	9 9.3–15.1	10 20.0–24.2	3 46.7–56.8	3 70.5–74.1
Xererpes fucorum	2 8.2–12.4	8 12.6–18.0	11 20.4–26.0	2 53.2–61.5	3 59.7–68.0

MERISTICS

	Range	Mode†
Vertebrae:		
Total	99–108	100–101;104–106
Precaudal	47–55	48;52–53
Caudal	50–56	50–54
Fins:		
Dorsal spines	XCIII–XCVIII	XCIII–XCV; XCVII–XCVIII
Dorsal rays	0	0
Anal spines	I	I
Anal rays	40–48	45–46
Pelvic	0	0
Pectoral‡	6–7 to 0	
Caudal:		
Principal	6+5–6	6+6
Procurrent:		
Upper	5–8	7
Lower	3–5	4–5
Gill rakers:		
Upper		
Lower		
Branchiostegals	5	5

LIFE HISTORY

Range: Pacific Grove, California, to Bahía Papalote, Baja California, & Isla de Guadalupe

Habitat: Kelp forests, upper canopy to ca. 12 m depth

Spawning season: Larvae collected in spring & summer

ELH pattern: Oviparous; demersal eggs; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larvae, 8.8 mm, 13.7 mm (R. F. Feeney)
Flexion larva, 13.5 mm (N. Arthur)
Postflexion larva, 22.0 mm (N. Arthur)

* Yatsu (1985) placed *U. sanctaerosae* in the genus *Apodichthys.*
† The lower modal counts given first are for specimens from Isla de Guadalupe, Mexico.
‡ Larvae have P_1 with 6–7 upper rays developing by early postflexion stage; these fins become greatly reduced during transformation & are absent after ca. 75 mm SL.

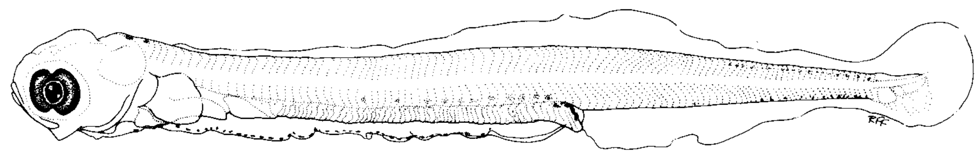
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

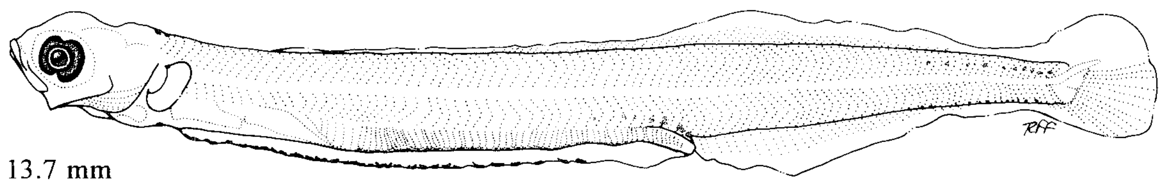
LARVAE
Hatching length: Perhaps near 9 mm
Flexion length: ca. 9.3–15.1 mm
Transformation length: >24.2 mm, <70.5 mm
Fin development sequence: C_1, A, D & P_1 & C_2
Pigmentation: *Flexion–postflexion*—0–few externally above midbrain; 1 externally over hindbrain, becoming internal by 10–14 mm; internal series over notochord, initially in last half of tail, extending full length of notochord by 13–20 mm; dorsally along gut, distinctly separate melanophores along full length or becoming continuous over posterior half; 0–3 on isthmus; series on ventral margin of anterior 60–90% of gut; internally near anterior margin of liver; series on ventral margin of posterior 30–70% of tail; specimens from Isla de Guadalupe are more heavily pigmented than those from southern California.
Diagnostic features: Myomeres 49–58+46–54=97–109 (usually 106–107 in southern California specimens, 99–101 in Isla de Guadalupe specimens); D spines XCIII–XCVIII, A I,40–48; P_1 never completes development; eye large relative to body size through flexion stage; melanophores over notochord & gut & along ventral margins of gut & tail; ventral tail pigment usually only on posterior half.

MORPHOMETRICS (range & mean in %)

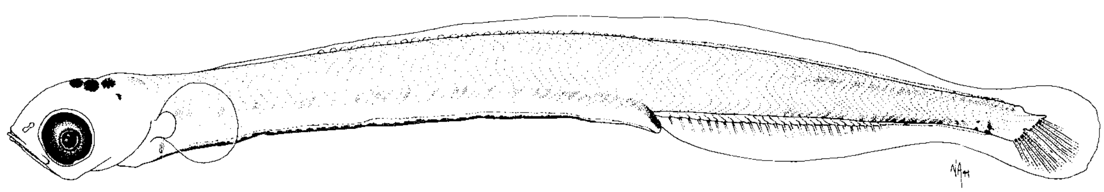
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			59–63 61	59–63 61	57–58 58	55–58 56
BD/BL			8–11 9	8–8 8	7–7 7	6–6 6
HL/BL			13–16 15	12–13 13	10–11 11	10–10 10
HW/HL			47–67 56	41–47 43	35–38 36	37–43 40
SnL/HL			11–23 18	20–25 22	24–26 25	24–26 25
ED/HL			31–41 37	23–27 26	19–21 20	18–21 20
P_1L/BL			5–6 5	3–5 4	0.2–0.2 0.2	0–0.1 0.1



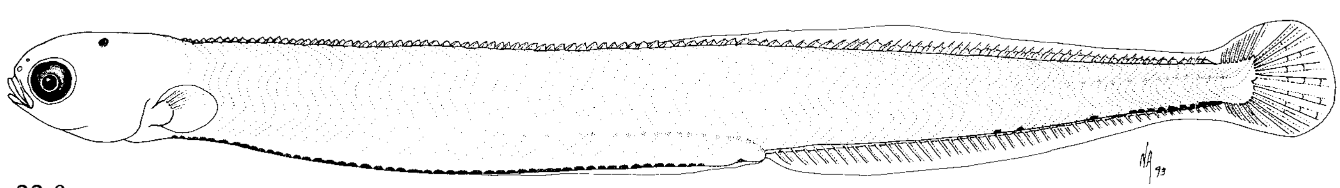
8.8 mm



13.7 mm



13.5 mm



22.0 mm

Figure Pholidae 1. Early flexion larva, 8.8 mm; mid-flexion larva, 13.7 mm (LACM 010–80–08–BB–01); flexion larva, 13.5 mm (SIO 65–65) showing heavier pigmentation of larvae from Isla de Guadalupe, Mexico; postflexion larva, 22.0 mm (CFRD Ref. Coll., Santa Rosa Island, California, March 13, 1950).

MERISTICS

	Range	Mode
Vertebrae:		
Total	84–93	90
Precaudal	50–54	51
Caudal	35–40	39
Fins:		
Dorsal spines	LXXXII–LXXXVII	LXXXIII–LXXXIV
Dorsal rays	0	0
Anal spines	I	I
Anal rays	29–38	30–32
Pelvic	0	0
Pectoral	12	12
Caudal:		
Principal	6–7+7	7+7
Procurrent:		
Upper	8–9	9
Lower	5–6	6
Gill rakers:		
Upper	1–2	
Lower	6–9	
Branchiostegals	5	5

LIFE HISTORY

Range: Banks Island, British Columbia, to Punta Escarpada, Baja California

Habitat: Intertidal to ca. 9 m depth among macroalgae, commonly in *Fucus*

Spawning season: Larvae collected in spring

ELH pattern: Oviparous; demersal eggs; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 8.2 mm (N. Arthur)
Flexion larva, 16.6 mm (N. Arthur)
Postflexion larvae, 21.4 mm, 26.0 mm (N. Arthur)

* Yatsu (1985) placed *X. fucorum* in the genus *Apodichthys*.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <8.2 mm
Flexion length: ca. 13–21 mm
Transformation length: >25 mm through ca. 59–61 mm
Fin development sequence: C_1, P_1, A, C_2, D
Pigmentation: *Preflexion–postflexion*—1 internally at nape, becoming more deeply embedded with increasing larval size; 1 on isthmus by 17 mm; 9–14 dorsolaterally along each side of gut, widely spaced anteriorly, becoming contiguous near terminus; 2 internally just anterior to liver coalescing to 1 by 21 mm; series on ventral margin of gut except near anus; series on ventral margin of tail except first 3–10 & last 2–4 postanal myomeres; series over notochord posteriorly; 1 internally under penultimate or antepenultimate vertebra. *Transformation*—Small melanophores cover upper half, spreading ventrad except on lower third of head & gut.
Diagnostic features: Myomeres 50–56+34–39=87–91 (usually 54–55+ 35–36=89–91); D LXXXII–LXXXVII; A I,29–38; melanophores dorsolaterally along gut are large & distinctly separate except near terminus; notochord pigment is posterior.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		59–67 63	64–68 66	67–70 68	67–68 68	63–67 65
BD/BL		7–10 9	7–8 7	7–10 8	8–10 9	8–9 9
HL/BL		13–17 15	11–13 12	11–13 12	12–13 12	11–13 12
HW/HL		63–66 64	47–62 55	42–49 45	36–43 39	39–42 40
SnL/HL		15–21 18	20–25 22	21–23 22	16–18 17	17–17 17
ED/HL		33–37 35	27–36 31	22–27 26	21–22 22	20–22 21
P_1L/BL		5–5 5	5–5 5	4–5 5	2–2 2	1–2 2

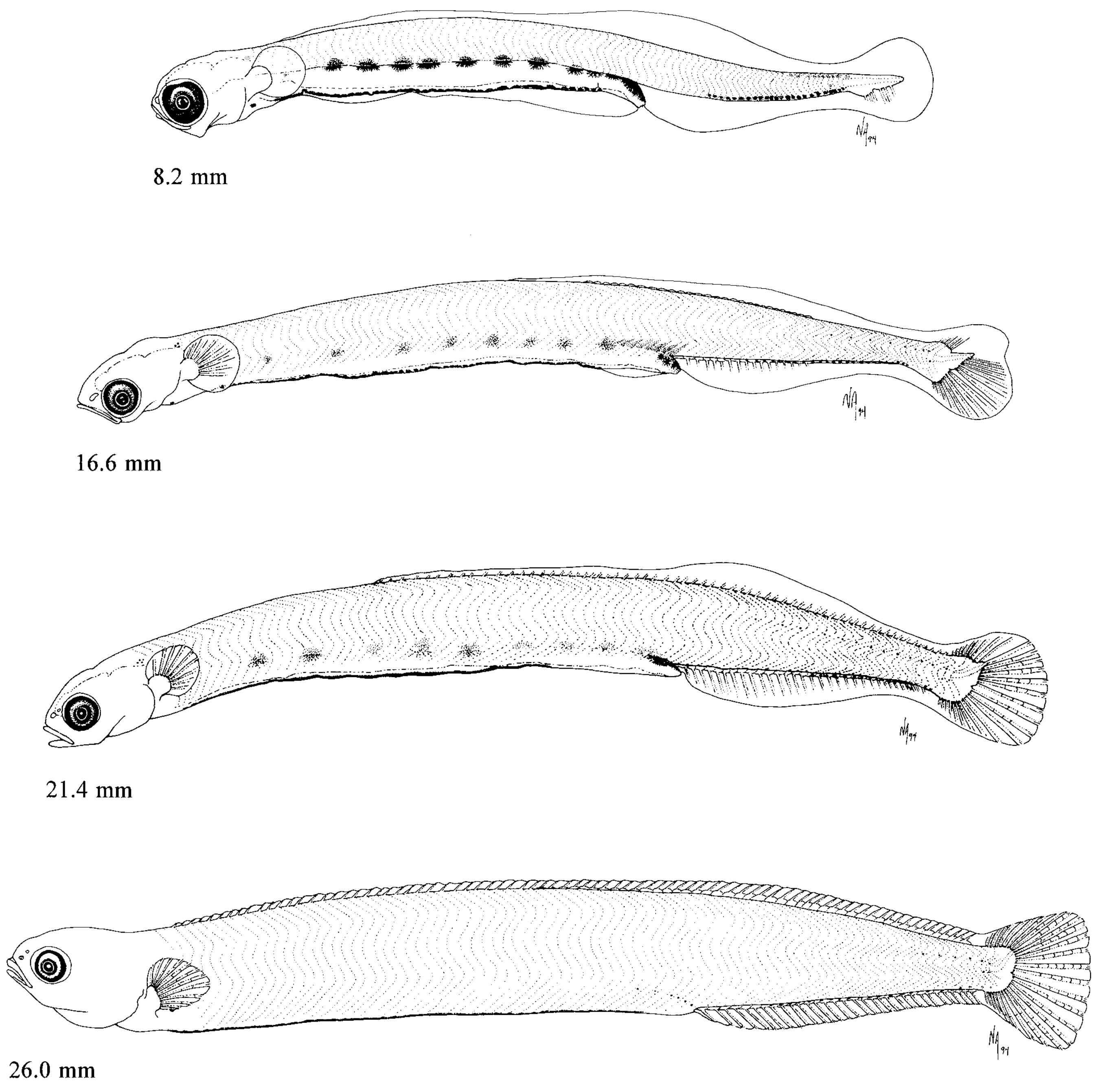


Figure Pholidae 2. Preflexion larva, 8.2 mm; flexion larva, 16.6 mm; early postflexion larva, 21.4 mm (SIO H47–76A); postflexion larva, 26.0 mm (CFRD Ref. Coll., Santa Rosa Island, California, March 13, 1950).

ANARHICHADIDAE: Wolffishes

W. WATSON

Anarhichadidae contains four species in two genera (Nelson 1994); only one species, the wolf-eel *Anarrhichthys ocellatus*, ranges into the northern part of the CalCOFI study area as far south as southern California (Eschmeyer et al. 1983). Although no wolf-eel larvae have been collected during CalCOFI surveys, pelagic juveniles have been taken in surface samples in the CalCOFI area north of Point Conception during other surveys.

Wolf-eels are large (≥2 m), benthic, eel-like residents of rocky bottom habitats on the continental shelf and upper slope (to 226 m depth). They are compressed, with preanal length <20% BL, and with a relatively small head and strong anterior canine teeth. The long, low dorsal fin is composed entirely of spines, and together with the long, low anal fin is confluent with the bluntly pointed caudal fin. Pelvic fins are absent. Wolf-eels are cryptically colored, usually in mottled browns or grays, with darker spots.

Wolf-eels are oviparous, spawning large (5.2–5.5 mm), spherical, adhesive eggs, each having a more or less opaque white chorion and a large (1.8–1.9 mm) yellow oil globule. The eggs are formed into a ball-shaped mass and brooded by both parents. Following an incubation period of ca. 3–4 months large larvae (usually ca. 30–45 mm) hatch with pigmented eyes, open mouth, small yolk sac, and typically with fully flexed notochord and fully formed fins. Early hatching larvae may be preflexion or flexion stage with incompletely developed caudal and/or pectoral fins; however, by the end of the yolk-sac stage wolf-eels are essentially fully developed nektonic juveniles. Early hatching larvae are lightly pigmented, primarily on the dorsal surface of the head, and internally over the notochord and gut, but before the end of yolk absorption the larvae are nearly completely pigmented except ventrally on the gut and on the fins. Pelagic juveniles range from evenly dark to barred. The pelagic phase may last from ca. two months to a year or more, with settlement at sizes ranging from 15–61 cm (Marliave 1987).

Owing to their large size, eel-like form with short preanal length and heavy pigmentation, and very high myomere and dorsal and anal fin ray counts (>200), "planktonic" wolf-eels cannot be confused with any other fish larvae in the CalCOFI area. The following description is based on the literature (Marliave 1987; Matarese et al. 1989) and on detailed observation of 14 eggs (5.2–5.5 mm), 12 yolk-sac larvae (18.6–41.0 mm: preflexion through postflexion), and 6 post yolk-sac specimens (47.6–90.2 mm). The eggs and all but the two largest "larvae" were reared specimens obtained from the Stephen Birch Aquarium-Museum, Scripps Institution of Oceanography. It is noteworthy that none of the specimens examined in this study had a preopercular spine such as was shown by Marliave (1975) for a 65–mm specimen (Figure Anarhichadidae 1). Meristic data were obtained from Clothier and Baxter (unpublished manuscript) and from counts made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	221–251	247–249
Precaudal	36–39	37–39
Caudal	183–214	204–210
Fins:		
Dorsal spines	CCXVIII–CCL	
Dorsal rays	0	
Anal spines	0–I	
Anal rays	180–233	
Pelvic	0	
Pectoral	19–20	
Caudal:		
Principal	5+5	
Procurrent:		
Upper	1	
Lower	1	
Gill rakers:		
Upper	3–5	
Lower	11–15	
Branchiostegals	6–7	

LIFE HISTORY

Range: Sea of Japan to Aleutian Islands, to southern California

Habitat: Demersal, usually on rocky bottom; intertidal to 226 m depth

Spawning season: October–February

ELH pattern: Oviparous; adhesive demersal eggs brooded by parents; planktonic larvae & pelagic juveniles

LITERATURE

Marliave 1975, 1987
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Eggs, 5.2–5.5 mm (W. Watson)
Newly hatched larva, 18.6 mm (W. Watson)

* Notochord flexion completed before hatching or during yolk-sac stage; yolk-sac larvae may be preflexion, flexion, or postflexion stage.
† Size at settlement.
‡ Post-yolk absorption.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 5.2–5.5 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 1.8–1.9 mm
Shell surface: Smooth
Pigment: Chorion semi-opaque white; OG yellow; late embryo with black eyes, melanophores on dorsum anteriorly & over gut
Diagnostic features: Large size, opaque white, adhesive, brooded by parents

LARVAE

Hatching length: 18.6–45 mm
Flexion length*: ca. 20–33 mm through ca. 34–37 mm
Transformation length†: ca. 150–610 mm
Fin development sequence: D & A & P, C
Pigmentation: Many (small) externally over midbrain & at nape initially; spreading over entire upper part of head; heavy internally around brain; internally over notochord, initially several rows tapering to a single row in last 30% of tail except none in last 10%; externally over entire trunk & tail after ca. 33 mm, becoming increasingly dense & spreading onto C by ca. 48 mm; heavy on upper 60–80% of gut, none ventrally; light ventrally on head after ca. 33 mm; on proximal 10–20% of all but first few A rays; little proximally on some D rays by 39 mm.
Diagnostic features: Large, very elongate larvae with preanal length usually 18–23% BL; myomeres, dorsal fin spines, & usually anal fin rays >200.

MORPHOMETRICS (range & mean in %)

	Y-S*	PrF*	F*	PoF‡	Tr	Juv
Sn-A/BL	18–32 22			19–22 20		
BD/BL	7–24 11			4–6 5		
HL/BL	9–14 10			8–11 9		
HW/HL	56–69 60			44–50 48		
SnL/HL	8–18 13			12–19 14		
ED/HL	35–45 41			33–42 35		
P_1L/BL	3–4 4			4–5 4		

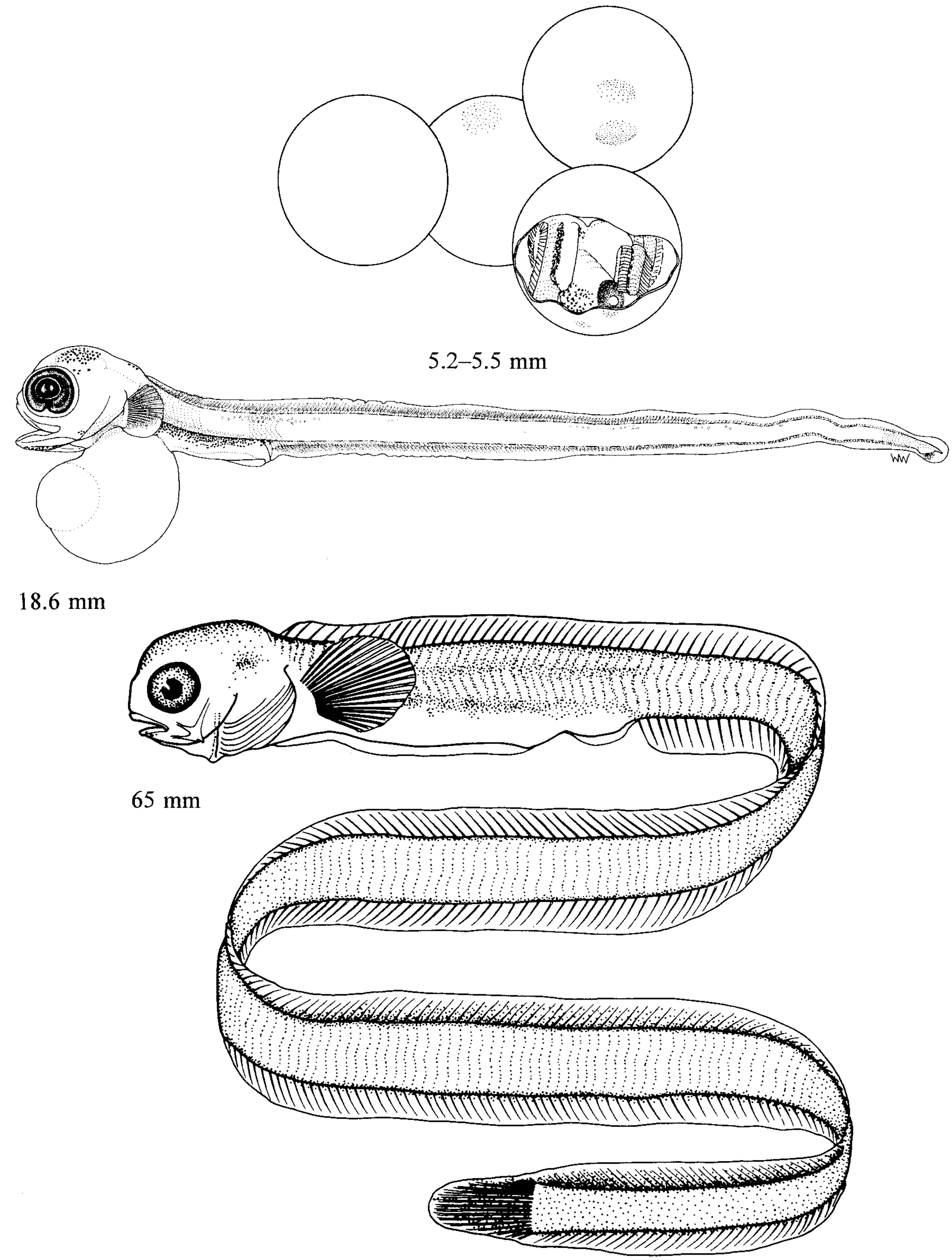


Figure Anarhichadidae 1. Eggs, 5.2–5.5 mm (chorion partially cut away to show embryo in lower right egg); newly hatched larva, 18.6 mm (CFRD Ref. Coll., reared at Stephen Birch Aquarium-Museum, SIO 94–3); pelagic juvenile, 65 mm (Marliave 1975; reproduced from Matarese et al. 1989).

TRACHINOIDEI

W. WATSON

The trachinoid fishes, originally identified by Günther (1860) as the family Trachinidae (including fishes ranging from pseudochromids to notothenioids in addition to the trachinids), subsequently were reorganized many times (e.g., Regan 1913; Greenwood et al. 1966; Nelson 1984), but monophyly of the suborder was not established (e.g., Nelson 1984; Watson et al. 1984a). Pietsch (1989) and Pietsch and Zabetian (1990) proposed a monophyletic Trachinoidei; however, Johnson (1993) questioned some parts of the analyses and suggested that monophyly has not yet been demonstrated. Nelson (1994) likewise suggested that the suborder may not be monophyletic. In this volume, we follow Eschmeyer's (1990) classification of the Trachinoidei as a convenience.

Most trachinoids, for which spawning is known, spawn spherical planktonic eggs, ca. 0.7–2.5 mm in diameter; Trichodontidae has eggs of ca. 3.5 mm diameter that are spawned in demersal masses (Watson et al. 1984a). The planktonic eggs of trachinoids hatch in ca. 2–6 days while the demersal eggs incubate for 2–12 months (Marliave 1981; Watson et al. 1984a). Larvae hatch from the planktonic eggs at lengths of ca. 2–4 mm with unpigmented eyes (partially pigmented in Champsodontidae and Trachinidae), moderate yolk sac, and an unformed mouth. Larval trichodontids are ca. 14.5 mm and well developed at hatching. Larval trachinoids are elongate (chiasmodontids, some champsodontids, creediids, leptoscopids, percophids, trichodontids) or robust (some champsodontids, pinguipedids, trachinids, uranoscopids), with preanal length usually <50% BL (longer in creediids and trichonotids) (Watson et al. 1984a; Leis and Trnski 1989; Neira and Gaughan 1989). Spination of the head and body and the sequence of fin development vary between, and in some cases, within families. Larval pigmentation likewise is quite variable, ranging from nearly absent to nearly complete. Development is direct, with few larval specializations. The chiasmodontid genus *Kali* passes through a pelagic stage termed the "gargaropteron," characterized by very long pectoral and pelvic fin rays.

At least 15 trachinoid species of four families occur in the CalCOFI study area; larvae of at least 7 species representing three families have been identified in CalCOFI ichthyoplankton samples. Larval trichodontids have not been collected during CalCOFI surveys and that family is not included here; refer to Marliave (1981) and Matarese et al. (1989) for description and illustrations.

Families included: Chiasmodontidae
Ammodytidae
Uranoscopidae

CHIASMODONTIDAE: Swallowers

W. WATSON AND E. M. SANDKNOP

The family Chiasmodontidae contains four genera and about 15 species (Nelson 1994); all four genera and 10 of the species (Table Chiasmodontidae 1) have been reported from the California Current vicinity. Eggs and larvae of *Chiasmodon niger* occur in small numbers in CalCOFI ichthyoplankton collections, primarily in spring and summer from southern California to central Baja California, and a few larval *Kali* and *Pseudoscopelus* have been taken off southern Baja California and farther south.

Chiasmodontids are small to medium-size (to ca. 26 cm) primarily tropical and subtropical meso- and bathypelagic piscivores. They are well known for their ability to swallow remarkably large prey. Chiasmodontids are moderately elongate and compressed, with preanal length about half of body length, a large head with very large mouth, and teeth that range from relatively small (*Dysalotus*) to very large (*Kali*). The dorsal fin is continuous but deeply notched, or consists of separate spinous and segmented ray portions (one or two pterygiophores between fins may lack spines). The pelvic fins are thoracic and the caudal fin is forked. *Dysalotus* has rows of strong spinules along the body; *Pseudoscopelus* has photophores ventrally. The chiasmodontids are evenly brown to black.

Spawning is unknown and little or nothing is known of the early life histories of most species. *Chiasmodon niger* spawns spherical planktonic eggs that are 1.1–1.2 mm in diameter and contain a homogeneous yolk with one or more oil globules 0.01–0.28 mm in diameter (multiple oil globules usually condense to one before hatching). Larvae hatch at about 3 mm with unpigmented eyes, an unformed mouth, and a moderate yolk sac. Larvae are elongate, with very short (<25% BL, *Chiasmodon*) to short (ca. 35–40% BL, *Pseudoscopelus*) preanal length through notochord flexion. All genera except *Kali* develop spinules on the body; in *Chiasmodon* and *Pseudoscopelus* these originate during the preflexion stage as one or two dorso- and ventrolateral rows along each side. In *Chiasmodon* many additional rows form, so that by early in the postflexion stage nearly the entire body is densely covered with spinules. In *Pseudoscopelus* few spinules are added after initial formation. In addition to lacking spinules, *Kali* is unique in developing elongate pelvic and pectoral fin rays early in the preflexion stage, before development of the other fins. The pelagic juvenile stage of *Kali*, characterized by these large fins, is termed the "gargaropteron" stage. Larval pigmentation typically is sparse with melanophores primarily on the head and gut. Prominent melanophore patches may occur dorsally and/or ventrally on the trunk and/or tail.

Larval chiasmodontids are unlikely to be confused with any other fish larvae in the CalCOFI study area. Larval *Lepidopus xantusi* (see Trichiuridae, this volume) are pigmented like larval *C. niger* but are easily distinguished by having more myomeres (>80 vs. 43–44), lacking body spinules, and developing elongate anterior dorsal fin spines early in the preflexion stage (lacking in *Chiasmodon*). Larval *Chiasmodon* can be distinguished from the other chiasmodontids by its extremely short preanal length (ca. 16–21% BL through early postflexion stage versus ≥30% for the other genera), dense covering of spinules, and characteristic pigment pattern. Larval *Kali* develop large pelvic and pectoral fins early in the preflexion stage, and always lack body spinules. Larval *Dysalotus* and *Pseudoscopelus* differ slightly in meristic characters (Table Chiasmodontidae 1); it is unknown how else they might be distinguished.

The following descriptions are based on examination of 20 eggs, 21 larvae (3 yolk-sac, 3.2–3.5 mm; 9 preflexion, 4.5–8.4 mm; 4 flexion, 9.3–11.3 mm; 5 postflexion, 13.5–17.3 mm), 3 transformation specimens (30.0–42.0 mm), and 3 juveniles (45.1–59.3 mm) of *C. niger* and 7 larval *Kali* (2 preflexion, 3.9 and 6.0 mm; 2 flexion, 7.1 and 7.2 mm; 3 postflexion, 8.0–10.0 mm). Based on meristic characters and a comparison with larvae from Johnston Atoll tentatively identified as *K. indica* (Figure Chiasmodontidae 1), the *Kali* described here are tentatively identified as *K. normani*. Too few larval *Pseudoscopelus* were available from CalCOFI collections to permit description; a more complete series of *Pseudoscopelus* sp. from Johnston Atoll is shown in Figure Chiasmodontidae 1 as an example of the genus. Meristic data were obtained from the literature (Norman 1929; Johnson 1969; Johnson and Cohen 1974) and from counts made during this study.

Table Chiasmodontidae 1. Meristic characters for the chiasmodontid species reported to occur in the California Current vicinity. All have I,5 pelvic fin rays and 9+8 principal caudal fin rays.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	BrR
Chiasmodon niger	20–22	21–24	43–46	IX–XIII, 26–29	I,25–29	12–15	9–11+ 9–11	7
C. subniger	19–20	24	43–44	XI–XIII, 25–29	I,24–28	13–15	9–11+ 9–11	7
Dysalotus oligoscolus	16	23–24	38–40	X–XII, 24–26	I,24–27	11	6–9+ 6–10	7
Kali indica	22–24	16–18	37–41	XI–XIV, 22–24	0–I, 21–25	11–13	8–10+ 8–12	6
K. macrodon	20–21	17	35–40	XI–XIII, 22–26	I,22–25	10–11	9+9	6
K. macrura	18–19	15–17	33–35	IX–XII, 18–21	I,17–20	11–13	8–10+ 8–10	6
K. normani	21–24	15–18	36–41	XII–XIII, 22–26	0–I, 23–26	12–13	5–7+ 6–8	6
Pseudoscopelus altipinnis	17	20	37	VIII+ 24–25	I,24–25	13	10–11+ 9–10	7
P. savagei	18	20	38	VIII+25	I,25	13		7
P. scriptus	16–18	19–22	37–38	VII–VIII+ 22–24	I,22–23	13	9–10+ 9–11	7

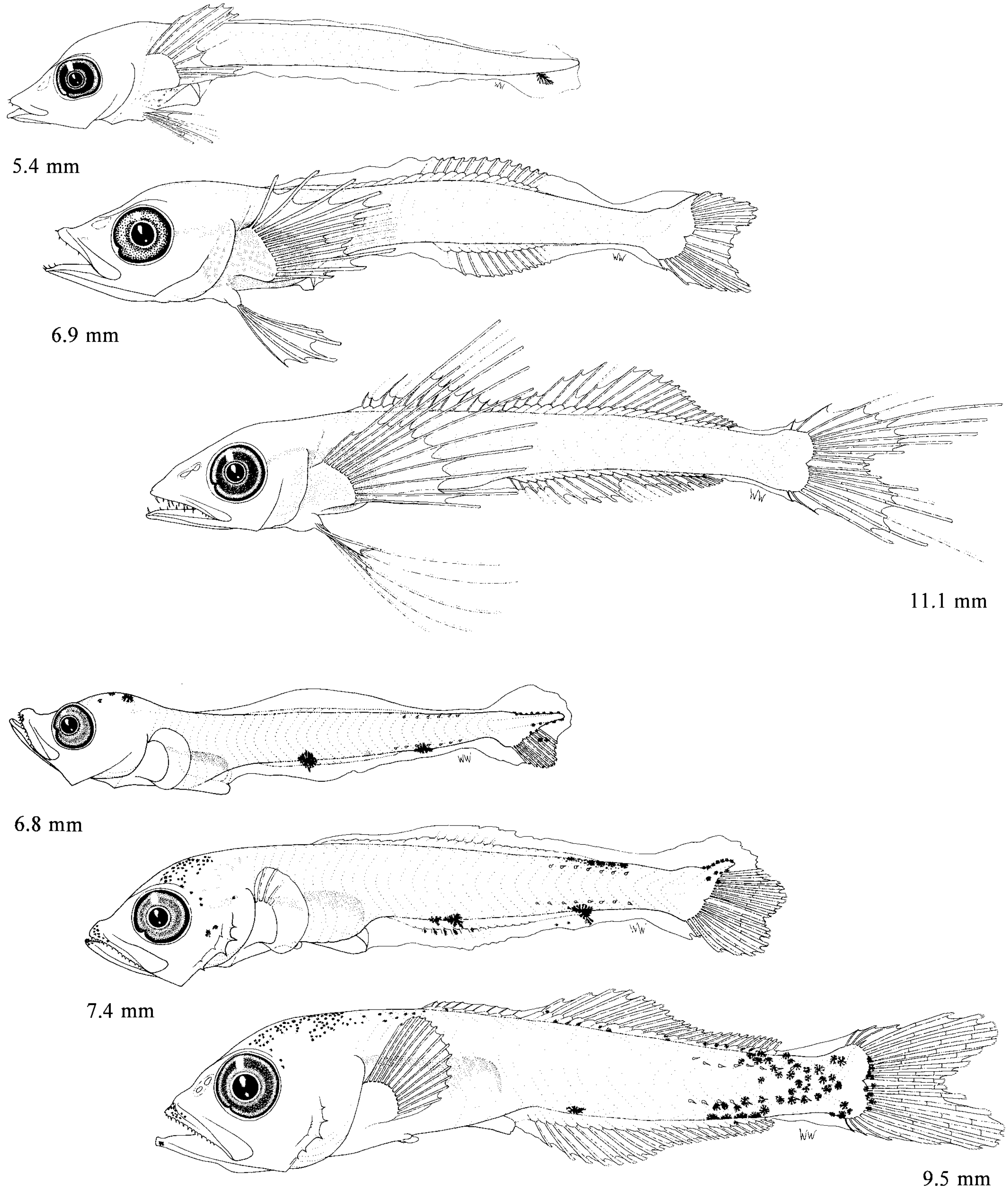


Figure Chiasmodontidae 1. *Kali* (*indica*?) preflexion larva, 5.4 mm (TC 8406, station 184); flexion larva, 6.9 mm (TC 8406, station 151); postflexion larva, 11.1 mm (TC 8406, station 222); and *Pseudoscopelus* sp. preflexion larva, 6.8 mm (TC 8406, station 150); flexion larva, 7.4 mm (TC 8406, station 151); postflexion larva, 9.5 mm (TC 8406, station 162). Original illustrations by W. Watson.

MERISTICS

	Range	Mode
Vertebrae:		
Total	43–46	44
Precaudal	20–22	20
Caudal	21–24	24
Fins:		
Dorsal spines	IX–XIII	XI
Dorsal rays	26–29	26
Anal spines	I	I
Anal rays	25–29	25–28
Pelvic	I,5	I,5
Pectoral	12–15	13
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–11	10–11
Lower	9–11	10–11
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	7	7

LIFE HISTORY

Range: Tropical & subtropical Atlantic, Indian, & Pacific Oceans; north to California in eastern Pacific

Habitat: Mesopelagic

Spawning season: In CalCOFI area, larvae collected in all months with highest catches April–May & August–September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Watson et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.1 mm (N. Arthur)
Yolk-sac larva, 3.2 mm (N. Arthur)
Preflexion larva, 6.5 mm (N. Arthur)
Flexion larva, 10.0 mm (N. Arthur)
Transformation specimen, 22.9 mm (N. Arthur)

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* Eye is slightly oval, becoming round in flexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.1–1.2 mm **Yolk:** Homogeneous
No. of OG: 1 to >100, usually condensing to 1
Diam. of OG: 0.24–0.28 mm; when present, smaller OG(s) are 0.01–0.06 mm
Shell surface: Smooth
Pigment: Chorion often tinted pale rose to amber; melanophores on OG & embryo by blastopore closure, 3–5 distinct melanophore patches on embryo before hatching
Diagnostic features: Shell diameter; OG number & sizes; pigmentation

LARVAE

Hatching length: ca. 3 mm
Flexion length: ca. 9–12 mm
Transformation length: 23–42 mm
Fin development sequence: P_1 & C_1, 2D & A, 1D, P_2 & C_2
Pigmentation: *Yolk-sac*—Under brain & over gut; 3 ventral patches on tail; usually some around margins of notochord tip. *Preflexion–postflexion*—On vomer, covering roof of mouth by 17 mm; under brain; externally over midbrain, spreading over fore- & hindbrain during postflexion stage; on gular region by ca. 10 mm; over gut & gas bladder; 0–few on P_1 base; usually few on distal half of P_1 blade or upper rays; 2 large dorsal patches on tail, third patch added on caudal peduncle during postflexion stage; 3 large ventral patches on tail; on D & A rays adjacent to dorsal & ventral patches by 17 mm; around notochord tip & on caudal finfold; distally on C by 14 mm.
Diagnostic features: Preanal length 16–34% BL through early postflexion stage; body covered with spinules, beginning at ca. 5.5 mm as single dorsolateral & ventrolateral rows; spiny supraoccular ridge by flexion stage; myomeres 42–44 (3–5+37–41 through early postflexion stage, 17+26 by transformation); prominent dorsal & ventral pigment patches.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	26–31 29	16–34 21	22–29 27	33–48 39	49–51 50	51–68 57
BD/BL	11–18 15	11–14 12	11–12 12	12–15 13	14–21 17	18–21 19
HL/BL	16–18 17	13–17 16	19–24 20	21–26 25	26–28 26	27–30 29
HW/HL	52–55 54	49–73 58	40–60 47	39–43 41	28–48 37	31–35 33
SnL/HL	9–14 12	24–35 31	32–35 33	33–35 34	25–34 28	23–24 24
ED/HL*	38–41× 34–36 40×35	29–42× 30–40 35×33	30–33 31	24–31 27	17–24 21	14–19 17
P_1L/BL	 1	2–5 4	6–8 7	10–14 12	15–18 17	20–24 22
P_2L/BL	0–0 0	0–0 0	0–0 0	3–5 4	7–10 8	11–14 13

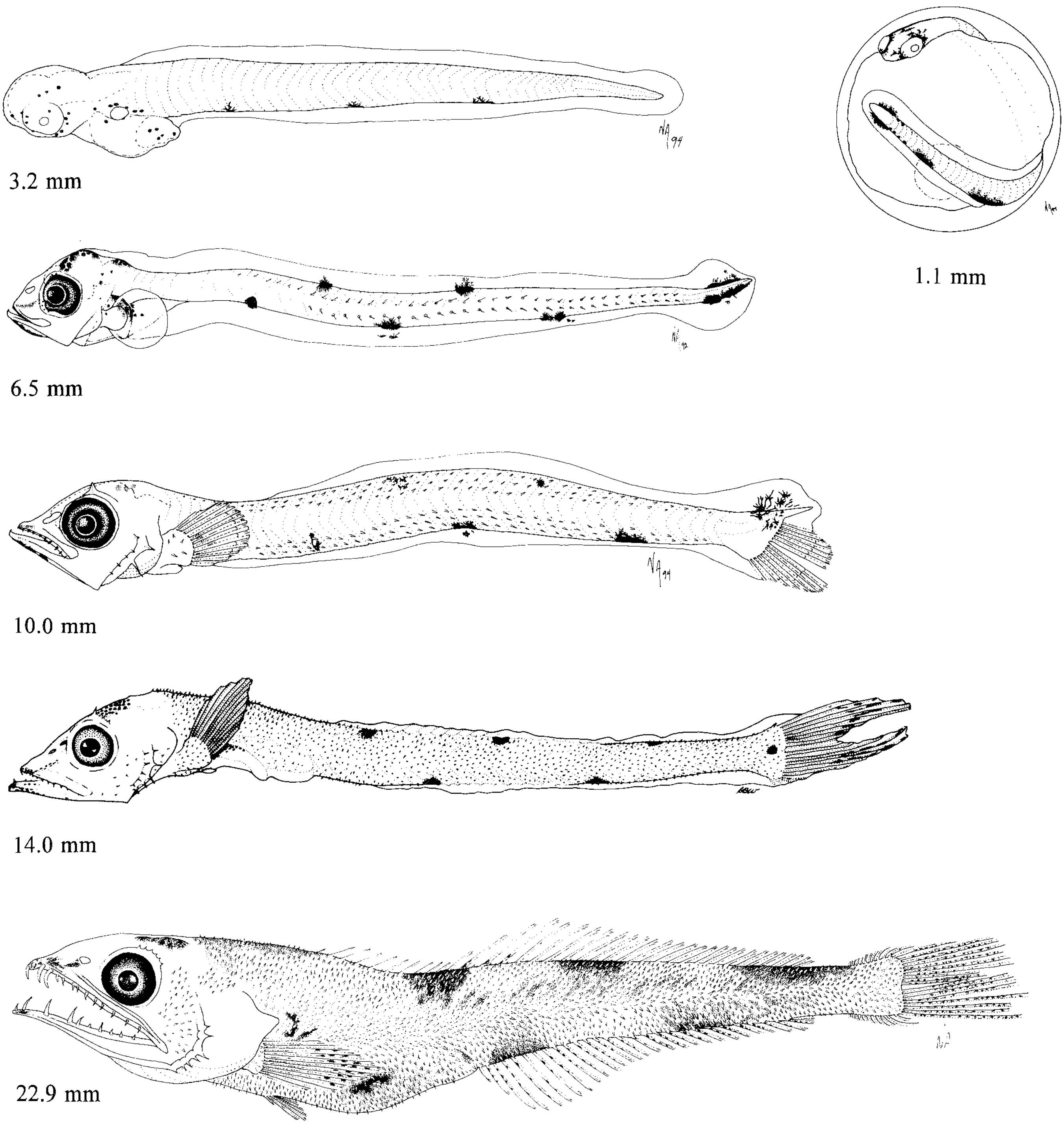


Figure Chiasmodontidae 2. Egg, 1.1 mm (CalCOFI 8104, station 103.3.60); yolk-sac larva, 3.2 mm (CalCOFI 6910, station 87.90); preflexion larva, 6.5 mm (CalCOFI 7503, station 100.80); flexion larva, 10.0 mm (CalCOFI 7205, station 20.135); postflexion larva, 14.0 mm (Watson et al. 1984a); transformation specimen, 22.9 mm (EASTROPAC II, station 46.151).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–41	38–39
Precaudal	21–24	22
Caudal	15–18	15–17
Fins:		
Dorsal spines	XII–XIII	XII–XIII
Dorsal rays	22–26	24
Anal spines	0–I	I
Anal rays	23–26	24
Pelvic	I,5	I,5
Pectoral	12–13	13
Candal:		
Principal	9+8	9+8
Procnrrent:		
Upper	5–7	6–7
Lower	6–8	6–7
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Worldwide, primarily in tropical seas; in eastern Pacific north to southern California

Habitat: Meso- & bathypelagic

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.9 mm (W. Watson)
Flexion larva, 7.2 mm (W. Watson)
Postflexion larva, 10.0 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.9 mm
Flexion length: ca. 7–8 mm
Transformation length:
Fin development sequence: P_1 & P_2, C_1, D & C_2, A
Pigmentation: *Preflexion–postflexion*—Ventrally & laterally on hindbrain & posteriorly on midbrain, may extend onto dorsal surface of hindbrain; occasionally little anteriorly on forebrain; externally dorsally on head, primarily over midbrain area, by ca. 10 mm; series on palatines; heavy on upper 75% or completely around gas bladder & gut, except none on terminal section of intestine.
Diagnostic features: Early development of large P_1 & P_2; no spines on head; myomeres 5–10+29–34=38–39; pigment largely restricted to roof of mouth, ventral surface of brain, gas bladder, & gut.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		27–31 29	33–36 35	37–46 42		
BD/BL		15–19 17	17–18 17	15–21 18		
HL/BL		19–21 20	19–26 23	24–30 27		
HW/HL		59–61 60	55–63 59	51–54 52		
SnL/HL		23–32 27	29–34 32	32–36 34		
ED/HL		36–41 39	32–35 34	30–34 32		
P_1L/BL		7–9 8	11†	31–34 32		
P_2L/BL		10–15 12	10†	38†		

* Four *Kali* species have been reported from the eastern Pacific. Meristic characters of the larvae included here are most consistent with *K. indica* & *K. normani*; since their pigmentation differs somewhat from central Pacific larvae tentatively identified as *K. indica*, these larvae are tentatively identified as *K. normani*.

† Fins intact in one specimen.

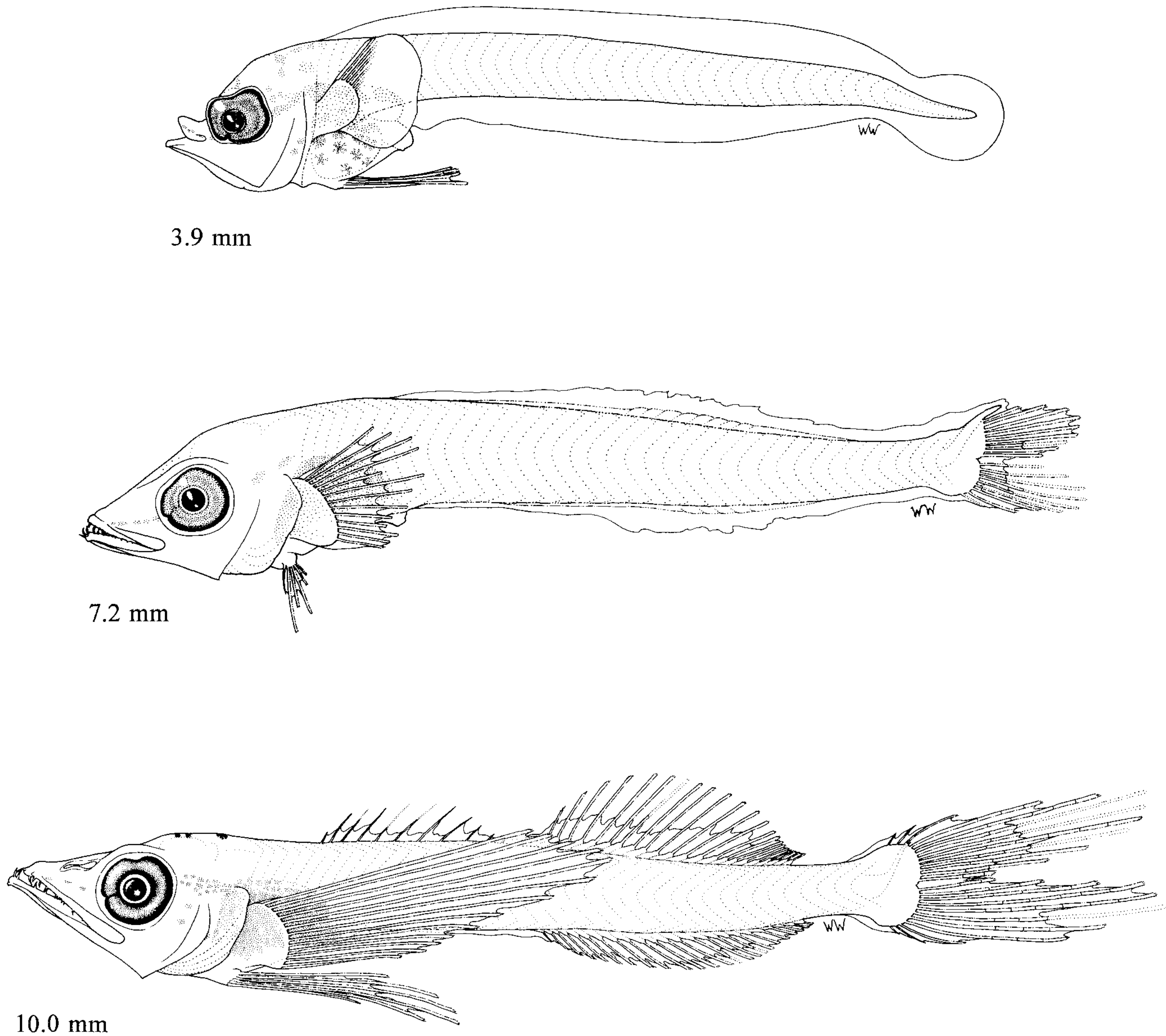


Figure Chiasmodontidae 3. Preflexion larva, 3.9 mm (TO 58–1, station 88); flexion larva, 7.2 mm (CalCOFI 5908, station 150.45); postflexion larva, 10.0 mm (EASTROPAC II, station 46.028).

AMMODYTIDAE: Sand lances

W. WATSON

Ammodytidae commonly was placed in its own suborder until 1990 when Pietsch and Zabetian (1990) placed it in Trachinoidei. The family contains about 19 species in five genera (Pietsch and Zabetian 1990); two species in two genera range into the California Current vicinity. *Ammodytes hexapterus* is a cool-water species that occurs as far south as southern California (Eschmeyer et al. 1983), while *Ammodytoides gilli* is a warm-water species that occurs at least as far north as Cabo San Lucas (Beebe and Tee-Van 1938). A few larvae of both species have been collected during CalCOFI ichthyoplankton surveys: *Ammodytes hexapterus* in surface samples north of Point Conception, California, and *Ammodytoides gilli* in oblique tows south of Punta Eugenia, Baja California Sur.

Ammodytids are small to medium-size (to ca. 35 cm) fish that range from the shallow subtidal zone, where they may bury in the sand, to the epipelagic zone well offshore. They are elongate, cylindrical to moderately compressed, with preanal length ca. 60% BL. The snout is pointed with a projecting lower jaw. The long dorsal fin and shorter anal fin contain only segmented rays. The caudal fin is forked and pelvic fins are absent except in *Embolichthys*. Sand lances are countershaded, typically with blue or green above and white or silvery below. Some species are utilized in commercial fisheries and most are considered important forage for larger fish, marine mammals, and birds.

Ammodytids are oviparous. *Ammodytes* spawns adhesive demersal eggs that are more or less spherical, 0.7–1.2 mm in diameter, with a single yellow to greenish-yellow oil globule 0.17–0.42 mm in diameter (e.g., Senta 1965; Russell 1976; Stevens et al. 1984). *Ammodytoides pylei* may spawn planktonic eggs (Randall et al. 1994). Larvae hatch at a length of ca. 3–7 mm with pigmented eyes, open mouth, and small yolk sac (e.g., Williams 1964; Russell 1976; Stevens et al. 1984; Matarese et al. 1989; this study). Larvae are elongate and cylindrical to compressed, with preanal length ca. 60–65% BL. The snout initially is short and rounded but it elongates and becomes pointed (Macer 1967; Russell 1976; Stevens et al. 1984). Dorsal and anal fin rays first form posteriorly and addition of rays is cephalad. Larval *Ammodytoides gilli* have elongate lower principal caudal fin rays during flexion and early postflexion stages. Larval pigmentation is moderately light, with melanophores largely limited to the dorsal and ventral margins of the body and gut. Development is direct, without a marked morphological transformation from the larval to the juvenile stage, and generally with only a gradual increase in pigmentation.

Larval *Ammodytes hexapterus* superficially resemble larval clupeids, engraulids, and osmerids during the preflexion and early flexion stages, but they have a shorter preanal length than the clupeids and osmerids (ca. 60% BL versus >70%), and a higher myomere count than the clupeids and engraulids (ca. 68–69 versus <60). Early larval *Ammodytoides gilli* resemble the tetragonurid *Tetragonurus cuvieri*, and the phosichthyid *Woodsia nonsuchae*, but have a discontinuous pigment band (usually 6–9 distinct patches) extending from the roof of the mouth and over the gut to near the end of the tail, while the others have a continuous band. The dorsal margin of the tail is pigmented along the last few myomeres in *T. cuvieri*, and this pigmented area expands, while in *A. gilli* the dorsal pigment is largely limited to the notochord tip and typically disappears during the preflexion stage. *W. nonsuchae* typically has 42 myomeres while *A. gilli* has 56–58. Once fin ray formation is underway, the ammodytids cannot be confused with any other fish larvae. The much different pigmentation, myomere counts, and larval distributions should preclude confusion of the two ammodytid species with one another.

The following descriptions are based on published literature and on detailed observations of 20 specimens of *Ammodytes hexapterus* and 21 *Ammodytoides gilli* (Table Ammodytidae 1). Meristic data were obtained from the literature (Bean 1894; Duncker and Mohr 1939; Matarese et al. 1989) and from counts made during this study.

Table Ammodytidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the ammodytid species description. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Ammodytes hexapterus	L[a]	L[a]	L[a]	L[a,b]	10 13.9–34.6	5 40.0–55.2	5 63.7–83.2
Ammodytoides gilli	0	2 3.0–3.6	5 3.1–3.8	6 5.1–6.8	7 6.9–13.1	1 39.3	0

[a] Matarese et al. 1989
[b] Kobayashi 1961

MERISTICS

	Range	Mode
Vertebrae:		
Total	65–74	67–69
Precaudal	40–47	44
Caudal	23–27	24–26
Fins:		
Dorsal spines	0	0
Dorsal rays	54–63	59–60
Anal spines	0	0
Anal rays	24–32	29
Pelvic	0	0
Pectoral	13–15	14
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	10–12	10–11
Lower	9–11	11
Gill rakers:		
Upper	3–6	
Lower	16–22	
Branchiostegals	6–8	7

LIFE HISTORY

Range: Japan, Okhotsk & Bering Seas, & Alaska to southern California

Habitat: Intertidal to ca. 50 m depth when near shore, also epipelagic; may bury in sand in shallow water

Spawning season: Winter

ELH pattern: Oviparous; demersal, weakly adhesive eggs; planktonic larvae

LITERATURE

Kobayashi 1961
Matarese et al. 1989
Okiyama 1988i
Stevens et al. 1984

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.67–0.91 mm
Yolk:
No. of OG: 1
Diam. of OG: 0.26 mm
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: 4–7 mm
Flexion length: 11–13 mm
Transformation length: 16–35 mm through ca. 55 mm
Fin development sequence: C_1, P_1 & D & A, C_2
Pigmentation: *Preflexion–flexion*—Few along ventral margin anteriorly on gut; ventrolateral series along each side of gut; series along ventral margin of tail; few on caudal. *Postflexion*—Few over midbrain & on snout & lower jaw by ca. 15 mm; internally on hindbrain by ca. 14 mm, under midbrain by 27 mm; under opercle by 27 mm; internal series over notochord by 14 mm; series along dorsal margin beginning posteriorly by ca. 17 mm & reaching nape by 27 mm; increasing along ventral margin of gut; few along lateral midline of last few myomeres; on hypural margin & proximally on C rays. *Transformation*—Increasing on head, dorsolaterally, & along lateral midline.
Diagnostic features: Large size at hatching, flexion & transformation stages; myomeres usually 68–69 (36–38+31–33); preanal length 57–64% BL; pigmented only on ventrum & C through flexion, on dorsum & internally over notochord in postflexion stage.

MORPHOMETRICS (range & mean in %)

	YS	PrF	F	PoF	Tr	Juv
Sn-A/BL				57–64 61	61–62 62	61–65 63
BD/BL				7–8 7	7–8 8	9–9 9
HL/BL				13–18 16	18–19 18	18–20 19
HW/HL				32–49 39	28–32 30	29–33 31
SnL/HL				24–36 30	31–35 33	29–33 32
ED/HL				18–27 23	18–21 20	19–22 20
P_1L/BL				3–10 6	9–11 10	10–11 10

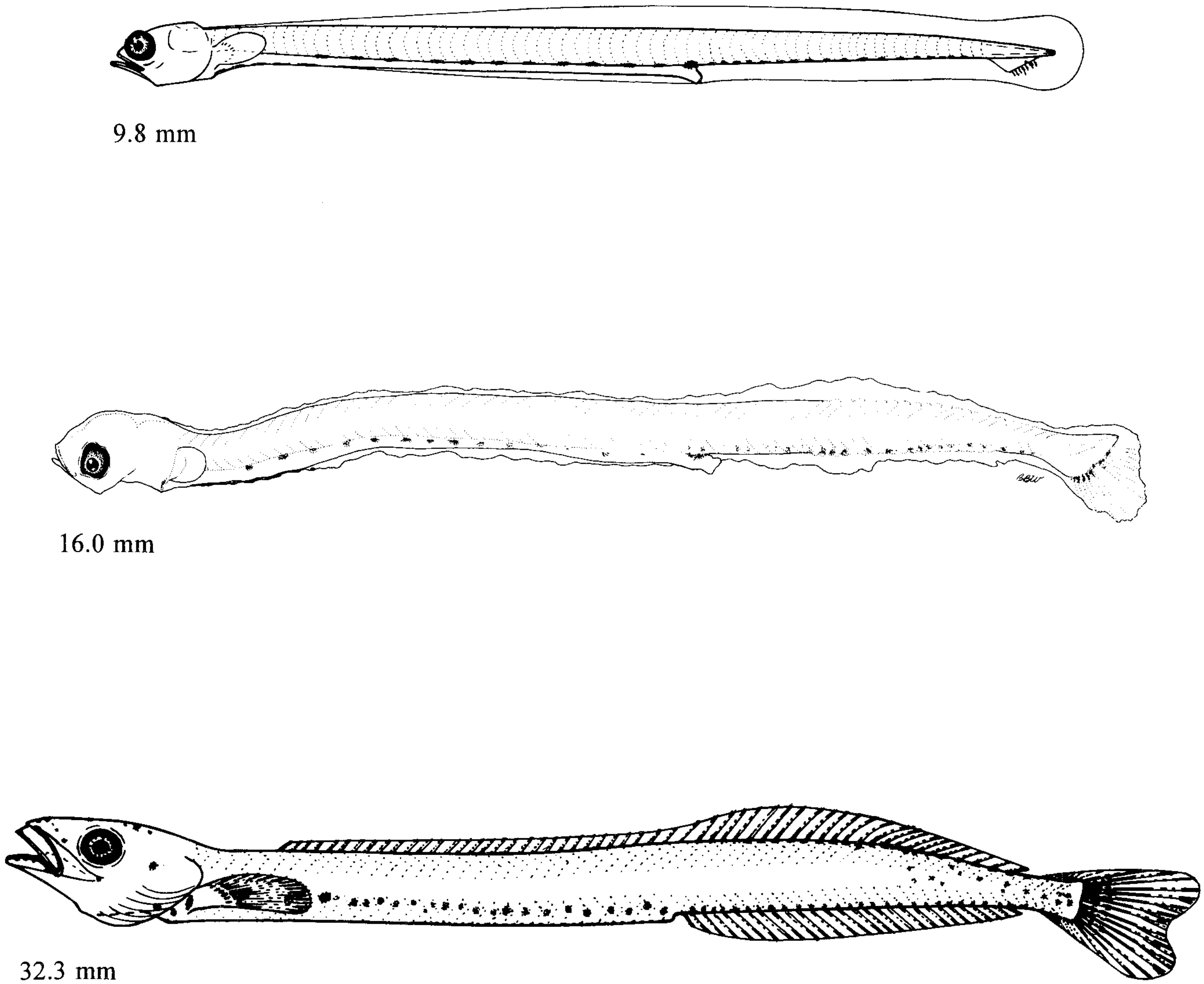


Figure Ammodytidae 1. Preflexion larva, 9.8 mm (Matarese et al. 1989); flexion larva, 16.0 mm (Stevens et al. 1984); late postflexion or transformation larva, 32.3 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	57	
Precaudal	32	
Caudal	25	
Fins:		
Dorsal spines	0	
Dorsal rays	46–47	
Anal spines	0	
Anal rays	22–24	
Pelvic	0	
Pectoral	13–15	
Caudal:		
Principal	8–9+7–8	
Procurrent:		
Upper	14	
Lower	14	
Gill rakers:		
Upper		
Lower		
Branchiostegals	7	

LIFE HISTORY

Range: Eastern Pacific, including at least vicinity of Cabo San Lucas & Gulf of Tehuantepec, Mexico

Habitat: Possibly seaward of continental shelf

Spawning season: In CalCOFI area, larvae collected February–October

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.3 mm (N. Arthur)
Flexion larva, 6.1 mm (N. Arthur)
Postflexion larvae, 7.6 mm, 13.1 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: Near 3 mm
Flexion length: ca. 5 mm–6.8 mm
Transformation length: Begins at >13 mm, <39 mm
Fin development sequence: C_1, D & A, P_1 & C_2
Pigmentation: *Yolk-sac–preflexion*—5–8 internal patches in roof of mouth, under hindbrain, & over gut & gas bladder, becoming nearly continuous band; on gular membrane by 3.7 mm; on isthmus; on ventral margin of gut & extending onto preanal finfold, series primarily anterior initially but extending full length of gut by 3.7 mm; on ventral margin of middle of tail, spreading cephalad & caudad; around margin of notochord tip & on caudal finfold, decreasing dorsally. *Flexion–postflexion*—Posterolaterally on midbrain by 13 mm; on lower jaw & internally over caudal vertebrae by 8.5 mm; along lower C rays by 5 mm, on upper central rays by 8.5 mm. *Transformation*—Heavy dorsally on head; dorsolaterally on trunk & tail; few on caudal peduncle; along margin of A; on all of C, heaviest along margin & central rays.
Diagnostic features: Myomeres 31–33+23–27=56–58 (usually 31+25); lower principal caudal rays elongate in flexion & early postflexion stages; pigment in distinct patches, becoming a nearly continuous band from tip of upper jaw to caudal peduncle; C pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	62–62 62	57–63 61	64–68 66	59–71 66	 62	
BD/BL	9–12 11	11–13 12	11–13 12	10–13 12	 10	
HL/BL	15–18 16	15–21 17	17–23 20	19–23 22	 23	
HW/HL	50–50 50	46–52 48	36–44 41	27–46 35	 28	
SnL/HL	12–15 13	9–21 14	16–26 22	23–30 27	 31	
ED/HL	37–37 37	33–37 35	24–29 26	22–27 24	 22	
P_1L/BL	4–5 5	5–6 6	5–8 6	6–10 7	 11	

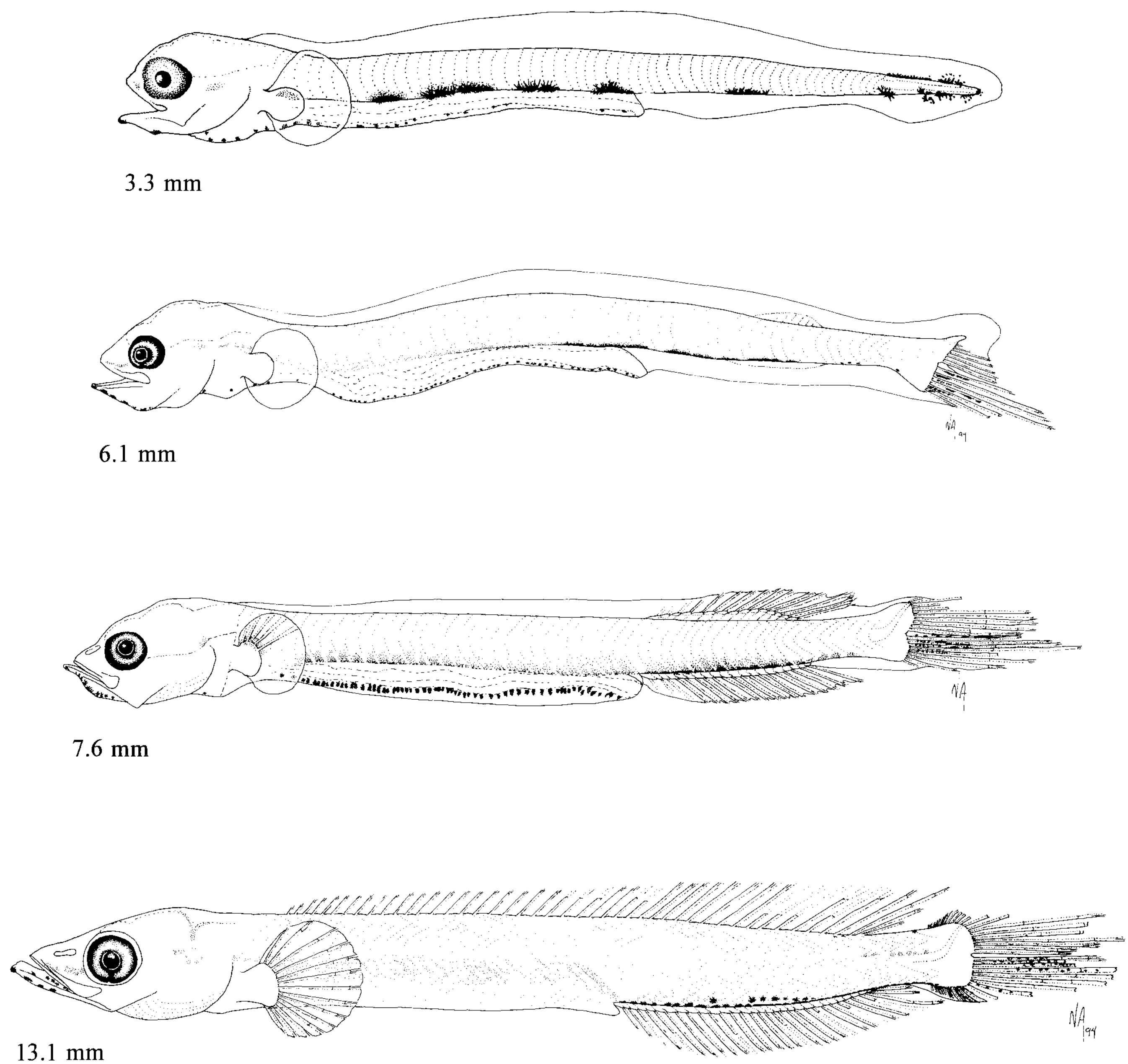


Figure Ammodytidae 2. Preflexion larva, 3.3 mm (IATTC 90044, station T2); flexion larva, 6.1 mm (TO 59–1, station 48); postflexion larvae, 7.6 mm (IATTC 90031, station MSH2 #1 Red), 13.1 mm (TO 58–1, station 100).

URANOSCOPIDAE: Stargazers

W. WATSON

Uranoscopidae contains about 50 species in eight genera (Nelson 1994). Both eastern Pacific species (Table Uranoscopidae 1) occur in the CalCOFI study area: *Astroscopus zephyreus* ranges along the Pacific coast from southern California to Peru and *Kathetostoma averruncus* ranges from Piedras Blancas Point, California, to Peru (Bussing and Lavenberg 1995c). Larval *K. averruncus* and pelagic juveniles of both species have been collected from January through August at stations near shore south of Punta Eugenia, Baja California Sur, during CalCOFI cruises.

Stargazers are small to medium-size (most ≤30 cm, largest species to ca. 75 cm) benthic ambush predators that bury in sandy and muddy bottom in warm water from the shallow subtidal zone to ca. 700 m depth (Eschmeyer et al. 1983; Pietsch 1989). A few species occur in brackish or fresh water. Uranoscopids are broad and somewhat depressed anteriorly, with a flat dorsal profile, eyes dorsal or dorsolateral, strongly oblique to vertical mouth opening, and with the mouth usually fringed with fimbriae. The pelvic fins are placed well ahead of the pectoral fins. Stargazers are cryptically colored, typically with mottled or spotted browns, greens, or blues above and a paler, more even color below.

The few species for which eggs are known spawn spherical planktonic eggs, 1.5–2.5 mm in diameter, that contain an unsegmented yolk with 0–27 oil globules ranging up to 0.15 mm in diameter (Mito 1966; Dekhnik 1973; Robertson 1975; Crossland 1981). The chorion is ornamented with a polygonal network in *Uranoscopus* (Mito 1966; Dekhnik 1973). *Uranoscopus japonicus* hatches at 3.7–4.4 mm with partially pigmented eyes, unformed mouth, large yolk sac, and moderately heavy pigmentation (Mito 1966). Larval stargazers are broad and deep-bodied, with a large, rounded head and with preanal length ca. 50–67% BL. Broad preopercular spines as well as other head and pectoral girdle spines and ridges form during flexion and early postflexion stages. Polygonal sculpturing on much of the skull is clearly visible by the end of notochord flexion. During the postflexion stage, the mouth opening shifts from nearly horizontal to nearly vertical and, near settlement, the eyes begin to shift dorsally. Larval pigmentation ranges from moderately light to heavy in the preflexion stage, typically becoming heavy during the postflexion stage, except on the last 2–3 myomeres and fins (Pearson 1941; Mito 1966; Dekhnik 1973; Crossland 1981; Leis and Trnski 1989).

Larval uranoscopids should not be confused with any other fish larvae in the CalCOFI study area, especially after notochord flexion when the fin rays are formed and the head and pectoral girdle spines and sculpturing are well developed. Preflexion stage larvae may superficially resemble some bramid, morid, or tetraodontid species but are readily distinguished by myomere count: 25–30 for the uranoscopids, 18–20 for the tetraodontids, and >35 for the bramids and morids. Larval *A. zephyreus* and *K. averruncus* may be distinguishable by myomere and dorsal fin ray counts (Table Uranoscopidae 1); the segmented rays are formed by mid- to late flexion stage. The cleithral spine is strongly developed by ca. 12 mm in *K. averruncus* but barely discernable in *A. zephyreus* as small as 20 mm. Pigmentation is similar in pelagic juveniles of both species, except that *K. averruncus* usually has at least a few melanophores along the proximal half of the anal fin (present in larvae as well), while *A. zephyreus* apparently lacks this pigment.

The following description is based on detailed examinations of 7 presettlement (4 flexion, 5.8–6.8 mm; 2 postflexion, 9.6 & 12.1 mm; 1 pelagic juvenile, 19.6 mm) and 5 benthic juvenile (59.5–74.6 mm) specimens of *Kathetostoma averruncus*. All *A. zephyreus* identified from CalCOFI collections were pelagic juveniles (20–40 mm); one of these is shown in Figure Uranoscopidae 1. Meristic data were obtained from Wade (1946) and from counts made during this study.

Table Uranoscopidae 1. Meristic characters for the uranoscopid species in the California Current vicinity. Both have 6 branchiostegal rays, I,5 pelvic fin rays, 7+6 principal caudal fin rays, and both lack gill rakers.

Species	Vertebrae			Fin Rays			
	PrCV	CV	Total	D	A	P_1	C_2
Astroscopus zephyreus	10–11	14–15	25	V,13	13–14	20–22	5–6+4–6
Kathetostoma averruncus	12–13	16–18	28–30	15–16	13–14	20–21	2–5+3–4

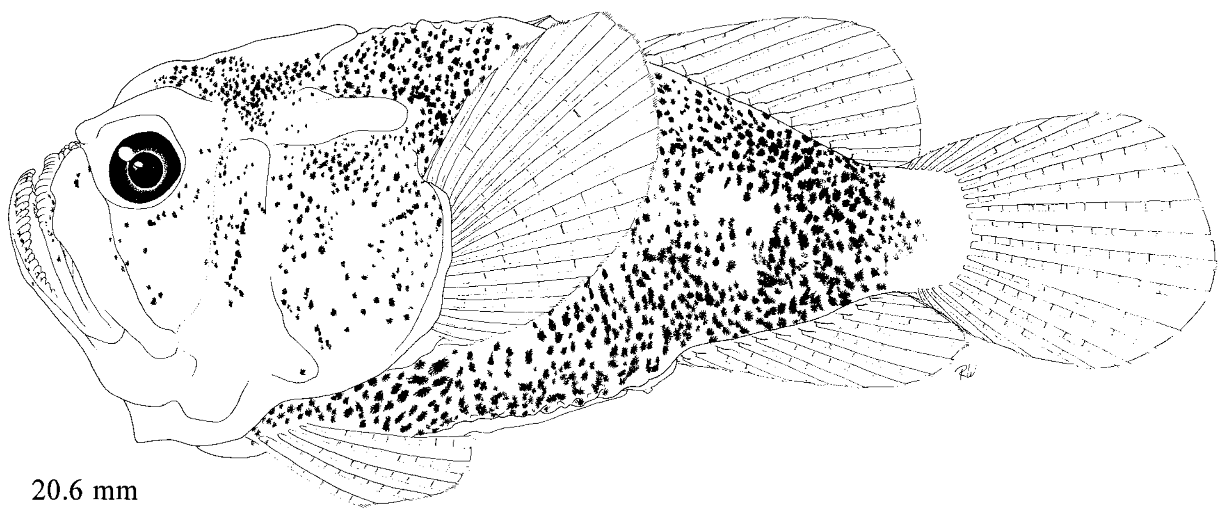


Figure Uranoscopidae 1. Pelagic juvenile *Astroscopus zephyreus*, 20.6 mm (CalCOFI 5703, station 123.50; original illustration by R. C. Walker).

MERISTICS

	Range	Mode
Vertebrae:		
Total	28–30	28–29
Precaudal	12–13	12
Caudal	16–18	16–17
Fins:		
Dorsal spines	0	0
Dorsal rays	15–16	15
Anal spines	0	0
Anal rays	13–14	13–14
Pelvic	I,5	I,5
Pectoral	20–21	20
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	2–5	3
Lower	3–4	3
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: Point Piedras Blancas, California, to Peru, primarily south of central Baja California

Habitat: Benthic on sandy bottom, 13–384 m depth

Spawning season: Larvae collected January through August in CalCOFI area

ELH pattern: Oviparous; presumably, eggs planktonic; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 6.8 mm (N. Arthur)
Postflexion larva, 9.6 mm (R. C. Walker)
Postflextion larva, 12.1 mm (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 5.8–6.8 mm
Transformation length: ca. 19.6 mm to <59.5 mm
Fin development sequence: C_1, P_1 & D & A, C_2, P_2
Pigmentation: *Flexion–postflexion*—Nearly completely pigmented except none on last 2–3 myomeres & caudal region, light on mandible & laterally on tail through flexion stage; 0–few on D base & rays (usually none on rays); heavy on A base, light to moderate on proximal half of fin; light to moderate on P_1 base, mainly on proximal half; on P_2 base. *Juvenile*—Dark above with lighter mottling, uniformly light below.
Diagnostic features: Myomeres 28–29; D rays 15–16, present by midflexion, no D spines; cleithral spine visible by ca. 9 mm, strong by ca. 12 mm; nearly completely pigmented; band of melanophores along proximal half of A.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	PJuv	BJuv
Sn-A/BL			51–71 61	66–67 66	72	52–59 55
BD/BL			34–49 42	43–50 47	47	28–36 33
HL/BL			26–48 37	41–42 42	45	30–37 35
HW/HL			74–99 91	94–106 100	105	94–111 104
SnL/HL			16–25 20	13–17 15	17	13–17 14
ED/HL			28–38 32	33–33 33	28	20–29 23
P_1L/BL			7–11 9	13–16 14	*	26–29 28
P_2L/BL			0.4–2 1	3–11 7	*	21–24 23

* Fins damaged.

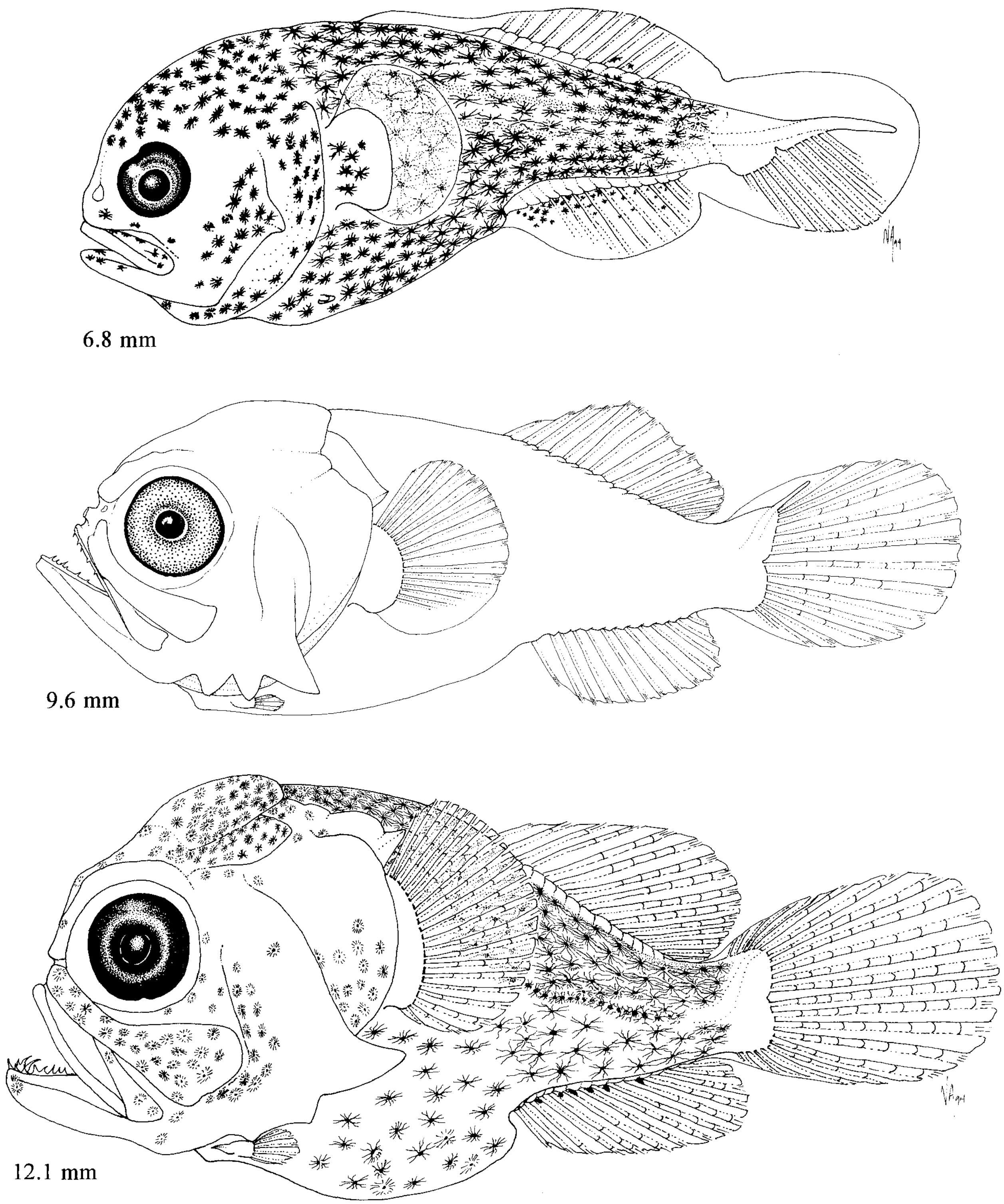


Figure Uranoscopidae 2. Early flexion larva, 6.8 mm (CalCOFI 5702, station 140.40; most pigment shown was added from a 6.7 mm specimen, CalCOFI 5701, station 127.34); postflexion larvae, 9.6 mm (CFRD Ref. Coll., Bahía Magdalena, Baja California Sur, August 1957; specimen completely bleached), 12.1 mm (CalCOFI 5704, station 140.50).

BLENNIOIDEI

W. WATSON

The perciform suborder Blennioidei, as originally defined (Regan 1912a), was a polyphyletic assemblage that included fishes now placed in the Blennioidei, Percoidei, Zoarcoidei, and the Ophidiiformes. The suborder subsequently was redefined several times (e.g., Jordan 1923; Berg 1940; Gosline 1968). Most recently, Springer (1993) limited the Blennioidei to the six families (over 700 species: Nelson 1994) of "tropical blennies": Blenniidae, Chaenopsidae, Clinidae, Dactyloscopidae, Labrisomidae, and Tripterygiidae. Monophyly of the suborder thus defined was proposed on the basis of five osteological synapomorphies involving the pectoral, pelvic, anal and caudal fins and the gill arches (Springer 1993). Interrelationships within the suborder and between the Blennioidei and other perciform suborders remain poorly known.

The blennioids, except the clinin and ophiclinin clinids and the labrisomid genera *Starksia* and *Xenomedea*, are oviparous as far as is presently known. Eggs typically are spherical to somewhat flattened, ca. 0.5–1.5 mm in diameter, and are attached to one another and/or to a nest substrate via adhesive filaments or pads. Parental care of the eggs, usually by the male, is the norm. Incubation periods typically are on the order of 1–3 weeks. Larvae hatch with pigmented eyes, open mouth, and a small to moderate yolk sac. Larvae typically are elongate, with preanal length ca. 30–50% BL. Larval pigmentation commonly is light, with melanophores primarily dorsally on the gas bladder and gut and along the ventral margin of the tail through at least the early part of the postflexion stage. Development is more or less direct, although some do pass through specialized larval stages, most notably the ophioblennius stage of some salariin blennies. Larvae typically are largely limited to shallow coastal waters.

At least 62 species, representing all six blennioid families, occur in the CalCOFI study area, primarily in the warmer waters south of Point Conception, California. Larvae of about half of these species, from all six families, have been identified in CalCOFI ichthyoplankton collections.

Families included:		
	Tripterygiidae	Chaenopsidae
	Labrisomidae	Dactyloscopidae
	Clinidae	Blenniidae

TRIPTERYGIIDAE: Triplefin blennies

W. WATSON

Tripterygiidae contains at least 115 species in 20 genera (Nelson 1994); at least one species each of *Axoclinus* and *Enneanectes* occur in the CalCOFI study area along the outer coast of central or southern Baja California and additional species of each, as well as *Crocodilichthys gracilis*, range to the vicinity of Cabo San Lucas, at the southern limit of the study area (Table Tripterygiidae 1; Rosenblatt 1959; Thomson et al. 1979; Allen and Robertson 1991). A few larvae of at least two types, possibly representing both *Axoclinus* and *Enneanectes*, have been collected southward from Isla de Guadalupe and Bahía Sebastián Vizcaíno during CalCOFI cruises; larval *C. gracilis* and one or two additional unidentified tripterygiid types were collected in the Gulf of California.

Tripterygiids are small (<10 cm) benthic residents of shallow (usually <10 m) tropical to temperate reefs. A few species inhabit algal beds or sandy bottom. They are elongate, with preanal length about half of body length. The dorsal fin is divided into a short first section and long second section consisting of spines, and a third section of segmented rays. The thoracic pelvic fin consists of a small spine and two rays; the caudal fin is truncate or rounded. Tripterygiids commonly have some branched pectoral fin rays. Most tripterygiids have ctenoid scales. Tripterygiids typically are cryptically colored in browns and greens, but reds, yellows and blues predominate on some species, and breeding males commonly are brightly colored or strongly marked with black pigment.

Courtship and spawning have been described for several species (e.g., Wirtz 1978; Thomson et al. 1979; Petersen 1989). Eggs brooded by the male parent are attached to the nest site via adhesive filaments arising from the basal pole or from all over the surface of each egg (e.g., Ruck 1973, 1980; Shiogaki and Dotsu 1973; Wirtz 1978). The spherical to slightly flattened eggs are 0.7–1.4 mm in diameter and contain a colorless to red-orange yolk with 10 to >100 small oil globules. Larvae 3–6 mm long hatch with pigmented eyes, an open mouth, and a small yolk sac (Ruck 1973, 1980; Shiogaki and Dotsu 1973, 1988; M. Brogan, pers. comm., July 1995). Larvae are elongate and slender, with preanal length ca. 40–50% BL (Leis and Rennis 1983; Miller et al. 1979; Ruck 1980; Shiogaki and Dotsu 1973, 1988). The gut coils during notochord flexion and the gas bladder shifts posteriorly during the postflexion stage. There are no spines on the head or pectoral girdle. Larval pigmentation ranges from sparse to rather heavy (e.g., Ruck 1980); typically, melanophores are located dorsally on the gas bladder and near the terminus of the hindgut, along the ventral margin of the tail, and often posteriorly on the dorsal margin of the tail (Leis and Rennis 1983; Miller et al. 1979; Shiogaki and Dotsu 1973, 1988; Brogan 1992). Melanophores may occur near the cleithral symphysis and on the hypural margin as well, and they commonly form on the head and extend farther along the dorsum during the postflexion stage.

Prior to formation of the dorsal fin, larval tripterygiids in the CalCOFI area resemble larval labrisomids, but usually can be distinguished from the labrisomids by combinations of pigment, meristic, and morphometric characters. The three separate dorsal fins of the tripterygiids, discernable by ca. 10 mm, immediately distinguish them from most other blennioid larvae. Meristic characters broadly overlap for the *Axoclinus* and *Enneanectes* species in and near the CalCOFI study area, and it is unknown how the larvae may be positively identified to species. Brogan (1992) pointed out that preflexion stage *A. carminalis* are deeper-bodied and have fewer melanophores on the ventral margin of the tail than other tripterygiids in the Gulf of California (usually ≤10 vs. ≥20, respectively) and that during the postflexion stage they lack pigmentation in the otic capsule in contrast to the others, which have otic pigment. Larval *C. gracilis* are easily distinguished from the other tripterygiids by meristic characters (e.g., Table Tripterygiidae 1).

Because all the tripterygiids taken in CalCOFI ichthyoplankton collections were postflexion stage larvae that cannot be positively identified to species, and since all of the larval types are similar in morphology and pigmentation, a separate detailed description is not given here. Instead, larvae that appear to represent a single species, probably *Axoclinus carminalis*, are shown in Figure Tripterygiidae 1 as an example. Refer to Leis and Rennis (1983), Matarese et al. (1984b), Miller et al. (1979), Ruck (1973, 1980), Shiogaki and Dotsu (1973, 1988) and Brogan (1992) for additional descriptions and illustrations of larvae.

Table Tripterygiidae 1. Meristic characters and geographic ranges for the tripterygiid species in the California Current vicinity. Meristic data are from Rosenblatt (1959) and Brogan (1992; pers. comm., July 1995); geographic ranges are from Rosenblatt (1959) and Thomson et al. (1979). All species have I,2 pelvic fin rays and 7+6 principal caudal fin rays. Gulf = Gulf of California.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	Range
Axoclinus carminalis	10	23–25	33–35	III+XII–XIII+8–10	II,15–19	14–16	8–9+7–9	Bahía Magdalena & central Gulf to Bahía Tangola, Oaxaca, Mexico
A. nigricaudus	10	24–25	34–35	III+XII–XIII+10–11	II,18–19	14–16	7–9+6–8	Gulf, Roca Consag to Cabo San Lucas
Crocodilichthys gracilis	12	30–31	42–43	III–IV+XV–XIX+10–14	II,24–28	14–16	8–9+8–9	Gulf, Roca Consag to Cabo San Lucas
Enneanectes reticulatus	10	23–24	33–34	III+XII+8–9	II,16–18	14–16	7–8+6–7	Lower Gulf to Puerto Escondido, Oaxaca, Mexico
E. sexmaculatus	10	23	33	III+X–XII+7–9	II,15–16	14–16	5–6+5–6	Central Gulf to Panama
Enneanectes sp.	10	24–25	34–35	III+XII–XIII+9–11	II,17–20	15–17	6–8+6–7	Isla de Guadalupe & Bahía Sebastián Vizcaíno to central Gulf

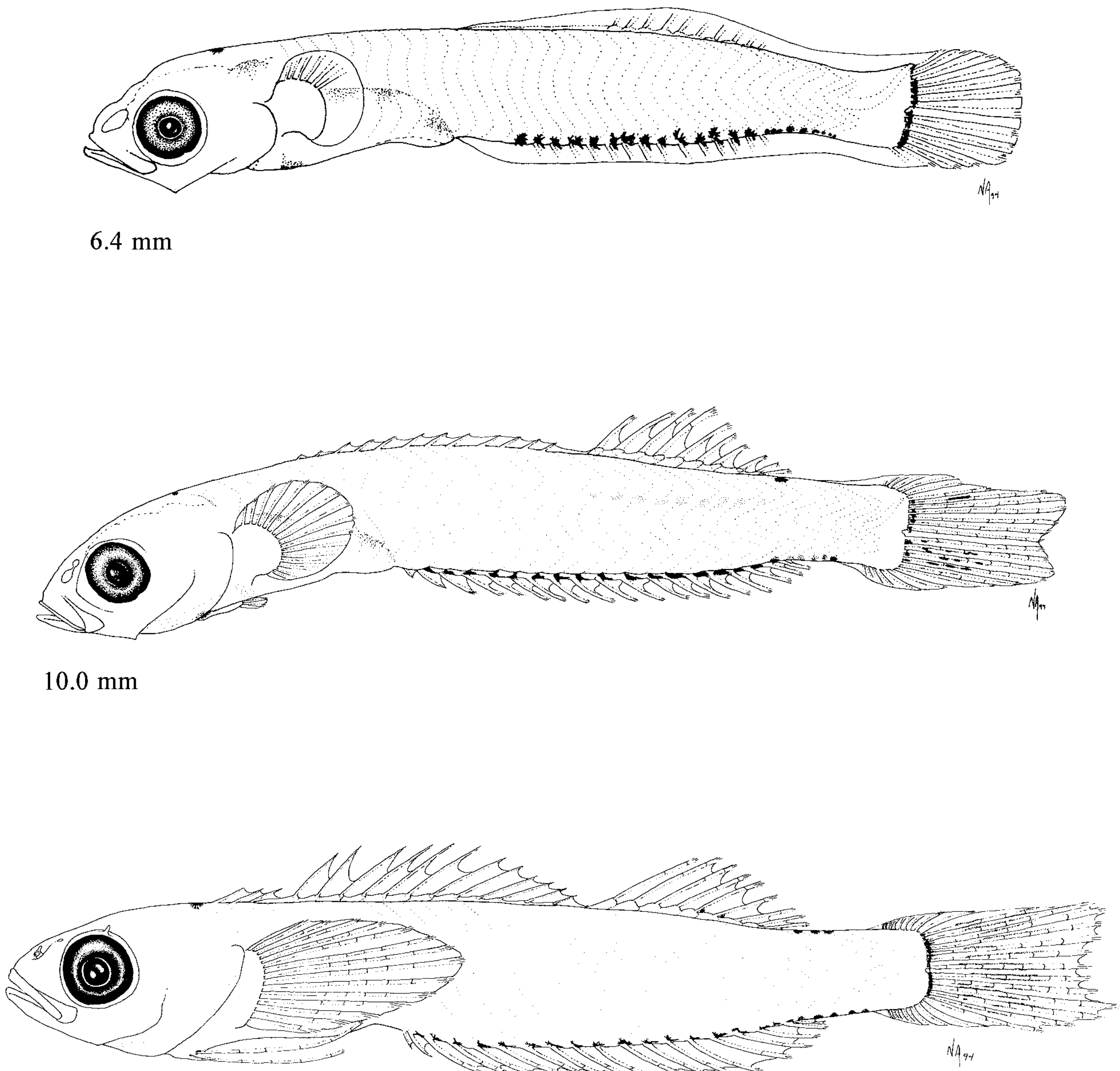


Figure Tripterygiidae 1. Postflexion larval tripterygiids, probably *Axoclinus carminalis*: 6.4 mm, 10.0 mm, 12.5 mm (CFRD Ref. Coll., Gulf of California; original illustrations by N. Arthur).

LABRISOMIDAE: Labrisomid kelpfishes

W. WATSON

Prior to 1975 the labrisomids were considered a tribe or subfamily (Labrisominae) of the kelpfish family Clinidae. Springer (1975) and George and Springer (1980) suggested that the labrisomids are not closely related to the clinids and should be considered a separate family, albeit one that is not well defined and may not be monophyletic (Springer 1993). Hastings and Springer (1994) subsequently removed *Neoclinus* and *Stathmonotus* from the Labrisomidae and placed them in the Chaenopsidae. Although many authors now accept the labrisomids as a separate family, others continue to include them in the Clinidae. Here, we consider the labrisomids a separate family.

Nineteen labrisomid species in nine genera occur within the CalCOFI study area (Table Labrisomidae 1). Three species (*Cryptotrema corallinum*, *Alloclinus holderi*, *Paraclinus integripinnis*) range from southern California to northern, central, and southern Baja California, respectively; most of the remainder range southward from central or southern Baja California. *Paraclinus tanygnathus* enters the CalCOFI study area only at its southern limit in the Cabo San Lucas vicinity. Larvae of six species representing five of the genera have been recognized in CalCOFI ichthyoplankton collections.

Most labrisomids are small (<20 cm) residents of shallow coastal rocky and coral reefs of the tropical and subtropical Americas. They are elongate and compressed, with preanal length no more than half of body length. They typically have cirri on the anterior nostrils, eyes, and nape. The dorsal fin is continuous, with more spines than soft rays or without soft rays in some species, the caudal fin is rounded, and the pelvic fins are thoracic, usually with one spine and three soft rays. Pectoral fin rays are unbranched. Most species are cryptically colored with shades of brown predominating, and are marked with bars, blotches, saddles or stripes.

Starksia (at least the Pacific species) and *Xenomedea* are ovoviviparous (Rosenblatt and Taylor 1971); the others for which reproduction is known are oviparous. Eggs are small (0.6–1.5 mm), round to elliptical, contain one or more oil globules, and are attached to one another or to a nest substrate via filaments that arise in a cluster from the basal pole (*Paraclinus*) or both poles (*Malacoctenus*) of each egg (Breder 1939; M. Brogan, pers. comm., July 1995). The egg cluster is brooded by the male or both parents. Larvae are ca. 3–4 mm long and well developed at hatching, with pigmented eyes, an open mouth, and a small to moderate yolk sac. They are elongate, slender, and compressed, with a short, straight gut (preanal length usually <45% BL) which coils after yolk absorption. The gas bladder is posterior. Larval *Labrisomus* and some *Malacoctenus* species develop small preopercular spines; all others for which larvae are known lack head spines. Melanophores are largely restricted to the dorsal surface of the gas bladder and hindgut, to the ventrum, and in some species to the dorsal surface of the head. The ventral tail pigment usually is a series of approximately one melanophore per myomere.

Preflexion and flexion stage labrisomids in the CalCOFI area may be confused with those of the blennioid families Chaenopsidae, Clinidae, Dactyloscopidae, and Tripterygiidae, and with some species of the zoarcoid families Bathymasteridae and Stichaeidae. Species-specific meristic and pigment characters, together with geographic location data, usually are required to identify these larvae, although at least some of the families can be eliminated from consideration on the basis of morphological characters. Preanal length is shorter in the dactyloscopids (usually <35% BL) and longer in the clinids (usually >45% BL) compared with the labrisomids (usually 35–44% BL). The bathymasterids and stichaeids have more myomeres than the labrisomids (≥48 versus <48). Myomere counts also distinguish most of the labrisomids from most of the chaenopsids: the labrisomids, except *Alloclinus* and *Cryptotrema*, have <40 myomeres while the chaenopsids, except *Coralliozetus*, have ≥40 myomeres. Only larval *Labrisomus*, at least some species of *Malacoctenus*, and larval dactyloscopids tentatively identified as *Gillellus* (see Dactyloscopidae, this volume) develop preopercular spines.

Among the labrisomid larvae, *Exerpes*, *Labrisomus*, *Malacoctenus* and *Paraclinus* have fewer than 40 myomeres, while *Alloclinus* has 40–42 and *Cryptotrema* has 45–49. *Labrisomus* is easily recognized by its preopercular spines (developing by 4–5 mm), and at least *L. multiporosus* and *L. xanti* have a distinctive, enlarged melanophore mid-way along the ventral margin of the tail. Large postflexion stage larvae tentatively identified as *Malacoctenus* sp(p). closely resemble larval *Labrisomus* but lack preopercular spines and the enlarged ventral tail melanophore. Brogan (1992) tentatively identified larval *M. hubbsi* and *M. tetranemus* from the Gulf of California and described both as having small preopercular spines until late in the postflexion stage. Larvae tentatively identified as *Exerpes asper* closely resemble *Paraclinus* but have early pelvic fin development. The characteristic long, pointed snout of *Exerpes* develops during the postflexion stage. Larval *Mnierpes*, *Starksia*, and *Xenomedea* have not been identified in CalCOFI samples.

The following descriptions are based on detailed examinations of 0–25 eggs and 20–35 larval and juvenile specimens of each species (Table Labrisomidae 2). Meristic data were obtained from the literature (Hubbs 1952, 1953a,b; Springer 1958; Rosenblatt and Parr 1969), from Clothier and Baxter (unpublished manuscript), from M. Brogan (pers. comm., July 1995), and from counts made during this study. Ecological information was obtained from these same literature sources and from Thomson et al. (1979) and Eschmeyer et al. (1983).

Table Labrisomidae 1. Meristic characters for the labrisomid species likely to be encountered along the Pacific coast of California and Baja California. All species have 7+6 principal caudal fin rays, I,3 pelvic fin rays (occasionally 0,3 or I,2 in *Paraclinus*), and 6 branchiostegal rays (rarely 5 or 7 in *Paraclinus*).

Species	Vertebrae			Fin Rays				Gill Rakers
	PrCV	CV	Total	D	A	P_1	C_2	
Alloclinus holderi	11–13	29–30	41–42	XXIV–XXVI,9–13	II,21–23	13–14	7–8+7–8	4+9
Cryptotrema corallinum	13–14	31–33	45–47	XXVI–XXVIII,11–13	I–II,24–27	13–15	8–9+8–9	4–5+8–12
Exerpes asper	10–11	23–25	34–35	III–IV+XXIII–XXVI,0–1	II,17–20	13–14	4–6+4–6	3+8
Labrisomus multiporosus	11	22–23	33–34	XVII–XX,11–13	II,17–19	13–15	7–8+6–8	2+7
L. striatus	11	23	34	XVIII,10–11	II, 17–18	13	6–7+4–7	4+9
L. wigginsi	11	23	34	XVII–XVIII,10–13	II,16–18	14–16	7+7	3+6
L. xanti	11	23	34	XVII–XIX,10–13	II,17–19	13–15	7–8+6–8	3+6–7
Malacoctenus hubbsi	11	26	37	XIX–XXI,9–13	II,18–23	13–15	7–8+7–8	10–14 total
M. tetranemus	10–12	24–26	36–37	XVIII–XX,9–12	II,18–20	13–15	7–8+8	11–15 total
M. zacae	11	25	36	XX–XXI,9–11	II,18–20	14	7–8+7–8	9–11 total
Mnierpes macrocephalus	9–10	28–29	38–39	XXI–XXIII,10–13	II,22–24	12–13	3–5+3–4	2+5
Paraclinus beebei	10–12	23	33–35	XXVII–XXIX	II,16–18	12–14	4+3–4	1+4
P. integripinnis	10–12	25–27	37–39	XXVII–XXXIII	II,18–21	12–14	3–5+4–5	2+4
P. magdalenae	9	24	33	XXVIII,1	II,19–20	13	3–4+4–5	
P. sini	9–11	23–24	33–34	XXVIII–XXX	II,16–20	12–14	3–4+4	1–2+3–4
P. tanygnathus	9–10	22–23	32	XXVI–XXVIII	II,16–18	12–13	3–4+3–4	
Starksia guadalupae	10	24	34	XX–XXI,9–10	II,17–20	13–14	4–6+3–6	2+6–8
S. spinipenis	10	24	34	XIX–XXI,8–10	II,16–19	13–15	5–6+5–6	3+8
Xenomedea rhodopyga	10–11	23–26	33–36	XX–XXIII,8–11	II,18–22	12–14	4–6+4–6	1–2+6–7

Table Labrisomidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the labrisomid species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Alloclinus holderi	0	0	10 4.4–7.2	6 7.9–8.7	11 9.4–20.9	3 20.4–21.3	3 22.5–29.9
Cryptotrema corallinum	0	0	10 3.9–8.4	6 8.5–9.5	2 9.7–11.5	0	2 46.1–50.4
Labrisomus multiporosus	0	0	10 3.1–5.5	5 5.7–7.2	10 7.1–17.6	0	2 15.7–16.9
L. xanti	0	1 2.7	10 2.8–6.2	1 6.8	10 7.4–20.4	1 20.1	5 15.7–30.5
Paraclinus integripinnis	25 0.9–1.0	5 3.8–4.0	10 4.1–6.0	5 6.1–6.9	10 6.6–8.9	0	5 14.0–25.2

MERISTICS

	Range	Mode
Vertebrae:		
Total	41–42	41
Precaudal	11–13	11
Caudal	29–30	30
Fins:		
Dorsal spines	XXIV–XXVI	XXV
Dorsal rays	9–13	11–12
Anal spines	II	II
Anal rays	21–23	23
Pelvic	I,3	I,3
Pectoral	13–14	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–8	8
Lower	7–8	7
Gill rakers:		
Upper	4	4
Lower	9	9
Branchiostegals	6	6

LIFE HISTORY

Range: Santa Cruz Island, California, to Punta San Pablo, Baja California Sur, & to Isla de Guadalupe

Habitat: Rocky bottom, subtidal to ca. 49 m depth

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; presumably, demersal eggs attached in nest; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.8 mm (B. Sumida MacCall)
Flexion larva, 8.7 mm (B. Sumida MacCall)
Postflexion larva, 14.6 mm (B. Sumida MacCall)
Juvenile, 22.5 mm (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.4 mm
Flexion length: ca. 7.8–9.0 mm
Transformation length: ca. 20–21 mm through ca. 22–23 mm
Fin development sequence: C_1, C_2, 2D & A, P_1, P_2 & 1D
Pigmentation: *Preflexion*—Series on ventral margin of tail from myomeres 12–16 to 38–40, ca. 1 per myomere; 1–4 ventrally near liver, becoming 1, internal by ca. 6 mm; 0–3 under midgut; 0–1 under & 1–2 over end of hindgut; dorsally on gas bladder. *Flexion*—1 at nape, 0–2 over midbrain. *Postflexion*—Double row along D ray bases by ca. 14 mm; 1 at isthmus; on snout, opercle, angular, C_1, & hypural margin by ca. 19 mm. *Transformation*—Dorsal patches by ca. 20 mm, lateral patches by ca. 21 mm; on P_1 by ca. 21 mm.
Diagnostic features: Preanal myomeres 10–12 (usually 10–11), 40–42 total (usually 41) ; no preopercular spines; preanal length usually 36–41% BL in larvae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–46 39	37–39 39	38–42 41	41–42 42	44–46 45
BD/BL		12–15 13	13–15 13	12–16 14	16–17 17	18–19 18
HL/BL		19–21 20	20–23 22	22–26 24	25–25 25	28–29 29
HW/HL		44–70 53	48–52 51	37–48 43	42–43 42	52–54 53
SnL/HL		13–29 23	24–30 27	22–31 27	25–28 27	21–24 23
ED/HL		33–39 36	32–35 33	25–32 29	26–29 28	27–29 28
P_1L/BL		4–7 5	5–7 6	6–18 10	18–19 18	24–29 26
P_2L/BL		0–0 0	0–0 0	0–13 4	11–14 12	16–21 18

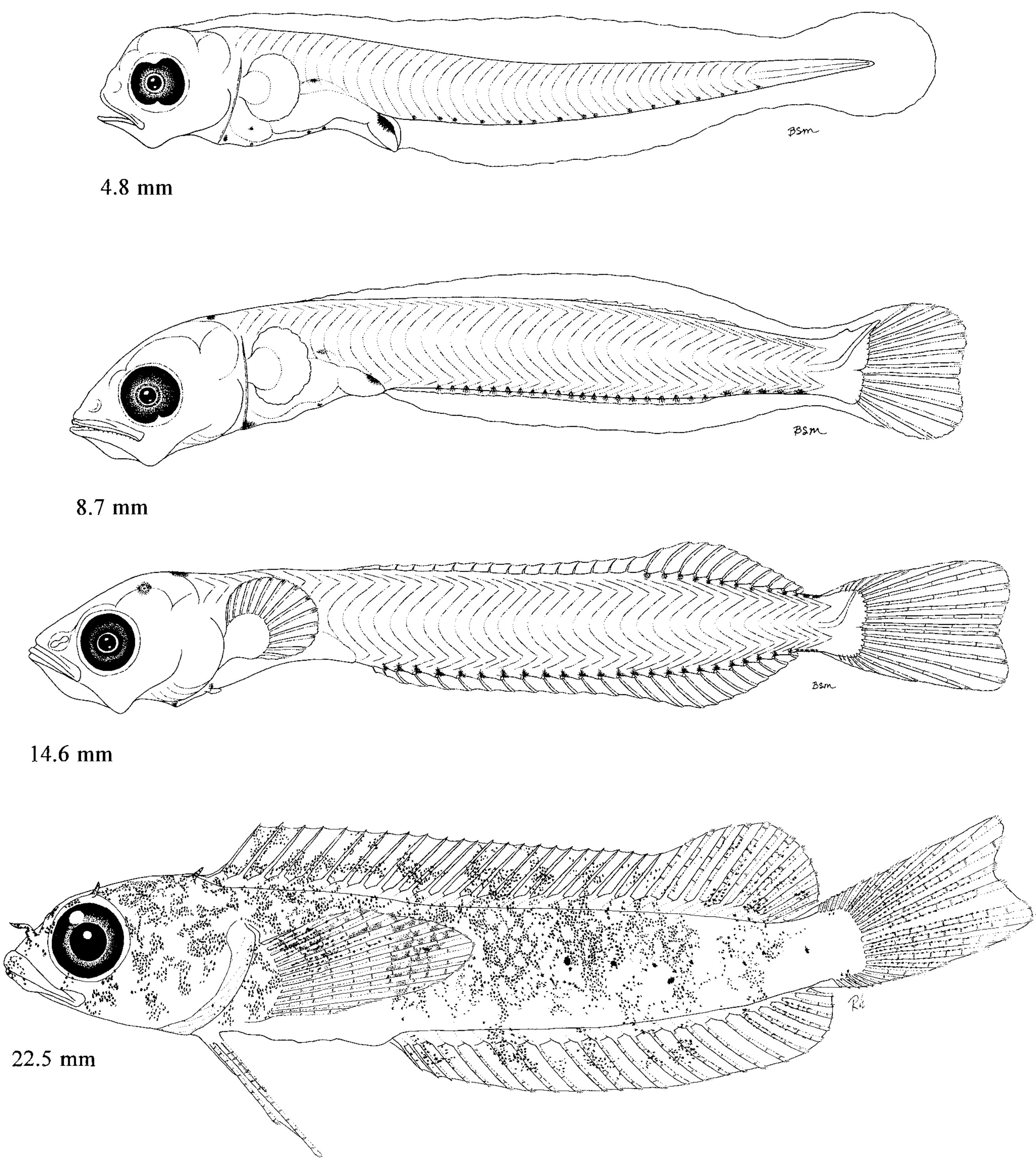


Figure Labrisomidae 1. Preflexion larva, 4.8 mm (CalCOFI 6608, station 110.32); late flexion larva, 8.7 mm (SIO 65–73); postflexion larva, 14.6 mm (SIO 65–53); juvenile, 22.5 mm (SIO 63–178). Scales are not shown on the juvenile specimen.

MERISTICS

	Range	Mode
Vertebrae:		
Total	45–47	45
Precaudal	13–14	14
Caudal	31–33	31
Fins:		
Dorsal spines	XXVI–XXVIII	XXVII
Dorsal rays	11–13	12–13
Anal spines	I–II	II
Anal rays	24–27	27
Pelvic	I,3	I,3
Pectoral	13–15	13–14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	8–9	8–9
Lower	8–9	8
Gill rakers:		
Upper	4–5	
Lower	8–12	
Branchiostegals	6	6

LIFE HISTORY

Range: Santa Cruz Island, California, to San Quintin, Baja California

Habitat: On rocky bottom, 24–91 m depth

Spawning season: Larvae collected August through January, primarily in August–September

ELH pattern: Oviparous; presumably, demersal eggs attached in nest; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.4 mm (W. Watson)
Flexion larva, 8.6 mm (W. Watson)
Postflexion larva, 11.5 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

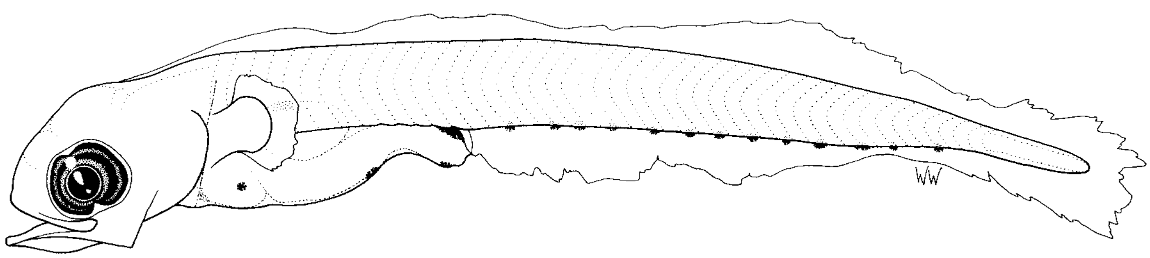
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

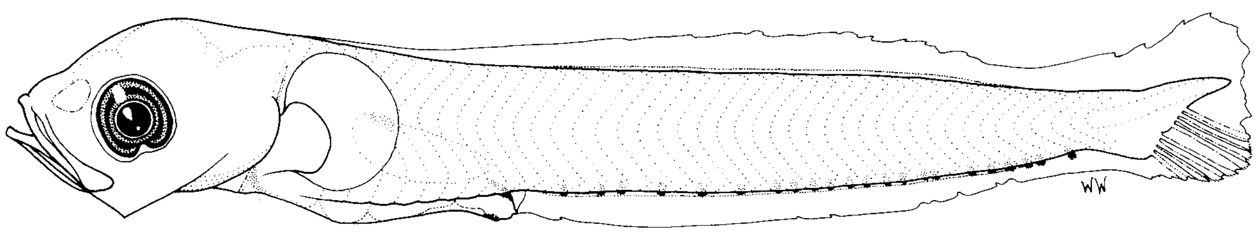
Hatching length: <3.9 mm
Flexion length: 8.5–9.5 mm
Transformation length: >11.5 mm
Fin development sequence: C_1, 2D, A & P_1 & C_2, 1D & P_2
Pigmentation: *Larvae*—None on head or dorsum; 1–2 dorsally on gas bladder; 1 dorsally on end of hindgut; 1 anteroventrally on liver & 1 ventrolaterally on each side of liver, all coalesce at anteroventral margin of liver by ca. 7 mm; 2 externally along ventral margin of hindgut, reduced to 1 near anus by 7.5 mm & none by 11.5 mm; 13–22 (usually 15–19) irregularly spaced along ventral margin of tail beginning at postanal myomere 3–5 (usually 3 or 4), number increases to 25–27 in postflexion stage.
Diagnostic features: Preanal length 40–46% BL (usually 42–43%); myomeres 10–13+33–37=46–49 (usually 13+34); D soft rays 11–13 (present after 11.5 mm); no pigment on head, dorsum, or internally over notochord to at least 11.5 mm; usually 15–19 irregularly spaced melanophores along ventral margin of tail through flexion stage, 25–27 in postflexion stage.

MORPHOMETRICS (range & mean in %)

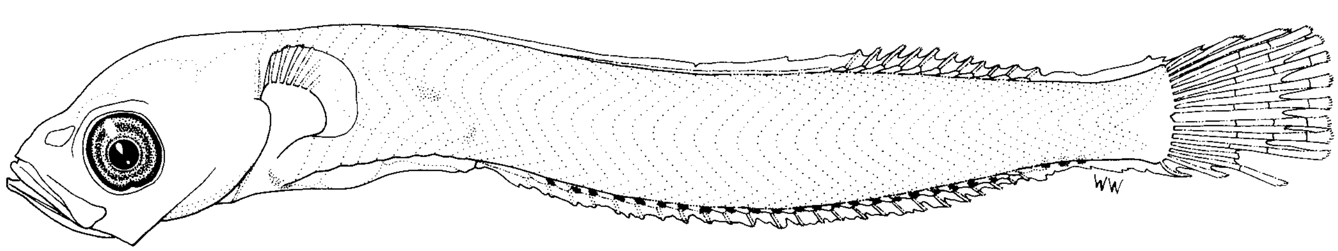
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		42–46 43	41–42 42	40–43 41		45–45 45
BD/BL		12–16 14	13–15 14	13–14 13		17–18 17
HL/BL		20–23 21	22–24 22	22–24 23		24–27 25
HW/HL		44–62 56	49–53 51	47–50 49		66–72 69
SnL/HL		13–29 23	27–30 28	29–32 31		23–28 25
ED/HL		29–44 35	27–30 29	27–27 27		22–25 24
P_1L/BL		3–6 5	5–6 5	5–6 6		21–25 23
P_2L/BL		0–0 0	0–0 0	0–0 0		19–19 19



5.4 mm



8.6 mm



11.5 mm

Figure Labrisomidae 2. Preflexion larva, 5.4 mm (CalCOFI 6608, station 103.29); early flexion larva, 8.6 mm (CalCOFI 6608, station 103.29); postflexion larva, 11.5 mm (CalCOFI 6608, station 97.30).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–34	34
Precaudal	11	11
Caudal	22–23	23
Fins:		
Dorsal spines	XVII–XX	XVIII
Dorsal rays	11–13	12–13
Anal spines	II	II
Anal rays	17–19	18–19
Pelvic	I,3	I,3
Pectoral	13–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–8	8
Lower	6–8	8
Gill rakers:		
Upper	2	2
Lower	7	7
Branchiostegals	6	6

LIFE HISTORY

Range: Bahía Sebastián Vizcaíno, Mexico, to Peru & in Gulf of California

Habitat: Shallow rocky bottom adjacent to sandy beaches

Spawning season: Larvae collected July through November, primarily August–October

ELH pattern: Oviparous with demersal eggs attached in nest (M. Brogan, pers. comm., July 1995); larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.5 mm (B. Sumida MacCall)
Flexion larva, 6.4 mm (B. Sumida MacCall)
Postflexion larva, 12.3 mm (B. Sumida MacCall)

* Eye is somewhat oval to round in preflexion stage, becoming consistently round in flexion or early postflexion stage; horizontal axis given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

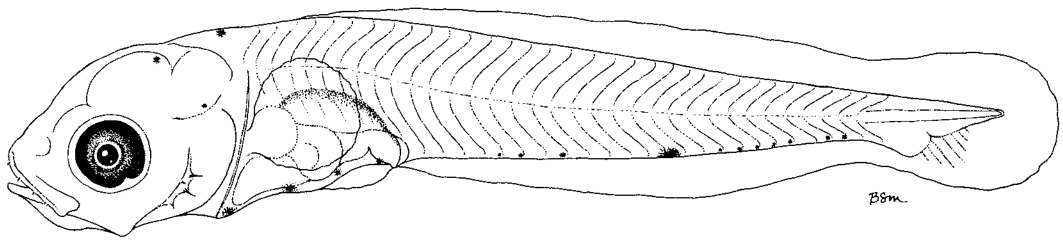
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

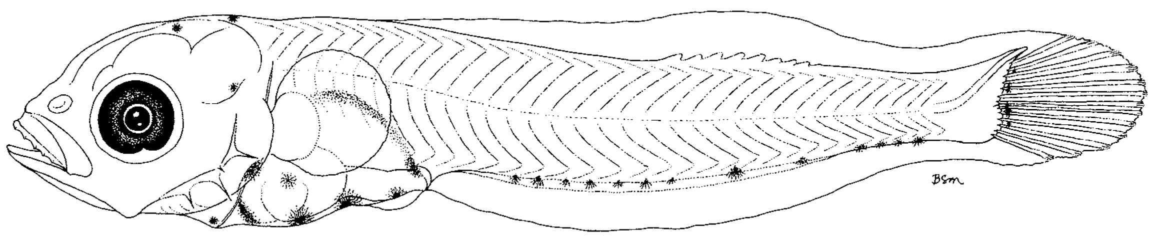
Hatching length: <3.1 mm
Flexion length: 5.7 mm to 7.1–7.2 mm
Transformation length: Variable within ca. 16–18 mm range
Fin development sequence: C_1, 2D & A, C_2, 1D & P_1, P_2
Pigmentation: *Preflexion*—4–12 on ventral margin of tail, 1 in middle is larger; 2–4 on ventral margin of gut; over foregut, gas bladder, end of hindgut; under hindbrain, on nape, pair over midbrain by ca. 5 mm. *Flexion*—On hypural margin; 1 on isthmus; 1 at middle of cleithrum; posteriorly over notochord. *Postflexion*—Along lower C_1 & on D ray bases by ca. 9 mm; 1–2 on upper opercle; increasing on dorsum & over notochord. *Juvenile*—Barred pattern (5–6 bars).
Diagnostic features: Prominent preopercular spines; preanal myomeres 8–10 (usually 9–10), 33–35 total (usually 33–34); preanal length usually 38–42% BL; usually light caudal pigment, little or none around urostyle; ventral melanophore series on tail, middle one large in preflexion & flexion stages.

MORPHOMETRICS (range & mean in %)

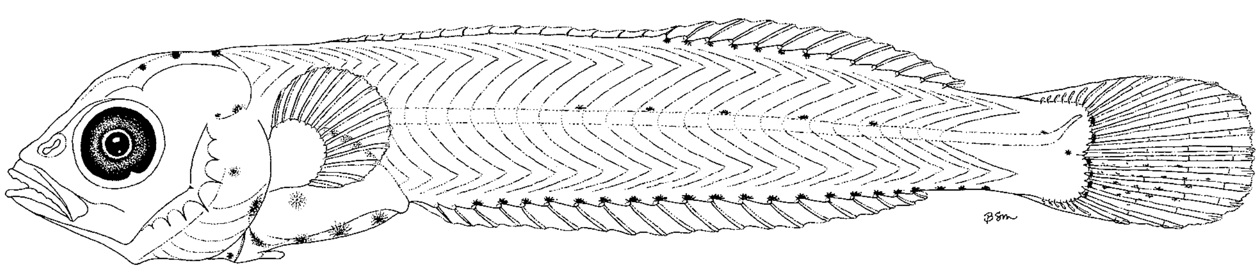
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		39–44 42	38–41 40	35–41 38		42–45 44
BD/BL		16–20 18	18–20 19	17–20 18		20–22 21
HL/BL		20–25 22	23–26 25	23–26 25		27–31 29
HW/HL		56–73 64	52–59 55	46–63 51		42–49 45
SnL/HL		13–28 23	28–30 29	15–35 29		25–28 26
ED/HL*		30–44× 28–39 38×33	29–33× 28–32 31×30	26–34× 26–32 29×29		27–30 29
P_1L/BL		4–7 6	5–7 6	5–21 11		22–24 23
P_2L/BL		0–0 0	0–0 0	0–15 5		20–21 20
PrSL/HL		0–8 4	13–16 14	2–15 9		0–0 0



5.5 mm



6.4 mm



12.3 mm

Figure Labrisomidae 3. Preflexion larva, 5.5 mm (CalCOFI 5708, station 120.40); flexion larva, 6.4 mm (CalCOFI 5211, station 133.30); postflexion larva, 12.3 mm (CalCOFI 5109, station 133.30).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34	34
Precaudal	11	11
Caudal	23	23
Fins:		
Dorsal spines	XVII–XIX	XVIII
Dorsal rays	10–13	11–13
Anal spines	II	II
Anal rays	17–19	19
Pelvic	I,3	I,3
Pectoral	13–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–8	7
Lower	6–8	7
Gill rakers:		
Upper	3	3
Lower	6–7	6–7
Branchiostegals	6	6

LIFE HISTORY

Range: Bahía Sebastián Vizcaíno, Baja California to Bahía Tenacatita, Jalisco, Mexico & Gulf of California

Habitat: Shallow rocky bottom, shelters in crevices

Spawning season: Larvae collected May through October, primarily August–September

ELH pattern: Oviparous with demersal eggs attached in nest (M. Brogan, pers. comm., July 1995); larvae are planktonic

LITERATURE

Brogan 1992

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.3 mm (B. Sumida MacCall)
Flexion larva, 6.8 mm (B. Sumida MacCall)
Postflexion larva, 10.1 mm (B. Sumida MacCall)
Transformation specimen, 20.1 mm (B. Sumida MacCall)

* Eye is somewhat oval, becoming round by the juvenile stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 2.7 mm
Flexion length: ca. 6.5–7.3 mm
Transformation length: Variable within ca. 15–21 mm range
Fin development sequence: C_1, 2D & A & C_2, P_1, 1D & P_2
Pigmentation: *Yolk-sac*—Cluster ventrally on yolk; series along ventral margin of gut; 1 each anteriorly & posteriorly over gut; 1 dorsally on gas bladder; 1 (very large) on ventral margin at middle of tail; little or none under notochord tip. *Preflexion*—1–2 (usually 1) large, ventrally at midtail; 1–3 under & 0–2 over central notochord tip by ca. 3.3 mm; 0–few ventrally on caudal finfold by 3.3 mm, may extend onto developing hypurals; 2–5 (usually 4) on ventral margin of gut; over foregut, gas bladder, hindgut; 1 on cleithrum at ca. 5 mm; under midbrain at ca. 4 mm; under hindbrain at ca. 6 mm. *Flexion*—1 shallowly internal at nape; forming on proximal third to half of C rays, may be quite heavy; increasing in & on urostyle area. *Postflexion*—Series along A base beginning posteriorly at ca. 7.5 mm; over notochord; over midbrain at ca. 10 mm; series along D base beginning posteriorly at ca. 18 mm. *Juvenile*—Barred.
Diagnostic features: Prominent preopercular spines; preanal myomeres 8–11 (usually 9), 33–34 total (usually 34); prominent ventral tail melanophore & moderate to heavy caudal pigment; prominent internal pigment around urostyle.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–48		38–42		49–52
	46	42	36	40	43	50
BD/BL		13–20		17–21		24–26
	19	18	16	19	21	25
HL/BL		19–23		23–27		32–34
	18	22	21	25	30	33
HW/HL		53–67		47–69		52–61
	84	61	65	54	43	58
SnL/HL		16–26		25–31		22–25
	20	21	29	28	26	23
ED/HL*		32–47× 30–39		28–35× 28–32		24–27
	50×40	38×33	31×29	32×30	27×26	26
P_1L/BL		4–6		6–19		22–26
	6	6	6	12	21	23
P_2L/BL		0–0		0.1–15		16–19
	0	0	0	7	15	18
PrSL/HL		0–10		2–13		0–0
	0	3	11	7	2	0

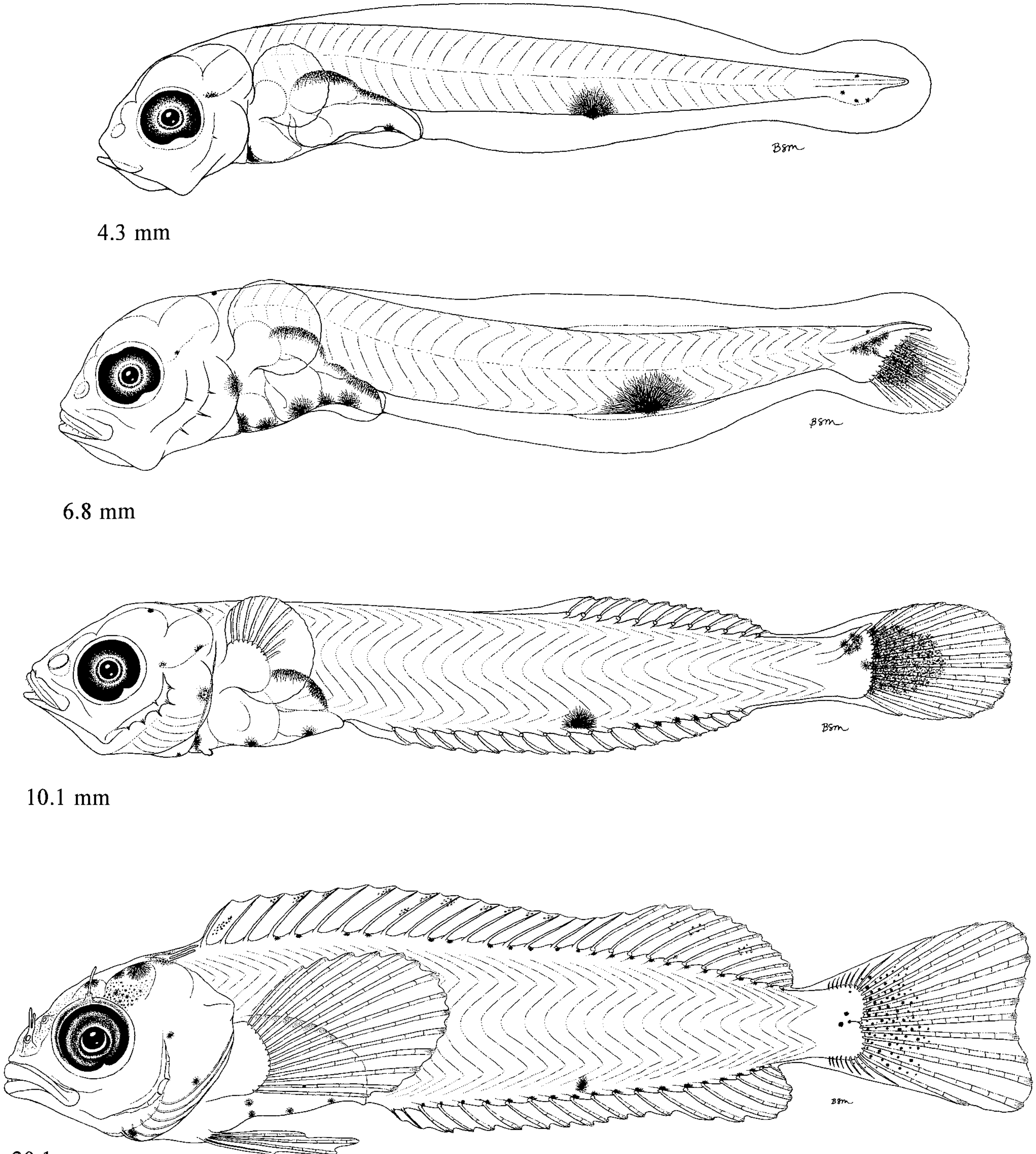


Figure Labrisomidae 4. Preflexion larva, 4.3 mm (CalCOFI 5308, station 123.50); early flexion larva, 6.8 mm (CalCOFI 5512, station 143.26); postflexion larva, 10.1 mm (CalCOFI 6410, station 118.39); transformation specimen, 20.1 mm (CFRD Ref. Coll., Gulf of California, April 5, 1952).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–39	37
Precaudal	10–12	11
Caudal	25–27	26
Fins:		
Dorsal spines	XXVII–XXXIII	XXXI–XXXII
Dorsal rays	0	0
Anal spines	II	II
Anal rays	18–21	20–21
Pelvic	0–I,3	I,3
Pectoral	12–14	13
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	3–5	4
Lower	4–5	4
Gill rakers:		
Upper	2	2
Lower	4	4
Branchiostegals	5–6	6

LIFE HISTORY

Range: Santa Cruz Island & Serena Cove, California, to Bahía Almejas, Baja California Sur

Habitat: Rocky bottom, tidepools to 15 m depth; usually ≤3 m depth.

Spawning season: Late spring to early fall with July–September peak

ELH pattern: Oviparous; eggs attached in clusters on benthic macrophytes; planktonic larvae

LITERATURE

Matarese et al. 1984b

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.9–1.0 mm (B. Sumida MacCall)
Yolk-sac larva, 3.8 mm (B. Sumida MacCall)
Preflexion larva, 5.6 mm (B. Sumida MacCall)
Flexion larva, 6.7 mm (W. Watson)
Postflexion larvae, 7.2 mm, 8.9 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.9–1.0 mm **Yolk:** Granular; 0.3–0.8 mm
No. of OG: 1 **Diam. of OG:** 0.2 mm
Shell surface: Ornamented—Triangular projections (side view) average 0.05 mm high; bundle of adhesive filaments attached at basal pole
Pigment: Late embryos with melanophores scattered on yolk, ventral tail pigment & gut pigment of larvae
Diagnostic features: Chorion ornamentation, diameter, & attachment in nests

LARVAE

Hatching length: 3.8–4.0 mm
Flexion length: 6.0 mm through ca. 6.6–6.9 mm
Transformation length: >9 mm, <14 mm
Fin development sequence: C_1, C_2, P_1, A, D, P_2
Pigmentation: *Preflexion–postflexion*—Irregular series of 12–20 on ventral margin of tail from myomeres 14–16 through 37–38; pair ventrolaterally near liver, coalesce at midline & move internally by 4.9 mm; 1 over, 1 under end of hindgut; dorsally on gas bladder; 1 on isthmus by 6.9–7.8 mm; 1 internally at nape by 8.3 mm. *Juvenile*—Completely pigmented, barred pattern; narrow bands on P_1, P_2; D ocellus present by ca. 20 mm.
Diagnostic features: Preanal myomeres 10–12 (usually 11), 37–39 total (usually 38); no preopercular spines; preanal length usually 41–45% BL; little or no caudal pigment; ventral melanophore series on tail, none larger than others in series.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	41–45 43	41–44 43	40–45 43	39–45 42		45–48 47
BD/BL	14–18 15	12–16 14	13–16 15	15–18 16		21–22 21
HL/BL	19–21 20	19–22 20	20–24 22	23–27 25		27–29 28
HW/HL	59–72 65	45–68 57	51–54 52	42–54 47		51–54 52
SnL/HL	11–20 16	18–24 21	19–27 25	22–30 26		22–26 24
ED/HL	39–50 44	34–50 41	31–32 32	24–34 27		21–24 23
P_1L/BL	5–7 6	7–12 9	9–12 10	6–18 12		20–21 20
P_2L/BL	0–0 0	0–0 0	0–0.3 0.1	1–11 4		11–15 14

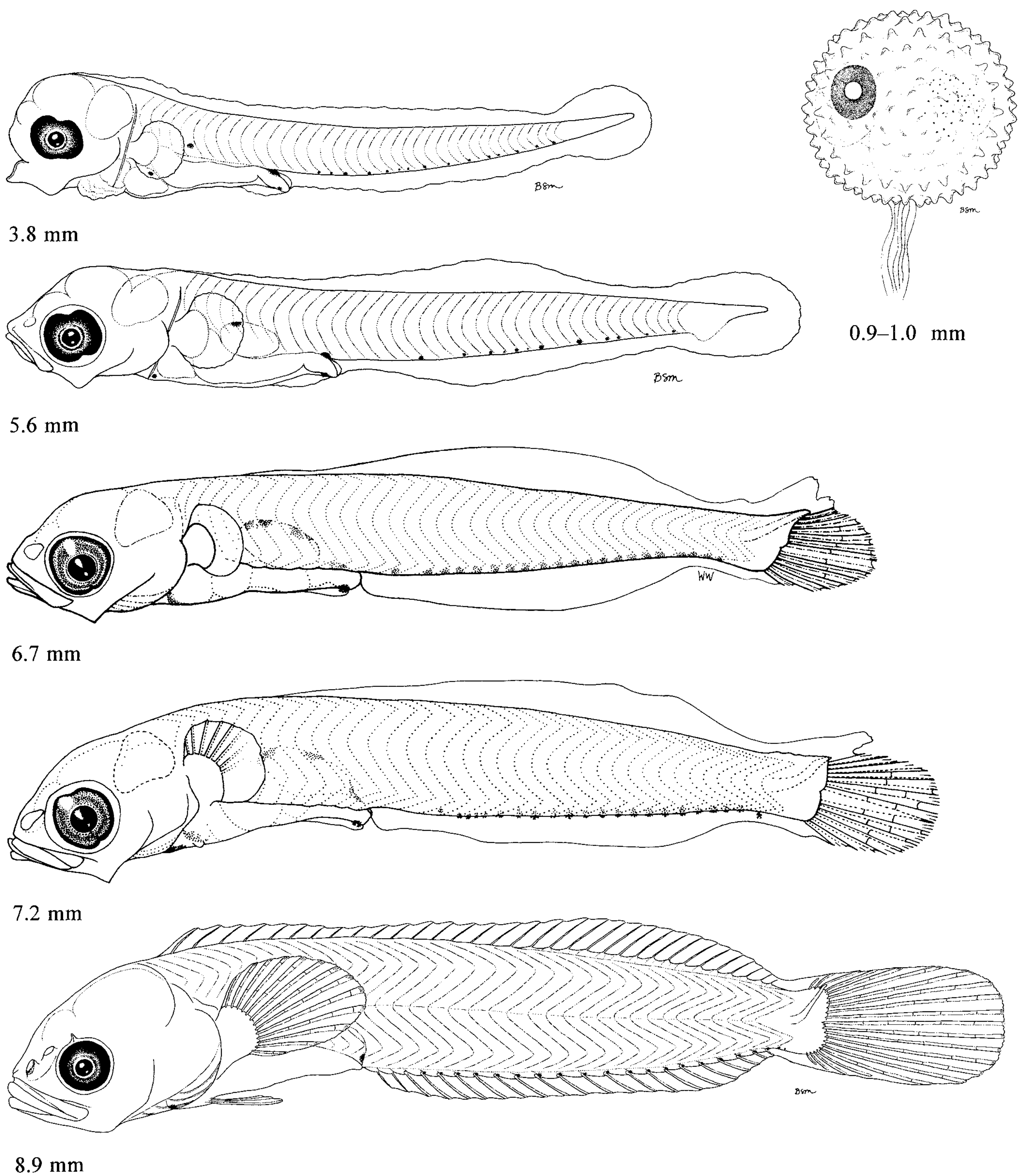


Figure Labrisomidae 5. Egg, 0.9–1.0 mm (CFRD Ref. Coll., La Jolla, California, 7 August 1955, under cobble, 3 m depth); yolk-sac larva, 3.8 mm; preflexion larva, 5.6 mm; flexion larva, 6.7 mm (MEC I93, station A–M); early postflexion larva, 7.2 mm (Matarese et al. 1984b); late postflexion larva, 8.9 mm (SIO H47–151).

CLINIDAE: Clinid kelpfishes

W. WATSON

The Clinidae as conceived by Hubbs (1952) was redefined by George and Springer (1980) to consist only of Hubbs' subfamily Clininae, together with the families Ophiclinidae and Peronedysidae which were placed in the clinid tribe Ophiclinini. Other fishes previously included in the Clinidae were placed in the Labrisomidae. Thus defined, the family Clinidae is represented in the California Current vicinity by three *Gibbonsia* species and *Heterostichus rostratus* (Table Clinidae 1; Stepien and Rosenblatt 1991). *Gibbonsia montereyensis*, *G. metzi*, and *H. rostratus* range from British Columbia to northern, central, and southern Baja California, respectively, while *G. elegans* ranges from central California to southern Baja California. Larvae of both genera have been taken in CalCOFI ichthyoplankton collections, but in small numbers since the larval distributions are primarily shoreward of the shallowest CalCOFI stations (e.g., Barnett et al. 1984).

Clinids are small (most <25 cm; *H. rostratus* to ca. 60 cm), largely demersal residents of shallow rocky reefs and kelp and seaweed beds in temperate marine waters. They are elongate and compressed with preanal length no more than half of body length. The dorsal fin is continuous, with more spines than soft rays, and often with the first three spines elongate. The caudal fin is rounded in most species, but forked in *H. rostratus*. Pelvic fins are thoracic. Pectoral fin rays are unbranched. Pigmentation commonly varies to blend with the habitat.

The myxodin clinids (includes all western hemisphere clinids) are oviparous (Hubbs 1952). *Heterostichus rostratus* spawns spherical eggs 1.2–1.4 mm in diameter that contain a greenish to purple yolk with a single reddish-brown oil globule ca. 0.3 mm in diameter (Barnhart 1932; Feder et al. 1974; Stepien 1986). The eggs are attached to one another and to the algal nest via long intertwining filaments which arise in a cluster of 15–20 strands from the basal pole of each egg. Larvae are ca. 5–6 mm long at hatching, with pigmented eyes, an open mouth, and a moderate yolk sac. They are elongate and slender, with preanal length ca. 45–50% BL through most or all of the larval stage. They have no spines on the head or pectoral girdle. The gut is a straight tube that deflects downward around the gas bladder but does not coil until the postflexion stage. The gas bladder typically is far anterior initially but shifts posteriorly to a position above the posterior part of the intestine by the postflexion stage. Larval pigmentation is largely restricted to the dorsal surfaces of the gas bladder and hindgut, and to the ventrum.

Preflexion and flexion stage clinids in the CalCOFI study area may be confused with the larvae of some bathymasterid and stichaeid species, and with chaenopsids, dactyloscopids, labrisomids, and tripterygiids. The labrisomids and especially the dactyloscopids have a shorter preanal length than the clinids, and the tripterygiids have fewer myomeres, while most stichaeids have more myomeres than the clinids. Many of the bathymasterid and stichaeid species are more heavily pigmented than the clinids. Although myomere counts for several chaenopsid species are similar to counts for the clinids, and the range of preanal lengths of larval chaenopsids encompasses the range for clinids, chaenopsid species that are sympatric with the clinids in the CalCOFI study area are easily distinguished from the clinids on the basis of myomere counts, preanal length, and pigmentation on the ventrum (see Chaenopsidae, this volume; Brogan 1992). Among the clinids, *Heterostichus* is easily distinguished from *Gibbonsia* by its higher myomere count, usually higher number of melanophores along the ventral margin of the tail, and in the postflexion stage by its higher dorsal and anal fin-ray counts as well as by its longer, more pointed snout. It is unknown how the *Gibbonsia* species are distinguished from one another before completion of the dorsal and anal fins; thereafter they often can be distinguished by small differences in meristic characters (e.g., Table Clinidae 1).

The following descriptions are based on literature and on detailed observations of 10 eggs and 40 larval and juvenile *H. rostratus*, 32 larval *Gibbonsia* sp. (probably *G. elegans*), and 5 juvenile *G. elegans* (Table Clinidae 2). Meristic data were obtained from Hubbs (1952), Clothier and Baxter (unpublished manuscript), and from counts made during this study. Ecological information was obtained from Frey et al. (1974) and Eschmeyer et al. (1983).

Table Clinidae 1. Meristic characters for the clinid species along the Pacific coast of California and Baja California. All have 6 branchiostegal rays, 7+6 principal caudal fin rays, and I,3 pelvic fin rays (rarely I,2 in *Gibbonsia elegans*).

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers
Gibbonsia elegans	16–18	30–32	47–49	XXXI–XXXV,5–8	I–III,21–25	11–13	6–7+6–7	4–5+8–12
G. metzi	18–20	32–34	50–53	XXXIV–XXXVII,7–10	II,24–29	11–13	6–7+7–8	3–4+7–8
G. montereyensis	16–17	32–35	49–51	XXXIV–XXXVI,5–8	II,23–28	11–13	7+7–8	2–5+7–10
Heterostichus rostratus	21–23	34–36	56–58	XXXIII–XXXVIII,11–13	II,31–35	12–14	7+6–7	5–8+12–13

Table Clinidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the clinid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Gibbonsia elegans	0	0	0	0	0	0	5 22.9–38.0
Gibbonsia sp.	0	5 4.6–4.8	10 4.6–6.4	5 6.6–8.0	11 8.4–20.0	1 21.0	0
Heterostichus rostratus	L[a,b], 10 1.2–1.3	5 5.1–5.6	10 6.2–7.5	6 7.4–9.3	10 10.3–25.1	4 30.9–35.5	5 47.3–58.4

[a] Barnhart 1932
[b] Stepien 1986

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–49	47–48
Precaudal	16–18	17
Caudal	30–32	30–31
Fins:		
Dorsal spines	XXXI–XXXV	XXXIII
Dorsal rays	5–8	7
Anal spines	I–III	II
Anal rays	21–25	24
Pelvic	I,2–3	I,3
Pectoral	11–13	12
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–7	7
Lower	6–7	7
Gill rakers:		
Upper	4–5	
Lower	8–12	
Branchiostegals	6	6

LIFE HISTORY

Range: Piedras Blancas Point, San Luis Obispo County, California, to Bahía Magdalena, Baja California Sur, & to Isla de Guadalupe

Habitat: Shallow subtidal to ca. 57 m depth, primarily ≤ ca. 20 m depth; usually resides among benthic macrophytes

Spawning season: Year-round with peak from February–April

ELH pattern: Oviparous; eggs attached in algal nest & brooded by male parent; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.8 mm (B. Sumida MacCall)
Flexion larva, 7.5 mm (B. Sumida MacCall)
Postflexion larva, 10.4 mm (B. Sumida MacCall)
Juvenile, 22.9 mm (R. C. Walker)

* Three *Gibbonsia* species occur in the study area; larvae described here are all field-collected specimens having meristic characters & geographic distribution most consistent with *G. elegans*, although *G. montereyensis* cannot be unequivocally excluded. Juveniles are *G. elegans*.

† The eye is somewhat oval, becoming round by transformation; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

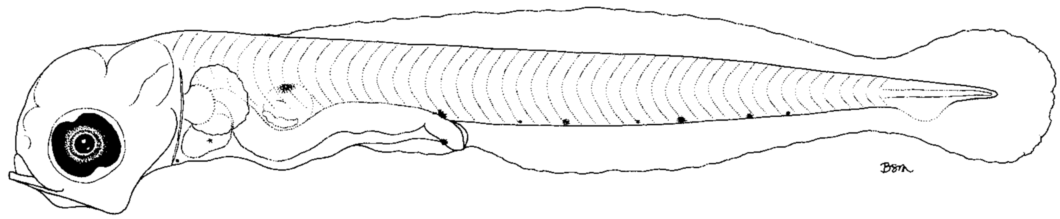
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

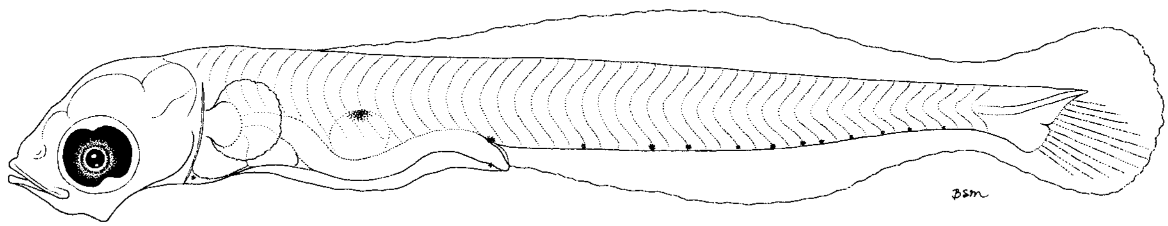
Hatching length: ca. 4.5 mm
Flexion length: ca. 6.5–8.0 mm
Transformation length: ca. 21–22 mm
Fin development sequence: C_1, 2D & A & C_2, P_1, 1D, P_2
Pigmentation: *Yolk-sac–flexion*—None on head or dorsum; 1–2 on dorsal surface of gas bladder; 1 internally over end of hindgut; 1 internally at anteroventral margin of liver; 1 external ventrolaterally over middle of liver on each side, migrates ventrad & cephalad to near internal liver melanophore by flexion stage; 0–3 (usually 2 in preflexion stage, 1 in flexion stage) along ventral margin of gut; 4–12 (usually 8–12) irregularly spaced along ventral margin of tail beginning at postanal myomere 4–7 (usually 5–6). *Postflexion*—Few internally on hindbrain & externally over midbrain beginning at ca. 20 mm; 1 each at bases of D rays & spines beginning posteriorly after 17 mm; 1 at each A ray base; on hypural margin beginning at ca. 17 mm. *Juvenile*—Completely pigmented with 7–8 darker bars.
Diagnostic features: Elongate, slender; preanal length 45–48% BL through 10 mm, 41–44% thereafter; myomeres 14–19+30–32=46–49 (usually 17+31–32); last 3–4 D rays more widely spaced than preceding rays (visible by ca. 13 mm); lightly pigmented; usually 8–12 melanophores on ventral margin of tail through flexion stage, 23–25 thereafter.

MORPHOMETRICS (range & mean in %)

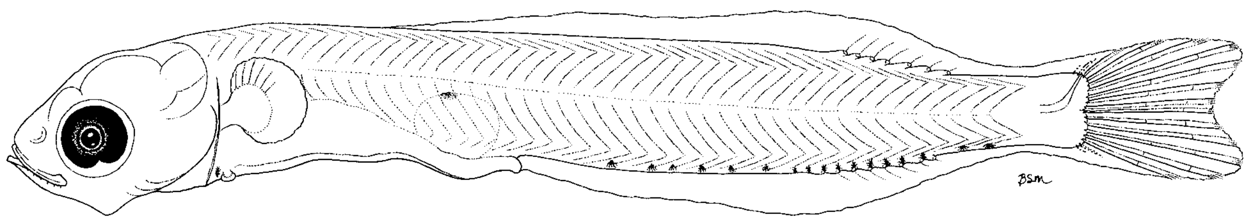
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	45–47	46–48	46–48	41–47		42–44
	46	47	47	44	36	43
BD/BL	12–16	11–13	11–12	11–16		15–20
	15	12	11	13	14	19
HL/BL	17–19	17–20	18–19	19–25		23–26
	18	18	19	21	20	25
HW/HL	70–75	58–78	54–60	39–54		46–54
	73	66	56	47	93	50
SnL/HL	14–19	12–24	23–26	22–30		22–25
	16	19	25	25	22	23
ED/HL†	43–45× 36–40	34–46× 33–40	32–35× 26–33	23–34× 22–29		22–28
	44×39	40×36	33×30	28×27	29	24
P_1L/BL	5–6	4–6	4–6	6–14		13–17
	6	5	5	9	13	15
P_2L/BL	0–0	0–0	0–0	0–11		11–14
	0	0	0	3	8	12



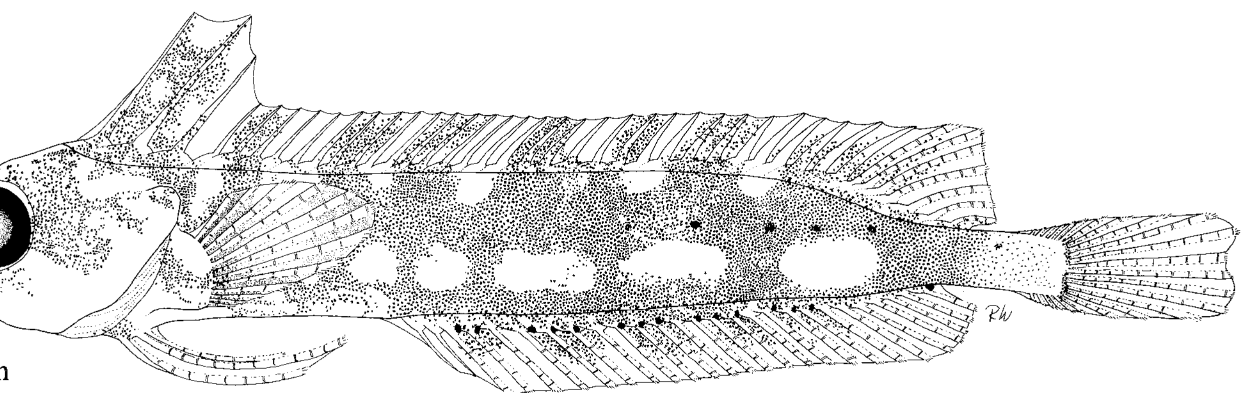
4.8 mm



7.5 mm



10.4 mm



22.9 mm

Figure Clinidae 1. Preflexion larva, 4.8 mm (MEC I05, station T–E, replicate 12); flexion larva, 7.5 mm (MEC I41, station A–M, replicate 2); postflexion larva, 10.4 mm (MEC I57, station LA–M); juvenile, 22.9 mm (CFRD Ref. Coll., Sunset Cliffs, San Diego, California, April 1950; specimen is unusual in that it has only six superior principal C rays).

MERISTICS

	Range	Mode
Vertebrae:		
Total	56–58	57
Precaudal	21–23	22
Caudal	34–36	35
Fins:		
Dorsal spines	XXXIII–XXXVIII	XXXVII
Dorsal rays	11–13	13
Anal spines	II	II
Anal rays	31–35	34
Pelvic	I,3	I,3
Pectoral	12–14	13
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7	7
Lower	6–7	6–7
Gill rakers:		
Upper	5–8	
Lower	12–13	
Branchiostegals	6	6

LIFE HISTORY

Range: British Columbia to Cabo San Lucas, Baja California Sur; primarily southern California & northern Baja California peninsula

Habitat: Kelp forests & rocky bottom with macrophyte cover; shallow subtidal to 40 m depth

Spawning season: Year-round with peak from February through April

ELH pattern: Oviparous; eggs attached in algal nest & brooded by male parent; planktonic larvae

LITERATURE

Barnhart 1932
Coyer 1982
Feder et al. 1974
Matarese et al. 1984b, 1989
Stepien 1986
Wang 1981
Watson 1987

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.2–1.3 mm (W. Watson)
Yolk-sac larva, 5.4 mm (W. Watson)
Postflexion larva, 11.4 mm (H. M. Orr)

EARLY LIFE HISTORY DESCRIPTION

EGGS

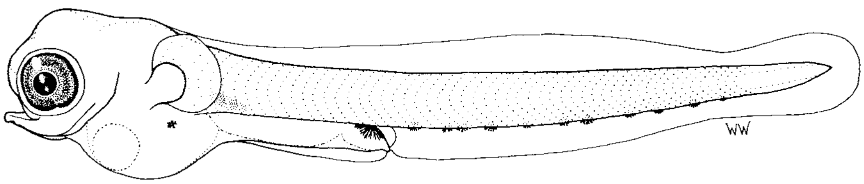
Shell diam.: 1.2–1.4 mm **Yolk:**
No. of OG: 1 **Diam. of OG:** ca. 0.3 mm
Shell surface: Cluster of ca. 15–20 long filaments attached at basal pole
Pigment: Yolk variably greenish, brown, or pink to purple; OG reddish brown; melanophores scattered on surface of yolk & on ventral margin of tail of late embryo
Diagnostic features:

LARVAE

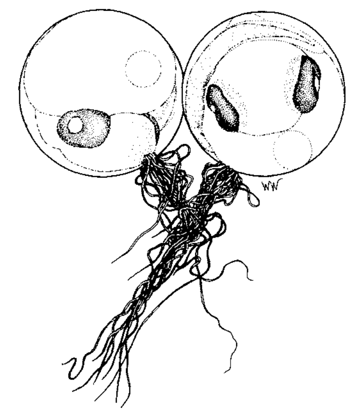
Hatching length: 5.1–6.2 mm
Flexion length: ca. 7.5–10.0 mm
Transformation length: ca. 30–45 mm
Fin development sequence: C_1, C_2, 2D & A, P_1, 1D, P_2
Pigmentation: *Yolk-sac–flexion*—None on dorsum or head; 1–2 on dorsal surface of gas bladder; 1 dorsally on end of hindgut; 1 midlaterally on each side of yolk sac, moving ventrad & cephalad to near ventral midline at anterior margin of liver by ca. 10 mm; 9–20 (usually 13–16) irregularly spaced along ventral margin of tail beginning at postanal myomere 3–9 (usually 3–6). *Postflexion*—Few internally over hindbrain & posteriorly on midbrain after 13 mm; pair externally over midbrain & 1–2 on opercle by 13.3 mm, increasing after ca. 20 mm; on jaws by ca. 21 mm; on snout by ca. 25 mm; irregular row along each side of D base & few scattered laterally on tail beginning at ca. 25 mm; increasing over gas bladder; 1 at each A ray base; row along each side of A base beginning at ca. 25 mm; proximally on P_2 at ca. 25 mm. *Transformation*—Heavy on upper half of head; 6–7 bars on trunk & tail, extending onto D & A.
Diagnostic features: Elongate, slender, preanal length usually 46–49% BL through ca. 14 mm & usually 41–43% thereafter; myomeres 18–21+34–40=54–59 (usually 19–20+36–38=56–58); lightly pigmented; usually 13–16 melanophores on ventral margin of tail through flexion stage, 24–35 thereafter.

MORPHOMETRICS (range & mean in %)

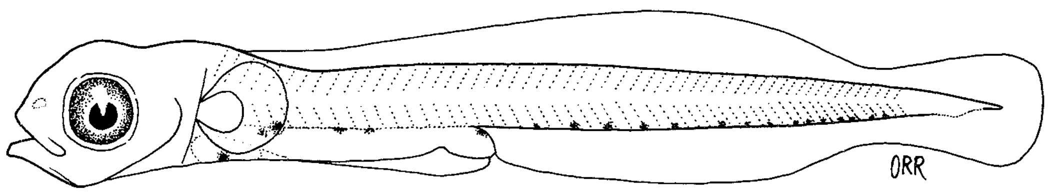
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	44–49 46	47–51 50	46–50 49	42–49 47	41–46 43	43–47 45
BD/BL	17–22 19	11–13 12	10–13 12	11–14 12	14–16 15	15–17 15
HL/BL	17–20 18	18–21 20	20–21 21	19–25 22	26–27 27	25–28 27
HW/HL	72–77 75	55–62 59	50–59 53	41–52 46	32–43 37	32–43 38
SnL/HL	12–17 14	16–29 23	22–33 28	25–30 28	26–27 27	30–33 31
ED/HL	38–43 41	30–36 33	26–31 28	22–27 25	20–22 21	19–22 20
P_1L/BL	4–5 4	4–6 5	4–6 5	4–13 6	14–15 14	14–15 15
P_2L/BL	0–0 0	0–0 0	0–0 0	0–11 2	10–11 10	10–11 11



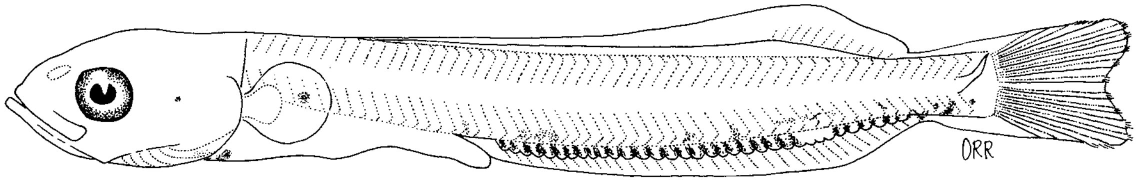
5.4 mm



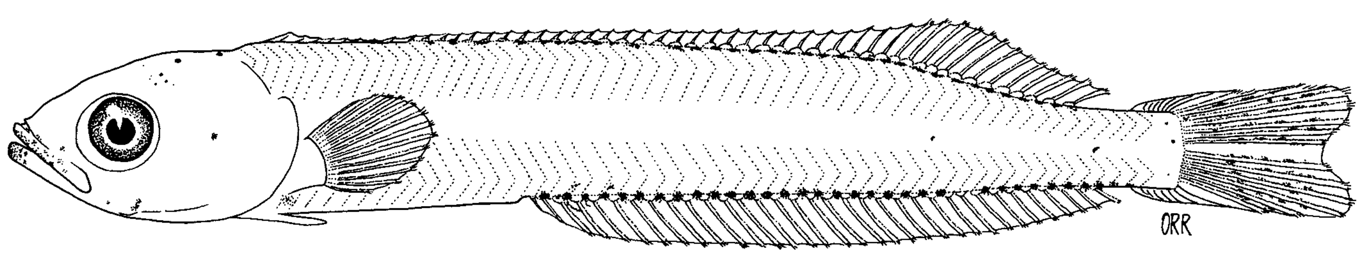
1.2–1.3 mm



6.5 mm



11.4 mm



21.2 mm

Figure Clinidae 2. Eggs, 1.2–1.3 mm (CFRD Ref. Coll., reared at Stephen Birch Aquarium-Museum, SIO, April 21, 1994); newly hatched larva, 5.4 mm (CFRD Ref. Coll., reared at SWFSC, 4 July 1975); preflexion larva, 6.5 mm (Matarese et al. 1984b); early postflexion larva, 11.4 mm (CFRD Ref. Coll.; although procurrent caudal rays are not shown on the drawing, specimens of this size typically have 1–2 superior and 1–2 inferior procurrent rays); late postflexion larva, 21.2 mm (Matarese et al. 1984b).

CHAENOPSIDAE: Tube blennies

W. WATSON

At least 15 chaenopsid species (including *Neoclinus* and *Stathmonotus*, which were transferred from Labrisomidae to Chaenopsidae by Hastings and Springer 1994) occur in the CalCOFI study area (Table Chaenopsidae 1), although eight of these enter the CalCOFI area only in the vicinity of Cabo San Lucas (Stephens 1963). *Coralliozetus micropes*, *C. rosenblatti*, *Protemblemaria bicirris*, and *Stathmonotus sinuscalifornici* range northward to the vicinity of Bahía Magdalena, while *Chaenopsis alepidota* and the *Neoclinus* species range northward to southern and central California, respectively. Böhlke (1957) recognized two subspecies of *C. alepidota*: *C. a. alepidota*, restricted to the Gulf of California, and *C. a. californiensis*, from southern California. Larval *Neoclinus* spp. have been taken in modest numbers in CalCOFI collections, and a few larvae identifiable as *C. alepidota* and *C. coheni* were taken in the Gulf of California.

Chaenopsids are small (most species <10 cm; maximum ca. 15 cm) residents of tropical and subtropical reefs or sandy bottom near reefs in shallow coastal waters, primarily in the Americas. All occupy abandoned invertebrate burrows, tubes, or shells; some species commonly reside in discarded bottles, cans, etc. The chaenopsids are elongate and compressed, usually with a continuous dorsal fin containing more spines than segmented rays, usually with a rounded caudal fin, and with thoracic pelvic fins. Pectoral fin rays are unbranched. Most species have orbital and nasal cirri, most lack scales, and most lack a lateral line. Sexual dimorphism is common. Pigmentation typically is cryptic although breeding males may be strikingly colored or patterned.

Chaenopsids are oviparous (Matarese et al. 1984b). Courtship and spawning have been described for some species (e.g., Stephens et al. 1966; Thomson et al. 1979; Hastings 1988) but eggs and larvae are largely undescribed. *Acanthemblemaria*, *Coralliozetus*, *Emblemaria*, and *Neoclinus* eggs are attached to the walls of the male parent's shelter and are brooded by him (Shiogaki and Dotsu 1972b; Stephens et al. 1966; Thomson et al 1979; Lindquist 1981; Hastings 1988). *Neoclinus* eggs are spherical, 0.9–1.5 mm in diameter, with an oil globule 0.2–0.3 mm in diameter (1–3 additional small oil globules in *N. uninotatus*), and are attached to one another and to the nest via a bundle of adhesive filaments which arises from the basal pole of each egg (Shiogaki and Dotsu 1972b; Lindquist 1981; Wang 1981; this study). Eggs of *Acanthemblemaria*, *Emblemaria*, and *Coralliozetus* lack adhesive filaments and instead are attached to the nest surface via a basal layer of adhesive substance (M. Brogan, pers. comm., July 1995). Larval *Neoclinus* are ca. 4–6.5 mm long and well developed at hatching, with pigmented eyes, an open mouth, and a small yolk sac (Shiogaki and Dotsu 1972b; Lindquist 1981). They are elongate and slender with a short, straight gut which coils during the flexion stage (preanal length <40% BL). The gut coils late in flexion or during the postflexion stage in *Acanthemblemaria* and *Coralliozetus*, but does not coil in *Stathmonotus* (Brogan 1992; pers. comm., July 1995). Larval chaenopsids lack spines on the opercular series bones and pectoral girdle. Pigmentation is light, with melanophores primarily on the gas bladder, gut, and ventrum through much of larval development. Melanophores may form on the dorsum and internally above the vertebral column in the postflexion stage.

Preflexion and flexion stage chaenopsid larvae may be confused with those of other blennioid species and some stichaeids and bathymasterids. Species-specific combinations of larval pigmentation, myomere counts and preanal length, together with geographic location data commonly are required to identify the larvae. Myomere counts should distinguish the chaenopsids from all tripterygiids except *Crocodilichthys* (c.f. Tables Chaenopsidae 1 and Tripterygiidae 1). Myomere counts also distinguish the chaenopsids, except *Coralliozetus*, from all labrisomids except *Alloclinus* and *Cryptotrema* (both genera are easily distinguished from the only sympatric chaenopsid genera, *Chaenopsis* and *Neoclinus*, by myomere counts and larval pigmentation). Larval dactyloscopids usually have a shorter preanal length (≤35% BL) than the chaenopsids (≥35% BL). Only *Chaenopsis alepidota* and the three *Neoclinus* species are sympatric with a few of the bathymasterid and stichaeid species; meristic and pigment characters readily distinguish the larvae of these families (see Bathymasteridae, this volume, and Matarese et al. 1989). Larvae of some of the chaenopsids can be distinguished from one another by use of meristic characters (Table Chaenopsidae 1), morphometric characters (e.g., the relatively long preanal length of *Stathmonotus*), and pigmentation (see Brogan 1992). Postflexion *Chaenopsis* resemble *N. stephensae* but are more elongate and slender (BD 10–11% BL), with a smaller eye (ca. 20% HL), a distinctly more pointed snout, and much different fin ray counts (Table Chaenopsidae 1).

The following descriptions are based on detailed examinations of 20 eggs, 3 flexion stage larvae (7.5–8.5 mm), 13 postflexion stage larvae (8.5–29.7 mm) and 4 juveniles (54.6–63.7 mm) of *Neoclinus blanchardi* and 10 preflexion (4.3–6.5 mm), 5 flexion (7.0–8.9 mm), 13 postflexion stage larvae (9.1–19.8 mm), 1 transformation specimen (21.2 mm) and 2 juveniles (48.0–49.2 mm) of *N. stephensae*. Meristic data were obtained from the literature (Hubbs 1953a; Stephens 1963; Stephens et al. 1966; Rosenblatt and McCosker 1988; Hastings and Springer 1994), from M. Brogan (pers. comm., July 1995), and from counts made during this study. Ecological information was obtained from Stephens (1963), Feder et al. (1974), Eschmeyer et al. (1983), and Hastings and Springer (1994).

Table Chaenopsidae 1. Meristic characters for the chaenopsid species that may occur in the CalCOFI study area. All species except *Stathmonotus sinuscalifornici* have 7+6 principal caudal fin rays (rarely 6+6 in *Coralliozetus angelica*), I,3 pelvic fin rays and 6 branchiostegal rays. *S. sinuscalifornici* has 5–6+5–7 principal caudal rays and I,2 pelvic rays.

	Vertebrae			Fin rays				
Species	PrCV	C	Total	D	A	P_1	C_2	Gill rakers
Acanthemblemaria balanorum	11–12	31–34	42–45	XXIII–XXV, 12–14	II,23–26	12–14	5–7+4–6	3+7–8
A. crockeri	11–12	32–35	44–47	XXIII–XXVII,12–15	II,24–28	13–14	5–7+4–6	4+10
A. macrospilus	9–13	30–33	40–44	XXIII–XXV,12–14	II,23–27	12–14	5–7+4–6	2+11
Chaenopsis alepidota	20	36–40	56–60	XVIII–XXI,32–38	II,34–39	12–14	5–7+5–6	+11–12
Coralliozetus angelica	10–11	25–27	35–37	XVIII–XX,10–12	II,18–21	13–14	2–4+2–4	2+5
C. micropes	10–11	27–29	37–39	XIX–XXI,11–13	II,21–24	12–14	2–4+2–4	1+7
C. rosenblatti	10–11	27–28	37–39	XVIII–XX,12–13	II,21–23	13	3–5+3–5	1+7
Ekemblemaria myersi	15–16	29–31	44–46	XIX–XXI,19–23	II,24–27	13–15	4–6+4–6	3+7
Emblemaria hypacanthus	12–13	28–30	40–43	XX–XXIII,13–16	II,21–25	13	3–4+3–4	3+9
Neoclinus blanchardi	14–15	32–35	46–49	XXIII–XXVII,15–18	II,26–30	14–15	7–8+6–7	4–6+8
N. stephensae	13–14	34–36	47–50	XXIV–XXVII,15–18	II,29–31	15	6–7+6–7	6–8+12–14
N. uninotatus	14	33–35	47–49	XXIII–XXVII,14–17	II,26–31	14–16	7+6–7	3–5+8–11
Protemblemaria bicirris	11–14	29–31	40–43	XX–XXII,14–16	II,23–25	14	4–5+4–5	3+8
P. lucasana	13–14	30–31	43–45	XXI–XXII,15–17	II,25–27	14	4+4	3+5–6
Stathmonotus sinuscalifornici	18–21	29–32	47–52	XL–XLVI	II,22–26	6–10	1–2+1–2	0+5

MERISTICS

	Range	Mode
Vertebrae:		
Total	46–49	47
Precaudal	14–15	14
Caudal	32–35	33
Fins:		
Dorsal spines	XXIII–XXVII	XXV
Dorsal rays	15–18	17
Anal spines	II	II
Anal rays	26–30	28–29
Pelvic	I,3	I,3
Pectoral	14–15	14–15
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–8	7
Lower	6–7	7
Gill rakers:		
Upper	4–6	
Lower	8	8
Branchiostegals	6	6

LIFE HISTORY

Range: San Francisco, California, to Isla Cedros, Baja California

Habitat: Occupies shells, bottles, invertebrate burrows, etc. on soft bottom along open coast, ca. 3–60 m depth

Spawning season: January through August

ELH pattern: Oviparous; eggs attached in nest & brooded by male parent; planktonic larvae

LITERATURE

Feder et al. 1974

ORIGINAL ILLUSTRATIONS (Illustrator)

Eggs, 0.9–1.0 mm (N. Arthur)
Flexion larva, 8.5 mm (W. Watson)
Postflexion larvae, 9.3 mm, 29.7 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.9–1.0 mm **Yolk:** Granular; 0.8–0.9 mm
No. of OG: 1 **Diam. of OG:** 0.2–0.3 mm
Shell surface: Smooth; tuft of long slender filaments attached at basal pole
Pigment: "Almost clear" (Feder et al. 1974)
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 7.5–8.5 mm
Transformation length: >29.1 mm, <54.6 mm
Fin development sequence: C_1, 2D & A, P_1 & C_2, P_2, 1D
Pigmentation: *Flexion*—Several dorsally, covering most of midbrain area; 1 large, internally, at nape; dorsally on gas bladder & hindgut; 1 internal, anteroventrally on liver; 1–4 external, ventrally, between isthmus & anus; 31 on ventral margin of tail beginning at postanal myomere 3–4; series begins to form posteriorly on dorsal margin near end of stage; internal series over notochord, beginning posteriorly by 8.5 mm. *Postflexion*—Increasing on head, extending over forebrain by 11.6 mm, on opercle & angular by 12.7 mm, below eye by 15 mm & on maxillary by 24.4 mm; 0–1 ventrally on gut; 29–31 ventrally on tail; increasing on dorsal margin, becoming double row by 9.3 mm & extending forward to level of anus or beyond by 15–20 mm. *Juvenile*—Completely pigmented, slightly darker above; 2 ocelli on spinous D.
Diagnostic features: Preanal length 35–40% BL (usually <39%); myomeres 11–13+34–36=46–48 (usually 12–13+35–36); soft D rays usually 17; A rays usually 28–29 (present by ca. 15 mm); moderate to heavy pigment dorsally on head, double row of melanophores dorsally on tail after ca. 9 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			38–38 38	35–40 37		45–49 47
BD/BL			14–16 16	14–16 15		17–18 17
HL/BL			21–24 23	21–23 22		25–26 26
HW/HL			50–58 54	46–56 51		47–59 53
SnL/HL			23–27 25	21–27 24		16–25 21
ED/HL			34–38 36	23–37 31		23–25 24
P_1L/BL			5–6 6	4–15 9		17–18 17
P_2L/BL			0–0 0	0–11 3		13–17 15

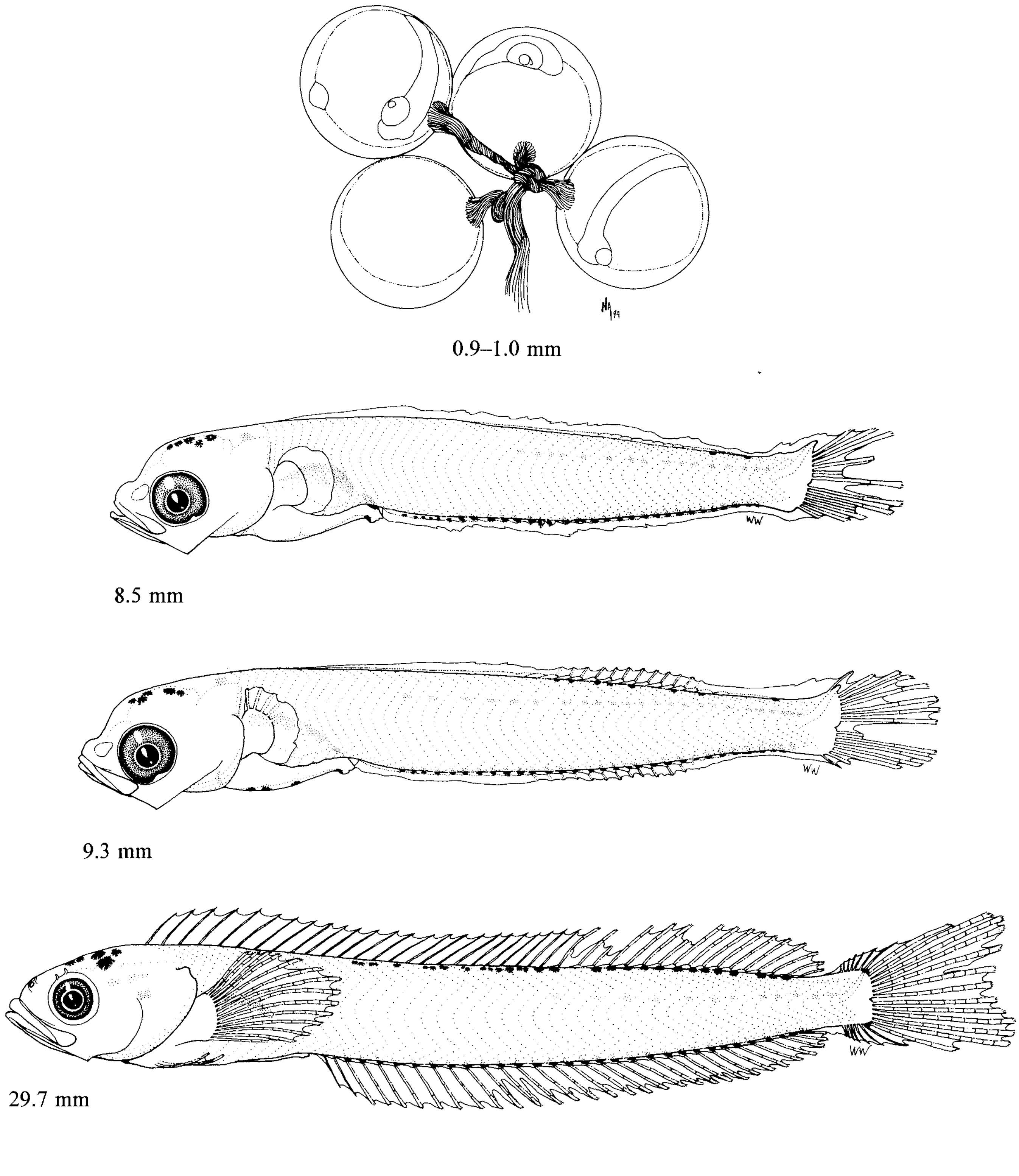


Figure Chaenopsidae 1. Eggs, 0.9–1.0 mm (CFRD Ref. Coll., collected off La Jolla, California, March 9, 1954); flexion larva, 8.5 mm (CalCOFI 8407, station 80.55 Manta); early postflexion larva, 9.3 mm (CalCOFI 7807, station 83.42); late postflexion larva, 29.7 mm (CFRD Ref. Coll., Bahía Asuncíon, Baja California Sur, night light collection, June 1950).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–50	48–50
Precaudal	13–14	13–14
Caudal	34–36	35
Fins:		
Dorsal spines	XXIV–XXVII	XXVI
Dorsal rays	15–18	17
Anal spines	II	II
Anal rays	29–31	30
Pelvic	I,3	I,3
Pectoral	15	15
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–7	7
Lower	6–7	7
Gill rakers:		
Upper	6–8	
Lower	12–14	
Branchiostegals	6	6

LIFE HISTORY

Range: Monterey, California, to Punta San Hipolito, Baja California Sur

Habitat: Occupies shells, holes & crevices in rocks, etc., in coastal waters & bays, ca. 3–27 m depth

Spawning season: Larvae occur primarily in winter & spring

ELH pattern: Oviparous; presumably, eggs attached in nest & brooded by male parent; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.5 mm (W. Watson)
Flexion larva, 7.0 mm (W. Watson)
Postflexion larvae, 10.3 mm, 18.8 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <4.3 mm
Flexion length: ca. 7–9 mm
Transformation length: ca. 21 mm to <48 mm
Fin development sequence: C_1, 2D & A & P_1 & C_2, P_2 & 1D
Pigmentation: *Preflexion–flexion*—1 or 2 internally at nape at ca. 6 mm, always 1 after 6.5 mm; heavy dorsally on gas bladder & hindgut; pair ventrally near liver, coalesces at midline by 6 mm & becomes internal by 7 mm; 2–3 ventrally on mid- & hindgut; 23–32 (usually 29–32) on ventral margin of tail beginning at postanal myomere 2–5 (usually 3–4). *Postflexion*—2 over midbrain by 10.4 mm, number increases after ca. 18 mm; ventral gut pigment reduced to 0–1; internal series over notochord by ca. 9 mm; 1 each at bases of most D rays after 19 mm. *Juvenile*—Completely pigmented; saddles dorsally & blotches laterally; light on fins.
Diagnostic features: Preanal length 34–39% BL (usually <38%); myomeres 11–13+35–38=47–50 (usually 12+36–37); soft D rays usually 17–18, A rays usually 30–31 (present by 10.5 mm); no dorsal pigment except at nape before 10 mm; prominent pair of melanophores over midbrain after 10 mm, no pigment along D base until after ca. 19 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–39 37	35–38 37	34–38 36	 43	35–36 36
BD/BL		14–16 15	11–16 14	12–15 14	 17	15–16 15
HL/BL		18–21 20	20–23 21	20–23 21	 24	19–21 20
HW/HL		58–75 65	42–64 54	42–59 51	 59	56–58 57
SnL/HL		16–30 23	23–28 26	22–28 25	 20	11–13 12
ED/HL		33–44 38	31–33 32	25–34 30	 26	26–29 28
P_1L/BL		6–6 6	5–7 6	4–13 7	 17	13–14 13
P_2L/BL		0–0 0	0–0 0	0–9 1	 13	10–11 10

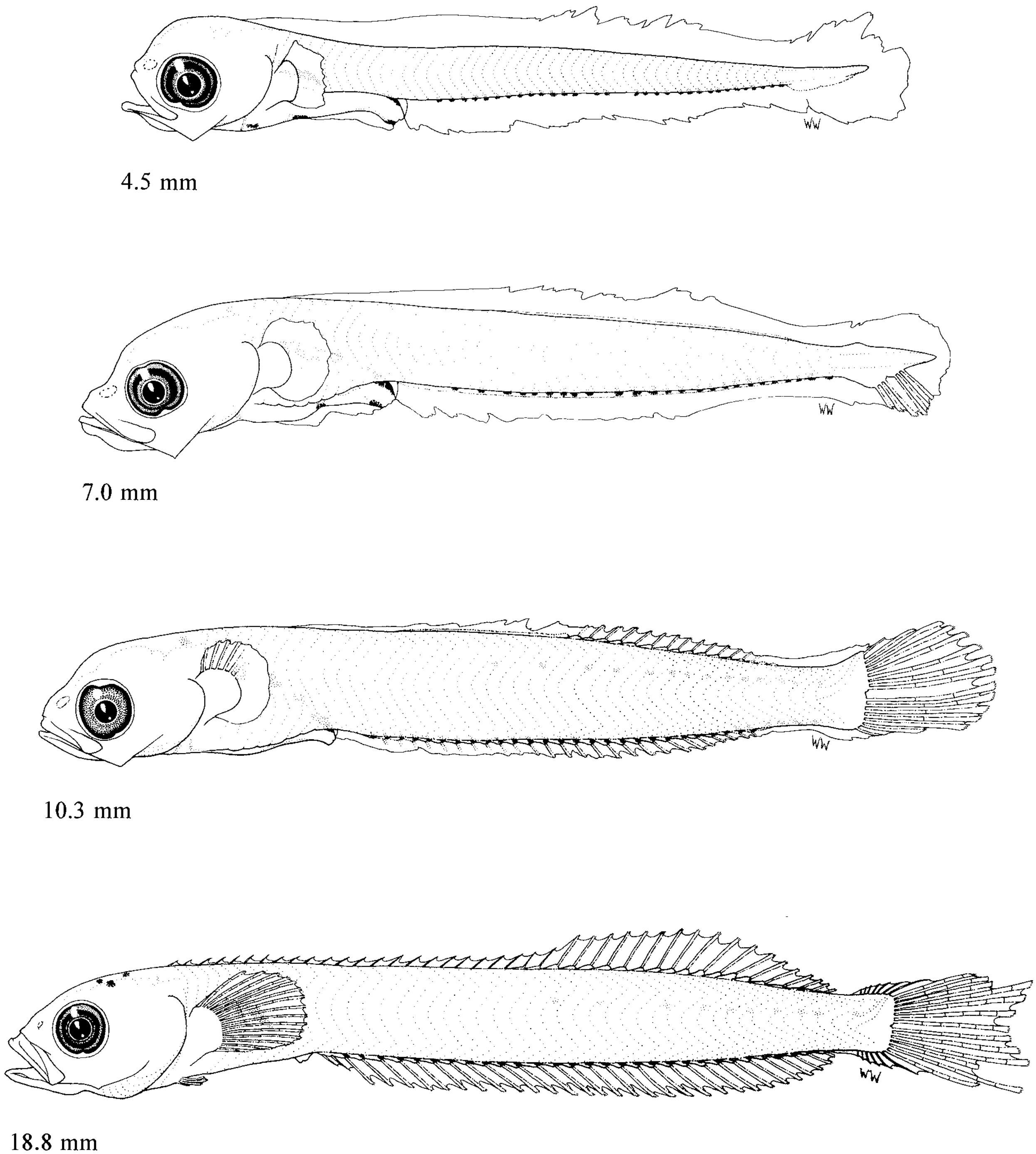


Figure Chaenopsidae 2. Preflexion larva, 4.5 mm; flexion larva, 7.0 mm (CalCOFI 8012, station 123.3.36 Manta); early postflexion larva, 10.3 mm (MEC I63, station C–M); late postflexion larva, 18.8 mm (CalCOFI 6610, station 110.32).

DACTYLOSCOPIDAE: Sand stargazers

W. Watson

Dactyloscopidae contains about 41 species in nine genera (Nelson 1994); ten species in five genera have been reported from the CalCOFI study area along the Pacific coast of Baja California Sur (Table Dactyloscopidae 1; Dawson 1975, 1976, 1977). Larvae of at least three species have been taken in nearshore CalCOFI ichthyoplankton collections south of Punta Eugenia, Baja California Sur, and from the Gulf of California.

Dactyloscopids are small (most species <10 cm; largest species to ca. 15 cm) tropical to warm-temperate demersal (usually nearly completely buried) residents of sandy bottom and reefs on the shallow continental shelves of the Americas. Some species occur in estuaries and may enter fresh water. The sand stargazers are elongate and slender, with a short preanal length, dorsal eyes (stalked in some species), and oblique mouth. Fringes of fimbriae typically are arrayed along the lips and upper part of the gill cover. The dorsal fin is long and continuous except that the first three or four spines may be separate, the caudal fin is rounded, and the pelvic fins are thoracic. Dactyloscopids have a unique branchiostegal respiratory pump (Todd 1973). Pigmentation is cryptic; dark bars, saddles, and mottled patterns over a lighter background are common, with colors ranging from white to dark brown.

Dactyloscopids are oviparous. Dawson (1974a, 1975, 1976, 1977, 1982) described ovarian eggs for a number of species, and Böhlke and Chaplin (1968) described incubation by male *Dactyloscopus*, *Dactylagnus*, and *Myxodagnus*, which carry an egg cluster beneath each pectoral fin. Petti (1969, cited in Dawson 1976) noted egg carrying by male *M. opercularis*. Ripe or nearly ripe ovarian eggs generally are about 0.9–1.2 mm in diameter. Hydrated ovarian eggs of *Dactyloscopus lunaticus* are quite similar to the eggs of the labrisomid, *Paraclinus integripinnis*. The *D. lunaticus* eggs are 1.0–1.2 mm in diameter, contain a granular yolk apparently lacking an oil globule, and are ornamented with low conical projections scattered over the chorion (Fig. Dactyloscopidae 1). The eggs are attached to one another by long intertwining filaments which are grouped in a cluster of 6–10 filaments at the basal pole of each egg. M. Brogan (pers. comm., July 1995) observed similar, fertilized eggs in *Dactylagnus mundus*, *Dactyloscopus pectoralis*, and *Myxodagnus opercularis*; these eggs differed from those of *D. lunaticus* primarily in egg size and size of the chorionic projections. Brogan (1992) described larvae of *Dactyloscopus pectoralis*, *Dactylagnus mundus*, and *Myxodagnus opercularis*. Larvae are elongate and slender, with a very short preanal length (usually <33% BL). The eyes are lateral through the postflexion stage, then shift dorsally during transformation. A few small preopercular spines develop during the preflexion stage and persist until transformation in larvae tentatively identified as *Gillellus*; there apparently are none in *Dactylagnus*, *Dactyloscopus*, and *Myxodagnus*. Pectoral and pelvic fins develop early in the putative *Gillellus* larvae, with rays forming before dorsal and anal fin rays. Transformation occurs at a small size and may be complete by 10–15 mm (e.g., Dawson 1975). Larval pigmentation occurs primarily on the dorsal surface of the gas bladder, along the ventrum, and often dorsally at the nape.

Larval dactyloscopids resemble larvae of many of the other blennioid species but have a shorter preanal length than any except some specimens of *Neoclinus*. The presence of preopercular spines distinguishes the putative larval *Gillellus* from all other blennioid larvae except blenniids, *Labrisomus*, and at least some *Malacoctenus* species. In addition, a variety of meristic, morphometric, and pigment characters distinguish the dactyloscopid larvae from the other blennioids (refer to the appropriate chapters).

The following description is based on examination of 19 larvae tentatively identified as *Gillellus semicinctus* (3 yolk-sac, 3.6–4.1 mm; 6 preflexion, 3.8–5.6 mm; 6 flexion, 6.1–6.7 mm; 4 postflexion, 7.6–9.5 mm) and 5 demersal, transformation specimens of *G. semicinctus* (11.7–15.4 mm). The larvae were collected at nearshore CalCOFI stations between Punta Eugenia and Punta Abreojos, Baja California Sur, where only *Dactyloscopus byersi heraldi*, *Dactylagnus mundus*, and *Gillellus semicinctus* have been reported (Dawson 1975, 1977). The meristic characters of the larvae are consistent with both *D. b. heraldi* and *G. semicinctus*, but the larvae have a larger eye, a deeper caudal peduncle, and somewhat different pigmentation than early transforming *D. b. heraldi* (Figure Dactyloscopidae 1). The larvae more closely resemble transforming *G. semicinctus* in all three characters and, in addition, larvae >8.5 mm have the same spacing of the first three dorsal spines displayed by *G. semicinctus* (different spacing in *D. b. heraldi*). However, because none of the demersal specimens has the preopercular spines or the melanophore series along the ventral margin of the tail that characterize the larvae, and intermediate specimens are unavailable, the larvae can be identified only tentatively as *G. semicinctus*. A partial developmental series of *Myxodagnus opercularis* is shown in Figure Dactyloscopidae 1 but is not described because too few specimens were available. No larval *Dactylagnus* were identified in CalCOFI collections. See Brogan (1992) for descriptions and illustrations of *D. mundus*, *Dactyloscopus pectoralis*, and *M. opercularis*. Meristic data (Table Dactyloscopidae 1) were obtained from Dawson (1975, 1976, 1977) and from counts made during this study.

Table Dactyloscopidae 1. Meristic characters for the dactyloscopid species along the Pacific coast of Baja California. All have 6 branchiostegal rays, I,3 pelvic fin rays, and 10 principal caudal fin rays (except *Heteristius cinctus* has 12 principal caudal rays). All lack gill rakers.

	Vertebrae			Fin rays			
Species	PrCV	C	Total	D	A	P_1	C_2
Dactylagnus mundus	12–14	34–41	49–52	VIII–XII,28–34	II,35–41	14–16	3–6+3–6
D. parvus	11–12	31–36	43–47	VIII–XI,25–29	II,29–34	12–14	3–5+3–4
D. byersi heraldi	10–12	31–35	42–45	XII–XV,24–27	II,29–33	12–13	3–5+2–4
D. fimbriatus elongatus	11–12	37–41	48–52	XII–XIV,32–36	II,37–41	13	4+3
Dactyloscopus lunaticus	11	32–35	43–46	X–XIII,27–31	II,31–35	13	4+3–4
D. pectoralis pectoralis	10–11	28–30	39–41	X–XIII,23–26	II,26–30	13	3–5+1–3
Gillellus arenicola	11	35–38	46–49	XIII–XV,27–31	II,34–38	12–13	3–4+3
G. semicinctus	11	31–35	42–46	XI–XIV,25–30	II,30–35	11–14	3–4+2–3
Heteristius cinctus	10	34–37	44–47	XIX–XXII,18–22	II,33–36	13–15	3–4+2–3
Myxodagnus opercularis opercularis	11–13	34–38	47–49	VII–XI,27–31	II,33–38	13–15	4–5+4–5

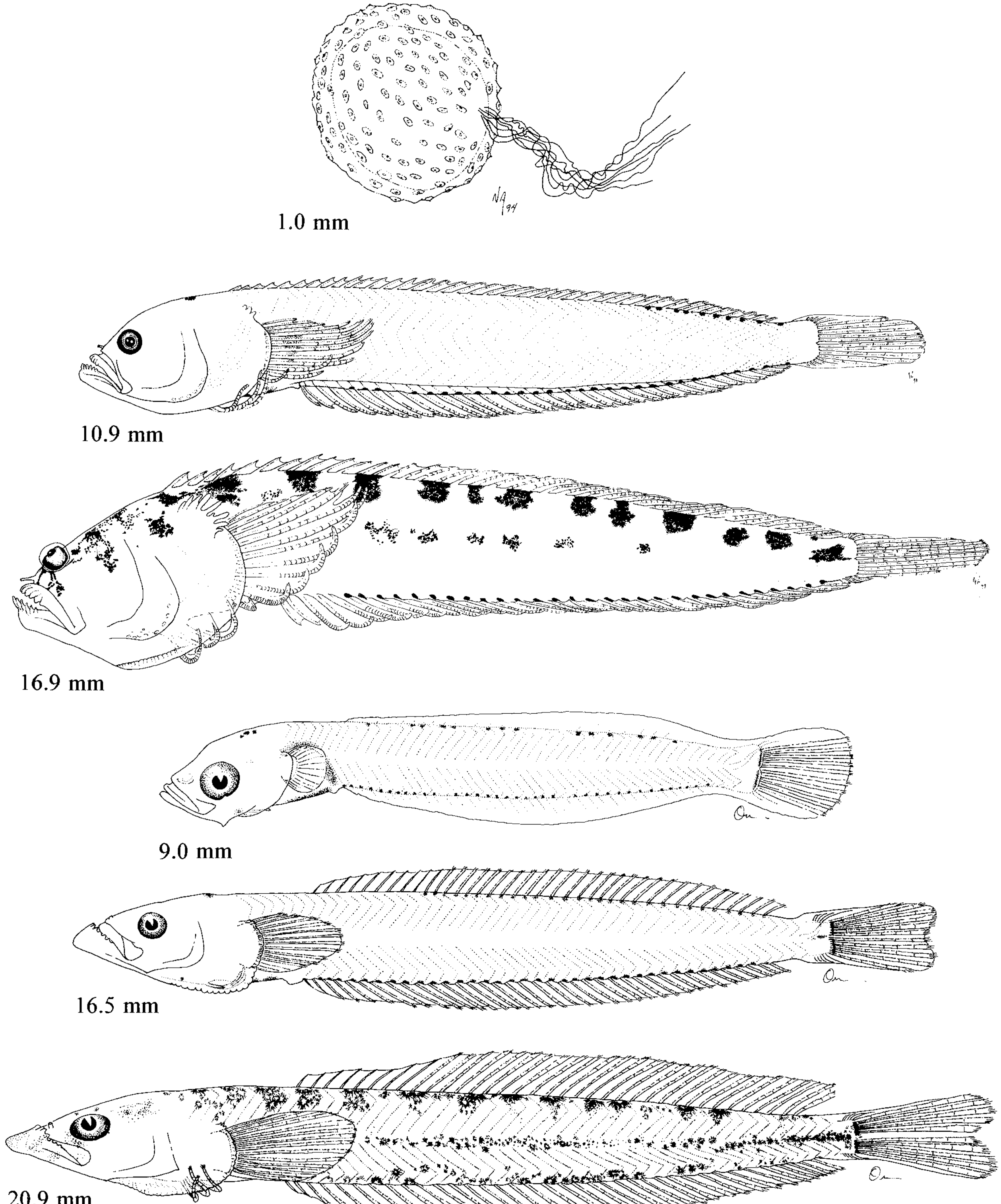


Figure Dactyloscopidae 1. Hydrated ovarian egg of *Dactyloscopus lunaticus*, 1.0 mm (from 44 mm female, SIO 65–282; original illustration by N. Arthur); transformation stage *Dactyloscopus byersi heraldi*, 10.9 mm (SIO 62–704) and early juvenile, 16.9 mm (SIO 62–706), original illustrations by N. Arthur; postflexion larva of *Myxodagnus opercularis opercularis*, 9.0 mm (CFRD Ref. Coll.), transformation specimen, 16.5 mm (SIO 59–225), and early juvenile, 20.9 mm (SIO 65–320) (original illustrations of *M. opercularis opercularis* by H. M. Orr; scales are not shown on the transformation and juvenile specimens).

MERISTICS†

	Range	Mode
Vertebrae:	42–46	43–44
Total	11	11
Precaudal	31–35	33–34
Caudal		
Fins:		
Dorsal spines	XI–XIV	XIII
Dorsal rays	25–30	28
Anal spines	II	II
Anal rays	30–35	32–33
Pelvic	I,3	I,3
Pectoral	11–14	12
Caudal:		
Principal	5+5	5+5
Procurrent:		
Upper	3–4	4
Lower	2–3	3
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	6	6

LIFE HISTORY

Range: *G. semicinctus*: Isla de Guadalupe, vicinity of Punta Eugenia to northwestern Gulf of California (Isla Ángel de la Guardia), Islas Revillagigedo, Nayarit, Mexico, to Colombia, Galápagos Islands; larvae: Pacific coast of Baja California Sur south of Punta Eugenia

Habitat: *G. semicinctus*: soft bottom at depths of 5 m to ≤137 m

Spawning season: All larvae collected in September

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.6 mm (N. Arthur)
Preflexion larva, 5.4 mm (N. Arthur)
Flexion larva, 6.4 mm (N. Arthur)
Postflexion larva, 9.5 mm (N. Arthur)
Transformation specimens, 13.3 mm, 14.7 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: near 3.5 mm
Flexion length: ca. 6–7 mm
Transformation length: >9.5 mm
Fin development sequence: C_1, P_1, P_2, 2D & A & C_2, 1D
Pigmentation: *Yolk-sac–postflexion*—None on head or dorsum; usually 1 each anteriorly & posteriorly on dorsal surface of gas bladder; 1 on isthmus adjacent to cleithral symphysis by ca. 5 mm; 0–4 along ventral margin of gut (usually 2–4); 1 internally on or near upper anterior surface of liver; 10–29 along ventral margin of tail beginning at ca. postanal myomere 3–4 or anal ray 2–4, usually ≤20 irregularly spaced through preflexion stage, 1 per A ray base in postflexion stage.
Diagnostic features: Elongate, slender; preanal length usually 30–32% BL; relatively large eye; myomeres 7–10+34–37=43–46 (usually 7–9+36); 1–4 (usually 3) small preopercular spines after 4.5 mm; no pigment on head or dorsum through at least 9.5 mm, light pigmentation on gas bladder & along ventral margin.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr‡	Juv
Sn-A/BL	30–34	30–35	31–35	29–32	30–35	
	32	32	32	31	33	
BD/BL	20–20	16–20	9–18	16–18	14–16	
	20	18	17	17	15	
HL/BL	20–22	20–23	20–23	21–22	25–27	
	21	22	21	22	26	
HW/HL	61–68	51–75	58–69	55–58	39–45	
	66	65	63	57	42	
SnL/HL	18–22	20–28	26–31	25–29	13–18	
	20	24	29	28	15	
ED/HL	41–43	33–44	30–35	25–29	19–20	
	42	37	32	27	20	
P_1L/BL	6–9	4–6	5–7	5–11	21–23	
	7	5	6	9	22	
P_2L/BL	0–0	0–0	0–2	3–8	11–14	
	0	0	1	6	12	

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* Larvae included here are field-collected specimens having meristic, morphological, & some pigmentation characters as well as geographic locations consistent with *Gillellus semicinctus*; however, the smallest available benthic specimens of *G. semicinctus* (ca. 12 mm) lack both the preopercular spines & melanophore series along the ventral margin of the tail that typify the larvae.

† Meristic data are given for *Gillellus semicinctus*. Counts for the larvae are D XII–XIII,28; A II,33; P_1 12; P_2 I,3; C_1 5+5; C_2 4+3; branchiostegal rays 6; myomeres 7–10+34–37=43–46.

‡ *Gillellus semicinctus*

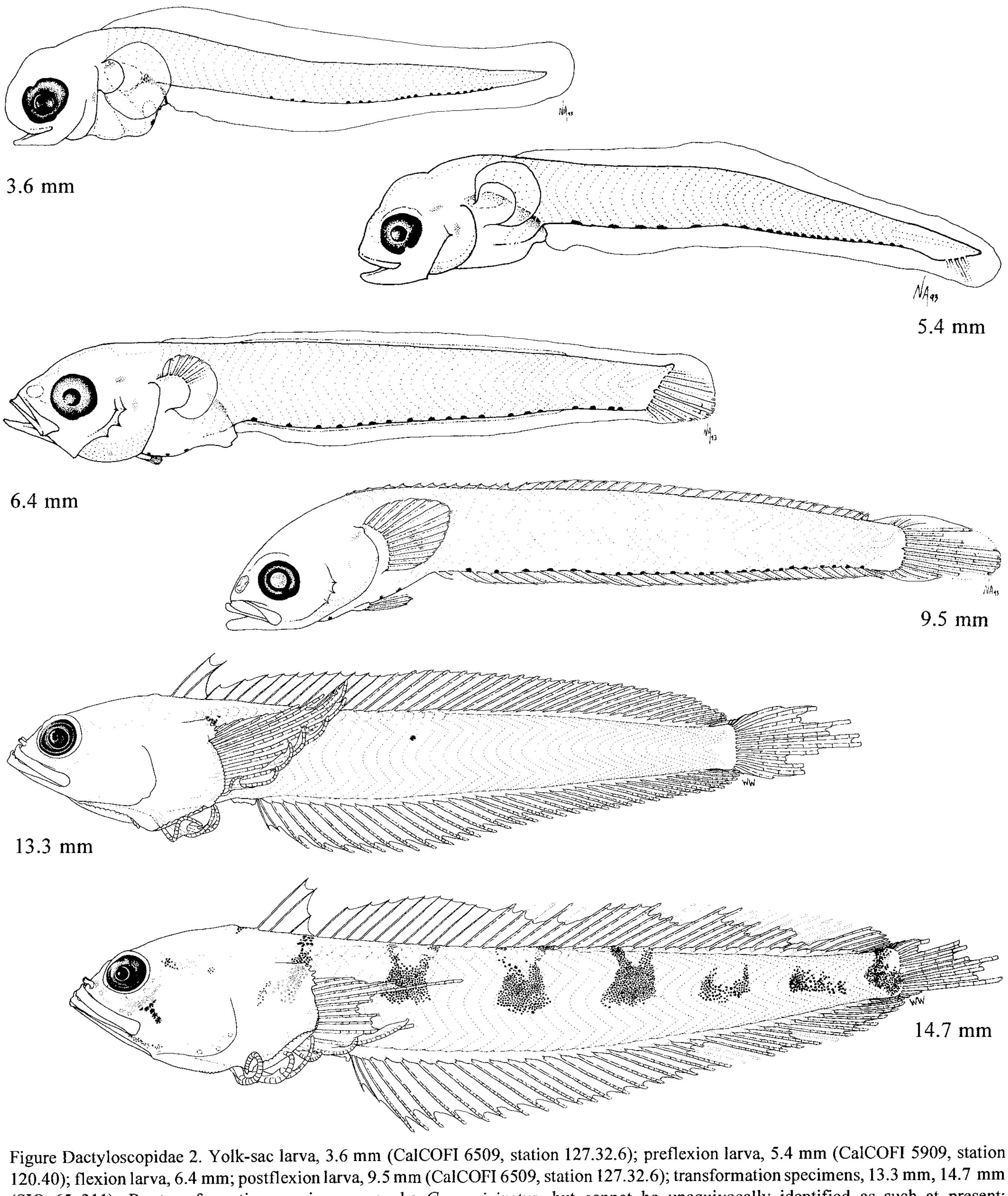

Figure Dactyloscopidae 2. Yolk-sac larva, 3.6 mm (CalCOFI 6509, station 127.32.6); preflexion larva, 5.4 mm (CalCOFI 5909, station 120.40); flexion larva, 6.4 mm; postflexion larva, 9.5 mm (CalCOFI 6509, station 127.32.6); transformation specimens, 13.3 mm, 14.7 mm (SIO 65–311). Pre-transformation specimens may be *G. semicinctus* but cannot be unequivocally identified as such at present; transformation specimens are *G. semicinctus*.

BLENNIIDAE: Combtooth blennies

W. WATSON

Blennidae contains about 345 species in 53 genera (Nelson 1994); four species, *Hypsoblennius gentilis*, *H. gilberti*, *H. jenkinsi*, and *Ophioblennius steindachneri*, occur along the Pacific coast of California and Baja California (*O. steindachneri* ranges northward only to Bahía Sebastián Vizcaíno). Two southern species, *H. brevipinnis* and *H. proteus*, whose reported adult distributions do not include the Pacific coast of the Baja California peninsula, have been collected as larvae in CalCOFI samples as far north as Bahía Almejas, and near Rocas Alijos, respectively. *Entomacrodus chiostictus* and *Plagiotremus azalea* range southward from the Gulf of California and the southern tip of Baja California Sur; their larvae have been collected in CalCOFI samples from the Gulf and in other plankton samples to the south.

Adult blenniids are small (typically <20 cm) demersal (except the semi-pelagic saber-toothed blennies) inhabitants of intertidal to shallow subtidal hard bottom (e.g., reefs, pilings, buoys). Blennies are diverse in appearance but all share at least some of the following externally visible characters: lack of scales, presence of jugular pelvic fins with 2–4 soft rays each, presence of relatively long continuous dorsal fin (deeply notched in some species), unbranched pectoral fin rays; and presence of variously developed cirri on the anterior nostril, above the eye, and on the nape. Most blennies have a rather blunt head and broad lips.

Spawning has been documented for several species (e.g., Breder and Rosen 1966; Matarese et al. 1984b). All are oviparous, with demersal eggs attached via adhesive pads or filaments to the surface of the nest and tended by the male or both parents. The egg has a smooth spherical to hemispherical chorion ca. 0.4–0.8 mm by 0.6–1.1 mm in diameter. The yolk is granular and typically contains one or more oil globules. In many species the yolk is pigmented, ranging from pale yellow to bright red-orange, and it may contain violet inclusions (e.g., Lebour 1927; Fishelson 1976; Stevens and Moser 1982; Labelle and Nursall 1985). Newly hatched larvae typically are ca. 2–3 mm long, have pigmented eyes, a functional mouth, and no more than a small yolk sac. Larvae typically are somewhat compressed and elongate with a preanal length less than half of body length. Preopercular spines commonly develop during the preflexion stage (except in the nemophin blennies, which lack preopercular spines); these may become quite large and/or elaborate in parablenniin and omobranchin genera. Many species develop supraoccular spines, as well. Pectoral fins often are large, especially in the salariin larvae. Many salariin larvae have large, hooked teeth in the lower or both jaws while nemophin larvae have large anterior canine teeth. Larval pigmentation typically is light (except nemophin larvae may be heavily pigmented) and largely restricted to the dorsal surfaces of the head and gut, ventral margins of the gut and tail, and the pectoral fins. Mottled or barred pigment patterns form during the gradual transformation to the demersal juvenile stage. Many salariin larvae pass through a pelagic juvenile stage, the ophioblennius, characterized by larval pigmentation, dentition, and body form, together with large size (up to nearly 7 cm in *O. steindachneri*) and cirri typical of the juvenile.

Larval blennids are easily distinguished from other larvae by a combination of myomere counts typically in the mid- to high 30s (overall range 29–50 in the CalCOFI area species), a moderately elongate form, a coiled gut with preanal length commonly ca. 40% BL (range 36–50% BL), preopercular spination, large and/or heavily pigmented pectoral fins, and other pigment largely restricted to the dorsum of the head and gut, and to the ventral margin. In the CalCOFI study area, larval *Hypsoblennius* are readily distinguished from the other genera by their large and numerous preopercular spines, heavy pectoral pigment, and relatively robust form. The salariin larvae, *E. chiostictus* and *O. steindachneri*, are more elongate and slender, with a relatively long and pointed snout, larger and usually less heavily pigmented pectoral fins, and only a few small preopercular spines. Both have large, hooked teeth, and both have little or no pigment on the tail. Larvae of the nemophin, *P. azalea*, are even more elongate and slender, lack pectoral pigment and preopercular spines, but have much heavier pigmentation on the body and higher myomere and dorsal and anal fin-ray counts (e.g., Table Blenniidae 1).

The following descriptions are based on literature (*H. jenkinsi*) and on detailed examinations of 17–40 specimens of each species (Table Blenniidae 2). Meristic data were obtained from Springer (1962, 1967), Smith–Vaniz (1976), Bath (1977), and counts made during this study. Principal sources of ecological information were Krejsa (1960), Springer (1967), Stephens et al. (1970), and Thompson et al. (1979).

Table Blenniidae 1. Meristic characters for the blenniid species reported to occur in the vicinity of the CalCOFI study area. All have 6 branchiostegal rays.

	Vertebrae			Fin rays					
Species	PrCV	CV	Total	D	A	P_1	P_2	C_1	C_2
Entomacrodus chiostictus	10	23–25	33–35	XIII,14–16	II,15–17	14	I,4	7+6	7–9+7–8
Hypsoblennius brevipinnis	9–10	20–21	29–31	XI–XIII,11–13	II,12–14	13–15	I,3–4	7+6	7–9+6–8
H. gentilis	10	24–25	34–35	XI–XIII,16–18	II,16–19	11–13	I,3	7+6	6–7+5–7
H. gilberti	10	27–28	37–38	XII–XIII,18–19	II,19–21	13–15	I,3	7+6	6–7+6–7
H. jenkinsi	10	24–25	34–35	XI–XIII,15–19	II,15–20	12–15	I,3	7+6	6–8+6–8
H. proteus	10	20–21	30–31	XI–XII,12–13	II,13–15	13–15	I,4	7+6	7–11+7–9
Ophioblennius steindachneri	10–11	24–25	35–36	XI–XIII,21–23	II,22–24	14–16	I,4	7+6	6–8+6–8
Plagiotremus azalea	14–16	32–35	47–50	VII–IX,31–36	II,27–30	12–13	I,3	6+5	6–9+6–9

Table Blenniidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the blenniid species descriptions. An "L" indicates literature used in the description.

Species	Eggs	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Entomacrodus chiostictus	0	3 2.7–2.8	1 2.7	0	10 6.6–21.6	5 19.7–21.6	5 19.8–23.5
Hypsoblennius brevipinnis	0	L[a]	8 3.0–4.4	3 4.5–5.1	10 5.2–14.7	5 16.2–17.0	5 16.3–20.5
H. gentilis	0	5 2.4–3.2	10 3.1–5.1	3 5.3–5.9	12 6.0–19.9	5 17.1–21.1	5 16.2–23.3
H. gilberti	0	0	10 3.2–6.2	5 5.7–7.6	10 7.5–21.4	5 20.8–22.0	5 22.8–32.6
H. jenkinsi	L[b], 10 0.6–0.7 × 0.7–0.8	L[b]	L[b]	L[b]	L[b]	L[b]	L[b]
H. proteus	0	0	0	0	10 5.8–15.4	6 16.0–18.4	5 17.3–26.1
Ophioblennius steindachneri	0	5 2.3–2.5	3 2.5–4.2	4 4.7–6.1	13 6.4–58.1	5 36.0–43.2	5 36.1–41.2
Plagiotremus azalea	0	0	10 2.1–5.6	0	2 7.2–13.6	0	5 26.8–33.0

[a] Brogan 1992
[b] Stevens and Moser 1982

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	34
Precaudal	10	10
Caudal	23–25	24
Fins:		
Dorsal spines	XIII	XIII
Dorsal rays	14–16	15
Anal spines	II	II
Anal rays	15–17	16
Pelvic	I,4	I,4
Pectoral	14	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–9	8
Lower	7–8	7–8
Gill rakers:		
Upper	0	0
Lower	14–20	15–18
Branchiostegals	6	6

LIFE HISTORY

Range: Central Gulf of California to Colombia & offshore islands

Habitat: Demersal on intertidal & shallow subtidal rocky bottom

Spawning season:

ELH pattern: Oviparous; eggs attached to the nest wall & tended by the male parent; larvae are planktonic

LITERATURE

Brogan 1992

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.8 mm (W. Watson)
Preflexion larva, 2.7 mm (W. Watson)
Postflexion larvae, 6.6 mm, 17.4 mm (W. Watson)

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* Information from M. Brogan (pers. comm., July 1995).
† Eyes initially somewhat oval, becoming round during the postflexion or transformation stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: 0.64–0.70 mm **Yolk:** Granular
No. of OG: **Diam. of OG:**
Shell surface: Smooth; adhesive pad at basal pole
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.3 mm
Flexion length: <6.6 mm
Transformation length: Variable within ca. 17.4–22.5 mm range
Fin development sequence: P_1 & C_1, 2D & A, 1D & C_2, P_2
Pigmentation: *Yolk-sac–preflexion*—1, internally, under hindbrain; dorsally on gut; few, anteroventrally on yolk sac, condensing to 1–3 anteroventrally on gut; many on distal 33–50% of P_1 blade; 3–4 on ventral margin of tail at last 10 myomeres. *Postflexion–transformation*—Internally on hindbrain, spreading onto midbrain by 9.7 mm; pair at anterior margin of midbrain; externally dorsally over midbrain by 9.7 mm, over forebrain by ca. 14 mm; on medial surface of upper preopercle by 12.7 mm; 0–1 on isthmus; gut pigment spreads ventrad; band on P_1 margin decreasing to 0–1 per fin-ray by ca. 20 mm; series over notochord by ca. 16 mm; 7–10 dorsal & lateral patches form during transformation stage.
Diagnostic features: Large hooked teeth anteriorly in jaws; small preopercular & supraocular spines; elongate P_1 with marginal pigment band; little or no trunk & tail pigment before transformation stage; pair of nuchal cirri form by ca. 17 mm; preanal myomeres 9–11 (usually 10), 34–36 total (usually 34–35).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	43–47 46	 40		39–46 42	38–47 42	44–51 46
BD/BL	18–22 20	 16		16–19 17	18–19 19	19–22 21
HL/BL	23–23 23	 21		22–29 25	21–24 22	22–24 23
HW/HL	57–75 68	 76		50–57 53	56–66 60	68–81 74
SnL/HL	5–18 10	 21		25–32 27	24–28 25	7–17 11
ED/HL†	41–44× 35–39			28–38× 28–40	24–29× 24–30	25–27
	42×37	41×31		31×32	27×28	26
P_1L/BL	7–7 7	 7		22–26 24	23–24 23	22–26 24
P_2L/BL	0–0 0	 0		0.3–17 11	16–16 16	17–18 17
PrSL/HL	0–0 0	 0		0–5 1	0–0 0	0–0 0

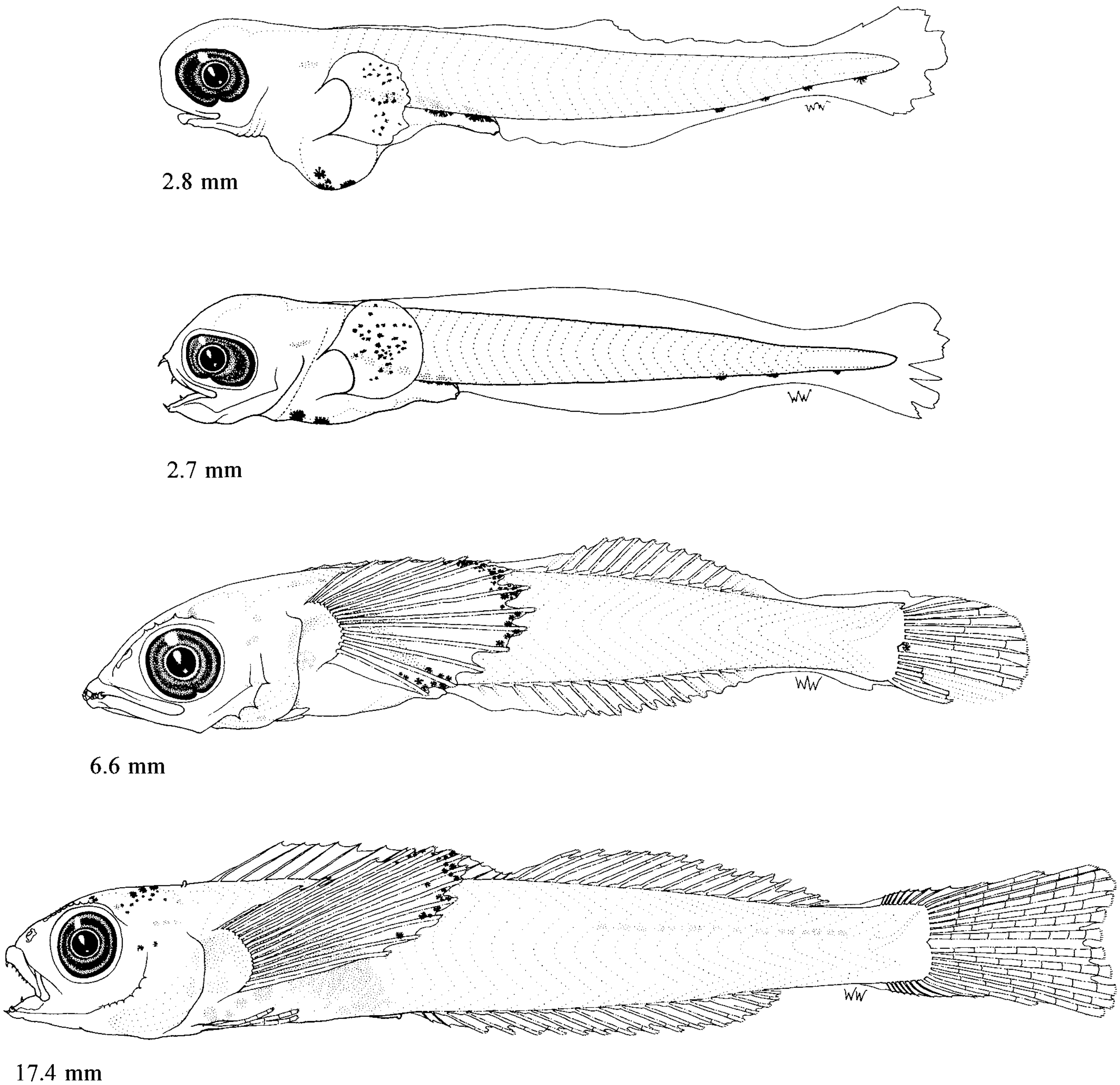


Figure Blenniidae 1. Yolk-sac larva, 2.8 mm (TO 58–1, station 11); early preflexion larva, 2.7 mm (TO 58–1, station 11); early postflexion larva, 6.6 mm (IATTC Mazatlán Project, station 1–15–0); late postflexion larva, 17.4 mm (CFRD Ref. Coll., Isla Socorro, night light and dip net collection, May 11, 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–31	30–31
Precaudal	9–10	10
Caudal	20–21	21
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	11–13	12
Anal spines	II	II
Anal rays	12–14	14
Pelvic	I,3–4	I,4
Pectoral	13–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–9	8
Lower	6–8	8
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Central Gulf of California to Peru; larvae may occur as far north as Bahía Almejas on Pacific coast of Baja California Sur

Habitat: Demersal, usually on hard bottom; inhabits barnacle or other shells; occasionally on floating logs

Spawning season: Possibly year-round (Krejsa 1960); larvae collected February–September

ELH pattern: Oviparous; demersal eggs attached to the nest wall & tended by the male parent; larvae are planktonic

LITERATURE

Brogan 1992
Krejsa 1960

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.0 mm (W. Watson)
Flexion larva, 4.6 mm (W. Watson)
Postflexion larva, 11.1 mm (W. Watson)
Transformation specimen, 16.2 mm (W. Watson)
Juvenile, 17.5 mm (W. Watson)

* Information from M. Brogan (pers. comm., July 1995).

EARLY LIFE HISTORY DESCRIPTION

EGGS*

Shell diam.: 0.51–0.58 mm **Yolk:** Granular
No. of OG: **Diam. of OG:**
Shell surface: Smooth; eggs embedded in thick adhesive mat
Pigment: Melanophores on yolk
Diagnostic features:

LARVAE

Hatching length: ca. 2 mm*
Flexion length: ca. 4.5–5.2 mm
Transformation length: ca. 16–17 mm
Fin development sequence: P_1, C_1, 2D, A, 1D & C_2, P_2
Pigmentation: *Yolk-sac*—On palatines; in otic capsule; dorsally on gut; ventrally on hindgut; on inner surface of P_1 base & blade; series on ventral margin of tail; pair under notochord tip. *Preflexion–postflexion*—Over mid- & hindbrain, increasing & spreading onto forebrain by 11.5 mm; at tip of mandible; on inner surface of gill cover in postflexion stage; spreading ventrolaterally over upper third of gut; heavy ventrally on gut, becoming sparse to absent by 11 mm; heavy on inner surface of P_1 base & on lower 50–60% of fin; 17–22 along ventral margin of tail, ca. 1 per myomere. *Transformation*—4–6 dorsal saddles form from anterior to posterior.
Diagnostic features: Low fin-ray & myomere counts (myomeres 29–31, usually 30: 7–8+22–23); inner preopercular shelf with 5–8 marginal spines & outer shelf with 1–5 marginal spines through flexion stage: 4–6 dorsal pigment saddles in transformation stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–44 41	42–45 44	43–50 46	46–52 49	52–58 54
BD/BL		21–29 24	26–27 27	27–31 28	28–30 29	28–33 30
HL/BL		23–29 26	26–29 27	26–34 30	27–31 29	28–33 31
HW/HL		59–75 67	63–72 68	61–75 68	61–93 72	62–87 76
SnL/HL		21–28 25	23–26 24	16–22 18	13–19 15	14–27 18
ED/HL		32–41 38	37–40 38	31–39 36	27–34 31	26–30 28
P_1L/BL		11–18 15	22–25 24	23–28 25	24–27 26	21–26 24
P_2L/BL		0–0 0	0.2–1 1	3–24 16	22–24 23	20–23 21
PrSL/HL		12–20 14	24–27 25	7–33 22	0–9 4	0–0 0

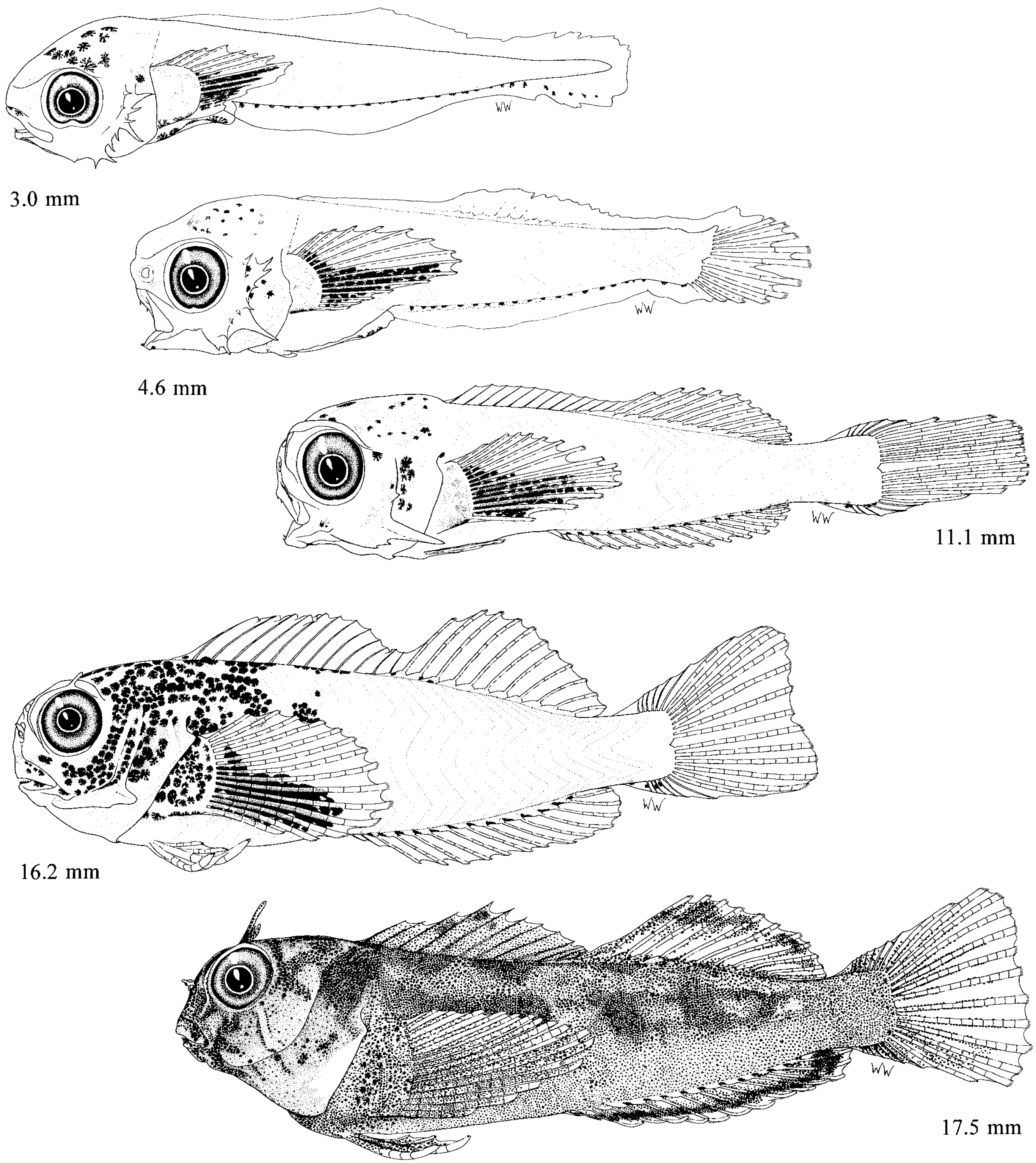


Figure Blenniidae 2. Preflexion larva, 3.0 mm (TO 58–1, station 71); flexion larva, 4.6 mm (TO 58–1, station 105); postflexion larva, 11.1 mm (CalCOFI 5109, station 147.20); early transformation specimen, 16.2 mm (TO 58–1, station 141); juvenile, 17.5 mm (SIO 64–120).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–35	35
Precaudal	10	10
Caudal	24–25	25
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	16–18	16–17
Anal spines	II	II
Anal rays	16–19	18
Pelvic	I,3	I,3
Pectoral	11–13	12
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–7	7
Lower	5–7	6–7
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Monterey, California, to Bahía Magdalena, Baja California Sur, & in upper Gulf of California

Habitat: Demersal, primarily in bays, estuaries, & rocky tidepools; shelter in crevices among rocks mussel beds, pilings, etc.

Spawning season: Year-round

ELH pattern: Oviparous; demersal eggs attached on the nest wall & tended by the male parent; planktonic larvae

LITERATURE

Brogan 1992
Ninos 1984
Stevens & Moser 1982

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.7 mm (W. Watson)
Flexion larva, 5.6 mm (W. Watson)
Postflexion larva, 13.0 mm (W. Watson)
Transformation specimen, 21.1 mm (W. Watson)

* Information from M. Brogan (pers. comm., July 1995).

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: 0.56–0.64 mm **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface: Smooth; eggs embedded in thick adhesive mat
Pigment:
Diagnostic features:

LARVAE
Hatching length: 2.3–2.6 mm
Flexion length: 5.2–5.9 mm
Transformation length: ca. 16–21 mm
Fin development sequence: P_1, C_1, 2D, A, C_2, 1D, P_2
Pigmentation: *Yolk-sac–preflexion*—Over mid- & hindbrain; internally at snout & floor of otic capsule; 0–1 near tip of lower jaw; forming on isthmus at ca. 4.5 mm & on inner surface of preopercle at ca. 5 mm; dorsally on gut, spreading ventrad; 1–4 under end of hindgut; heavy on mesial surface of P_1; 26–30 on ventral margin of tail, ca. 1 per myomere. *Flexion–transformation*—Increasing pigmentation on head; usually 21–23 in ventral tail series; 4–6 along hypural margin; series over notochord beginning under 2D by 8.8 mm; dorsal patches along D base beginning anteriorly at ca. 13–14 mm. *Juvenile*—Mottled pattern; 6 dorsolateral saddles.
Diagnostic features: P_1 11–13 (usually 12), all visible by ca. 4.5 mm; myomeres 34–37 (usually 35–36: 8–10+26–28); by ca. 6 mm inner preopercular shelf with 3 marginal spines, central spine much larger than others; 6 dorsal pigment saddles.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	36–39 37	36–42 38	36–41 39	40–48 43	44–49 46	47–49 49
BD/BL	15–22 19	19–22 21	21–22 21	21–25 23	23–27 25	24–26 25
HL/BL	20–23 21	20–26 22	24–27 26	26–29 28	26–30 28	28–32 31
HW/HL	75–83 79	62–83 74	54–63 59	52–67 58	53–77 66	54–59 57
SnL/HL	15–20 18	18–26 21	19–27 22	16–22 17	14–19 16	13–15 14
ED/HL	44–49 47	35–48 42	37–37 37	27–39 35	32–34 33	25–33 30
P_1L/BL	7–8 8	6–15 10	16–22 19	20–24 22	23–26 25	21–25 23
P_2L/BL	0–0 0	0–0 0	0–0.4 0.1	0–16 9	16–20 18	19–22 20
PrSL/HL	0–3 1	3–10 6	13–21 18	10–34 20	3–10 6	0–0 0

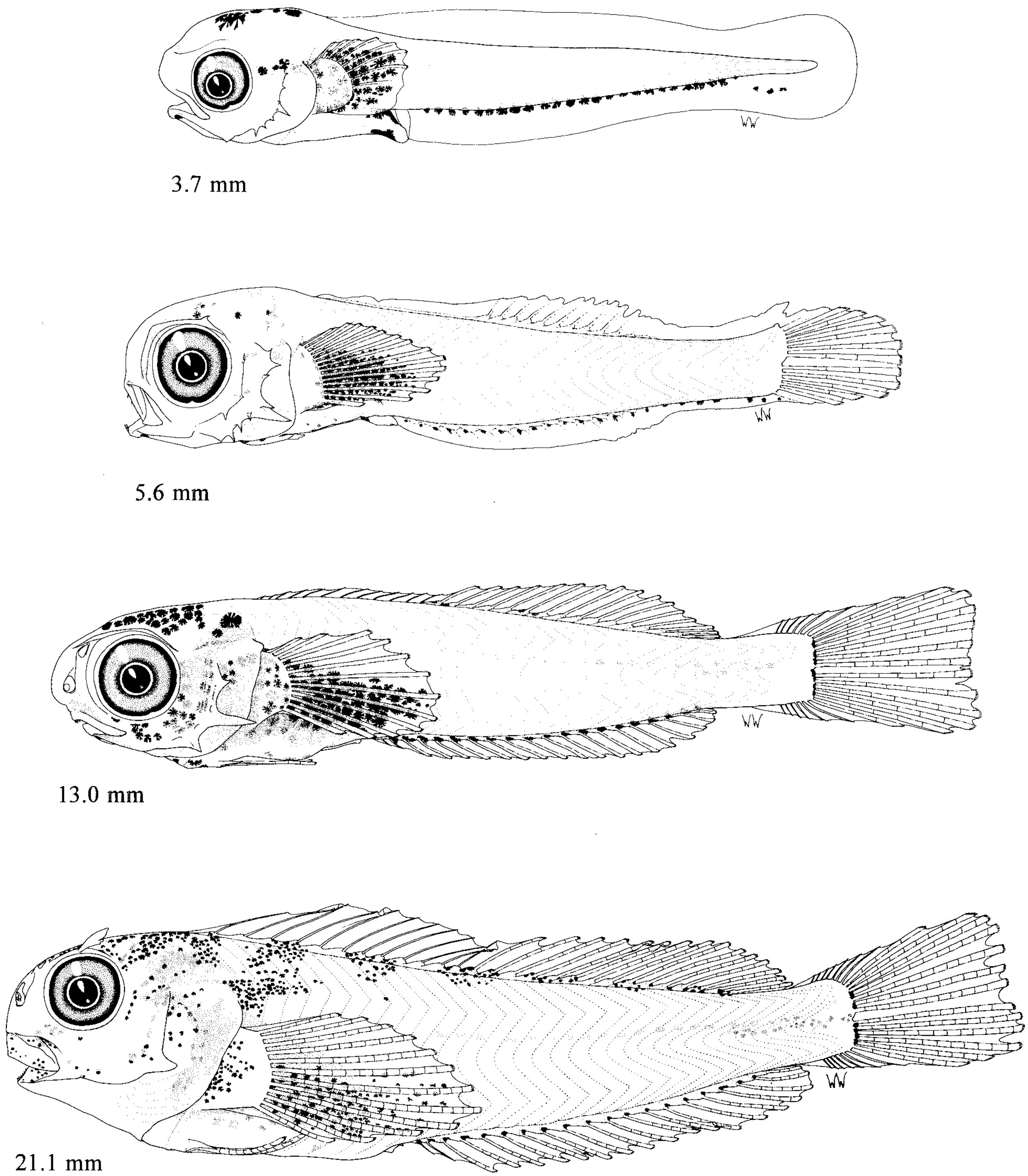


Figure Blenniidae 3. Preflexion larva, 3.7 mm (CFRD Ref. Coll., reared at SWFSC, day 13, August 25, 1977); flexion larva, 5.6 mm (CalCOFI 8108, station 120.30, Manta net); postflexion larva, 13.0 mm (CalCOFI 7501, station 123.38); transformation specimen, 21.1 mm (CalCOFI 5706, station 113G.45).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–38	37
Precaudal	10	10
Caudal	27–28	27
Fins:		
Dorsal spines	XII–XIII	XII
Dorsal rays	18–19	18–19
Anal spines	II	II
Anal rays	19–21	20
Pelvic	I,3	I,3
Pectoral	13–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–7	7
Lower	6–7	6–7
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Point Conception, California, to Bahía Magdalena, Baja California Sur

Habitat: Demersal on rocky bottom in intertidal & shallow (<20 m depth) subtidal areas

Spawning season: June–September (Stephens et al. 1970); larvae collected June–October

ELH pattern: Oviparous; eggs attached to the nest wall & guarded by the male parent; planktonic larvae

LITERATURE

Ninos 1984
Stephens et al. 1970
White 1977

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.0 mm (W. Watson)
Flexion larva, 7.0 mm (W. Watson)
Postflexion larvae, 9.0 mm, 17.8 mm (W. Watson)

* Eyes somewhat oval, becoming round or nearly so during the flexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

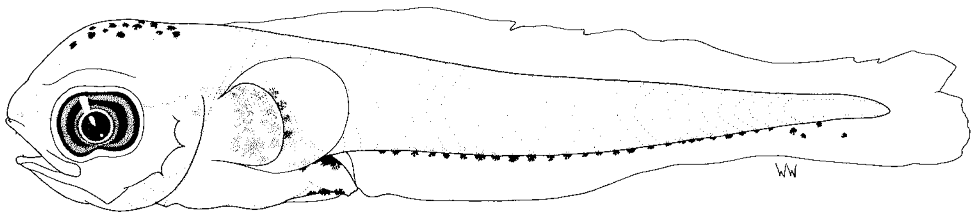
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

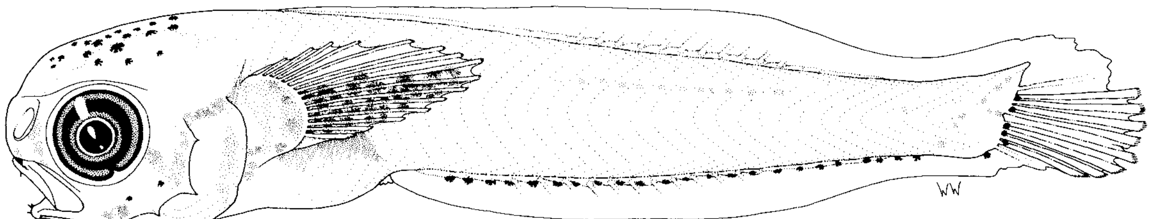
Hatching length: ca. 3 mm
Flexion length: ca. 6–7.5 mm
Transformation length: ca. 21–22 mm
Fin development sequence: P_1, C_1, 2D, A, C_2, 1D, P_2
Pigmentation: *Preflexion*—Over mid- & hindbrain; over forebrain by 5–6 mm; internally at snout & under brain; on isthmus by 4.5 mm; dorsally on gut, spreading ventrad; 1–3 under end of hindgut; on mesial surface of P_1 base; 0–4 at proximal margin of P_1 blade, spreading distad after 4 mm; 25–27 on ventral margin of tail; 1–2 internally & 2–4 externally under notochord tip. *Flexion–postflexion*—Increasing on head, gut, & P_1; 22–25 on A base & tail; several on hypural margin; series forming over notochord by 6.4–7.0 mm; on D ray bases & some C rays after 9 mm; 7–8 patches along D base by 19 mm. *Transformation*—Dorsal patches become saddles beginning anteriorly.
Diagnostic features: Myomeres 36–38 (usually 37: 9–10+27–28); preopercular spines always small, 3 principal spines (all similar size); many small melanophores over brain after ca. 3.5 mm; little pigment on P_1 blade before 4 mm; melanophores over notochord by ca. 6.5 mm; internal pigment under notochord tip; ca. 6–8 dorsal pigment patches before settlement.

MORPHOMETRICS (range & mean in %)

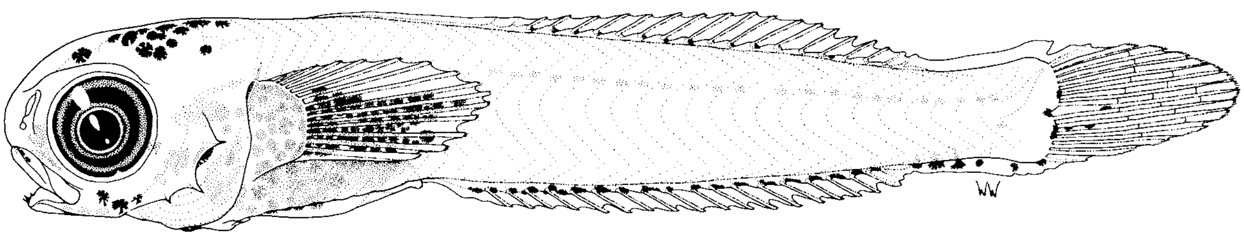
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–40 38	37–38 38	38–45 40	43–48 45	46–53 50
BD/BL		18–22 20	19–22 20	19–22 20	21–25 23	24–27 25
HL/BL		22–24 23	23–25 24	25–28 26	27–29 28	20–31 28
HW/HL		63–76 71	38–81 63	53–66 60	61–67 64	59–72 68
SnL/HL		16–27 21	19–20 20	18–22 20	15–20 17	15–21 19
ED/HL*		38–47× 31–44	36–39× 34–38	29–40	27–29	22–28
		41×37	38×36	36	29	25
P_1L/BL		5–12 9	14–19 16	20–25 22	23–25 24	24–27 26
P_2L/BL		0–0 0	0–0 0	0–17 8	17–18 17	18–20 19
PrSL/HL		0–6 4	4–7 5	6–11 9	0.5–4 2	0–0 0



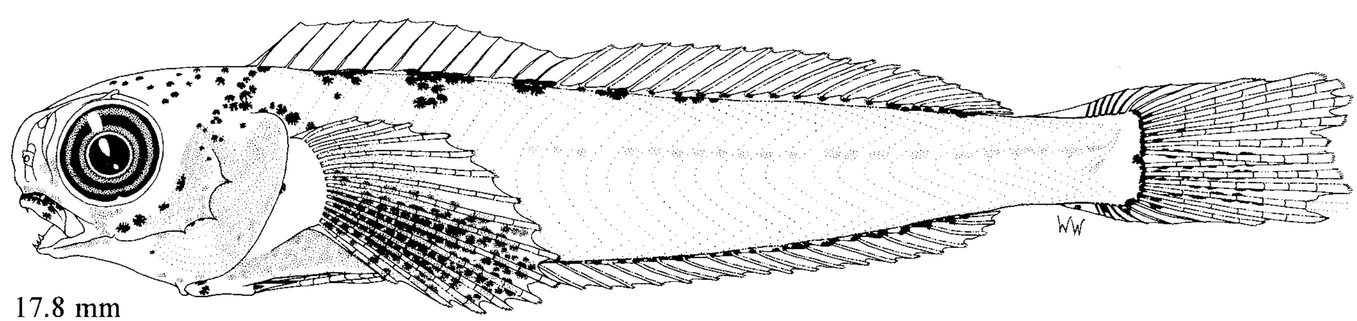
4.0 mm



7.0 mm



9.0 mm



17.8 mm

Figure Blenniidae 4. Preflexion larva, 4.0 mm (CalCOFI 6407, station 90.28); flexion larva, 7.0 mm (CalCOFI 6606, station 87.33); postflexion larva, 9.0 mm (CalCOFI 8108, station 103.3.29); late postflexion larva, 17.8 mm (CalCOFI 7210, station 100.35).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–35	34
Precaudal	10	10
Caudal	24–25	24
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	15–19	16
Anal spines	II	II
Anal rays	15–20	18
Pelvic	I,3	I,3
Pectoral	12–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–8	6
Lower	6–8	6
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Coal Oil Point, Santa Barbara County, California, to Puerto Marquis, Baja California Sur, & in upper Gulf of California

Habitat: Demersal; shelters in mussel & scallop shells, worm tubes, etc.; intertidal to ca 20 m depth (usually subtidal)

Spawning season: May–September (Stephens et al. 1970)

ELH pattern: Oviparous; eggs attached to the nest wall & tended by the male parent; larvae are planktonic

LITERATURE

Ninos 1984
Stevens & Moser 1982
Stephens et al. 1970

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.7 × 0.8 mm (W. Watson)
Preflexion larva, 4.5 mm (N. Arthur)
Flexion larva, 4.7 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.69–0.80 mm **Yolk:** Granular; 0.68–0.76 mm
No. of OG: ≥10 in cluster **Diam. of OG:** 0.02–0.09 mm
Shell surface: Unsculptured; adhesive disc at basal pole
Pigment: Oil globules yellow; violet inclusions in yolk in young eggs; melanophores on yolk surface & embryo
Diagnostic features:

LARVAE

Hatching length: ca. 2.5 mm
Flexion length: ca. 4.0 mm through 5.3–5.7 mm
Transformation length: 10–13 mm through ca. 18 mm
Fin development sequence: P_1, C_1, 2D & A, C_2, P_2, 1D
Pigmentation: *Preflexion–flexion*—Over mid- & hindbrain; under middle of preopercle; internally on pharyngobranchials & ethmoid cartilage; dorsally on gut, spreading ventrad; 1–2 under end of hindgut; heavy on mesial surface of P_1; 21–27 on ventral margin of tail; 0–5 on caudal finfold under notochord tip, along hypural margin in flexion stage. *Postflexion–transformation*—Increasing head & gut pigment; series forms over notochord beginning after ca. 5 mm; 5–7 saddles along D base, beginning anteriorly at ca. 10–11 mm.
Diagnostic features: Myomeres 33–35 (usually 34: 8–10+24–26); 3 principal preopercular spines, upper 2 of similar size, both become longer than the others after ca. 4 mm; no more than 3–4 anterior pigment saddles before settlement.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL					41–47	46–48
		38	40	44	45	47
BD/BL					23–27	25–29
		21	22	25	26	27
HL/BL					25–31	27–29
		21	24	27	28	28
SnL/HL					10–18	12–17
		19	18	13	14	14
ED/HL					35–47	34–36
		46	43	45	40	35
P_1L/BL					25–33	30–31
		13	22	30	30	31
PrSL/HL					3–15	0–0
		7	11	15	7	0

* Values calculated from Stevens & Moser (1982), Table 1.

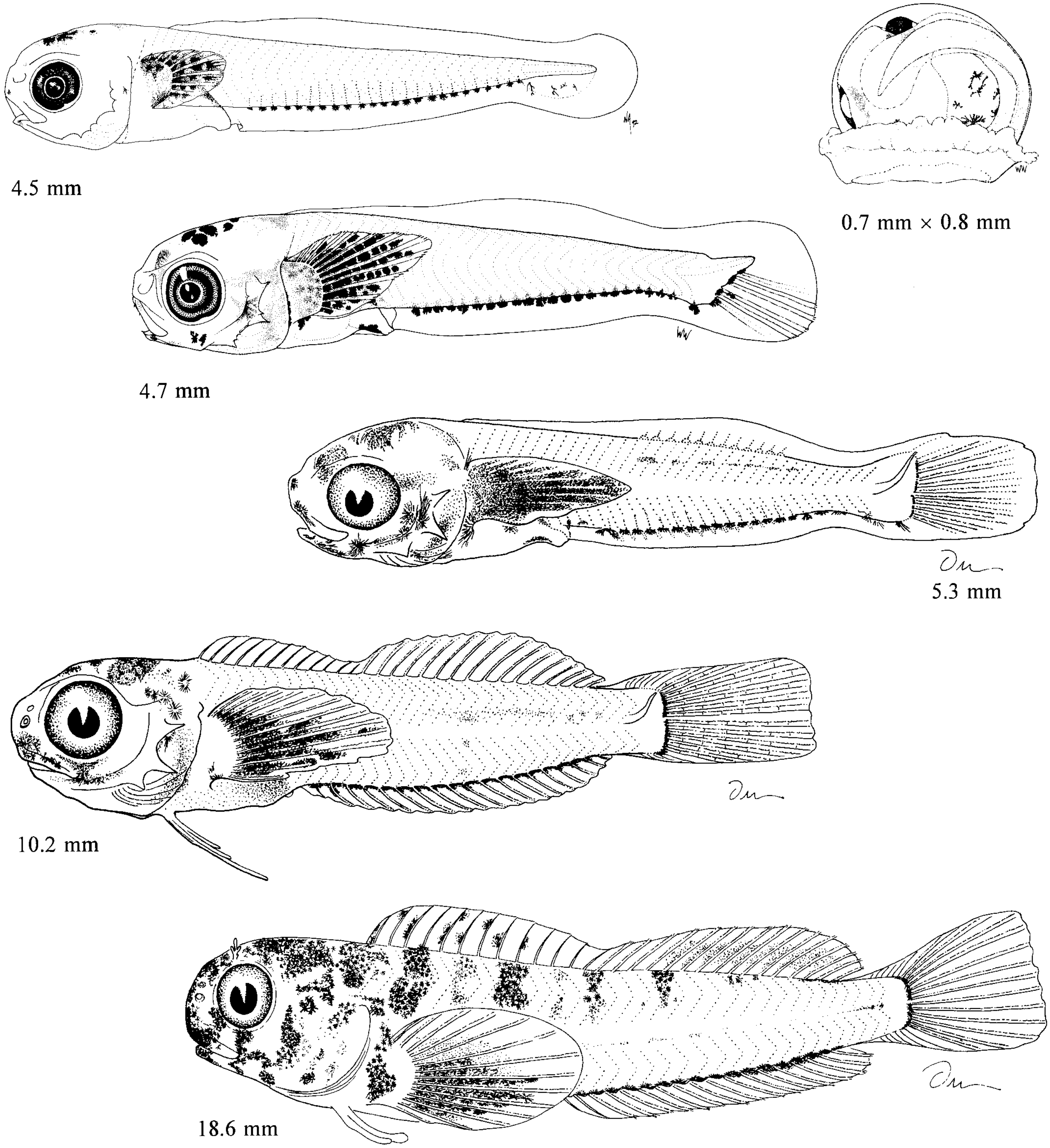


Figure Blenniidae 5. Egg, 0.7 mm × 0.8 mm (CFRD Ref. Coll., reared at SWFSC, 22 days after spawning, December 26, 1978); preflexion larva, 4.5 mm (CFRD Ref. Coll., reared at SWFSC, day 15, July 31, 1978); early flexion larva, 4.7 mm (CFRD Ref. Coll., reared at SWFSC, day 23, August 8, 1978); early postflexion larva, 5.3 mm; late postflexion larva, 10.2 mm; transformation specimen, 18.6 mm (Stevens and Moser 1982).

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–31	31
Precaudal	10	10
Caudal	20–21	21
Fins:		
Dorsal spines	XI–XII	XII
Dorsal rays	12–13	12
Anal spines	II	II
Anal rays	13–15	14
Pelvic	I,4	I,4
Pectoral	13–15	14
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	7–11	7–9
Lower	7–9	7–9
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Endemic to Islas de Revillagigedo (Krejsa 1960); larvae collected as far north as Rocas Alijos, Baja California Sur

Habitat: Demersal, on rocky or coral substrate

Spawning season: At least February–May (Krejsa 1960)

ELH pattern: Oviparous; presumably, demersal eggs attached to the nest wall & tended by the male parent; larvae are planktonic

LITERATURE

Krejsa 1960

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larvae, 5.8 mm, 11.5 mm (W. Watson)
Transformation specimen, 17.5 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <5.8 mm
Transformation length: 16 mm through ca. 17.3–18.4 mm
Fin development sequence: P_1, C_1, 2D, A, C_2, 1D, P_2
Pigmentation: *Postflexion–transformation*—On mid- & hindbrain, spreading onto forebrain by ca. 9 mm; on ethmoid cartilage; at lower jaw symphysis; on inner surface of preopercle; 0–few on isthmus & ventrally on gut; dorsally on gut, spreading ventrad; on inner surface of P_1 base, becoming lighter, absent after ca. 13 mm; heavy along lower 6–7 P_1 rays; 15–22 on ventral margin of tail; over notochord, beginning posteriorly at ca. 11.5 mm; 4 saddles along D base, beginning posteriorly at ca. 12.5 mm.
Diagnostic features: Low myomere & fin-ray counts (myomeres 29–32, usually 9+22–23); supraocular spine present until ca. 9 mm; central preopercular spine much longer than the others; pigment on P_1 base becomes light after ca. 11 mm, usually absent after ca. 13 mm; 4 dorsal saddles, forming from posterior to anterior.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				42–46 45	42–46 44	49–54 51
BD/BL				23–26 24	23–25 24	22–26 25
HL/BL				27–32 30	26–28 27	27–30 29
HW/HL				55–65 60	53–60 57	57–69 65
SnL/HL				15–21 19	17–26 20	14–18 16
ED/HL				39–45 41	31–37 35	24–31 26
P_1L/BL				24–30 27	24–26 25	22–26 24
P_2L/BL				1–19 10	16–21 19	20–24 21
PrSL/HL				12–27 20	0–7 2	0–0 0

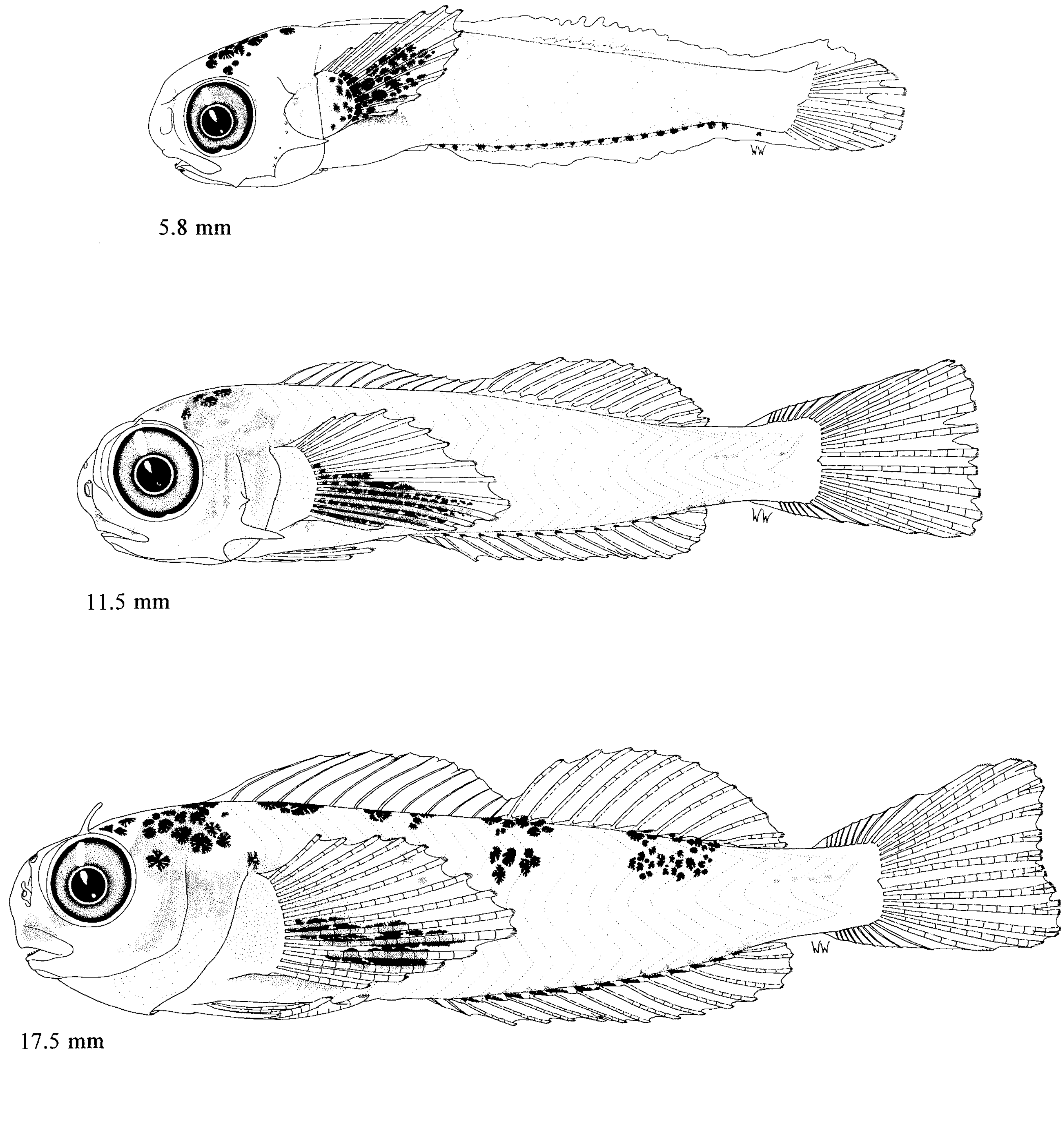


Figure Blenniidae 6. Early postflexion larva, 5.8 mm (CalCOFI 5908, station 133.70); postflexion larva, 11.5 mm; transformation specimen, 17.5 mm (CFRD Ref. Coll., Isla Socorro, nightlight and dip net collection, May 11, 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–36	35
Precaudal	10–11	10–11
Caudal	24–25	24–25
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	21–23	22
Anal spines	II	II
Anal rays	22–24	23
Pelvic	I,4	I,4
Pectoral	14–16	15
Caudal:		
Principal	7+6	7+6
Procurrent:		
Upper	6–8	7
Lower	6–8	7
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Bahía Sebastián Vizcaíno, Baja California & Gulf of California to Peru

Habitat: Demersal, shelters in crevices in rocky bottom; intertidal & shallow subtidal zones

Spawning season: Larvae collected throughout the year

ELH pattern: Oviparous; eggs attached to the nest wall & tended by the male parent; larvae are planktonic

LITERATURE

Brogan 1992
Springer 1962

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.5 mm (W. Watson)
Preflexion larva, 3.3 mm (W. Watson)
Flexion larva, 4.7 mm (W. Watson)
Postflexion larva, 6.4 mm (W. Watson)
Pelagic juvenile ("ophioblennius" stage), 40.2 mm (W. Watson)

* Information from M. Brogan (pers. comm., July 1995).
† Eye somewhat horizontally elongate, becoming round by the postflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS*
Shell diam.: 0.54–0.58 mm **Yolk:** Granular
No. of OG: **Diam. of OG:**
Shell surface: Smooth; basal adhesive pad
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 2.5 mm
Flexion length: ca. 4.5–6.1 mm
Transformation length: Variable within 36–66 mm range
Fin development sequence: P_1, C_1, 2D, A, 1D, C_2, P_2
Pigmentation: *Yolk-sac–preflexion*—Internally under brain; present or absent in roof of mouth; 0–2 at tip of snout; over gas bladder & gut; ventrally on yolk sac, condenses onto anterior part of gut & disappears by ca. 4 mm; on ventral margin of tail, at first 3–7 postanal myomeres; on inner surface of P_1. *Flexion–postflexion*—Over midbrain by 4.7 mm, hindbrain by 6 mm, forebrain by 14.8 mm; on inner surface of preopercle by 28.8 mm; ventral tail pigment disappears by 4.7 mm; P_1 pigment decreases after 7 mm, absent by 28.8 mm; stripe along D base after 28.8 mm & on A by ca. 37 mm; bar on hypural margin by 28.8 mm. *Transformation*—Body & fins become completely pigmented, darker patch behind eye.
Diagnostic features: Large hooked teeth in front of upper & lower jaws; small preopercular spines in flexion & early postflexion stages; no supraocular spines; elongate P_1 with pigment scattered along rays; ventral pigment on first few preanal myomeres in preflexion stage; high D & A ray counts; preanal myomeres 10–13 (usually 11–12), 35–36 total; very large size at transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	49–51 50	47–50 49	40–46 45	37–43 41	41–42 42	43–45 44
BD/BL	16–18 17	16–19 18	18–38 24	16–21 19	22–23 22	24–26 25
HL/BL	21–24 22	20–28 24	24–28 26	22–26 24	24–26 25	25–28 26
HW/HL	50–68 57	51–61 56	48–54 51	42–55 49	56–64 59	59–72 67
SnL/HL	11–22 17	18–36 26	27–31 29	21–31 26	14–25 19	13–22 19
ED/HL†	36–38× 31–38 37×34	26–43 28–35 32×30	26–33× 22–33 29×27	27–34 29	27–30 29	27–33 30
P_1L/BL	5–8 7	4–20 14	29–34 31	18–43 28	22–24 23	21–25 23
P_2L/BL	0–0 0	0–0 0	0–0 0	0–16 8	15–16 15	14–16 15
PrSL/HL	0–0 0	0–0 0	3–6 4	0–4 1	0–0 0	0–0 0

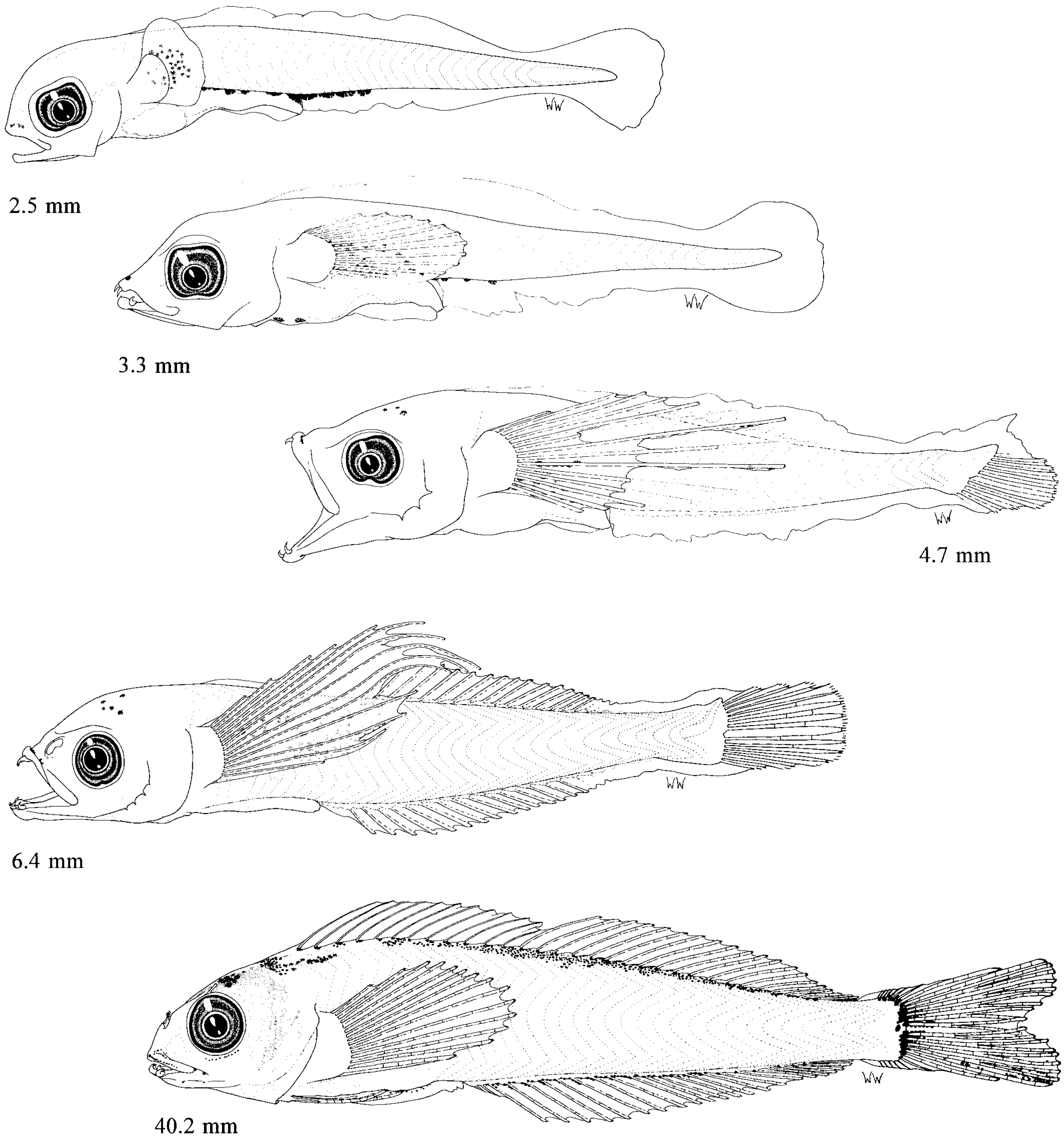


Figure Blenniidae 7. Yolk-sac larva, 2.5 mm (TO 58–1, station 11); preflexion larva, 3.3 mm (CalCOFI 5708, station 153G.35); flexion larva, 4.7 mm (IATTC Mazatlán Project, station 1–14–0); postflexion larva, 6.4 mm (CalCOFI 5209, station 145.5G.27); "ophioblennius" stage, 40.2 mm (CFRD Ref. Coll., Los Frailes, Baja California Sur, night light and dip net collection, March 23, 1957).

MERISTICS

	Range	Mode
Vertebrae:		
Total	47–50	48
Precaudal	14–16	15
Caudal	32–35	33
Fins:		
Dorsal spines	VII–IX	VIII
Dorsal rays	31–36	34
Anal spines	II	II
Anal rays	27–30	29
Pelvic	I,3	I,3
Pectoral	12–13	12
Caudal:		
Principal	6+5	6+5
Procurrent:		
Upper	6–9	7
Lower	6–9	7
Gill rakers:		
Upper	0	0
Lower	10	10
Branchiostegals	6	6

LIFE HISTORY

Range: Gulf of California to Peru, including offshore islands

Habitat: Shelters in mollusc tubes on rocky bottom in shallow water, often swims above bottom; mimics *Thalassoma lucasanum*

Spawning season: Larvae collected in late spring & summer

ELH pattern: Oviparous; eggs attached to the nest wall & tended by parent; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.6 mm (W. Watson)
Postflexion larvae, 7.2 mm, 13.6 mm (W. Watson)

* Information from M. Brogan (pers. comm., July 1995).

EARLY LIFE HISTORY DESCRIPTION

EGGS*

Shell diam.: 0.53–0.64 mm **Yolk:** Granular
No. of OG: **Diam. of OG:**
Shell surface: Basal adhesive pad
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.1 mm
Flexion length: ca. 6–7 mm
Transformation length: >13.6 mm, <26.8 mm
Fin development sequence: P_1, C_1, P_2, D & A
Pigmentation: *Preflexion*—Heavy external dorsal pigment, forebrain to nape; internally on hindbrain; externally on gular membrane & isthmus; heavy, anteriorly & dorsally on gut, lighter ventrally; series of large dorsolateral & ventrolateral melanophores along trunk & tail, a few, small, around notochord tip. *Postflexion*—Increasing head pigment; dorsolateral pigment on tail forms 4 saddles, ventrolateral pigment aggregates into corresponding ventral bars; saddles & bars extend onto D & A; internally above & below vertebral column posteriorly.
Diagnostic features: Series of large dorsolateral & ventrolateral melanophores in preflexion stage, becoming bars in postflexion stage; P_1 unpigmented; no head spines; large canine teeth in front of upper & lower jaws; myomeres 9–11+36–38; high D & A ray counts.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–42 38		47–50 49		43–47 45
BD/BL		15–23 19		22–24 23		14–17 15
HL/BL		18–30 22		26–27 27		22–24 23
HW/HL		60–89 71		76–87 81		47–56 50
SnL/HL		17–26 21		14–16 15		19–23 22
ED/HL		33–49 42		32–40 36		26–29 28
P_1L/BL		7–9 7		14–16 15		11–13 12
P_2L/BL		0–1 0.1		10–13 11		8–10 9

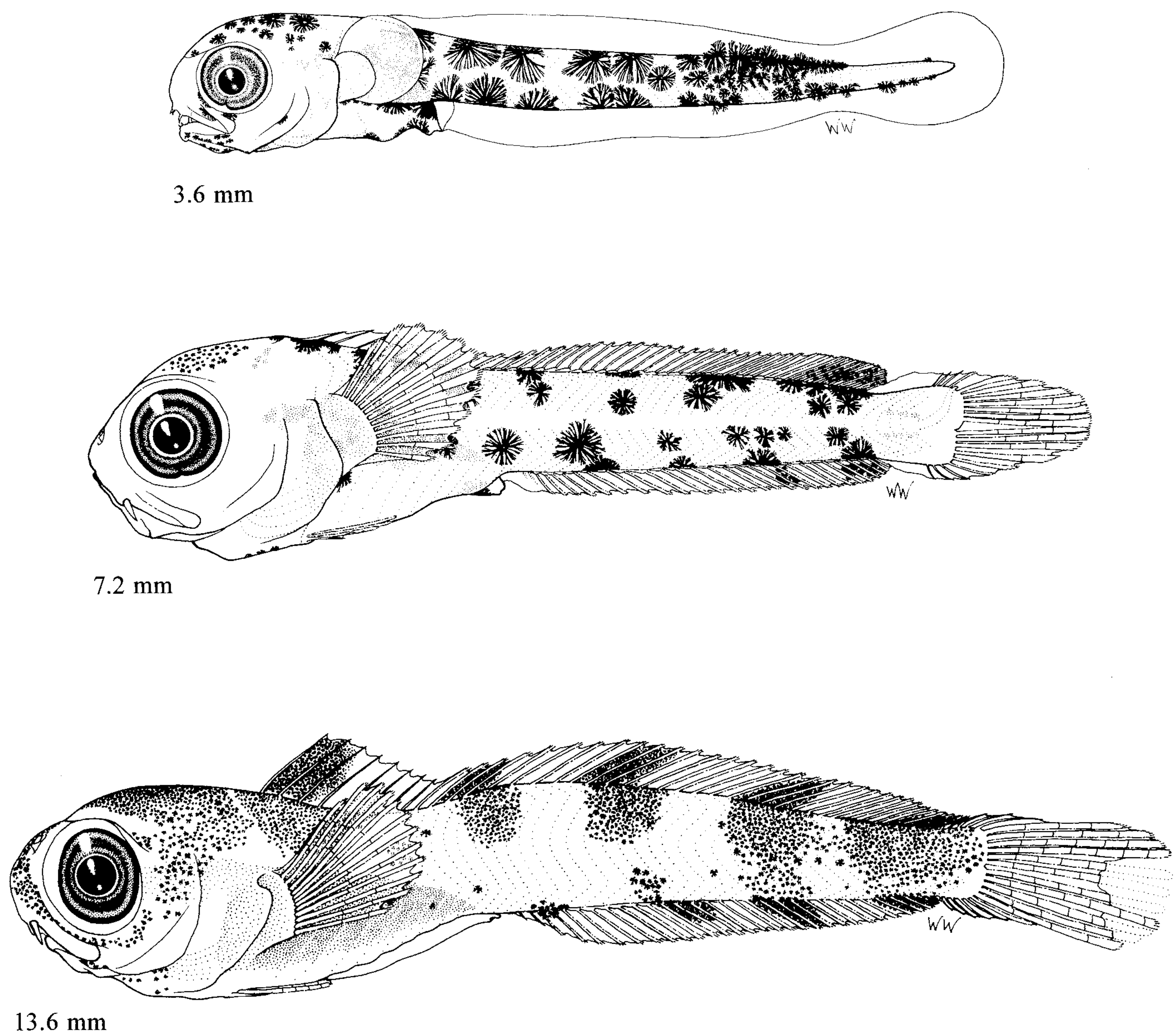


Figure Blenniidae 8. Preflexion larva, 3.6 mm (IATTC 90030, station PAB #1 Grn); early postflexion larva, 7.2 mm (CalCOFI 6208–9A, net mouth size series IV, 80 cm net); late postflexion larva, 13.6 mm (SIO 63–299).

ICOSTEIDAE: Ragfish

W. WATSON

Icosteus aenigmaticus, the only member of the family Icosteidae and the suborder Icosteoidei, ranges throughout the northern half of the CalCOFI study area, northward to Alaska and westward to Japan, in deep shelf waters and beyond. Eggs and larvae occur from time to time in CalCOFI collections, usually in small numbers, primarily north of Point Conception, California, seaward of the continental shelf, in winter and spring.

Ragfish are large (to ca. 2 m) carnivorous residents of the epi- and mesopelagic zones of the North Pacific Ocean. They are soft-bodied, moderately elongate (juveniles are deeper-bodied), with preanal length a little less than half of body length, head with blunt snout and small eyes, long-based dorsal and anal fins consisting only of segmented rays, a deeply indented caudal fin (rounded in juveniles), and no pelvic fins as adults (pelvic fins develop in larvae but are lost at the end of the juvenile stage). Adults are uniformly dark brown; juveniles typically are lighter brown and mottled.

Ragfish are oviparous, spawning large (2.8–3.1 mm), spherical, planktonic eggs that have a smooth, clear to amber or rose-tinted chorion, and contain an unpigmented homogeneous yolk with a single large (0.4–0.6 mm) oil globule. Larvae hatch at ca. 6.5 mm with an open mouth, pigmented eyes, a moderate yolk sac, and the characteristic larval pigment pattern largely in place. Larvae are elongate, becoming deeper-bodied during the flexion and postflexion stages, with preanal length less than half of body length. The gut initially is in the form of an S-shaped fold; it coils during the yolk-sac stage, and shortens as the coil tightens early in the preflexion stage. The eye, initially moderately large and round to distinctly oval, becomes consistently round and relatively smaller as the larvae develop. Up to seven small spines form along the posterior preopercular margin beginning early in the flexion stage. Median finfolds are very broad. The dorsal and anal fin pterygiophores form in the finfolds, well away from the body margin. The light to moderate larval pigmentation occurs primarily on the head, gut, dorsum and finfolds and changes relatively little during development.

Ragfish eggs are readily distinguished from all others in the CalCOFI area by chorion and oil globule diameter, and in late stages by the embryonic pigmentation. Larvae likewise are distinctive and should not be confused with any other fish larvae in the CalCOFI area, except perhaps during the preflexion stage when they share some pigment characters with larval Dover sole, *Microstomus pacificus* (see Pleuronectidae, this volume). Preflexion stage Dover sole are more elongate than ragfish, have fewer myomeres (50–55 vs. 66–70), have less dorsal and more ventral pigment, and lack the dorsal head pigment that ragfish always have.

The following description is based on literature (Matarese et al. 1984a, 1989; Kojima 1988c) and on examination of 21 larvae (5 yolk-sac, 7.3–9.7 mm; 9 preflexion, 8.1–11.1 mm; 5 flexion, 13.0–15.4 mm; 2 postflexion, 16.7–17.8 mm).

MERISTICS

	Range	Mode
Vertebrae:		
Total	65–70	68
Precaudal		23
Caudal		45
Fins:		
Dorsal spines	0	0
Dorsal rays	50–56	55
Anal spines	0	0
Anal rays	34–44	39
Pelvic*	0 or I,4–5	0 or I,4
Pectoral	20–22	21
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	6–9	
Lower	6–9	
Gill rakers:		
Upper	1	1
Lower	6	6
Branchiostegals	6	6

LIFE HISTORY

Range: North Pacific Ocean, Alaska to southern California to & Japan

Habitat: Epi- & mesopelagic

Spawning season: Winter–spring; larvae collected primarily January–May in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Kojima 1988c
Matarese et al. 1984a, 1989

* Adults lack pelvic fins.

EARLY LIFE HISTORY DESCRIPTION

EGGS

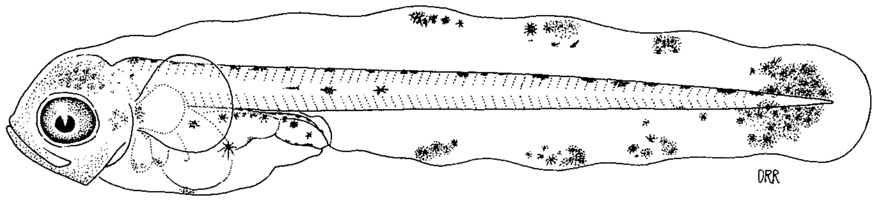
Shell diam.: 2.8–3.1 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.42–0.60 mm
Shell surface: Smooth
Pigment: Chorion sometimes amber to rose tinted; melanophores form on head, dorsum, finfold, & intestine of embryo, & on OG & yolk
Diagnostic features: Diameter, OG, pigmentation on late embryo

LARVAE

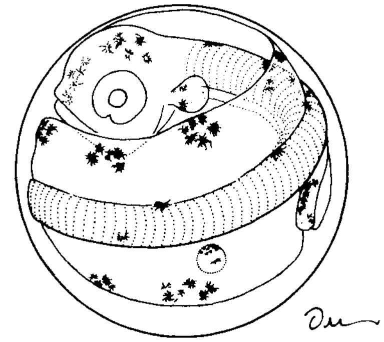
Hatching length: 6.5 mm
Flexion length: ca. 11–17 mm
Transformation length: >28.5 mm
Fin development sequence: C_1, P_1, P_2, D & A, C_2
Pigmentation: *Yolk-sac–preflexion*—On upper half of head, spreading ventrad & forming on dentary & gular region to completely surround head by ca. 10 mm; scattered in 1 or 2 rows along dorsal margin; few laterally, mainly along lateral midline; on upper half of gut, spreading ventrad to surround gut by ca. 10 mm; 0–few on ventral margin of tail, usually only on posterior half; 3–6 patches near margin along dorsal finfold; 3 patches on ventral finfold, heavy on caudal finfold & around notochord tip. *Flexion–postflexion*—Increasing on head, decreasing on dorsum & caudal region; on P_1 & P_2 bases by 13 mm; proximally along P_1 rays by 13.7 mm; along P_2 rays by ca. 15 mm.
Diagnostic features: Large larvae with short preanal length, moderately deep, rounded head, broad median finfold, early forming P_2, & small preopercular spines beginning in flexion stage (ca. 13 mm); myomeres 17–23+45–51=66–70 (usually 20+47–48); small melanophores cover much or all of head & gut, series along dorsum; 3 or more prominent blotches on dorsal & ventral finfolds; heavy caudal pigment, becoming lighter in postflexion stage.

MORPHOMETRICS (range & mean in %)

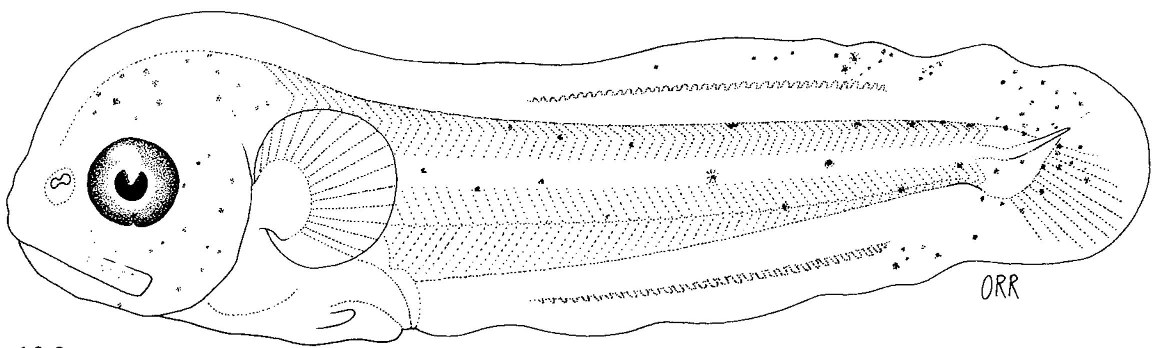
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	39–47 43	36–46 42	37–41 38	42–45 43		
BD/BL	16–19 18	15–22 19	22–28 24	27–32 30		
HL/BL	16–19 18	18–22 20	17–25 20	23–23 23		
HW/HL	64–76 70	58–82 69	77–98 85	85–104 95		
SnL/HL	13–23 18	15–24 21	20–27 24	22–30 26		
ED/HL	35–45 38	33–39 36	32–38 35	31–36 33		
P_1L/BL	4–6 5	5–6 6	6–9 7	11–11 11		
P_2L/BL	0–0 0	0–0.4 0.04	1–4 2	6–6 6		



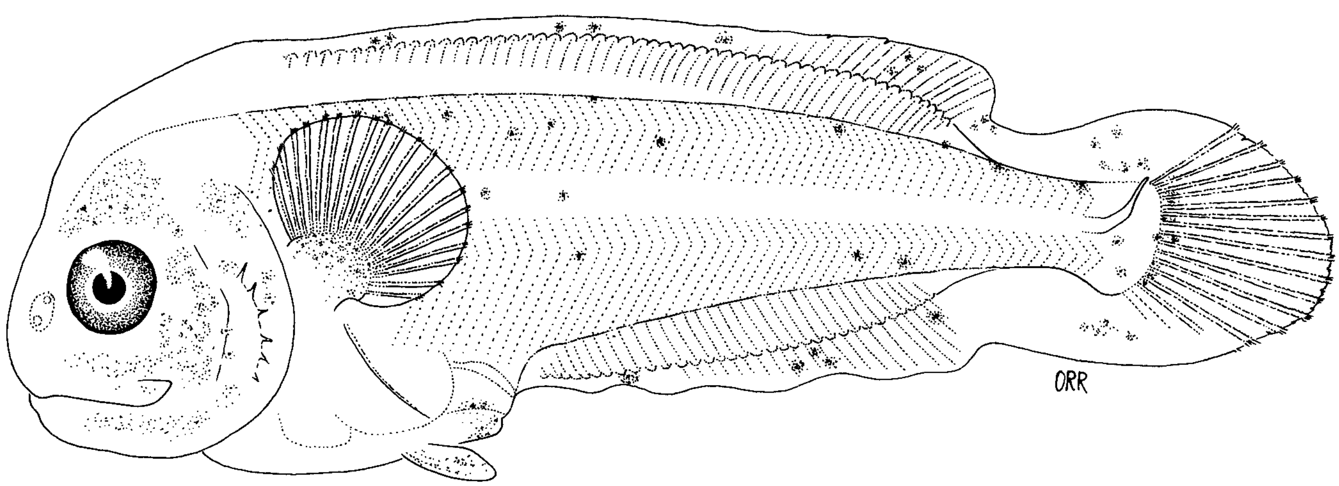
9.5 mm



2.8 mm



10.2 mm



28.5 mm

Figure Icosteidae 1. Egg, 2.8 mm; preflexion larva, 9.5 mm; flexion larva, 10.2 mm; postflexion larva, 28.5 mm (Matarese et al. 1984a).

CALLIONYMIDAE: Dragonets

W. Watson

Callionymidae, one of the two members of the perciform suborder Callionymoidei, contains about 130 species in 18 genera (Houde 1984b; Nelson 1994). The family is represented in the eastern Pacific Ocean by a single species, *Synchiropus atrilabiatus* (Nakabo 1982 placed *S. atrilabiatus* in *Foetorepus*), which ranges from the lower Gulf of California and southern tip of Baja California to Ecuador. A few larvae and small pelagic juveniles have been taken in CalCOFI collections from the Gulf of California and near Cabo San Lucas, but they are far more common farther south, off Central America.

Adult callionymids are small (typically <10 cm) demersal residents on soft bottom in all warm seas. They are characterized by having large, more or less dorsal eyes, small mouth, a large preopercular spine often bearing one or more secondary spines, and two separate dorsal fins. Sexual dimorphism is common. Some of the more colorful species are well known in the aquarium trade.

Spawning has not been described for *S. atrilabiatus*, but has been documented for other callionymids (e.g., Breder and Rosen 1966). Callionymids are oviparous, spawning small (0.55–0.97 mm), transparent, spherical planktonic eggs that lack oil droplets (e.g., Houde 1984b). The chorion may be ornamented or not, depending on species. Larvae hatch at a length of 1-2 mm, initially lack a functional mouth, and have unpigmented eyes and a large yolk sac (e.g., Mito 1966; Russell 1976). Preanal length is about half of body length. Following yolk absorption, larvae are small, robust, and somewhat compressed, but become more cylindrical in the postflexion stage. The characteristic preopercular spine begins to develop during, or just after, notochord flexion. The elongate notochord tip is prominent well into the postflexion stage. The caudal fin begins to form late in the preflexion stage, anal and second dorsal fins begin to form late in flexion, and the others form early in the postflexion stage. Initially, pigmentation is light, but it quickly becomes rather heavy on the head, the gut, and the dorsal and ventral margins of the body. A series of melanophores along the lateral midline of the tail is common.

Callionymid larvae are relatively easily distinguished from other larvae on the basis of their characteristic pigment pattern, elongate notochord tip, low myomere count (21–22), and the preopercular spine of postflexion and older specimens. The following description of *S. atrilabiatus* is based on detailed examinations of 23 larvae and transformation specimens (5 preflexion, 2.5–3.8 mm; 5 flexion, 4.1–4.7 mm; 8 postflexion, 4.4–5.1 mm; 5 tranformation, 8.3–12.5 mm) and five juveniles (14.2–21.6 mm).

MERISTICS

	Range	Mode
Vertebrae:		
Total	21	21
Precaudal	7	7
Caudal	14	14
Fins:		
Dorsal spines	IV	IV
Dorsal rays	9–10	9
Anal spines	0	0
Anal rays	8–9	8
Pelvic	I,5	I,5
Pectoral	19–24	21–22
Caudal:		
Principal	5+5	5+5
Procurrent:		
Upper	2–3	3
Lower	2	2
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Southern tip of Baja California Sur & lower Gulf of California to Ecuador

Habitat: Soft bottom of outer continental shelf, offshore banks, & seamounts

Spawning season: Larvae collected throughout the year; young larvae taken primarily during summer

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.5 mm, 3.6 mm (N. Arthur)
Flexion larva, 4.1 mm (N. Arthur)
Postflexion larvae, 5.6 mm, 8.3 mm (N. Arthur)

* Eye is horizontally elongate; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 4–4.7 mm
Transformation length: ca. 8.3–12.5 mm
Fin development sequence: C_1, 2D & A, 1D & C_2, P_1, P_2
Pigmentation: *Preflexion*—Dorsally on head to anterior margin of eye; under brain & in roof of mouth; little on lower jaw & gular membrane; little along opercular series of bones; completely surrounding gut; dorsolaterally & ventrolaterally on body to ca. myomere 20; along lateral midline at ca. myomeres 6–19. *Flexion–postflexion*—Increasing pigment on all areas; on branchiostegal membrane & P_1 base by ca. 4 mm; extending onto D by ca. 8.3 mm. *Transformation*—Uniform body pigment becoming mottled pattern.
Diagnostic features: Long, unpigmented notochord tip, extensively pigmented on dorsum, ventrum, & on lateral midline of tail; large preopercular spine after ca. 5 mm; myomeres 9–10+11–13=21–22.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		51–58 54	50–58 54	59–70 63	59–66 61	56–58 57
BD/BL		24–36 29	24–32 28	27–34 30	23–27 26	22–27 25
HL/BL		26–30 28	26–35 30	35–41 38	34–39 36	34–39 36
HW/HL		59–63 61	58–63 60	59–71 67	62–77 70	59–78 70
SnL/HL		20–27 23	15–21 18	11–16 14	13–21 16	14–18 16
ED/HL*		37–43× 28–35 39×32	31–37× 27–32 35×30	32–38× 24–34 34×31	29–33× 27–33 31×30	26–31× 18–31 28×26
P_1L/BL		4–8 6	6–8 7	8–12 9	10–13 12	14–15 14
P_2L/BL		0–0 0	0–3 1	0–12 6	10–17 13	19–21 20

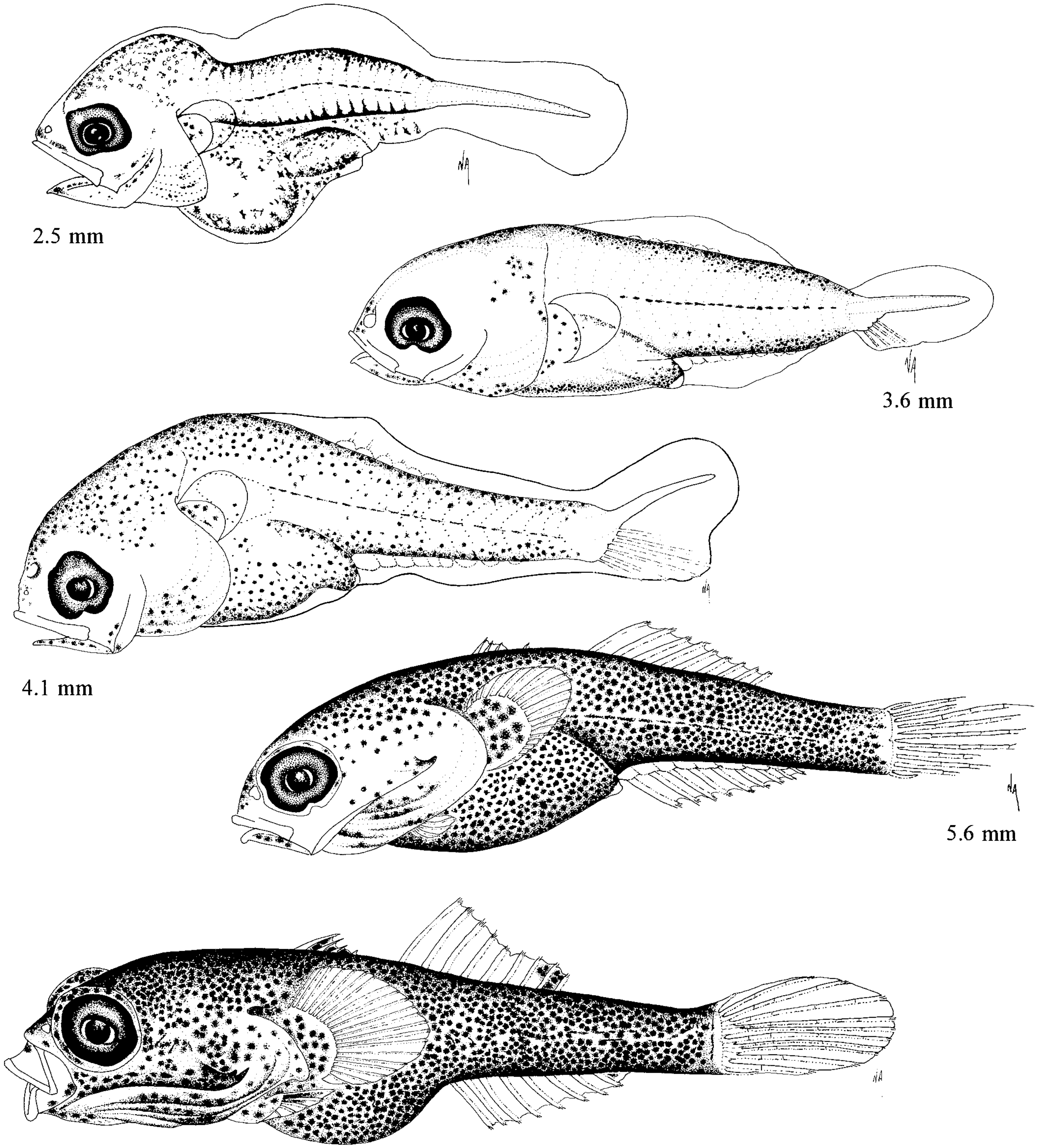


Figure Callionymidae 1. Early preflexion larva, 2.5 mm (CalCOFI 5209, station 147G.31); late preflexion larva, 3.6 mm (EASTROPAC I, station 14.001); flexion larva, 4.1 mm (TO 59–1, station 28); postflexion larva, 5.6 mm (EASTROPAC, station F44); late postflexion larva, 8.3 mm (CalCOFI 5602, station 157G.85).

GOBIOIDEI

W. WATSON

Gobioidei is a very large suborder (ca. 2000 species) of marine, estuarine and freshwater, primarily benthic, perciform fishes. Monophyly of the suborder is well established and accepted, but classification within the suborder is unsettled although it has been the subject of considerable study. Current classifications separate the gobioids into two to seven families, not all monophyletic. Here we follow Eschmeyer's (1990) classification in which the Gobioidei contains six families, and we add the Schindleriidae as a seventh family following Johnson and Brothers (1993). Three of the seven families, Eleotridae, Gobiidae, and Microdesmidae, occur in the CalCOFI study area, and Schindleriidae (*Schindleria praematura*) occurs nearby, at the Islas de Revillagigedos, Mexico. See Miller (1973), Hoese (1984), Harrison (1989), Pezold (1993), Nelson (1994), and references cited in those works for discussions of gobioid classification.

Gobioids are oviparous, with round to elliptical eggs commonly smaller than ca. 2 mm (longest axis ranges from ca. 0.4–5.8 mm) that are attached to a nest substrate via adhesive filaments at the basal pole (Ruple 1984). Eggs commonly contain several small oil globules that may condense to a single globule before hatching. Incubation periods typically are on the order of a day to a week. Larvae hatch with unformed to open mouth, unpigmented to fully pigmented eyes, and moderate to small yolk sac. Larvae are moderately to very elongate, slightly to strongly compressed, usually with preanal length a little less, to a little more, than half of body length (nearer one-third BL in the amblyopines). The gut commonly is more or less straight, but it is coiled in the amblyopines (Ruple 1984; Leis and Trnski 1989) and is folded or looped posteriorly in the xenisthmids and in at least some of the eleotrids (Leis et al. 1993; this study). Larval gobioids typically have a prominent gas bladder located midway to posteriorly over the gut; it moves posteriorly with development in the eleotrids, microdesmids, xenisthmids, and schindleriids (Leis and Rennis 1983; Ruple 1984; Watson et al. 1984b; Leis et al. 1993; this study). The head typically is small to moderate with small to moderate, round or oval eyes, and a rounded snout. There are no spines on the head and pectoral girdle, except in the xenisthmids (Leis et al. 1993). Larval pigmentation ranges from nearly absent to nearly complete. Almost all larval gobioids are pigmented dorsally on the gas bladder. Pigmentation dorsally on the gut and along the ventral margins of the gut and tail are common as well, and many species are pigmented on the dorsum of the trunk and/or tail.

At least 2 eleotrid, 21 gobiid, and 2 microdesmid species occur in the CalCOFI study area. Larvae of 17 of these 25 species have been identified in CalCOFI ichthyoplankton samples, primarily from inshore stations south of Point Conception, California.

Families included: Eleotridae
Gobiidae
Microdesmidae

ELEOTRIDAE: Sleepers

W. WATSON

The taxonomic status of the eleotrids is not fully resolved; some workers consider them a gobiid subfamily (e.g., Hoese and Gill 1993) while others place them in their own family (e.g., Birdsong et al. 1988; Nelson 1994). We follow Eschmeyer (1990) in treating them as a separate family. At least two (Table Eleotridae 1) of the approximately 150 eleotrid species (Nelson 1994) occur in the CalCOFI study area (Hubbs et al. 1979). *Dormitator latifrons* has been reported as far north as Palos Verdes, California but is primarily tropical and subtropical. *Eleotris picta* ranges from the Gulf of California to Ecuador and enters the CalCOFI study area at the southern tip of Baja California Sur. Larvae tentatively identified as *D. latifrons* have been taken at nearshore CalCOFI stations off southern Baja California Sur and larvae of another species, possibly *Erotelis armiger*, have been taken at nearshore stations in the vicinities of Bahía Asuncion and Bahía San Juanico, Baja California Sur. No larval *Eleotris picta* have been recognized in CalCOFI collections.

Eleotrids are small to medium-size (most species <30 cm, largest to ca. 60 cm), primarily benthic residents of soft bottom in estuarine and freshwater habitats. Some species occur in shallow coastal marine waters and at least one species is a coral reef resident. Almost all are tropical and subtropical. Eleotrids closely resemble gobiids but differ in having six branchiostegal rays (five in gobiids), pelvic fins well separated (pelvic fins united in a cup-like disc in most gobiids), and (commonly) a longer caudal peduncle. Most eleotrids are cylindrical to somewhat depressed, often with a somewhat flattened head. There are two separate dorsal fins, the first of 2–10 (commonly 6 or 7) spines and the second of 1 spine and 6–17 (usually ≤10) segmented rays. The anal fin contains 1 spine and 6–13 (usually ≤10) segmented rays. The caudal fin is rounded, usually with 15 principal rays. Pigmentation is cryptic, usually dark brown to black, often with mottling or bars.

Little eleotrid early life history information is available. *Eleotris oxcephala* spawns pear-shaped eggs ca. 0.3 × 0.4 mm that are attached via adhesive filaments at the basal (narrow) pole of each egg to a nest wall (Dôtu and Fujita 1959). The eggs are tended by both parents. Larval *E. oxycephala* are 0.9–1.1 mm long at hatching and have an unformed mouth, unpigmented eyes, and a moderate yolk sac (op. cit.). Following yolk absorption, eleotrid larvae are moderately elongate and compressed, becoming strongly compressed in some species, with preanal length just under 50% BL, increasing to just over 50% BL by the postflexion stage. The head is moderately small, with moderate to small, often oval, eyes. There are no spines on the head or pectoral girdle. The gut initially is straight. In at least some species the hindgut develops an S-shaped bend posteriorly, then folds, with the terminal section becoming nearly vertically oriented; this process begins late in the preflexion stage or during notochord flexion. The prominent gas bladder shifts posteriorly from a position just behind the level of the pectoral fin base early in the preflexion stage to a position just ahead of the anus by mid- to late postflexion stage. Larval pigmentation is light, occurring primarily on the ventral margin, dorsally on the gas bladder, and on the caudal fin. Some species are lightly pigmented on the dorsal margin of the tail and on the head, as well. Pigmentation typically changes little during larval development.

Larval eleotrids closely resemble larval gobiids but tend to be more compressed, often have somewhat vertically elongate eyes (gobiids typically have round or horizontally elongate eyes), and may have a characteristic fold in the hindgut which the gobiids lack. Most eleotrids have ≤10 soft rays in the anal and second dorsal fins, while gobiids commonly have >10 in each fin. Postflexion stage eleotrids typically have a longer caudal peduncle than the gobiids. Larvae of the two eleotrid species reported from the CalCOFI study area may be distinguishable by meristic characters (Table Eleotridae 1); it is unknown whether there are other distinguishing characters. The putative *Erotelis armiger* larvae are easily distinguished from *D. latifrons* by differences in pigmentation on the dorsum, in the otic capsules, internally in the tail, and on the anal and caudal fins (c.f. Figures Eleotridae 1 and 2). Dorsal and anal fin-ray counts readily separate postflexion stage larvae as well: *D. latifrons* usually has D VII+I, 8–9; A I, 9; putative *E. armiger* has D VI+I, 11–12; A I, 10–11.

The following description is based on examination of two preflexion (1.7 and 2.2 mm) and nine postflexion (3.5–9.9 mm) larvae tentatively identified as *Dormitator latifrons*, and on three juvenile *D. latifrons* (15.3–25.0 mm). The putative *E. armiger* larvae are not described separately, but are shown in Figure Eleotridae 1. Fin-ray and myomere counts for these larvae are consistent with fin-ray and vertebral counts for *E. armiger*, but a positive identification cannot be made since intermediate specimens that would link the larvae with adults are unavailable and *E. armiger* has not been reported from the Pacific coast of Baja California Sur (it has been recorded at La Paz, on the Gulf coast: Jordan and Evermann 1896; Abitia-Cárdenas et al. 1994). Meristic data were obtained from Miller and Lea (1972) and from counts made during this study. Ecological information is from Hubbs (1953) and Eschmeyer et al. (1983).

Table Eleotridae 1. Meristic characters for the eleotrid species in the California Current vicinity. Both have I,5 pelvic fin rays, 8+7 principal caudal fin rays, and 6 branchiostegal rays.

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	P_1	C_1
Dormitator latifrons	11–12	15–16	27–28	VII–VIII+I,8–9	I,8–9	13–15	9–10+8–10
Eleotris picta	10	15	25	V+I,8	I,8	18	11–12+11–12

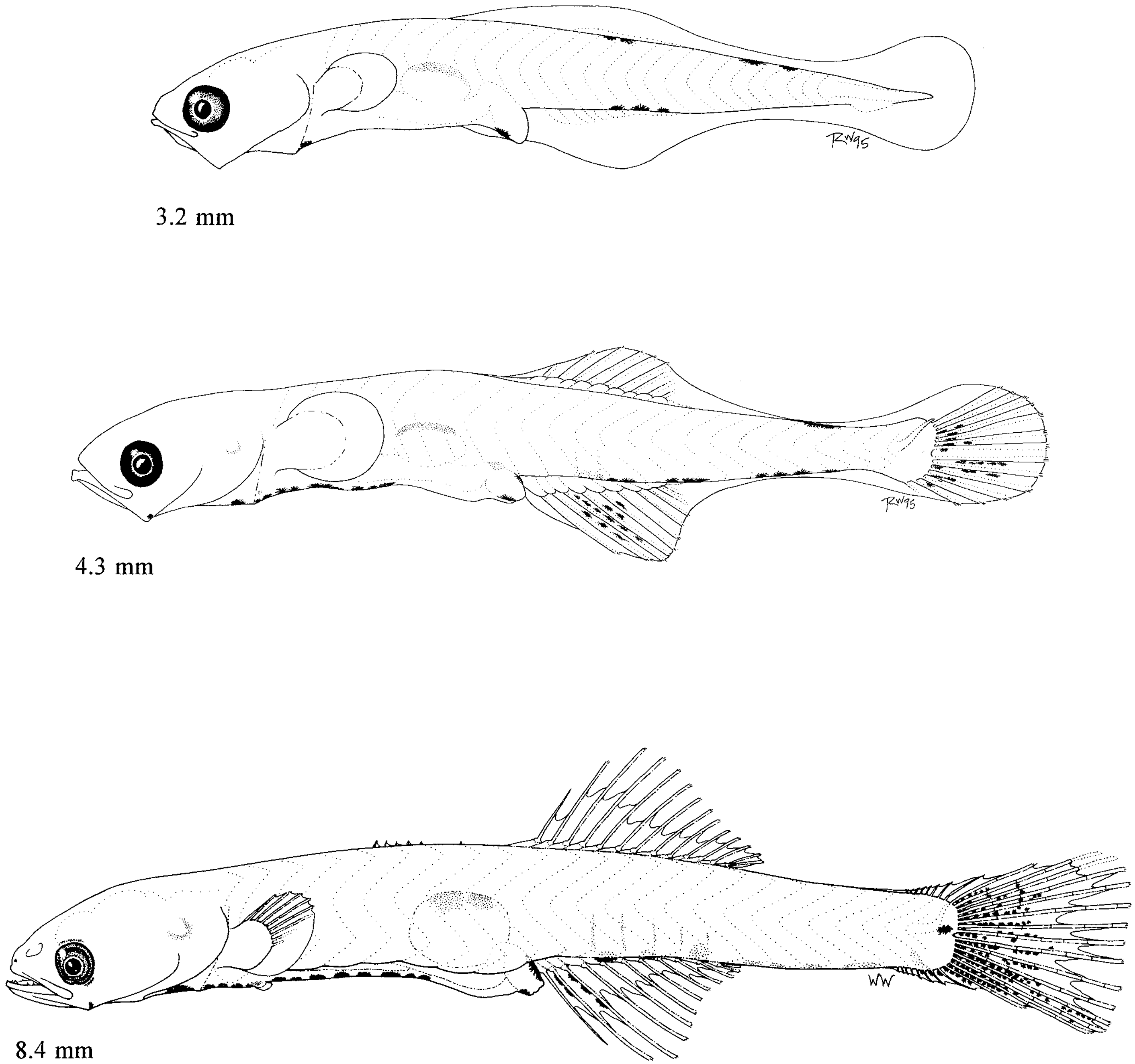


Figure Eleotridae 1. Eleotridae, perhaps *Erotelis armiger*: preflexion larva, 3.2 mm (CalCOFI 5909, station 137.23; original illustration by R. C. Walker); late flexion larva, 4.3 mm (CalCOFI 5909, station 127.34; original illustration by R. C. Walker); postflexion larva, 8.4 mm (CalCOFI 5210, station 137.23; original illustration by W. Watson).

MERISTICS

	Range	Mode
Vertebrae:		
Total	27–28	27
Precaudal	11–12	12
Caudal	15–16	15
Fins:		
Dorsal spines	VII–VIII+I	VII+I
Dorsal rays	8–9	8
Anal spines	I	I
Anal rays	8–9	9
Pelvic	I,5	I,5
Pectoral	13–15	14–15
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–10	10
Lower	8–10	9
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Palos Verdes, California, to Guayaquil, Ecuador, including Gulf of California

Habitat: On soft bottom in estuaries, bays & shallow coastal waters; enters freshwater

Spawning season:

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 1.7 mm (W. Watson)
Postflexion larvae, 3.5 mm, 8.0 mm (R. C. Walker)

* Larvae described here are tentatively identified as *D. latifrons* based primarily on meristic characters; however, owing to the lack of late postflexion stage & transformation specimens this identification cannot be confirmed; juveniles are *D. latifrons.*

† Eyes are somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

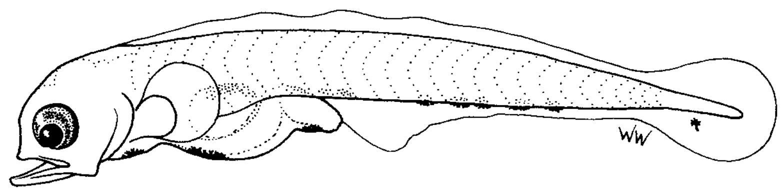
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

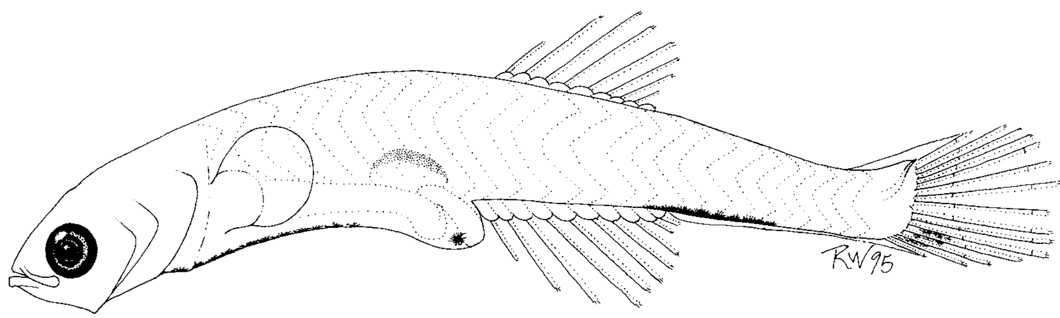
Hatching length: <1.7 mm
Flexion length: >2.2 mm, <3.5 mm
Transformation length: >9.9 mm, <15.0 mm
Fin development sequence: C_1 & A & 2D, 1D & C_2, P_1, P_2
Pigmentation: *Preflexion*— ≥3 on ventral margin of gut, just posterior to cleithral symphysis, at midgut, & just anterior to anus; dorsally on gas bladder; 0–1 dorsally at terminus of gut; on ventral margin of tail at postanal myomeres 1 or 2 & series from midtail to myomere 20 or 21; 1 ventrally on caudal finfold. *Postflexion*—1 (small) in otic capsule by ca. 6 mm; 1 at angular; 1–3 on ventral margin of isthmus; series on ventral margin of gut to level of gas bladder; 0–1 each dorsally & ventrally at terminus of hindgut (usually 0 dorsally; 1 ventrally); dorsally on gas bladder; 2–6 pairs along A base; ca. 4–8 on ventral margin of caudal peduncle; proximally on lower C_1 rays; distally on C_1 rays by ca. 6.5 mm, appearing as ventral blotch, dorsal & ventral blotches, or band across all rays.
Diagnostic features: No pigment on haemal arches of anterior caudal vertebrae or on A rays; C pigment only proximally on lower rays before ca. 6.5 mm, then in discrete blotches or band; D usually VII+I,8 & A usually I,9 (2D & A countable by ca. 4 mm, 1D by ca. 6.5 mm); P_1 usually 14–15 (countable by ca. 9 mm).

MORPHOMETRICS (range & mean in %)

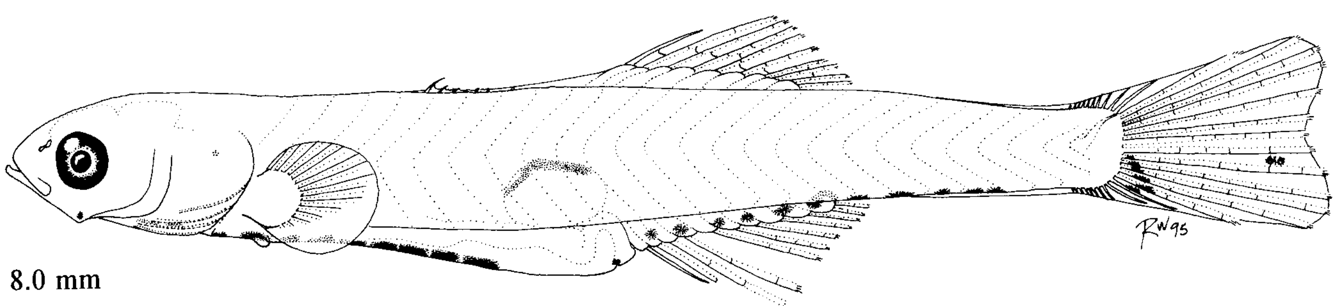
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–48 45		51–57 54		57–58 57
BD/BL		15–17 16		13–17 14		22–26 23
HL/BL		18–23 21		22–24 23		30–32 31
HW/HL		56–56 56		32–43 36		56–60 57
SnL/HL		14–16 15		18–23 20		19–20 19
ED/HL†		28–38× 30–38 33×34		17–23× 19–24 19×21		26–28× 23–27 27×26
P_1L/BL		6–7 7		6–10 7		21–25 24
P_2L/BL		0–0 0		0–2 0.4		18–23 21



1.7 mm



3.5 mm



8.0 mm

Figure Eleotridae 2. Preflexion larva, 1.7 mm (CalCOFI 7210, station 157G.150); early postflexion larva, 3.5 mm (CalCOFI 7210, station 157G.150); later postflexion larva, 8.0 mm (CalCOFI 6001, station 153.70).

GOBIIDAE: Gobies

W. WATSON

Gobiidae contains about 1875 species in 212 genera (Nelson 1994); about 21 species in 16 genera occur in the CalCOFI study area (Table Gobiidae 1). The larvae of most of these are restricted to nearshore waters and rarely occur in CalCOFI samples. A few species have larval distributions that extend, or are centered, farther from shore, and these do occur regularly in CalCOFI samples. The more offshore species are *Coryphopterus nicholsii*, *Lepidogobius lepidus*, *Lythrypnus dalli*, and *L. zebra*.

Most adult gobies are small (<10 cm) demersal residents of bays, estuaries, lagoons, and the nearshore open coast. There are many freshwater species, as well. The marine species occupy a variety of habitats ranging from intertidal mudflats to reefs as deep as 150 m. Many of the soft-bottom residents shelter in invertebrate burrows or construct their own burrows. Gobies are elongate, somewhat compressed to somewhat depressed, with preanal length usually about half of body length (shorter in the amblyopines). There are one or two dorsal fins (most commonly two); when two fins are present, the first is composed of a few flexible spines and the second of a spine (usually) and a few to several segmented rays. The anal fin usually contains one spine in addition to the few to several segmented rays. The pelvic fins commonly are connected to form a cup-like disc. Pigmentation is extremely variable, ranging from drab and cryptic to bright and strikingly patterned. Some species are nearly transparent. Some of the larger species are utilized in subsistence fisheries and some of the more colorful species are utilized in the aquarium trade.

Gobies are oviparous, with elliptical, attached, demersal eggs that typically are ca. 2–4 mm long and contain one to several oil globules. Parental care of the nest is common. The planktonic larvae hatch with pigmented eyes, a functional mouth, and a small yolk sac. Larvae are elongate, with preanal length ca. 45–60% and with a prominent gas bladder more or less centrally located over the straight gut. In older postflexion stage larvae, the pelvic fins are united to form a cup-like disc and two separate dorsal fins are apparent (in most species). Larval pigmentation ranges from light to heavy, but most commonly is relatively light through at least the beginning of the postflexion stage, with melanophores primarily dorsally on the gas bladder, dorsally and ventrally on the gut, along the ventral margin of the tail, and often on the dorsal margin of the trunk and/or tail.

Larval gobiids are distinctive and probably will not be confused with any other fish larvae in the CalCOFI study area except eleotrids, and during the preflexion stage, perhaps scarids. The gobiids tend to be less compressed than the eleotrids and scarids, and to have round or horizontally elongate eyes in contrast to the somewhat vertically elongate eyes of the eleotrids and scarids. The gobiids lack the fold in the hindgut that is typical of the eleotrids and the anterior gut fold and gut rugosity that are characteristic of the scarids. Identification to species of the gobiid larvae is more difficult. For larval gobiids collected off California and northern Baja California, a combination of dorsal pigment characters and myomere counts usually will reduce the number of potential identifications for any specimen from 13 or 14 to 2 or 3 (Table Gobiidae 2); fin ray counts (Table Gobiidae 1) may aid in the identification of postflexion stage specimens. The following descriptions usually will permit identification to the species level (note that some descriptions are based on incomplete developmental series: Table Gobiidae 3). Some species cannot always be unequivocally separated. These are: *Lythrypnus dalli* and *L. zebra* prior to completion of the anal and second dorsal fins; *Clevelandia ios* and lightly pigmented (dorsally) specimens of *Lepidogobius lepidus* from late in the preflexion stage through early flexion; and *C. ios*, *Ilypnus gilberti* and *Quietula y-cauda* during all larval stages.

The following species accounts are based primarily on detailed examinations of 12–40 specimens each of 13 species (Table Gobiidae 3); the description of *Tridentiger trigonocephalus* was taken primarily from the literature (Dôtu 1958; Wang 1981). Unpublished work on *Clevelandia*, *Ilypnus*, *Lepidogobius* and *Quietula* by Michael Sowby and James Rounds was instrumental in completing those species' descriptions.

The primary sources for adult meristic, distribution, and habitat data were Miller and Lea (1972), Thompson et al. (1979), Eschmeyer et al. (1983), and Clothier and Baxter (unpublished manuscript). Additional counts were made during the present study.

Table Gobiidae 1. Meristic characters for the goby species likely to be encountered in the CalCOFI study area. All species have 5 branchiostegal rays (rarely 3 or 4 in *Clevelandia ios* and *Coryphopterus nicholsii*), 8+7 principal caudal fin rays, and I,5 pelvic fin rays.

Species	Vertebrae	Fin rays				GR
		D	A	P_1	C_2	
Acanthogobius flavimanus	33–35	VIII–IX+0–I,12–14	0–I,11–12	20–22	11–13+11–12	3+9
Bathygobius ramosus	26	V–VI+0–I,8–10	0–I,7–10	17–21	7–9+6–8	0+8
Clevelandia ios	36–37	IV–VI+0–I,14–17	0–I,13–17	18–21	8–11+7–11	1–3+5–7
Coryphopterus nicholsii	26	V–VIII+I–II,9–15	0–I,11–13	16–24	11–13+10–12	1–2+8–9
C. urospilus	26	VI+I,8–9	I,8–9	18–21	8–10+8–9	1–2+5–6
Ctenogobius sagittula	26	VI+I,12–13	I,13–14	16–17	7–8+7–8	1+4–5
Eucyclogobius newberryi	33–35	VI–VII+I,9–12	I,8–11	19–21	9–12+9–11	1–2+7–8
Gillichthys mirabilis	31–33	IV–VIII+0–III,9–14	I–III,8–14	18–23	9–13+8–13	1–4+9–12
Gobulus crescentalis	26–27	VII+I,11	I,9–10	16–18	6–7+5–6	1+7–8
Ilypnus gilberti	32–34	V+0–I,13–17	0–I,12–16	21–22	7–9+7–9	3–5+10–11
Lepidogobius lepidus	37–38	VI–IX+0–I,14–18	0–I,12–16	20–24	10–15+9–14	2–3+8–11
Lethops connectens	34–36	VI–VII+0–I,12–14	0–I,12–13	20–21	9–13+9–12	1–2+9–11
Lythrypnus dalli	26–27	VI–VII+0–I,15–19	0–I,12–15	16–20	7–9+6–9	0–1+7–10
L. pulchellus	26–27	VI+I,10–12	I,8–10	17–21	6–7+5–6	1–2+6
L. zebra	26	VI+0–I,11–14	0–I,8–11	18–21	6–8+5–7	0–2+9
Microgobius brevispinis	27	VII+I,15–18	I,15–18	19–22	9–10+9	4+16
M. cyclolepis	27	VII+I,14–16	I,15–16	22–24	9–10+8–9	5+16
M. tabogensis	27	VII+I,15–17	I,15–17	19–23	8–9+7–9	4+13
Quietula y-cauda	33–34	IV–V+I,13–15	0–I,12–15	19–22	7–9+7–9	2–4+8–10
Tridentiger trigonocephalus	26–27	VI+I,11–12	I,10–11	20–22	11–13+10–13	2–3+7–8
Typhlogobius californiensis	30–32	II–III+0–I,10–12	I,7–10	15–16	8–9+7	2+8–11

Table Gobiidae 2. Characters useful in the identification of larval gobiids from California and northern Baja California. Myomere counts are: range (above), typical counts (below, in parentheses).

	Number of dorsal melanophores prior to transformation		Myomere counts		
	Usually:				
Species	≤2	≥3	Preanal	Postanal	Total
Acanthogobius flavimanus	X		10–13 (11–12)	21–24 (22–23)	32–35 (34)
Clevelandia ios	X		13–16 (14–15)	18–23 (21–22)	33–37 (35–36)
Coryphopterus nicholsii		X	9–11 (10)	15–18 (16–17)	25–28 (26–27)
Eucyclogobius newberryi		X	13–14 (13–14)	18–20 (19–20)	32–34 (32–33)
Gillichthys mirabilis		X	13–17 (13–14)	14–19 (17–19)	29–33 (32)
Ilypnus gilberti	X		11–13 (12)	19–22 (20–21)	31–34 (32–34)
Lepidogobius lepidus	X*	X*	13–16 (14–15)	21–24 (23)	36–39 (36–38)
Lethops connectens		X	13–15 (15)	19–21 (21)	33–36 (34–36)
Lythrypnus dalli		X	8–10 (9)	17–19 (17)	25–27 (26)
L. zebra		X	8–10 (9)	16–18 (17)	25–27 (26)
Quietula y-cauda	X		11–15 (13–14)	19–22 (20–21)	31–35 (33–34)
Tridentiger trigonocephalus	X		10–13	13–14	24–26
Typhlogobius californiensis		X	15–17 (16)	14–16 (15)	30–32 (31–32)

*Usually ≥3 in preflexion and early flexion stages, ≤2 in later flexion and postflexion stages.

Table Gobiidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the gobiid species descriptions. An "L" indicates literature used in the description.

Species	Eggs	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Acanthogobius flavimanus	L[a,b]	5 4.5–5.3	10 5.0–6.9	1 6.7	5 8.8–10.8	0	4 34.1–38.9
Clevelandia ios	L[c], 7	2 2.0–2.3	10 3.5–5.5	5 5.0–6.0	10 6.1–14.1	5 14.2–17.2	5 17.6–23.0
Coryphopterus nicholsii	L[b,d]	1 2.8	10 2.9–6.1	5 5.8–6.8	8 6.6–15.5	5 16.5–19.5	5 21.8–25.9
Eucyclogobius newberryi	0	0	1 4.3	0	10 7.3–13.8	3 13.4–14.9	3 16.3–23.2
Gillichthys mirabilis	L[e]	0	6 3.8–5.1	0	7 7.0–11.4	0	5 12.4–17.8
Gobulus crescentalis	0	0	9 2.3–3.4	1 3.9	10 5.2–7.7	0	1 14.9
Ilypnus gilberti	L[f]	0	10 3.8–5.4	5 5.0–5.7	10 6.0–15.0	5 13.8–16.1	5 20.8–23.8
Lepidogobius lepidus	L[b]	5 3.2–3.5	10 3.8–6.3	5 6.1–7.1	10 7.0–23.2	5 24.6–28.9	5 29.9–43.3
Lethops connectens	0	0	0	0	2 19.8–26.6	5 22.2–28.3	5 30.8–42.9
Lythrypnus dalli	0	3 2.0–2.2	10 2.4–3.6	2 4.1–4.1	8 4.4–12.9	5 9.5–10.4	5 10.5–13.6
L. zebra	0	0	10 2.8–4.3	5 4.0–5.0	12 4.8–10.2	3 10.2–11.6	5 12.2–16.2
Quietula y-cauda	L[f]	1 2.8	10 3.5–5.1	6 5.0–5.8	8 5.7–9.6	6 10.0–12.9	5 16.4–19.3
Tridentiger trigonocephalus	L[g]	0	2 2.7–2.7	0	L[g]	L[g]	L[g]
Typhlogobius californiensis	L[h]	4 3.0–3.4	10 3.0–5.2	4 5.0–5.8	10 6.4–11.7	0	1 26.9

[a] Dôtu and Mito 1955
[b] Wang 1981
[c] Prasad 1959
[d] Ebert and Turner 1962
[e] Weisel 1947
[f] Brothers 1975
[g] Dôtu 1958
[h] MacGinitie 1939

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	33
Precaudal	12–13	13
Caudal	20–21	20
Fins:		
Dorsal spines	VIII–IX+0–I	VIII+I
Dorsal rays	12–14	13–14
Anal spines	0–I	I
Anal rays	11–12	11
Pelvic	I,5	I,5
Pectoral	20–22	20–22
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–13	11–13
Lower	11–12	11–12
Gill rakers:		
Upper	3	3
Lower	9	9
Branchiostegals	5	5

LIFE HISTORY

Range: Estero Americano to Ensenada, Baja California (introduced; range expanding)

Habitat: Intertidal mudflats & shallow soft bottom of bays & estuaries; may enter fresh water

Spawning season: Winter–spring

ELH pattern: Oviparous; demersal eggs attached on wall of brooding burrow; planktonic larvae

LITERATURE

Dôtu & Mito 1955
Mori 1988
Wang 1981

* Eye slightly horizontally elongate in yolk-sac stage, becoming round during preflexion stage, then slightly oval again in juveniles; horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 5.0–5.8 × 0.96 mm **Yolk:** ca. 0.8–0.9 mm diam.
No. of OG: "Many" condensing to 1 **Diam. of OG:** ca. 0.2–0.3 mm (1)
Shell surface: Unornamented; cluster of adhesive filaments at basal end
Pigment: Yolk yellowish; late embryo—over OG & hindgut, posteroventrally on yolk, & on dorsal & ventral margins at midtail
Diagnostic features: Chorion elliptical, narrower at basal end

LARVAE

Hatching length: 4.5–4.6 mm
Flexion length: ca. 6.7–6.9 mm to <8.6 mm
Transformation length: ca. 16–18 mm
Fin development sequence: C_1, A, 2D, C_2, 1D, P_1 & P_2
Pigmentation: *Preflexion*—1 (elongate) on ventral margin at midtail, 1(smaller) opposite on dorsal margin; 2–7 (usually 3) on ventral margin of gut; 1–2 (usually 1) over hindgut; dorsally on gas bladder. *Late preflexion–postflexion*—Irregular double row forms on sides of A base; at bases of lower C rays; 1 at angular late in postflexion stage. *Transformation*—Head, dorsal margin, lateral, & fin (except P_2) pigment develops & increases.
Diagnostic features: Usually 1 elongate melanophore on ventral margin of tail in preflexion stage; an irregular double row on A base in postflexion stage; little on dorsum before transformation (ca. 16 mm); preanal length usually ≤50% BL through flexion stage; preanal myomeres 10–13 (usually 11–12), total myomeres 32–35 (usually 34).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	45–46	46–53		54–57		53–56
	46	49	50	55		54
BD/BL	17–19	13–17		14–16		16–17
	18	15	14	15		17
HL/BL	18–20	19–22		24–26		29–31
	19	20	20	25		30
HW/HL	62–65	50–68		52–56		59–62
	64	56	56	54		60
SnL/HL	16–21	15–22		20–23		26–30
	18	18	18	22		28
ED/HL*	34–39× 29–32	25–34		21–22		21–23× 18–19
	36×30	30	27	21		22×19
P_1L/BL	3–6	3–4		3–4		18–20
	4	4	5	4		19
P_2L/BL	0–0	0–0		1–1		20–21
	0	0	0	1		21

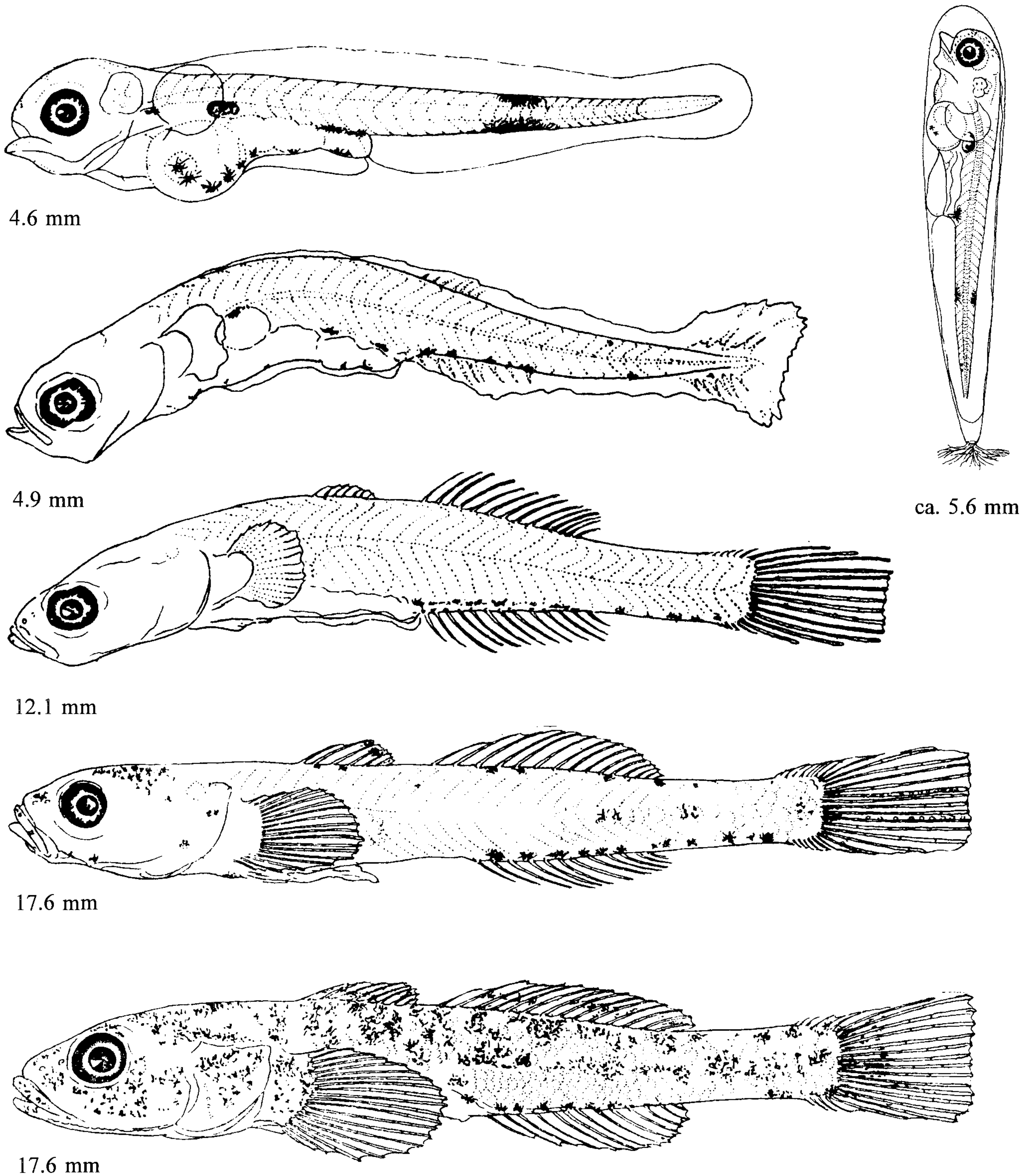


Figure Gobiidae 1. Egg, ca. 5.6 mm long; newly hatched larva, 4.6 mm; preflexion larva, 4.9 mm; postflexion larva, 12.1 mm; transformation specimen 17.6 mm; early juvenile, 17.6 mm (Dôtu and Mito 1955).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–37	36
Precaudal	15	15
Caudal	21–22	21
Fins:		
Dorsal spines	IV–VI+0–I	IV–V+I
Dorsal rays	14–17	14–15
Anal spines	0–I	I
Anal rays	13–17	14–15
Pelvic	I,5	I,5
Pectoral	18–21	18–19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	8–11	9–10
Lower	7+11	8–9
Gill rakers:		
Upper	1–3	
Lower	5–7	
Branchiostegals	3–5	5

LIFE HISTORY

Range: Rivers Inlet, British Columbia, to Bahía San Bartolome, Baja California Sur

Habitat: Intertidal mudflats & soft bottom of estuaries, lagoons, & shallow open coast; shelters in invertebrate burrows

Spawning season: Early to mid-winter through mid- to late summer

ELH pattern: Oviparous; demersal eggs attached on walls of burrow & guarded by male; planktonic larvae

LITERATURE

Brothers 1975
Matarese et al. 1989
Prasad 1959
Wang 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 2.5 mm long (B. Sumida MacCall)
Preflexion larva, 3.8 mm (B. Sumida MacCall)
Flexion larva, 5.1 mm (B. Sumida MacCall)
Postflexion larva, 12.0 mm (B. Sumida MacCall)
Juvenile, 14.9 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.3–2.6 × 0.7–0.8 mm **Yolk:** 0.4–0.6 mm diam.
No. of OG: "Many" condensing to 1 **Diam. of OG:** ca. 0.2 mm (1)
Shell surface: Unsculptured; cluster of adhesive filaments at basal pole
Pigment: Yolk yellowish; late embryo—over gut, on posterior surface of yolk sac, on ventral margins of hindgut & tail, & posteriorly on dorsal margin of tail.
Diagnostic features: "Club-shape" chorion, flattened at ends.

LARVAE

Hatching length: 2.0–3.0 mm
Flexion length: 5.0–5.5 mm through 6.0–6.1 mm
Transformation length: ca. 14.2–17.2 mm
Fin development sequence: C_1, A, 2D, C_2, P_2, P_1, 1D
Pigmentation: *Preflexion–flexion*—Single rows on ventral margins of gut (3–14, usually 7–9) & tail (4–11, usually 5–6); 1–2 over hindgut; dorsally on gas bladder; 0–1 at angular; 1 posteriorly on dorsal margin of tail. *Postflexion*—2–6 on ventral margin of gut, usually anteriorly only; double row on anterior 50–75% of A base; under hindbrain late in postflexion stage. *Transformation*—Dorsal, then dorsolateral pigment forms.
Diagnostic features: Preanal myomeres 13–16 (usually 14–15 in preflexion stage, 13–14 in postflexion stage), total myomeres 33–37 (usually 35–36); usually 5–10 melanophores on ventral margin of tail, irregular double row anteriorly on A base, 1–2 over hindgut, little on dorsum before transformation (ca. 14 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	54–71 62	53–58 56	55–89 58	53–61 56	55–57 56	55–58 57
BD/BL	 13*	13–18 15	14–17 15	14–16 15	13–16 14	15–19 16
HL/BL	17–23 20	20–23 22	22–25 24	23–26 25	25–29 26	29–33 30
HW/HL	75–78 77	43–53 47	43–47 46	41–48 43	40–46 43	42–53 48
SnL/HL	10–13 12	17–21 20	19–23 21	19–22 20	17–21 19	20–24 21
ED/HL†	57–75× 48–55 66×51	26–36× 24–30 31×26	25–30× 21–23 27×22	21–25× 21–23 23×22	19–23× 19–20 22×20	20–22× 18–19 21×18
P_1L/BL	 *	3–6 5	4–5 5	5–13 8	12–18 15	18–20 19
P_2L/BL	 0	0–0 0	0–0 0	0.3–18 9	16–21 18	9–22 20

* Both specimens damaged; body depth could not be measured in one & P_1 length could not be measured in either.
† Eye slightly to moderately elongate (horizontally); horizontal axis is given first, vertical second.

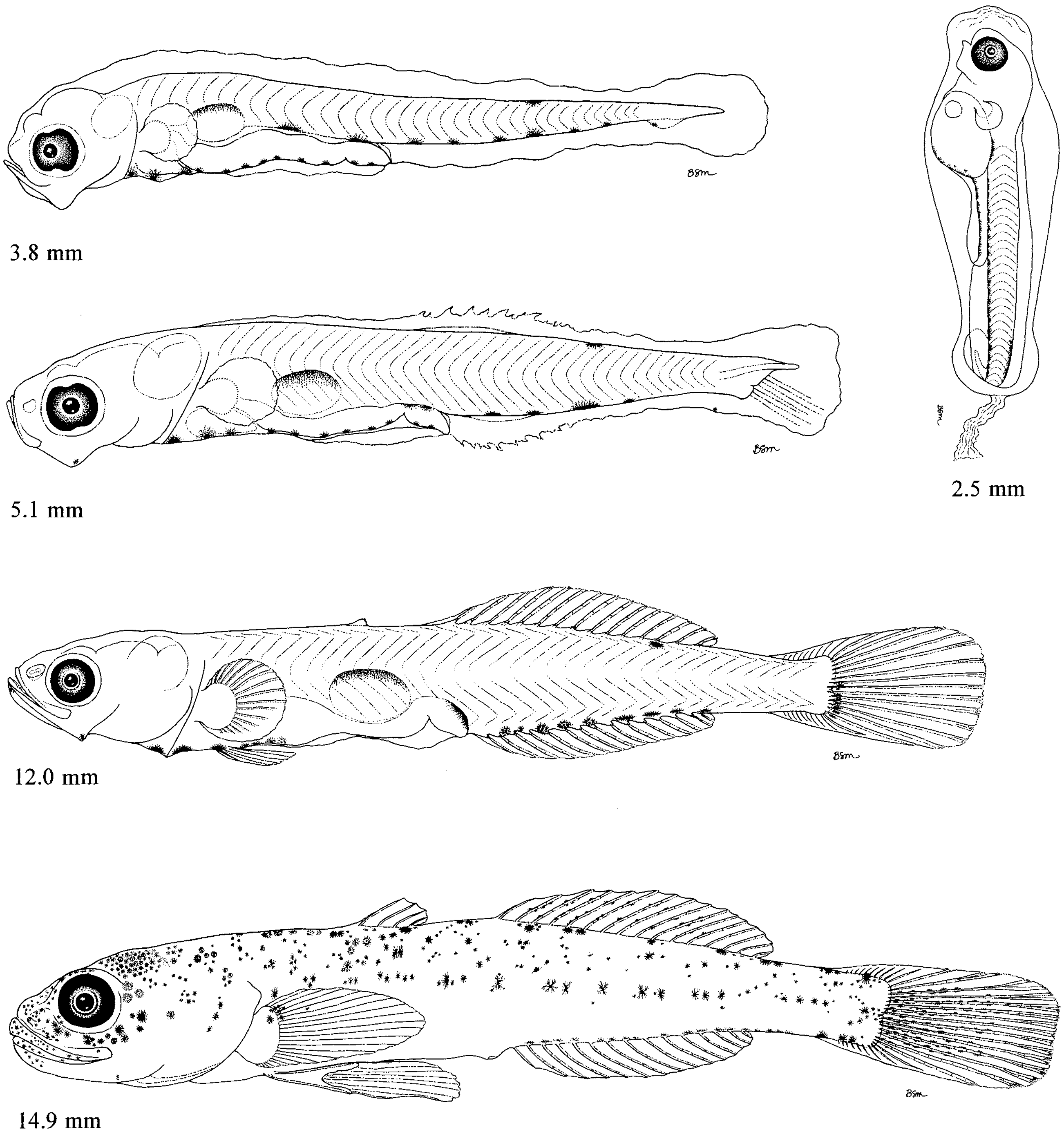


Figure Gobiidae 2. Egg, 2.5 mm long (CFRD Ref. Coll., April 5, 1974); preflexion larva, 3.8 mm (MEC I91, station A–M); flexion larva, 5.1 mm (MEC I107, station LA–M); postflexion larva, 12.0 mm (SK 87–536 Bottom, April 28, 1987); juvenile, 14.9 mm (SIO 56–62). Scales are not shown on the juvenile specimen.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	11	11
Caudal	15	15
Fins:		
Dorsal spines	IV–VIII+I–II	VI+I
Dorsal rays	9–15	13
Anal spines	0–I	I
Anal rays	11–13	11
Pelvic	I,5	I,5
Pectoral	16–24	22–23
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–13	11–12
Lower	10–12	11
Gill rakers:		
Upper	1–2	2
Lower	8–9	9
Branchiostegals	3–5	5

LIFE HISTORY

Range: Queen Charlotte Island, British Columbia, to about Punta Rompiente, Baja California Sur

Habitat: Sandy bottom near rocky areas, intertidal to 106 m depth; pelagic juveniles may occur far offshore

Spawning season: Probably year-round; primary season is February through October

ELH pattern: Oviparous; demersal eggs attached under rocks & guarded by male; planktonic larvae

LITERATURE

Ebert & Turner 1962
Matarese et al. 1989
Wang 1981
Wiley 1973

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.9 mm (A. Kubo)
Preflexion larva, 3.7 mm (H. M. Orr)
Flexion larva, 5.6 mm (H. M. Orr)
Postflexion larva, 14.0 mm (H. M. Orr)
Transformation specimen, 25.5 mm (H. M. Orr)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.1–2.2 × 0.48–0.5 mm **Yolk:**
No. of OG: "Many" **Diam. of OG:**
Shell surface: Unornamented, no adhesive filaments
Pigment: Yolk yellowish to pale pink; late embryo with melanophore series over gut & along ventral margin of tail
Diagnostic features: Spindle-shape chorion lacking adhesive filaments

LARVAE

Hatching length: 2.8–3.0 mm
Flexion length: 5.8–6.1 mm through 6.6–6.8 mm
Transformation length: ca. 16–25 mm
Fin development sequence: C_1, A, 2D, C_2, P_1, 1D, P_2
Pigmentation: *Preflexion–flexion*—On dorsal margin at ca. myomere 21–25, extending forward to myomere 8–10 after ca. 3 mm, gap forms in middle of series during flexion stage; series over gut & gas bladder, continuing posteriorly along ventral margin of tail; usually 6–11 ventrally on gut & isthmus; on angular; posterolaterally on midbrain & sides of hindbrain by ca. 6 mm; on lower C_1 bases. *Postflexion–transformation*—3 dorsal saddles; laterally near C; double row along A base; on gular region; increasing dorsolaterally & on fins (1D, P_1, C).
Diagnostic features: In preflexion–flexion larvae, preanal length usually ≤50% BL before 5 mm BL, series of melanophores extending from foregut to near end of tail, & dorsal pigment on posterior half of tail; in postflexion–transformation larvae, 3 dorsal saddles, preanal myomeres 9–11 (usually 10), & total myomeres 25–28 (usually 25–27).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		45–53	51–55	54–56	54–59	55–58
	48	50	53	55	57	56
BD/BL		12–15	13–15	13–17	16–18	19–21
	18	14	14	14	17	20
HL/BL		17–23	23–24	24–29	28–30	30–32
	16	21	24	27	29	31
HW/HL		37–65	37–41	33–38	33–43	39–57
	71	46	39	35	39	49
SnL/HL		16–22	16–18	18–22	21–27	24–27
	18	19	17	20	24	26
ED/HL		28–44	26–29	25–28	26–28	25–27
	49	33	27	26	27	26
P_1L/BL		3–5	3–5	4–14	14–18	23–25
	4	4	5	6	16	24
P_2L/BL		0–0	0–0	0–8	9–15	18–22
	0	0	0	2	13	20

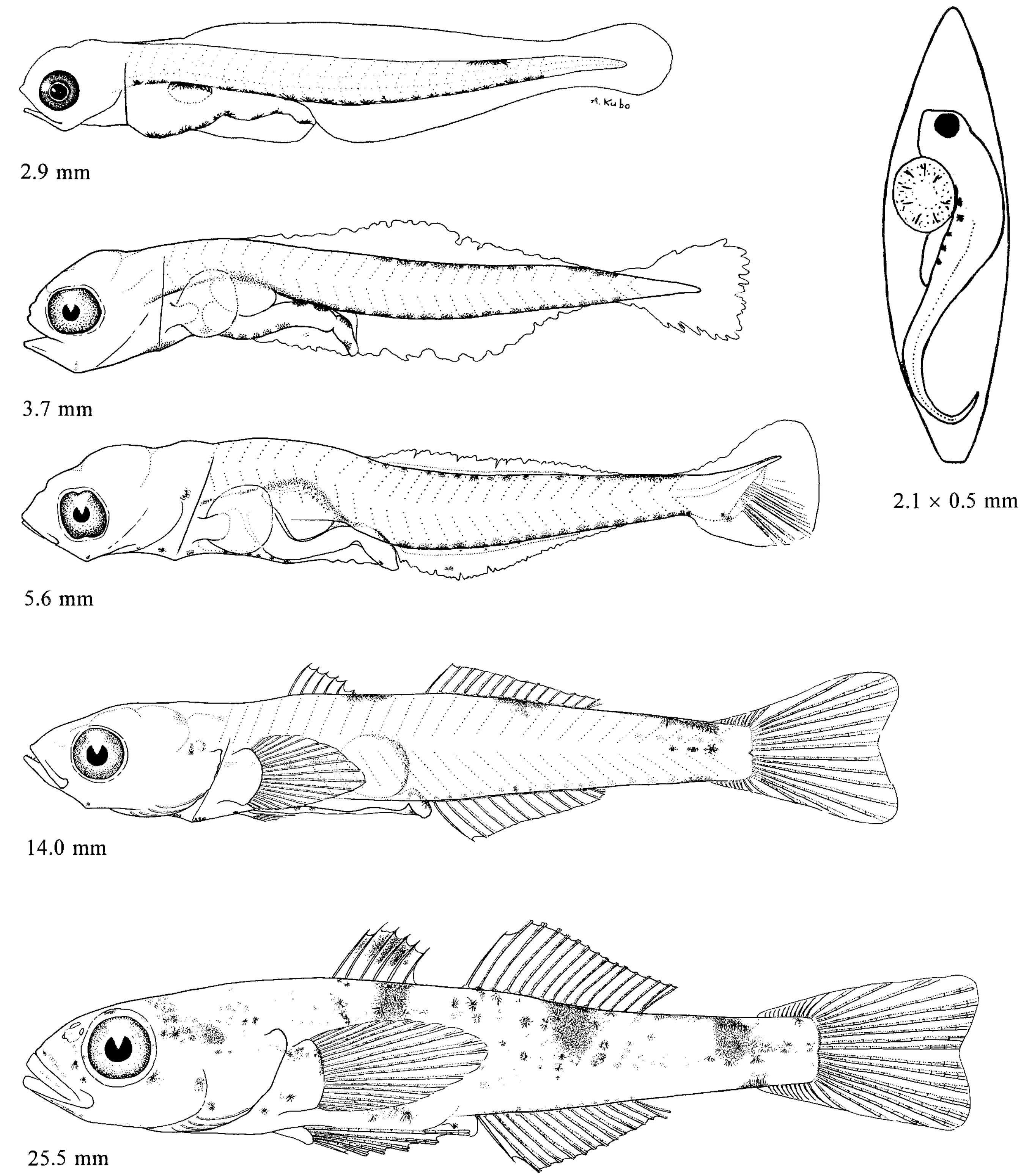


Figure Gobiidae 3. Egg, 2.1 mm long × 0.5 mm wide (Ebert and Turner 1962); recently hatched larva, 2.9 mm (reared by A. Kubo, July 1977); preflexion larva, 3.7 mm; flexion larva, 5.6 mm; postflexion larva, 14.0 mm; transformation specimen, 25.5 mm (CalCOFI).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–35	34
Precaudal	15–16	15
Caudal	18–20	19
Fins:		
Dorsal spines	VI–VII+I	VI+I
Dorsal rays	9–12	11
Anal spines	I	I
Anal rays	8–11	10
Pelvic	I,5	I,5
Pectoral	19–21	21
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–12	10–11
Lower	9–11	9–10
Gill rakers:		
Upper	1–2	
Lower	7–8	
Branchiostegals	5	5

LIFE HISTORY

Range: Lake Earl, Del Norte County, to Agua Hedionda Lagoon, San Diego County, California

Habitat: Shallow soft bottom of bays & coastal lagoons

Spawning season:

ELH pattern: Oviparous; male constructs nesting burrow; planktonic larvae

LITERATURE

Brothers 1975

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.3 mm (B. Sumida MacCall)
Postflexion larva, 7.3 mm (B. Sumida MacCall)
Transformation specimen, 13.8 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

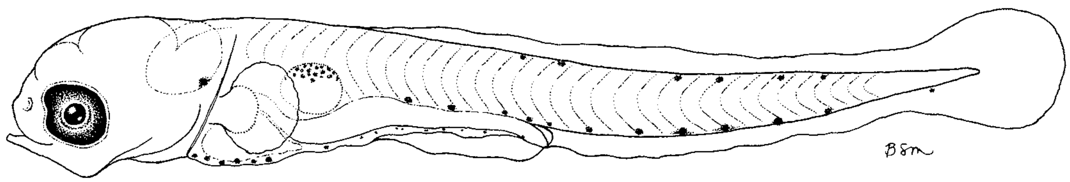
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

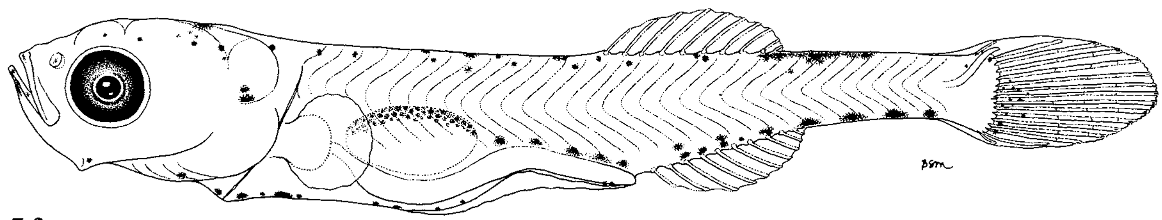
Hatching length:
Flexion length:
Transformation length: ca. 13.4–13.8 mm through ca. 14.9–16.3 mm
Fin development sequence: C_1, A, 2D, C_2, P_1 & 1D, P_2
Pigmentation: *Preflexion*—Irregular row on dorsal margin; over gas bladder & hindgut; single rows on ventral margins of gut & tail; under hindbrain. *Postflexion*—Irregular double row from nape to 2D, then single row to myomere 28–30; double row along A base, then single to last myomere; on hindbrain & posteriorly on midbrain; externally, dorsally & laterally on head; on both jaws; on bases of middle C rays. *Transformation*—Increasing on dorsum, dorsolaterally, on fins (D, A, C); series forming along lateral midine, especially on tail.
Diagnostic features: Irregular dorsal series of melanophores, small anteriorly; several over hindgut; double row along A base; much pigment on top of head in postflexion stage; preanal myomeres usually 13–14, total myomeres 32–33.

MORPHOMETRICS (range & mean in %)

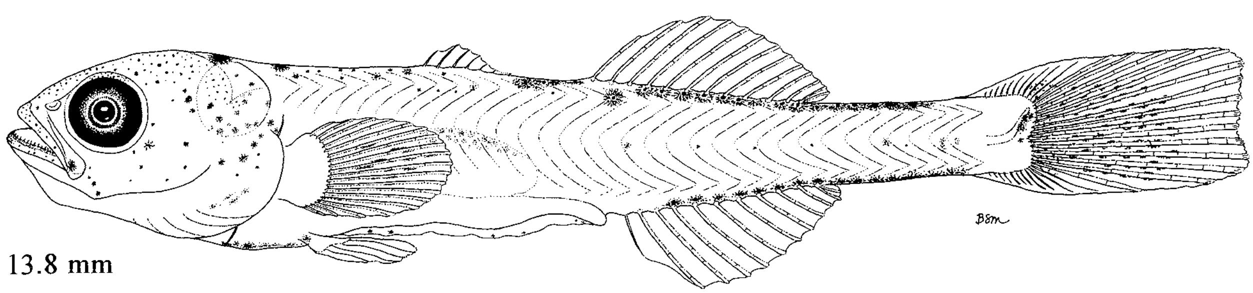
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				56–64	57–59	57–58
		51		58	58	57
BD/BL				15–20	17–18	20–21
		14		16	17	20
HL/BL				26–29	27–30	27–31
		21		27	29	29
HW/HL				38–55	35–55	55–74
		50		45	48	63
SnL/HL				19–24	20–23	18–22
		18		22	21	21
ED/HL				21–30	23–25	20–23
		36		23	24	21
P_1L/BL				4–15	13–15	19–19
		4		8	14	19
P_2L/BL				0.1–10	9–13	16–20
		0		4	10	18



4.3 mm



7.3 mm



13.8 mm

Figure Gobiidae 4. Preflexion larva, 4.3 mm (MEC I119, station LA–M); postflexion larva, 7.3 mm (MEC I119, station LA–E); transformation specimen, 13.8 mm (SIO 72–87).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–33	32
Precaudal	14–15	14
Caudal	17–18	18
Fins:		
Dorsal spines	IV–VIII+0–III	VI+I
Dorsal rays	9–14	10–12
Anal spines	I–III	I
Anal rays	8–14	10–12
Pelvic	I,5	I,5
Pectoral	18–23	19–21
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–13	10–12
Lower	8–13	10–12
Gill rakers:		
Upper	1–4	3
Lower	9–12	12
Branchiostegals	5	5

LIFE HISTORY

Range: Tomales Bay, California, to Bahía Magdalena, Baja California Sur, & Gulf of California

Habitat: Intertidal & shallow subtidal mudflats of bays, estuaries, & lagoons; shelters in invertebrate burrows

Spawning season: September–January through May–July

ELH pattern: Oviparous; demersal eggs attached to walls of brood chamber & guarded by male; planktonic larvae

LITERATURE

Barlow 1961
Eigenmann 1892
deVlaming 1972
Wang 1981
Weisel 1947

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.6 mm (B. Sumida MacCall)
Postflexion larva, 7.0 mm (B. Sumida MacCall)

* Eye somewhat horizontally elongate in larvae; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.8–3.4 mm × 1.1 mm **Yolk:** 0.75–0.87 mm diam.
No. of OG: "Many" condensing to 1 **Diam. of OG:**
Shell surface: Unsculptured; cluster of adhesive threads at narrow pole; short, fine filaments cover chorion.
Pigment: Yolk yellow; late embryo—series along dorsal & ventral margins of tail.

Diagnostic features: Chorion "club-shaped," short gelatinous filaments cover chorion in eggs >24 hr old.

LARVAE

Hatching length: ca. 3.0–4.0 mm
Flexion length: ca. 5.5–6.5 mm
Transformation length: >ca. 10.5 mm through ca. 12–15 mm
Fin development sequence: C_1, A, 2D, C_2, 1D & P_2, P_1
Pigmentation: *Preflexion*—Single row on dorsal margin from head to midtail (usually 9 melanophores, all large); single row on ventral margin of tail (usually 8–9 melanophores, all large); continuous series over hindgut (3–5), gas bladder & foregut; usually 1 in roof of mouth; 1 at mandibular symphysis; 1 at angular; 7–10 on ventral margin of gut (usually none ventrally on hindgut). *Postflexion*—Series under vertebral column; on lateral midline posteriorly. *Transformation*—Pigmentation increases on head, dorsum, dorsolaterally, & on fins (D, A, C); barred pattern forms.
Diagnostic features: Single rows of large melanophores dorsally, ventrally, & over gut; little lateral pigment before transformation except posteriorly on lateral midline in postflexion stage; preanal myomeres 13–17 (usually 13–14), total myomeres 29–33 (usually 32).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		55–59 57		58–63 60		57–58 57
BD/BL		16–17 16		15–20 18		18–20 19
HL/BL		23–25 24		27–31 28		29–31 30
HW/HL		49–59 54		35–44 41		47–51 48
SnL/HL		17–24 19		20–23 22		18–20 19
ED/HL*		29–35× 26–29		23–27× 20–23		22–24
		33×27		25×22		23
P_1L/BL		5–6 5		5–16 8		15–21 18
P_2L/BL		0–0 0		0–20 7		20–24 22

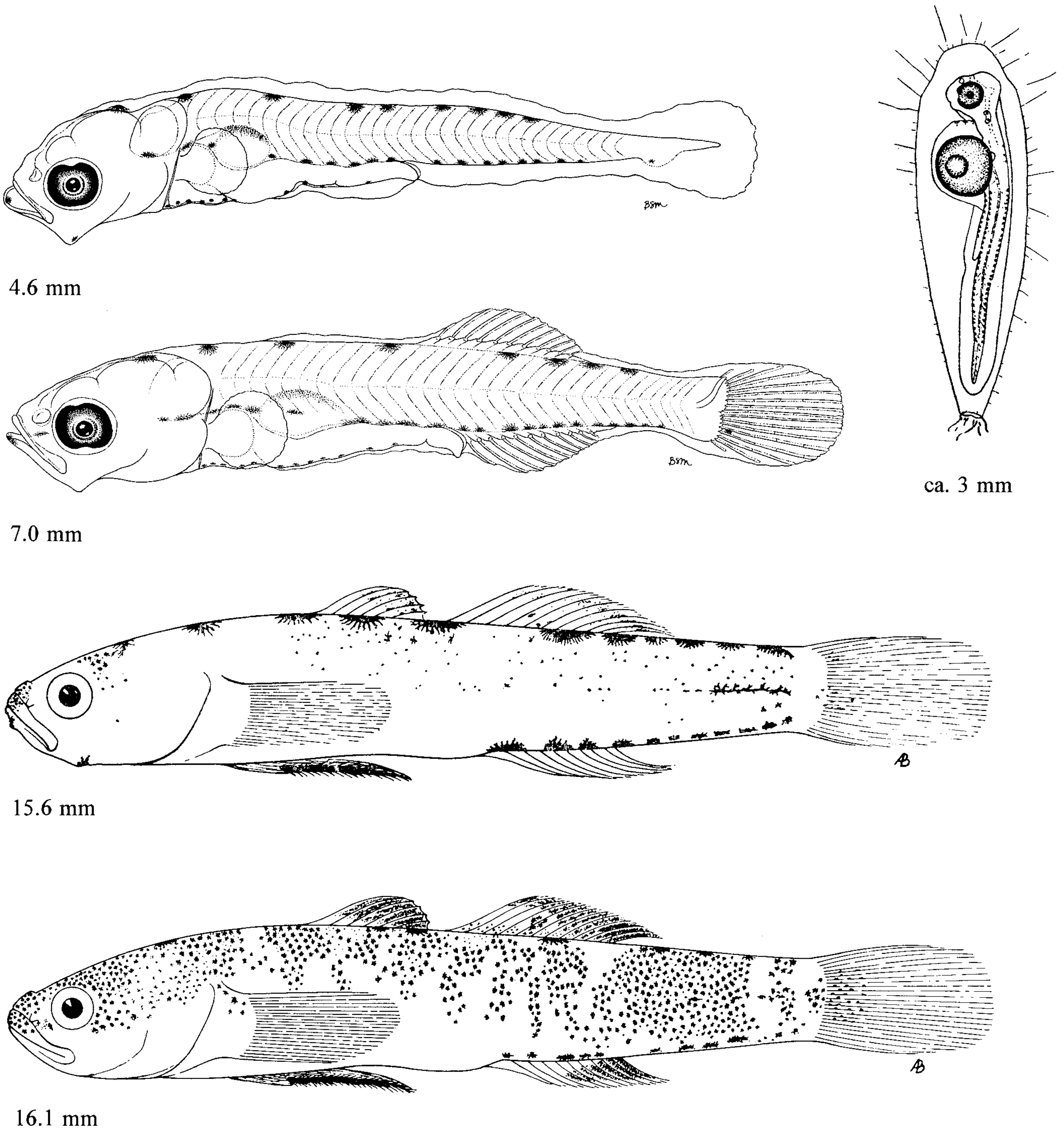


Figure Gobiidae 5. Egg, ca. 3 mm long (Weisel 1947); preflexion larva, 4.6 mm (MEC I95, station B–M); postflexion larva, 7.0 mm (MEC I55, station LB–E); late postflexion larva, 15.6 mm; transformation specimen, 16.1 mm (Barlow 1961).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	27
Precaudal	10–11	11
Caudal	16	16
Fins:		
Dorsal spines	VII+I	VII+I
Dorsal rays	11	11
Anal spines	I	I
Anal rays	9–10	10
Pelvic	I,5	I,5
Pectoral	16–18	18
Caudal:		
Principal	8+7	15
Procurrent:		
Upper	6–7	6
Lower	5–6	6
Gill rakers:		
Upper	1	
Lower	7–8	
Branchiostegals	5	5

LIFE HISTORY

Range: Pacific coast of Baja California Sur south from Bahía Magdalena, & in Gulf of California

Habitat: Subtidal (ca. 1.5–18 m depth) cobble or sand bottom adjacent to reefs; shelters in rock crevices & under rocks

Spawning season:

ELH pattern: Oviparous with demersal eggs; larvae are planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.4 mm (B. Sumida MacCall)
Flexion larva, 3.9 mm (B. Sumida MacCall)
Postflexion larvae, 6.0 mm, 7.5 mm (B. Sumida MacCall)

* Eye usually slightly horizontally elongate; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

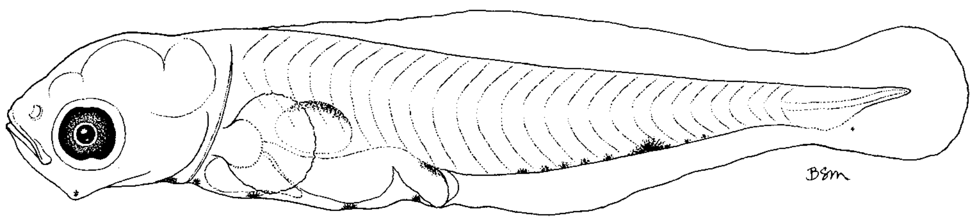
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

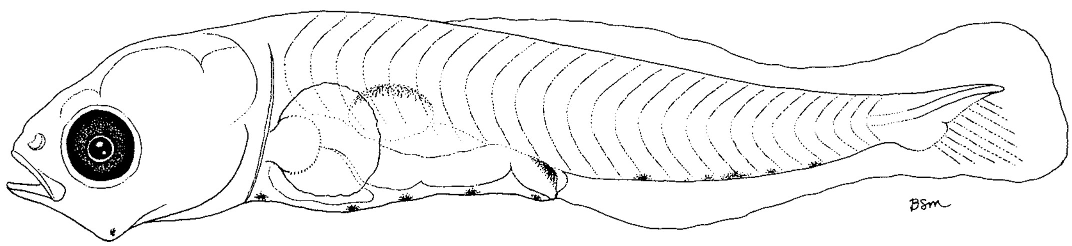
Hatching length: <2.3 mm
Flexion length: ca. 3.9 mm to <5.2 mm
Transformation length: >7.7 mm, <14.9 mm
Fin development sequence: C_1, 2D & A, C_2, 1D & P_1 & P_2
Pigmentation: *Preflexion–postflexion*—4–5 ventrally from postanal myomeres 1–2 to 5–8, becoming a double row (2–4 pairs) along A base in postflexion stage; 1–2 (large) ventrally at postanal myomeres 8–12 (usually 9–11), & 0–4 (small) at postanal myomeres ca. 14–16; 0–1 (usually 1) at isthmus; 3–6 (usually 4–5) along ventral margin of gut; dorsally on gas bladder; 1 over end of hindgut; 0–1 at angular (usually 1 in preflexion stage, 0 in postflexion stage); 1 ventrolaterally anteriorly on each side of hindbrain in postflexion stage.
Diagnostic features: 1–2 large ventral melanophores, usually at postanal myomeres 9–11; 2–4 pairs of melanophores along A base in postflexion stage; no dorsal pigment on larvae; preanal myomeres 9–11 (usually 10), total myomeres 26–27 (usually 26).

MORPHOMETRICS (range & mean in %)

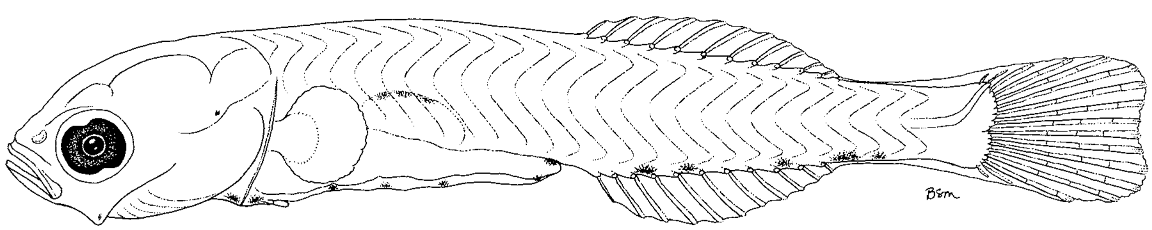
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–52 49	57	56–60 58		61
BD/BL		16–19 18	18	17–19 18		17
HL/BL		21–25 23	27	27–30 29		31
HW/HL		46–64 54	53	45–50 47		50
SnL/HL		8–23 19	21	20–28 22		19
ED/HL*		27–42× 26–35 35×31	28×25	20–23× 20–22 21×21		19×17
P_1L/BL		4–6 5	5	5–14 8		22
P_2L/BL		0–0 0	0	0.3–13 5		20



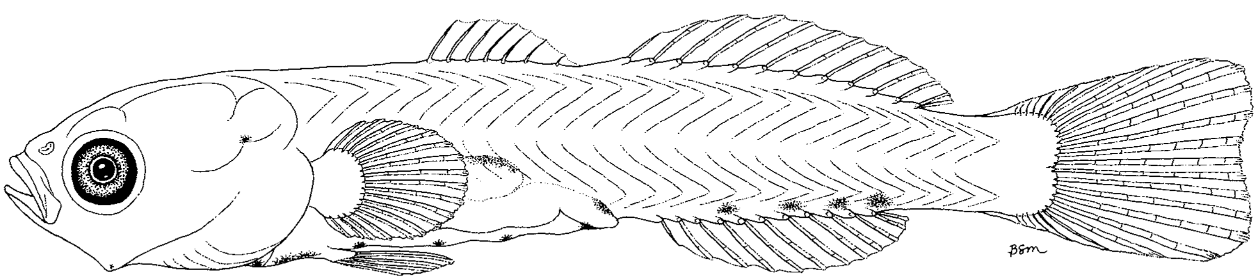
3.4 mm



3.9 mm



6.0 mm



7.5 mm

Figure Gobiidae 6. Preflexion larva, 3.4 mm (CalCOFI 6509, station 133.21); early flexion larva, 3.9 mm (CalCOFI 6509, station 127.32.6); postflexion larva, 6.0 mm (CalCOFI 6509, station 127.32.6); late postflexion larva, 7.5 mm (CalCOFI 6509, station 127.32.6).

MERISTICS

	Range	Mode
Vertebrae:		
Total	32–34	33
Precaudal	13–14	14
Caudal	18–20	19
Fins:		
Dorsal spines	V+0–I	V+I
Dorsal rays	13–17	15
Anal spines	0–I	I
Anal rays	12–16	14
Pelvic	I,5	I,5
Pectoral	21–22	21
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	7–9	8
Lower	7–9	7–8
Gill rakers:		
Upper	3–5	4
Lower	10–11	10–11
Branchiostegals	5	5

LIFE HISTORY

Range: Tomales Bay, California, to Bahía Magdalena, Baja California Sur, & in Gulf of California

Habitat: Shallow soft bottom of estuaries, bays, lagoons, & open coast; constructs burrows

Spawning season: Year-round

ELH pattern: Oviparous; demersal eggs attached on walls of burrow & guarded by male; planktonic larvae

LITERATURE

Brothers 1975
Wang 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.0 mm (B. Sumida MacCall)
Flexion larva, 5.7 mm (B. Sumida MacCall)
Postflexion larva, 11.0 mm (B. Sumida MacCall)
Transformation specimen, 18.2 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 3.3 mm long **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface: Unsculptured; cluster of adhesive filaments at basal pole
Pigment: Yolk yellowish
Diagnostic features: Chorion elliptical, "club-shaped"

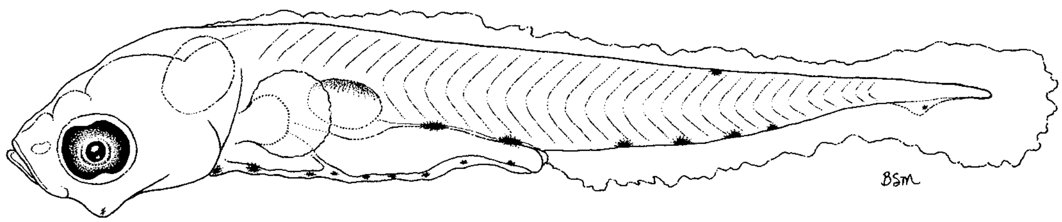
LARVAE

Hatching length: ca. 3.1 mm
Flexion length: 5.0–5.4 mm through 5.7–6.0 mm
Transformation length: 13.4–15.0 mm to ca. 20 mm
Fin development sequence: C_1, A, 2D, C_2, P_1 & P_2, 1D
Pigmentation: *Preflexion-postflexion*—Single row on ventral margin of gut (2–12 total, usually 10 in preflexion stage, 5 in postflexion stage) & on tail (3–7, usually 4–5); 1 posteriorly on dorsal margin of tail (rarely 0); 1–2 (usually 2) over hindgut; dorsally on gas bladder; 0–1 at angular; under hindbrain, beginning in flexion stage. *Transformation*—"Patches" along vertebral column; pairs along dorsal margin (posterior 1–3 often single); increasing on head, dorsum, dorsolaterally, & on fins.
Diagnostic features: Single row of large melanophores (usually 4–5) on ventral margin of tail, 1–2 over hindgut; ventral gut pigment not restricted to anterior half; little dorsal pigment before beginning of transformation stage (ca. 13–15 mm); preanal myomeres 11–13 (usually 12), total myomeres 31–34.

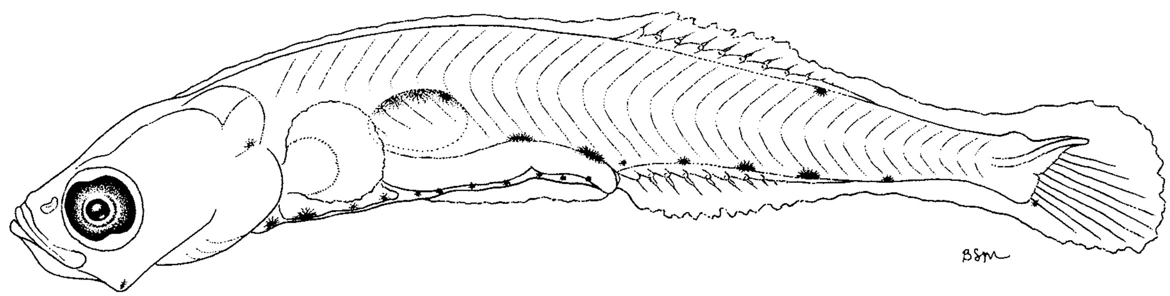
MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		52–58 55	58–59 58	55–60 57	55–59 57	55–60 57
BD/BL		14–16 15	15–19 16	15–17 16	17–18 18	17–19 18
HL/BL		21–25 23	24–26 25	25–29 26	29–32 30	29–31 30
HW/HL		45–53 49	43–48 46	41–52 46	42–44 43	39–56 45
SnL/HL		17–21 19	19–24 21	17–21 19	15–17 17	18–21 19
ED/HL		24–32× 21–27 28×24	24–27× 21–23 25×22	22–26× 20–25 24×22	21–24× 17–22 23×19	18–21× 14–18 20×15
P_1L/BL		4–7 5	5–6 5	5–12 8	15–17 16	16–18 17
P_2L/BL		0–0 0	0–0 0	0.2–23 13	23–24 24	22–24 23

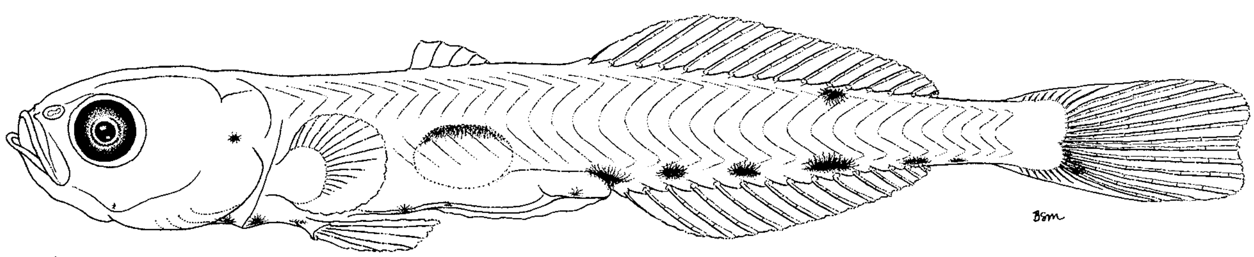
* Eye slightly to moderately elongate; horizontal axis is give first, vertical second.



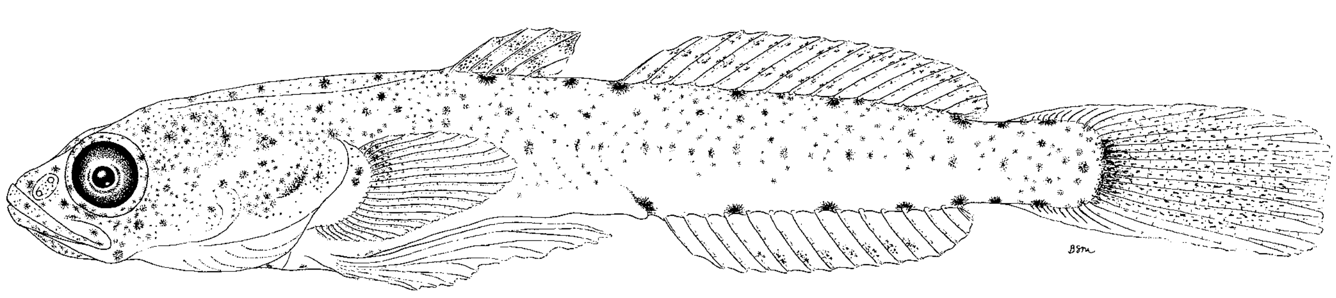
4.0 mm



5.7 mm



11.0 mm



18.2 mm

Figure Gobiidae 7. Preflexion larva, 4.0 mm (MEC I96, station LA–E); flexion larva, 5.7 mm (MEC I96, station LB–M); postflexion larva, 11.0 mm (MEC I05, station T–E, replicate 13); transformation specimen, 18.2 mm (SIO H48–51).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–38	37
Precaudal	15	15
Caudal	22–23	22
Fins:		
Dorsal spines	VI–IX+0–I	VII+I
Dorsal rays	14–18	15
Anal spines	0–I	I
Anal rays	12–16	13
Pelvic	I,5	I,5
Pectoral	20–24	20–23
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	10–15	12–13
Lower	9–14	12
Gill rakers:		
Upper	2–3	
Lower	8–11	
Branchiostegals	5	5

LIFE HISTORY

Range: Welcome Harbor, British Columbia, to Isla Cedros, Baja California

Habitat: Muddy bottom, intertidal to 201 m depth; bays, estuaries, open coast; shelters in invertebrate burrows

Spawning season: Possibly year-round; principally October through June

ELH pattern: Oviparous; demersal eggs attached in burrow; planktonic larvae

LITERATURE

Matarese et al. 1989
Wang 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (B. Sumida MacCall)
Flexion larva, 6.4 mm (B. Sumida MacCall)
Postflexion larva, 14.5 mm (B. Sumida MacCall)
Juvenile, 32.6 mm (B. Sumida MacCall)

* Eye round to slightly elongate (horizontally) through flexion stage, becoming consistently round during postflexion stage; horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS (Data for unfertilized eggs only)
Shell diam.: 1.2–1.8 × 0.8–1.0 mm **Yolk:**
No. of OG: "Many" **Diam. of OG:**
Shell surface: Unornamented except at anchor point
Pigment: Yolk yellowish
Diagnostic features: Elliptical

LARVAE
Hatching length: ca. 3.0–3.2 mm
Flexion length: 6.2–6.3 mm through ca. 7.1–7.5 mm
Transformation length: ca. 24–29 mm
Fin development sequence: C_1, A, 2D, C_2, P_2, 1D, P_1
Pigmentation: *Preflexion*—1–4 (usually 3–4) on dorsal margin; 1 large melanophore on ventral margin at midtail plus 0–7 smaller; usually 6–7 on ventral margin of gut; 1 over foregut; dorsally on gas bladder; usually 2 over hindgut; usually 1 at angular. *Flexion*—1–2 on dorsal margin; double row along A base; at bases of a few lower C rays. *Postflexion*—0–1 on dorsal margin; under hindbrain by ca. 12 mm; at mandibular symphysis by ca. 14 mm; blotch on C base. *Transformation*—4–6 blotches laterally; 8–10 dorsolateral saddles; bands on D, A, C.
Diagnostic features: *Preflexion*—Usually 3–4 melanophores evenly spaced along dorsal margin; large melanophore on ventral margin at midtail. *Flexion–postflexion*—Symmetrical double row along A base; preanal myomeres 13–16 (usually 14–15), total myomeres 36–39 (usually 36–38); transformation at ca. 24 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	53–56 55	53–57 55	54–61 58	52–59 56	55–57 56	55–56 55
BD/BL	14–18 16	14–18 16	15–16 15	14–17 15	15–16 16	15–17 16
HL/BL	20–22 21	22–24 23	23–26 24	24–28 26	26–27 27	27–28 27
HW/HL	49–51 50	44–57 50	44–49 46	40–47 43	39–44 42	38–50 42
SnL/HL	14–20 16	16–25 21	21–25 23	19–25 23	22–24 23	22–26 23
ED/HL*	39–41× 33–39	27–38× 24–33	26–28× 24–27	21–26× 21–26	22–25	23–24
	39×36	32×29	27×26	24×24	23	23
P_1L/BL	4–5 4	4–6 5	4–5 4	3–11 6	12–16 14	16–16 16
P_2L/BL	0–0 0	0–0 0	0–0 0	0.3–17 8	18–20 19	17–20 19

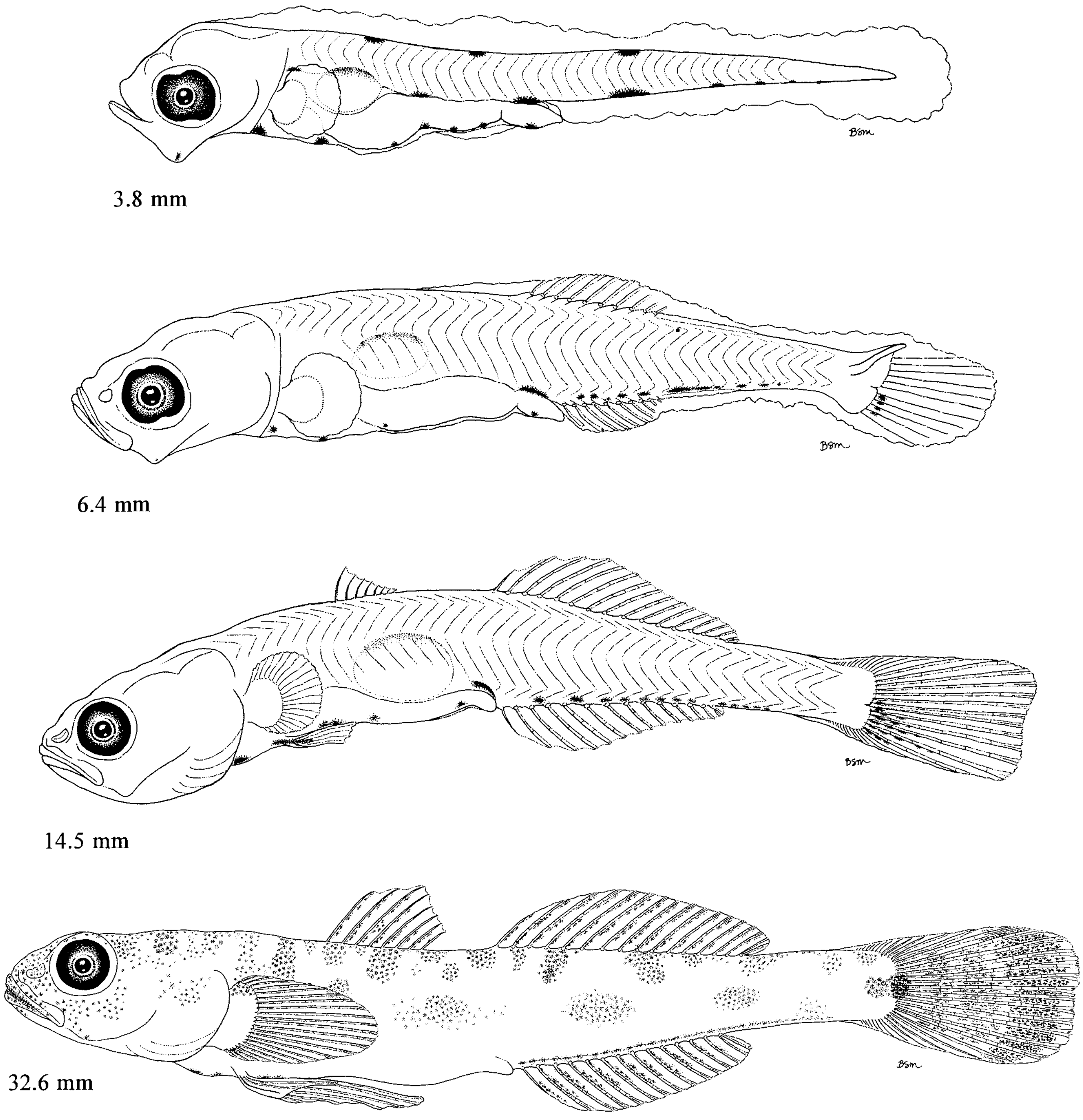


Figure Gobiidae 8. Preflexion larva, 3.8 mm (MEC I95, station B–M); flexion larva, 6.4 mm (MEC I91, station LA–M); postflexion larva, 14.5 mm (MEC I95, station LD–M); juvenile, 32.6 mm (SIO 84–90). Scales are not shown on the juvenile specimen.

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	36
Precaudal		15
Caudal		21
Fins:		
Dorsal spines	VI–VII+0–I	VI+I
Dorsal rays	12–14	13–14
Anal spines	0–I	I
Anal rays	12–13	12–13
Pelvic	I,5	I,5
Pectoral	20–21	20–21
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	9–13	11–12
Lower	9–12	10–11
Gill rakers:		
Upper	1–2	2
Lower	9–11	9–10
Branchiostegals	5	5

LIFE HISTORY

Range: Carmel, California, to Cabo Colnett, Baja California

Habitat: Intertidal to ca. 20 m depth; on rocky bottom & kelp holdfasts, juveniles often in kelp canopy

Spawning season:

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Transformation specimen, 26.6 mm (B. Sumida MacCall)
Juvenile, 28.3 mm (R. C. Walker)

* Eye becomes horizontally elongate during transformation stage; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

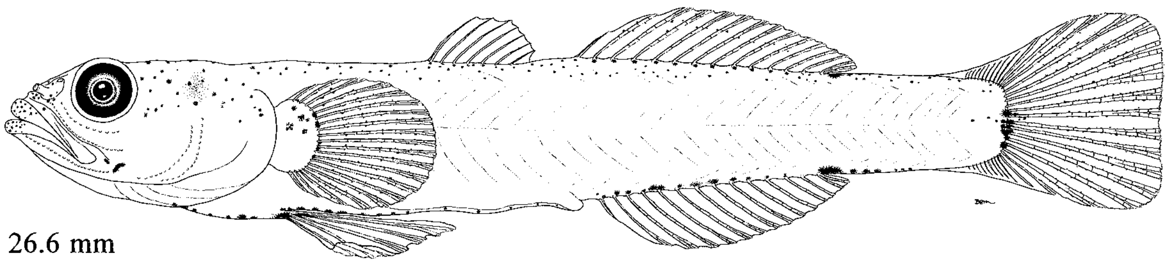
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

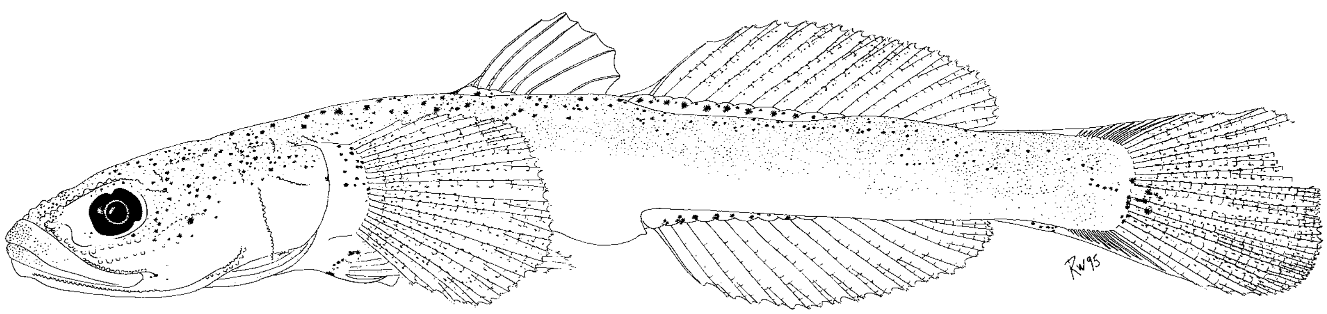
Hatching length:
Flexion length:
Transformation length: ca. 20–30 mm
Fin development sequence:
Pigmentation: *Postflexion*—Irregular double row along anterior 50–75% of A base, single row posteriorly; single row on ventral margin from isthmus to mid- or hindgut, may bifurcate posterior to P_2 base; peppering over dorsum, dorsolaterally on head, & on lips; 1 at angular; on sides of hindbrain; on bases of upper P_1 rays; dense patch on C base; fin pigmentation increases. *Transformation*—Increasing dorsally, laterally, & on fins; series posteriorly along vertebrae.
Diagnostic features: Preanal myomeres 13–15 (usually 15), total myomeres 33–36 (usually 34–36); large blotch on C base, double row along A base in postflexion stage; large size at transformation (≥22 mm); small, oval eye in transformation & older stages.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				54–57 55	56–60 57	55–60 57
BD/BL				13–15 14	13–15 14	14–15 15
HL/BL				26–28 27	26–28 28	26–29 28
HW/HL				39–55 47	38–48 43	46–53 49
SnL/HL				23–27 25	22–28 25	20–24 22
ED/HL*				19–20 20	15–19× 12–17 17×14	10–13× 8–10 11×9
P_1L/BL				15–17 16	18–19 19	17–19 18
P_2L/BL				16–17 17	18–20 19	18–20 19



26.6 mm



28.3 mm

Figure Gobiidae 9. Early transformation specimen, 26.6 mm (SK 88–122, Mission Beach, California, January 27, 1988); juvenile, 28.3 mm (SIO H51–239). Scales are not shown.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	26
Precaudal	10	10
Caudal	16–17	16
Fins:		
Dorsal spines	VI–VII+0–I	VII+I
Dorsal rays	15–19	15–16
Anal spines	0–I	I
Anal rays	12–15	12–13
Pelvic	I,5	I,5
Pectoral	16–20	18–19
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	7–9	7–8
Lower	6–9	7–8
Gill rakers:		
Upper	0–1	
Lower	7–10	
Branchiostegals	5	5

LIFE HISTORY

Range: Morro Bay, California, to Isla de Guadalupe, Baja California, & in Gulf of California

Habitat: Open rocky areas, intertidal to 76 m depth

Spawning season: Spring–summer

ELH pattern: Oviparous; demersal eggs attached on brood chamber (e.g., shells), guarded by male; planktonic larvae

LITERATURE

Wiley 1976

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.2 mm (B. Sumida MacCall)
Preflexion larva, 2.8 mm (B. Sumida MacCall)
Flexion larva, 4.1 mm (B. Sumida MacCall)
Postflexion larva, 6.4 mm (B. Sumida MacCall)
Transformation specimen, 10.5 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 2.0–2.2 mm
Flexion length: ca. 4.0–4.4 mm
Transformation length: ca. 9.5–13 mm
Fin development sequence: C_1, A, 2D, C_2, P_1 & 1D, P_2
Pigmentation: *Preflexion–flexion*—Single row on ventral margin of tail from postanal myomeres 1–3 to 11–13 & corresponding row on dorsal margin of tail; 0–2 on isthmus; 1–2 anteriorly on ventral margin of gut; 1–2 ventrally on midgut; 0 (rarely, 1) ventrally on hindgut; dorsally on gas bladder; dorsally on most or all of hindgut; 1 at angular. *Postflexion*—Double rows along anterior half of A base & posterior half of 2D base; 1 ventrolaterally on each side of hindbrain. *Transformation*—General increase in pigmentation from head toward tail & on fins (except C); bars form.
Diagnostic features: Pigment ventrally on tail begins at third postanal myomere (rarely, first or second); melanophore rows along dorsal & ventral margins of middle of tail; preanal length <50%BL in preflexion stage larvae; 5–7 bars form during transformation stage; preanal myomeres 8–10 (usually 9), total myomeres 25–27 (usually 26).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	46–49 47	42–51 47	48–52 50	53–60 55	51–55 53	53–57 56
BD/BL	17–19 17	13–18 15	16–17 17	17–20 18	22–24 23	22–24 23
HL/BL	19–23 21	18–25 21	23–24 23	25–30 28	31–33 32	30–33 32
HW/HL	50–57 54	43–64 55	49–53 51	37–50 44	38–50 46	46–50 47
SnL/HL	18–29 22	15–26 22	16–17 17	19–21 20	13–16 14	11–13 12
ED/HL	36–45 41	33–45 38	30–33 31	24–31 27	26–31 29	29–36 33
P_1L/BL	5–5 5	4–6 5	5–6 5	5–16 8	20–28 24	27–31 29
P_2L/BL	0–0 0	0–0 0	0–0 0	0.4–23 7	21–26 24	27–31 29

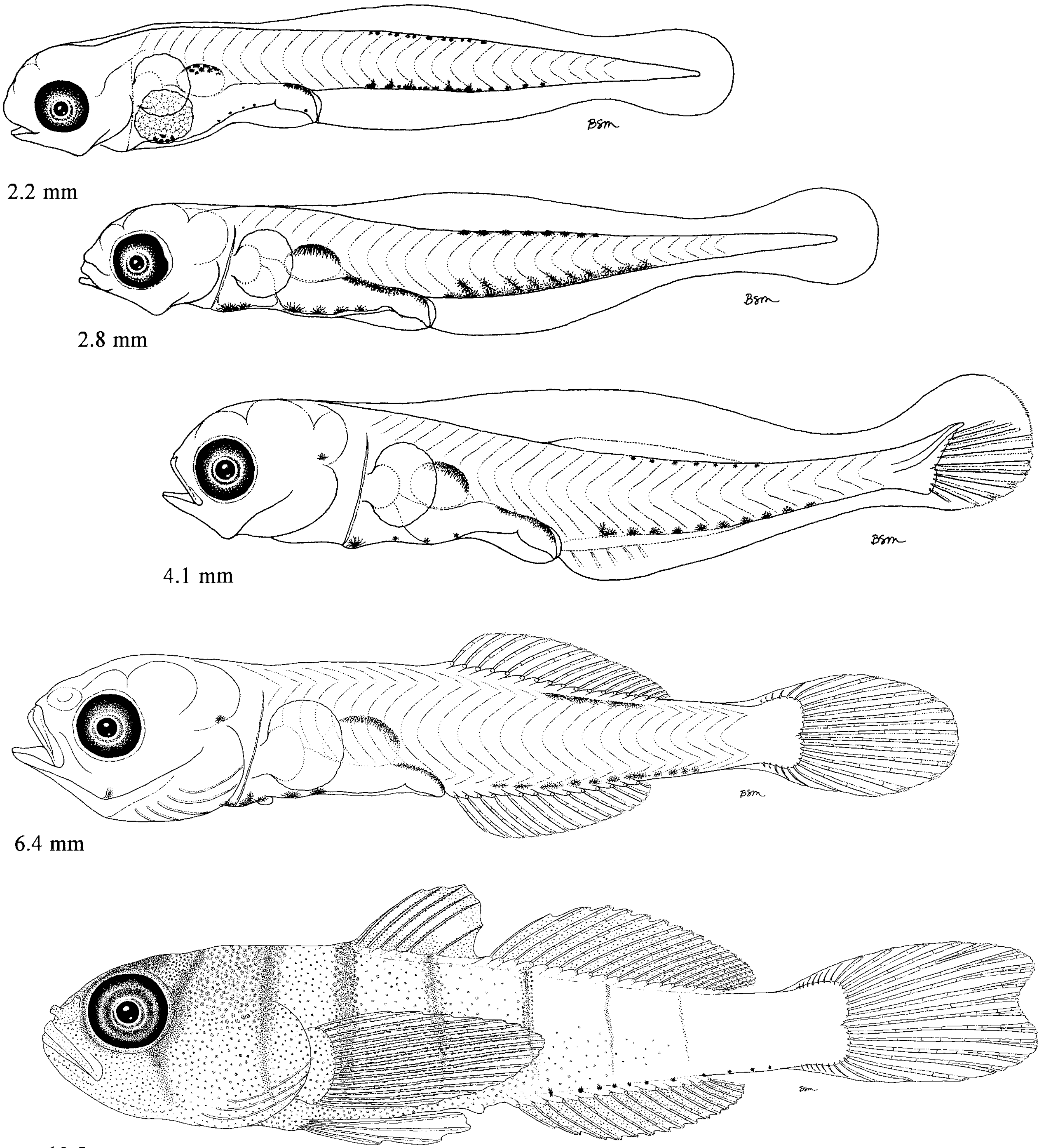


Figure Gobiidae 10. Yolk-sac larva, 2.2 mm (CFRD Ref. Coll., reared at SWFSC, day 1, March 3, 1978); preflexion larva, 2.8 mm (CFRD Ref. Coll., reared at SWFSC, day 7, April 10, 1978); flexion larva, 4.1 mm (CFRD Ref. Coll., reared at SWFSC, day 21, April 24, 1978); postflexion larva, 6.4 mm (CalCOFI 6410, station 100.80); transformation specimen, 10.5 mm (SIO 65–329). Scales are not shown.

MERISTICS

	Range	Mode
Vertebrae:		
Total	26	26
Precaudal	10	10
Caudal	16	16
Fins:		
Dorsal spines	VI+0–I	VI+I
Dorsal rays	11–14	12
Anal spines	0–I	I
Anal rays	8–11	9
Pelvic	I,5	I,5
Pectoral	18–21	20
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	6–8	7
Lower	5–7	6
Gill rakers:		
Upper	0–2	
Lower	9	
Branchiostegals	5	5

LIFE HISTORY

Range: Carmel Bay, California, to Isla Clarión, Mexico

Habitat: Rocky areas, usually in crevices or caves; intertidal to 97 m depth

Spawning season: Spring–autumn

ELH pattern: Oviparous; demersal eggs attached to roof of shelter, guarded by male; planktonic larvae

LITERATURE

Wiley 1976

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (B. Sumida MacCall)
Flexion larva, 5.0 mm (B. Sumida MacCall)
Postflexion larva, 5.7 mm (B. Sumida MacCall)
Juvenile, 11.6 mm (B. Sumida MacCall)

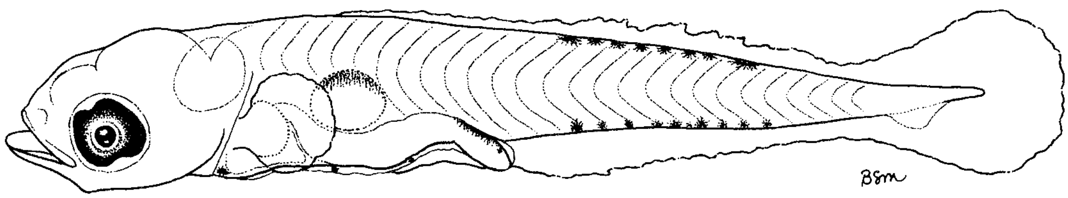
EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

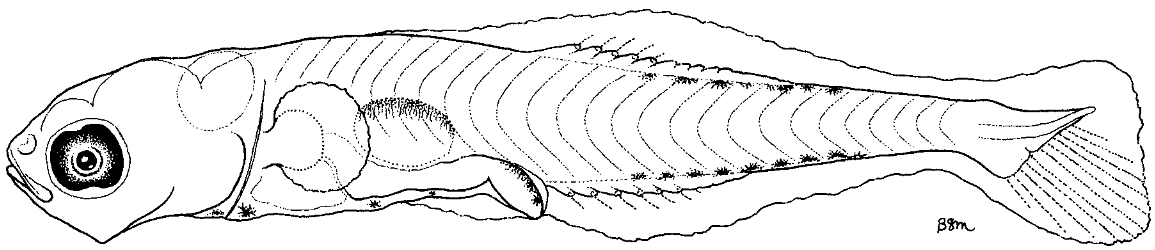
LARVAE
Hatching length:
Flexion length: ca. 4–5 mm
Transformation length: ca. 10–12 mm
Fin development sequence: C_1, A, 2D, C_2, P_1, 1D & P_2
Pigmentation: *Preflexion–flexion*—Single row on ventral margin of tail from postanal myomere 3–5 to 11–13 & corresponding row on dorsal margin; 1 anteriorly on ventral margin of gut, 1–2 ventrally on midgut, none ventrally on hindgut; dorsally on gas bladder; 4–5 dorsally on hindgut; 1 at angular; 1 anteriorly under hindbrain. *Postflexion*—Double rows along A & 2D bases; 3–6 ventrally from isthmus to P_2 base; pair posteriorly on midbrain; 1 anterolaterally on each side of hindbrain. *Transformation*—General increase in pigmentation from head to tail & on all fins; bars form.
Diagnostic features: Pigment ventrally on tail begins at postanal myomere 4 (occasionally 3, rarely 5); melanophore rows along dorsal & ventral margins of tail; ≥13 bars form during transformation stage; preanal myomeres 8–10 (usually 9), total myomeres 25–27 (usually 26).

MORPHOMETRICS (range & mean in %)

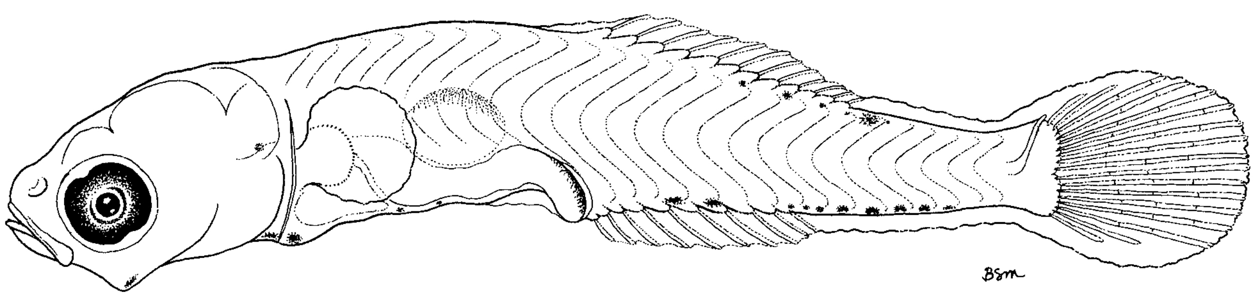
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–54 51	49–52 50	47–56 53	53–56 55	52–57 55
BD/BL		12–17 15	16–17 16	14–23 17	21–21 21	21–22 22
HL/BL		20–26 23	22–26 24	23–33 27	30–33 32	29–31 30
HW/HL		42–50 47	42–46 44	41–56 45	52–52 52	55–65 61
SnL/HL		17–25 20	16–21 18	13–23 19	14–16 15	13–18 15
ED/HL		29–38 33	28–34 30	26–31 28	31–34 32	30–33 32
P_1L/BL		4–6 6	4–7 5	5–27 8	23–29 26	28–34 31
P_2L/BL		0–0 0	0–0 0	0–25 3	27–32 30	29–34 31



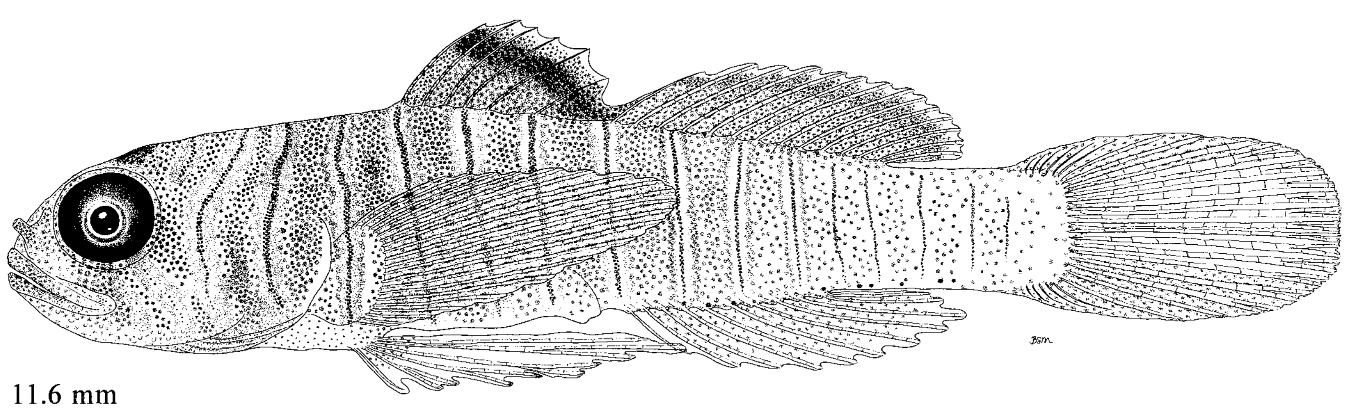
3.8 mm



5.0 mm



5.7 mm



11.6 mm

Figure Gobiidae 11. Preflexion larva, 3.8 mm (CalCOFI 7510, station 110.34); flexion larva, 5.0 mm (CalCOFI 7510, station 97.29); postflexion larva, 5.7 mm (CalCOFI 6610, station 110.32); juvenile, 11.6 mm (SIO 65–51). Scales are not shown.

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–34	33
Precaudal	13–14	14
Caudal	18–20	19
Fins:		
Dorsal spines	IV–V+I	V+I
Dorsal rays	13–15	14–15
Anal spines	0–I	I
Anal rays	12–15	13–14
Pelvic	I,5	I,5
Pectoral	19–22	21
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	7–9	8
Lower	7–9	7–8
Gill rakers:		
Upper	2–4	
Lower	8–10	
Branchiostegals	5	5

LIFE HISTORY

Range: Morro Bay, California, to Bahía Magdalena, Baja California Sur, & in Gulf of California

Habitat: Shallow soft bottom of estuaries, bays, lagoons & open coast; may occupy invertebrate burrows, males construct burrows

Spawning season: Year-round

ELH pattern: Oviparous; demersal eggs attached on walls of burrow & guarded by male; planktonic larvae

LITERATURE

Brothers 1975

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (B. Sumida MacCall)
Flexion larva, 5.3 mm (B. Sumida MacCall)
Postflexion larva, 9.3 mm (B. Sumida MacCall)
Transformation specimen, 10.3 mm (B. Sumida MacCall)

* Eye slightly to moderately elongate; horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

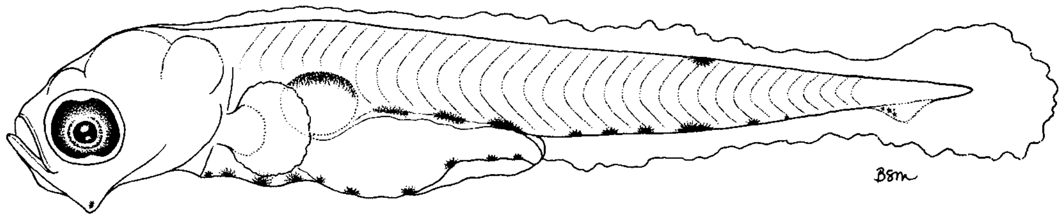
Shell diam.: 3.4 mm long **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface: Unsculptured; cluster of adhesive filaments at basal pole
Pigment:
Diagnostic features: Elliptical, "club-shaped" chorion

LARVAE

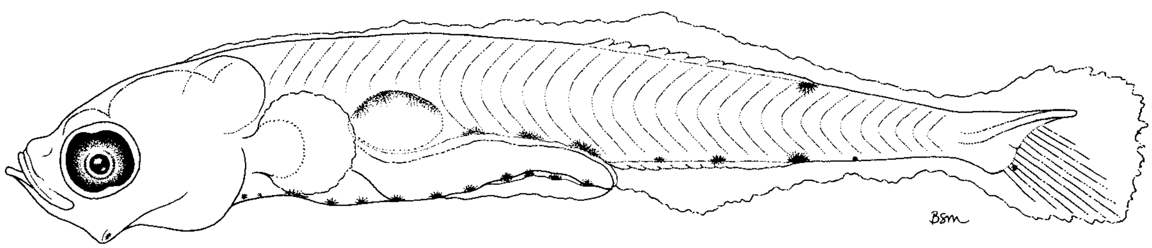
Hatching length: ca. 2.8–3.0 mm
Flexion length: 5.0–5.1 mm through 5.7–5.8 mm
Transformation length: ca. 9.5–12 mm
Fin development sequence: C_1, A, 2D, C_2, P_1 & P_2, 1D
Pigmentation: *Preflexion–postflexion*—Single row on ventral margin of gut (5–14 melanophores, usually 7–11) & on tail (4–11, usually ≤7 through flexion stage, 6–10 in postflexion stage); 3 over hindgut; dorsally on gas bladder; 1 at angular; 1–2 (usually 1) posteriorly on dorsal margin of tail. *Late postflexion*—Under hindbrain; 1–2 on bases of upper P_1 rays. *Transformation*—Series on vertebral column; lateral series; pairs (becoming single posteriorly) on dorsal margin; increases on head, dorsum, dorsolaterally & on fins.
Diagnostic features: 3 melanophores over hindgut; single row (usually 4–10 small melanophores) on ventral margin of tail; on P_1 late in postflexion stage; little dorsal pigment before transformation (ca. 10 mm); preanal myomeres 11–15 (usually 13–14), total myomeres 31–35 (usually 33–34).

MORPHOMETRICS (range & mean in %)

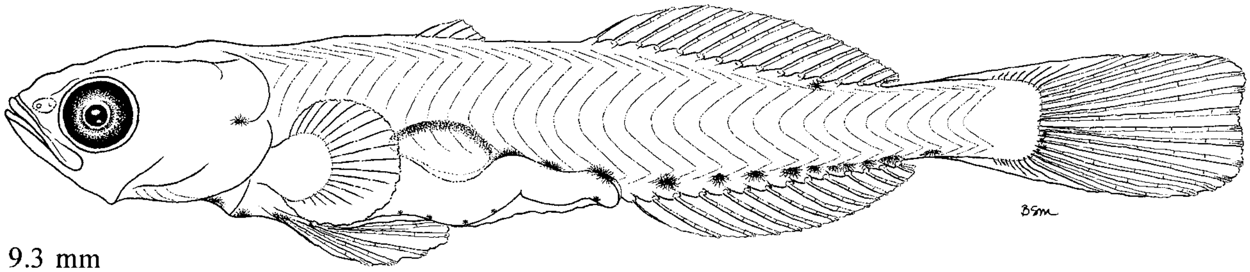
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		52–59	57–61	56–60	57–59	53–59
	55	55	58	58	58	56
BD/BL		13–16	13–17	15–17	16–18	17–18
	16	15	15	16	17	18
HL/BL		22–24	23–27	25–27	28–31	28–32
	20	23	25	26	30	30
HW/HL		45–52	42–46	42–48	44–49	41–44
	57	48	44	45	46	42
SnL/HL		15–20	18–26	19–24	18–25	19–21
	7	17	21	21	21	19
ED/HL*		26–34× 22–29	24–29× 20–27	23–25× 18–24	22–26× 21–24	20–22× 19–21
	43×27	30×26	26×23	24×22	24×22	21×20
P_1L/BL		4–6	4–6	5–15	12–20	17–19
	7	5	5	8	16	18
P_2L/BL		0–0	0–0.3	0.2–18	20–23	19–21
	0	0	0.1	7	21	20



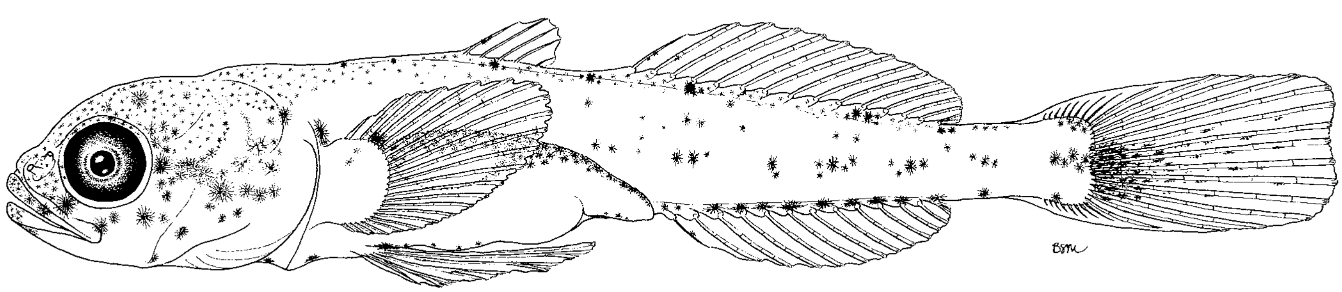
3.8 mm



5.3 mm



9.3 mm



10.3 mm

Figure Gobiidae 12. Preflexion larva, 3.8 mm (MEC I91, station LA–M); flexion larva, 5.3 mm (MEC I47, Auriga R7); postflexion larva, 9.3 mm (SK 87–535 Bottom, April 28, 1987), transformation specimen, 10.3 mm (SK 87–536 Bottom, April 28, 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	26–27	26
Precaudal	10	10
Caudal	16–17	16
Fins:		
Dorsal spines	VI+I	VI+I
Dorsal rays	11–12	11–12
Anal spines	I	I
Anal rays	10–11	10–11
Pelvic	I,5	I,5
Pectoral	20–22	
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	11–13	11
Lower	10–13	10
Gill rakers:		
Upper	2–3	
Lower	7–8	
Branchiostegals	5	5

LIFE HISTORY

Range: San Francisco Bay to Los Angeles Harbor, California; an introduced species

Habitat: Bays; among shells & in crevices among fouling organisms on hard substrates

Spawning season: Spring–autumn

ELH pattern: Oviparous; demersal eggs attached to surface of brood chamber, guarded by male

LITERATURE

Dôtu 1958
Mori 1988
Wang 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.7 mm (M. T. Vona)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: ca. 1.4 × 0.6 mm **Yolk:**
No. of OG: ca. 10, condensing to 1 **Diam. of OG:**
Shell surface: Unsculptured; cluster of adhesive filaments at basal pole
Pigment: Yolk yellowish; late embryo pigmented on hindgut & ventral margin of tail
Diagnostic features: Chorion elliptical, pointed at distal end

LARVAE

Hatching length: ca. 2.4 mm
Flexion length:
Transformation length: ca. 14–15 mm
Fin development sequence:
Pigmentation: *Preflexion*—Dorsally on gas bladder; over end of hindgut; 2–3 on ventral margin of hindgut; 1 on ventral margin of tail at myomere 9–11. *Postflexion*—Irregular double row along A base, continuing as single row posteriorly; 2–3 on ventral margin from isthmus to P_2 base; at bases of a few lower C rays. *Transformation*—Midlateral stripe on body; increasing on C base. *Juvenile*—Increasing on dorsum, dorsolaterally, laterally, & on C.
Diagnostic features: Lightly pigmented before transformation; little gut pigment; midlateral stripe forms during transformation stage; preanal myomeres 10–13, total myomeres 24–26.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL						
BD/BL						
HL/BL						
HW/HL						
SnL/HL						
ED/HL						
P_1L/BL						
P_2L/BL						

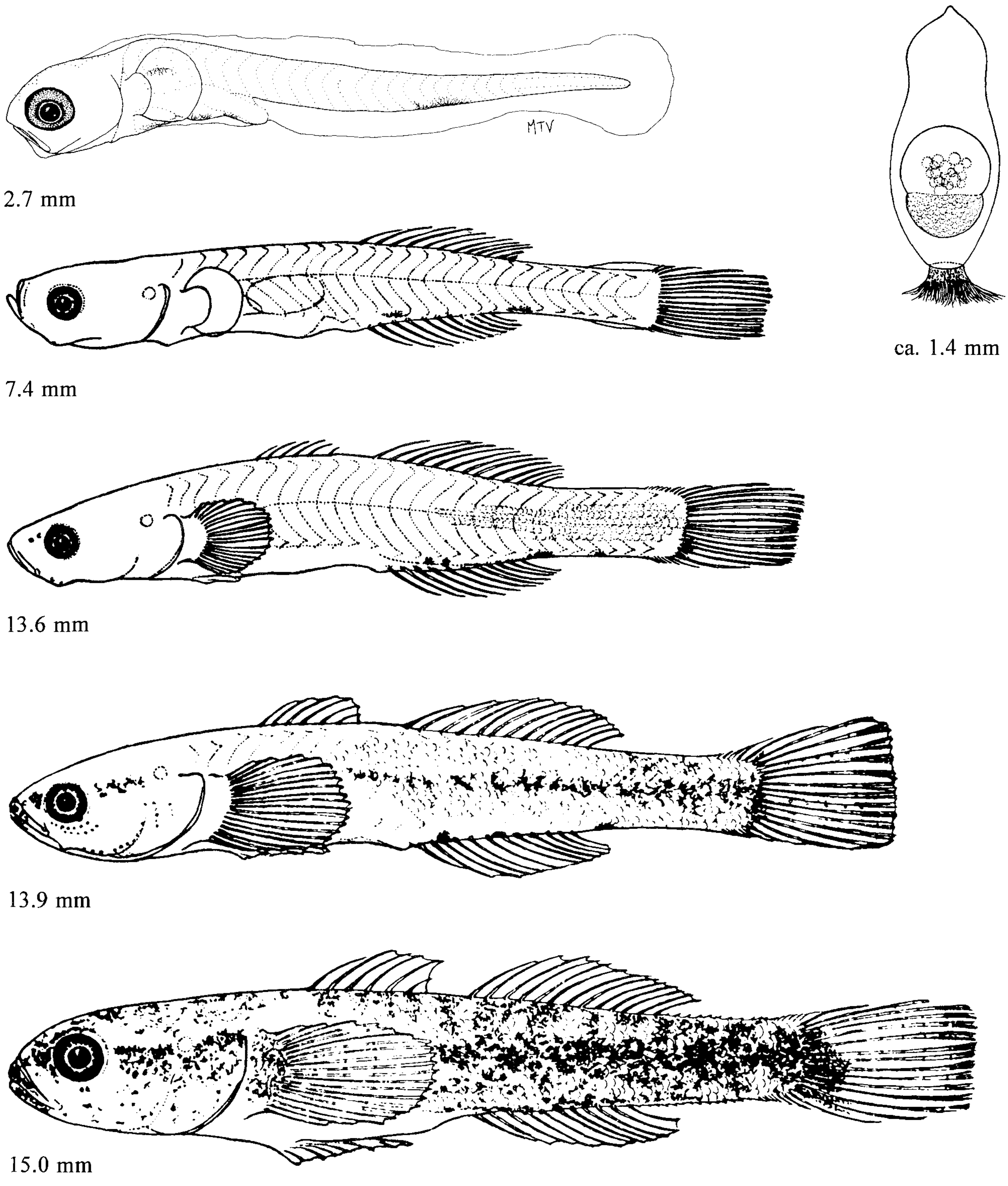


Figure Gobiidae 13. Egg, ca. 1.4 mm (Dôtu 1958); preflexion larva, 2.7 mm (CFRD Ref. Coll., MMWD, tow 2, San Francisco Bay, June 21, 1991); postflexion lavae, 7.4 mm, 13.6 mm; transformation specimen, 13.9 mm; juvenile, 15.0 mm (Dôtu 1958).

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–32	31
Precaudal	16–18	17
Candal	12–15	14
Fins:		
Dorsal spines	II–III+0–I	III+I
Dorsal rays	10–12	10–12
Anal spines	I	I
Anal rays	7–10	7–9
Pelvic	I,5	I,5
Pectoral	15–16	15–16
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	8–9	8
Lower	7	7
Gill rakers:		
Upper	2	2
Lower	8–11	9
Branchiostegals	5	5

LIFE HISTORY

Range: Near San Simeon Point, California, to Bahía Magdalena, Baja California Sur

Habitat: Rocky areas & sand bottom adjacent to rocks, intertidal to ca. 15 m depth; usually resides in *Callianassa affinis* burrows

Spawning season: Spring–summer, primarily May–July

ELH pattern: Oviparous; demersal eggs attached on burrow walls, tended by both parents; planktonic larvae

LITERATURE

MacGinitie 1939

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.4 mm (B. Sumida MacCall)
Flexion larva, 5.8 mm (B. Sumida MacCall)
Postflexion larva, 11.7 mm (B. Sumida MacCall)

* Eye slightly to moderately elongate throughout larval development; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

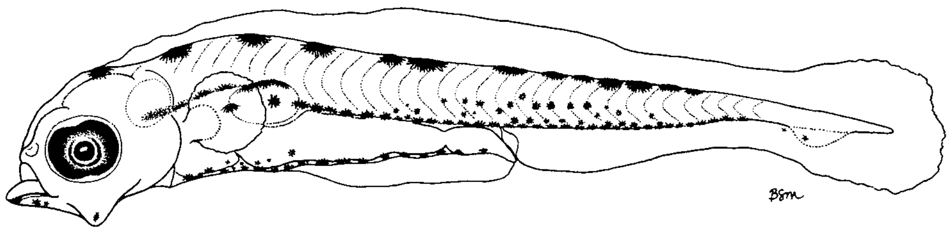
Shell diam.: 2.7–2.9 × 0.68–0.72 mm **Yolk:**
No. of OG: 1 **Diam. of OG:**
Shell surface: Unsculptured, cluster of adhesive filaments at narrower (basal) pole
Pigment:
Diagnostic features: Elliptical, "club-shaped" chorion

LARVAE

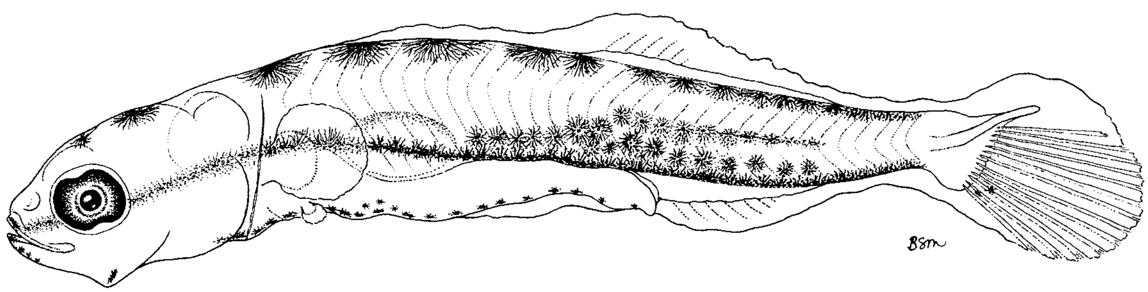
Hatching length: 3.0–3.3 mm
Flexion length: 5.0–5.2 mm through ca. 6 mm
Transformation length: >11.7 mm, <26.9 mm
Fin development sequence: C_1, A, 2D, P_1 & C_2, P_2, 1D
Pigmentation: *Preflexion*—Single row on dorsal margin from head to near end of tail (usually >12 melanophores, all large); heavy on ventrum, especially along anterior half of gut & at ca. myomeres 17–27; laterally & ventrolaterally from ca. myomeres 15–22; continuous series from roof of mouth, under hindbrain, to over gut & gas bladder; series on gular area & on isthmus. *Flexion–postflexion*—Increasing laterally, ventrolaterally, & on head; at bases of some lower C rays.
Diagnostic features: Heavy dorsal, ventral, & ventrolateral pigment; series over gut to roof of mouth appears as stripe through mideye; long preanal length (usually >60% BL); preanal myomeres 15–17 (usually 16), total myomeres 30–32 (usually 31–32).

MORPHOMETRICS (range & mean in %)

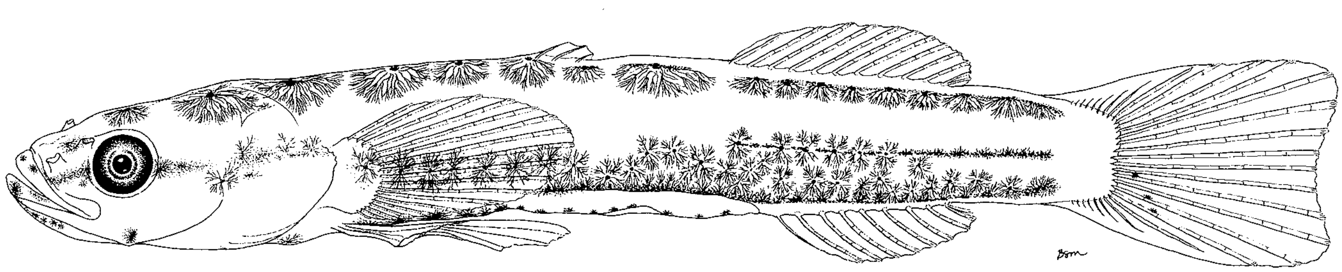
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	58–61 60	56–69 62	64–66 65	63–68 65		68
BD/BL	13–16 15	11–19 16	14–16 15	14–16 14		18
HL/BL	19–21 20	17–31 23	24–27 26	24–28 26		32
HW/HL	47–55 50	42–53 49	40–46 42	39–54 44		50
SnL/HL	7–17 14	13–26 19	18–23 21	19–25 23		21
ED/HL*	37–43× 29–38 41×34	26–48× 24–36 37×29	26–30× 21–25 28×22	21–26× 18–22 23×20		5
P_1L/BL	3–6 4	4–6 5	4–5 5	5–18 12		21
P_2L/BL	0–0 0	0–0 0	0–3 2	1–20 12		18



3.4 mm



5.8 mm



11.7 mm

Figure Gobiidae 14. Preflexion larva, 3.4 mm (MEC I46, station B–N, replicate 2); flexion larva, 5.8 mm (CalCOFI 6706, station 83.43); postflexion larva, 11.7 mm (MEC I30, station LS–M, replicate 1).

MICRODESMIDAE: Wormfishes, dartfishes, hover gobies

W. WATSON

Microdesmidae contains about 60 species in two subfamilies (Nelson 1994); at least two of these, belonging to the subfamily of wormfishes (Microdesminae), occur at the southern end of the CalCOFI study area (Table Microdesmidae 1). Representatives of the other subfamily, Ptereleotrinae, occur nearby in the Gulf of California (Allen and Robertson 1994). Although adults of *Clarkichthys bilineatus* have been recorded only from the Cabo San Lucas vicinity within the CalCOFI study area (Dawson 1974b), its larvae have been collected as far north as the vicinity of Punta Abreojos, Baja California Sur. *Microdesmus dorsipunctatus*, reported to range northward to Bahía Almejas, Baja California Sur (Dawson 1968), is represented in CalCOFI collections by four larvae taken near shore between about Boca de Soledad and Punta Marquis, Baja California Sur. Larvae of another *Microdesmus* species, possibly *M. multiradiatus*, are relatively common in nearshore ichthyoplankton collections from the Gulf of California.

Microdesmids are small (commonly <15 cm; largest species to ca. 30 cm) planktivorous inhabitants of shallow soft bottom, rubble, and reef habitats in warm seas. Some species are estuarine. Microdesmines typically hover just above the bottom to feed, and shelter in burrows in sandy or muddy bottom. Ptereleotrines commonly hover higher above reefs or rubble bottom. Microdesmids are elongate and compressed (especially so in the microdesmines), with preanal length usually near half of body length. The head is small and, in microdesmines, the eyes are small. Microdesmines have a small, oblique mouth opening and a heavy, protruding lower jaw. Ptereleotrines have a nearly vertical mouth opening. Microdesmines have a continuous dorsal fin with ca. 10–30 spines and 26–66 soft rays, while ptereleotrines have separate dorsal fins, the first of 4–6 spines and the second with 1 spine and 20–30 soft rays. Pigmentation in the microdesmines typically is cryptic, ranging from plain grey, brown, or greenish, to barred, spotted, or striped patterns. Ptereleotrines often are more brightly colored and/or strikingly patterned.

Microdesmid early life histories are not well known. *Gunnellichthys* spawns small, spherical eggs (Smith 1958), while ovarian eggs of *Clarkichthys bilineatus* are oval (Dawson 1974b). The demersal eggs of *Gunnellichthys* apparently lack the typical gobioid attachment filaments (Smith 1958). Larval microdesmines hatch at <2 mm with pigmented eyes, an open mouth, and a small yolk sac (e.g., Leis and Rennis 1983). They are elongate, slender, and slightly compressed, becoming more compressed with growth. The gut is a straight tube extending to about 50–60% BL. Preanal length changes little during larval development. The prominent gas bladder is anterior initially but moves posteriorly as the larvae develop, reaching its final position near the terminus of the gut late in the postflexion stage. The head is moderately small, initially with large, oval to round eyes which become relatively smaller and round; the snout is short and round. The prominent, protruding microdesmine lower jaw becomes apparent during the postflexion stage. There are no spines on the head or pectoral girdle. Principal caudal fin rays are the first to begin developing, just before or during notochord flexion (ca. 3–5 mm). Next, dorsal and anal soft rays begin developing simultaneously, followed by dorsal spines, pectoral fin rays, and finally pelvic fin rays. Addition of dorsal and anal soft rays is both cephalad and caudad from near the anterior end, while dorsal spines are added cephalad from the posterior end. Larval pigmentation is light to moderate, with melanophores on the gas bladder, dorsal margin of the gut, often on the ventral margin of the gut, along the ventral margin of the tail, and commonly on the dorsal margin of the trunk and/or tail, at least during the postflexion stage. Postflexion stage larvae also may develop melanophores along the lateral midline of the caudal peduncle, and on at least the central or lower caudal fin rays. Larval development is direct, without a morphologically distinct transformation to the benthic juvenile stage.

Larval microdesmines should be easy to distinguish from all other larvae in the CalCOFI study area. Key characters are the slender, elongate form with preanal length near half of body length, prominent gas bladder, myomere counts (range 44–66 in our area), pigmentation largely limited to the gut and ventrum (except dorsal and lateral dashes present on the caudal peduncle in postflexion stage larvae), and fin ray counts in larger postflexion stage larvae. Larvae of the microdesmid species in the CalCOFI area are distinguished primarily by meristic characters. Small or damaged specimens cannot always be identified to species.

The following description of *Clarkichthys bilineatus* is based on examination of three flexion (4.0–4.5 mm), four postflexion (6.1–11.0 mm), and two juvenile (25.2–28.0 mm) specimens. *Microdesmus dorsipunctatus* is not described since only four postflexion stage specimens (4.4–5.6 mm) were available. Pigmentation of these specimens differs little from that of small postflexion stage *C. bilineatus*. The putative larval *M. multiradiatus* likewise are pigmented much like *C. bilineatus*. Meristic data and ecological information were obtained from Dawson (1968, 1974b).

Table Microdesmidae 1. Meristic characters for the microdesmid species in the CalCOFI study area. Both have I,3 pelvic fin rays.

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	P_1	C_2
Clarkichthys bilineatus	21–23	23–25	45–47	XVII–XIX, 28–32	28–31	11–12	5–7+5–7
Microdesmus dorsipunctatus	24–26	28–31	53–56	XV–XVII, 38–43	34–38	12–14	6+6

MERISTICS

	Range	Mode
Vertebrae:		
Total	45–47	46
Precaudal	21–23	22
Caudal	23–25	24
Fins:		
Dorsal spines	XVII–XIX	XVIII
Dorsal rays	28–32	29–30
Anal spines	0	0
Anal rays	28–31	29–30
Pelvic	I,3	I,3
Pectoral	11–12	11
Caudal:		
Principal	8+7	8+7
Procurrent:		
Upper	5–7	
Lower	5–7	
Gill rakers:		
Upper		
Lower		
Branchiostegals	5	5

LIFE HISTORY

Range: Vicinity of Cabo San Lucas, Baja California Sur, to Colombia and the Galápagos Islands; larvae collected as far north as vicinity of Punta Abreojos, Baja California Sur

Habitat: Rocky tidepools and reefs to 7.6 m depth

Spawning season: Larvae collected August–October

ELH pattern: Oviparous; larvae are planktonic

LITERATURE

Dawson 1974b

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 4.0 mm (R. C. Walker)
Postflexion larva, 11.0 mm (R. C. Walker)

* Fin ray complements are complete and the striped adult pigment pattern is present by at least 18 mm, but squamation is incomplete until about 50 mm. Sexual maturity is attained by 34 mm (Dawson 1974b).

EARLY LIFE HISTORY DESCRIPTION

EGGS

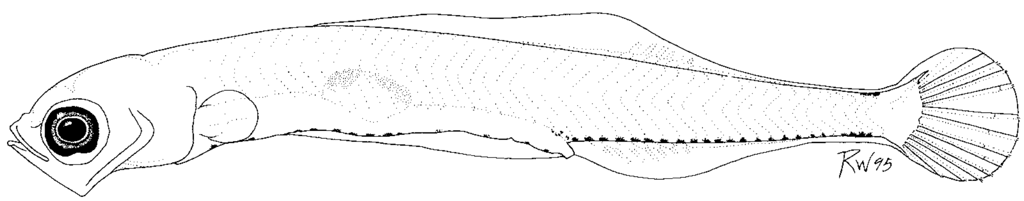
Shell diam.: 0.5 × 0.7 mm (ovarian eggs) **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

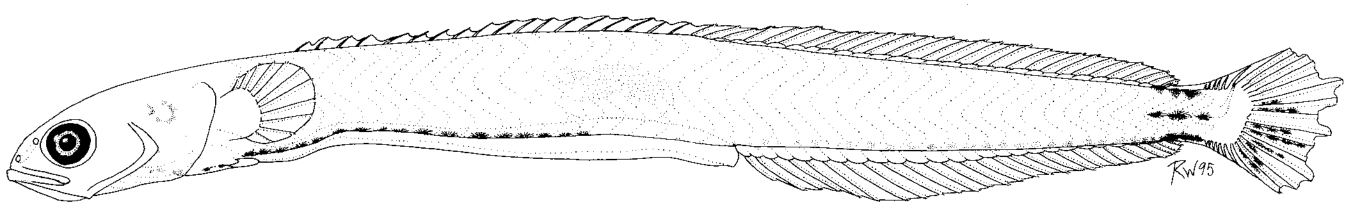
Hatching length:
Flexion length: <4 mm through 4.5 mm
Transformation length:* >11 mm, < 18 mm
Fin development sequence: C_1, 2D & A, C_2, 1D, P_1, P_2
Pigmentation: *Flexion–postflexion*—Crescentic patch posteroventrally in otic capsule during postflexion stage; 0–1 on angular; 2–few on isthmus in postflexion stage; dorsally on gas bladder; 2–3 over hindgut; series ventrolaterally along anterior third to two-thirds of gut in postflexion stage; series along ventral margin of gut, decreasing in postflexion stage to 1 at P_2 base by 11 mm; 16–25 along ventral margin of tail, last 2–4 larger; 2–3 on lateral midline of caudal peduncle after 8 mm; 2–6 on dorsal margin of caudal peduncle; proximally on lower principal C rays in postflexion stage, spreading distad and onto upper rays after 8 mm.
Diagnostic features: Myomeres 44–48 (most commonly 23+23–24); D soft rays usually 29–30; A rays usually 29–30 (all present by 11 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			62–63 62	53–61 58		54–55 55
BD/BL			12–14 13	9–12 10		8–8 8
HL/BL			21–21 21	17–21 18		14–14 14
HW/HL			41–44 42	35–36 35		38–45 41
SnL/HL			17–19 18	15–21 18		17–19 18
ED/HL			28–30 29	20–24 22		13–15 14
P_1L/BL			5–6 5	4–5 5		9–9 9
P_2L/BL			0–0 0	0–0.4 0.1		6–8 7



4.0 mm



11.0 mm

Figure Microdesmidae 1. Late flexion larva, 4.0 mm (TO 58–1, station 62); postflexion larva, 11.0 mm (CalCOFI 5708, station 133G.40).

SPHYRAENIDAE: Barracudas

E. M. SANDKNOP AND W. WATSON

Sphyraenidae traditionally has been considered related to Mugilidae and Polynemidae and has been placed near them in most classifications, either as its own suborder or as part of a larger suborder, Mugiloidei. However, Johnson (1986) provided evidence that the sphyraenids belong to the Scombroidei as the primitive sister group to the other scombroids—a view that is gaining acceptance (e.g., Roberts 1993; Nelson 1994). In this volume, for the sake of consistency with Eschmeyer's (1990) classification, we place Sphyraenidae in its own suborder near Scombroidei.

Sphyraenidae contains about 20 species in the genus *Sphyraena* (de Sylva 1984b); three of these occur in the CalCOFI study area. *Sphyraena argentea* ranges throughout the latitudinal extent of the study area but is uncommon north of southern California, *S. lucasana* ranges from Bahía Sebastián Vizcaíno, Baja California through the Gulf of California, and *S. ensis* ranges from the Cabo San Lucas vicinity and the Gulf of California to Peru. Larval *S. argentea* occur relatively commonly in CalCOFI ichthyoplankton samples collected between May and November, primarily at inshore stations between Point Conception and Cabo San Lazaro. A few larval *S. ensis* have been collected in summer from the Cabo San Lucas vicinity and Gulf of California during CalCOFI surveys, but they are most common farther south along the coast of mainland Mexico and Central America. No larval *S. lucasana* have been identified in CalCOFI collections.

Barracudas are medium-size to large (ca. 40–180 cm) schooling or solitary predators (primarily piscivorous) in all warm seas. They include both commercially exploited and highly regarded sport species and most are considered quite palatable, although larger individuals may contain ciguatera toxin in some areas. Barracudas are elongate, cylindrical to slightly compressed, with preanal length about two-thirds of body length. The snout is long and the mouth large, with a projecting lower jaw and strong, fanglike teeth. The two dorsal fins are short-based and widely separated; the short-based anal fin is below the second dorsal fin. Pelvic fins are abdominal and the caudal fin is forked. The body is covered with small cycloid scales. Barracudas typically are countershaded in shades of brown, green, blue or grey dorsally and silvery or white below, often with some barring or with a midlateral stripe or series of blotches.

Sphyraenids are oviparous, with planktonic eggs and larvae (e.g., Walford 1932; de Sylva 1984b; Kinoshita 1988a; Ikeda and Mito 1988). Eggs are spherical, 0.7–1.6 mm in diameter, with a smooth chorion, a narrow perivitelline space, weakly segmented yolk, and a single oil globule 0.2–0.4 mm in diameter (e.g., Barnhart 1927; Walford 1932; Orton 1955; Houde 1972; Ikeda and Mito 1988). Larvae are ca. 1.8–2.6 mm long and relatively undeveloped at hatching, with unpigmented eyes, an unformed mouth, pectoral fins lacking or present as buds, and a large yolk sac with the oil globule located anteriorly (*S. borealis*: Houde 1972; *S. pingus*: Uchida et al. 1958b; Ikeda and Mito 1988) or posteriorly (*S. argentea*: Orton 1955). Larvae are elongate, with a straight gut extending to ca. 60–80% BL throughout development. The snout initially is short and rounded but quickly elongates, beginning early in the preflexion stage. Prominent teeth develop in both jaws during the preflexion stage. The eyes are relatively large and oval to round initially, becoming consistently round by the postflexion or transformation stage. Spination on the head is limited to a few small preopercular spines, and a few small interopercular spines in some species. Some species apparently lack head spination (e.g., Houde 1972). Principal caudal rays are the first fin rays to begin forming, at about the beginning of notochord flexion, followed by simultaneous development of the soft rays of the anal and second dorsal fins during notochord flexion. Addition of rays in both fins is anterior, or both anterior and posterior from the middle, depending on species. Rays begin forming in the other fins during the postflexion stage; the sequence appears to be species-specific. Larval barracudas typically are lightly to moderately pigmented initially, with melanophores primarily on the dorsum, dorsally on the gut, often ventrally on at least the first few postanal myomeres, and on the oil globule and/or yolk sac. Pigmentation typically becomes moderately heavy to quite heavy during the postflexion stage.

Barred or striped patterns are common. Transformation to the juvenile stage is gradual and direct.

Barracuda eggs resemble the spherical planktonic eggs of many fish species in the CalCOFI study area. An egg diameter of ca. 1.0–1.4 mm (*S. argentea*), presence of a single oil globule, and a weakly segmented yolk is a combination of characters shared with a smaller number of taxa, and spawning in shallow coastal waters during summer further reduces the list. Late embryos are distinctively pigmented and should present few identification problems; however, identification of earlier stage eggs remains problematic. Larvae are readily identifiable as barracudas by a combination of characters including the elongate shape with straight gut extending to about two-thirds of body length, the long, pointed snout and large mouth (except in yolk-sac larvae), the short-based, posteriorly placed anal and second dorsal fins (first visible in the flexion stage), the widely separated dorsal fins (late postflexion stage), 24 myomeres, and pigmentation.

The following descriptions are based on examination of 34 specimens of *S. argentea* and 32 *S. ensis* (Table Sphyraenidae 1). Meristic data were obtained from Miller and Lea (1972), de Sylva (1984b), Allen and Robertson (1994) and counts made during this study. Ecological information is from Walford (1937), Eschmeyer et al. (1983), and Allen and Robertson (1994).

Table Sphyraenidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the *Sphyraena* species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Sphyraena argentea	10	4	7	5	3	1	4
	1.3–1.4	2.7–3.4	3.1–5.2	5.5–7.2	8.8–10.8	25.5	30.8–55.0
S. ensis		1	4	6	7	1	3
	0	1.6	2.7–3.8	4.2–6.3	7.3–12.3	17.0	30.7–50.0

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	12–13	13
Caudal	11–12	11
Fins:		
Dorsal spines	V+I	V+I
Dorsal rays	8–10	9
Anal spines	I–II	II
Anal rays	8–10	9
Pelvic	I,5	I,5
Pectoral	13–16	13
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	9
Lower	7–8	8
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	7	7

LIFE HISTORY

Range: Kodiak Is., Alaska to Cabo San Lucas, Baja California Sur & the Gulf of California; uncommon north of Point Conception, California

Habitat: Schools in coastal waters, near surface to ca. 18 m depth

Spawning season: Larvae collected throughout the year with July–September maximum

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Barnhart 1927
Orton 1955
Walford 1932

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.1 mm (R. C. Walker)
Yolk-sac larva, 3.4 mm (R. C. Walker)
Preflexion larva, 4.7 mm (R. C. Walker)
Flexion larva, 7.1 mm (R. C. Walker)
Postflexion larva, 14.8 mm (R. C. Walker)

* The eye is oval, becoming nearly round by the juvenile stage; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.0–1.4 mm **Yolk:** Segmented; 1.0–1.2 mm diam.
No. of OG: 1 **Diam. of OG:** 0.30–0.38 mm
Shell surface: Smooth
Pigment: Advanced embryo with melanophores on midbrain; series on dorsal & ventral margins; on dorsal & ventral finfolds; few posteriorly on yolk.
Diagnostic features: Diameter; weakly segmented yolk; pigmentation of advanced embryo

LARVAE

Hatching length: ca. 2.3 mm
Flexion length: ca. 5.5–7.2 mm
Transformation length: ca. 25.5 mm to <46.8 mm
Fin development sequence: C_1, 2D & A, C_2 & P_1, 1D & P_2
Pigmentation: *Yolk-sac*— 0–2 over forebrain; several dorsolaterally over midbrain, patch at nape, & irregular series dorsally on trunk & tail to myomere 15–18, becoming continuous; 1–2 on articular; series over gut, continuing on ventral margin of first 3–5 postanal myomeres; few scattered on yolk sac, becoming concentrated anteroventrally on gut; 1–2 ventrally on gut near anus; 1–few each, distally on preanal & anal finfolds near anus; bar forms at first 3–5 postanal myomeres; few over & under notochord tip initially, none dorsally by end of stage. *Preflexion*—Series anteriorly on both jaws; increasing on dorsum; in roof of mouth; series on gular area & isthmus; few on lower preopercular margin; spreading ventrolaterally from dorsum beginning at myomere 7–8, forming broad bar (myomeres 8–18) in some. *Flexion*—Increasing on all areas; few on snout; sparse patch on opercle by 7 mm; 0–few proximally on A late in stage. *Postflexion*—Becoming nearly completely pigmented except on caudal peduncle through ca. 11 mm; usually lighter laterally on head & trunk. *Transformation*—Spreading from caudal peduncle onto proximal part of C; 2D & A nearly covered.
Diagnostic features: P_2 well behind P_1 (apparent by ca. 9 mm); compared with *S. ensis*, more heavily pigmented dorsally on head & trunk, less heavily pigmented ventrally on gut, preanal finfold, & on tail through early postflexion stage; single broad bar on tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	59–63	64–68	67–73	69–76		66–73
	61	66	70	74	71	69
BD/BL	7–14	13–21	13–18	12–15		11–13
	11	16	14	13	12	12
HL/BL	21–24	27–31	30–34	30–38		34–34
	22	28	32	34	33	34
HW/HL	56–71	43–65	31–38	26–30		23–30
	62	50	34	28	27	27
SnL/HL	7–13	17–38	30–37	35–38		45–46
	10	26	34	37	43	46
ED/HL*	38–46× 28–38	27–35× 21–26	23–27× 16–21	22–23× 18–20		19–24× 15–21
	40×33	31×23	25×19	23×19	20×18	21×18
P_1L/BL	0–5	5–7	5–6	3–5		9–11
	2	6	6	4	10	10
P_2L/BL	0–0	0–0	0–0	2–3		7–9
	0	0	0	3	2	8

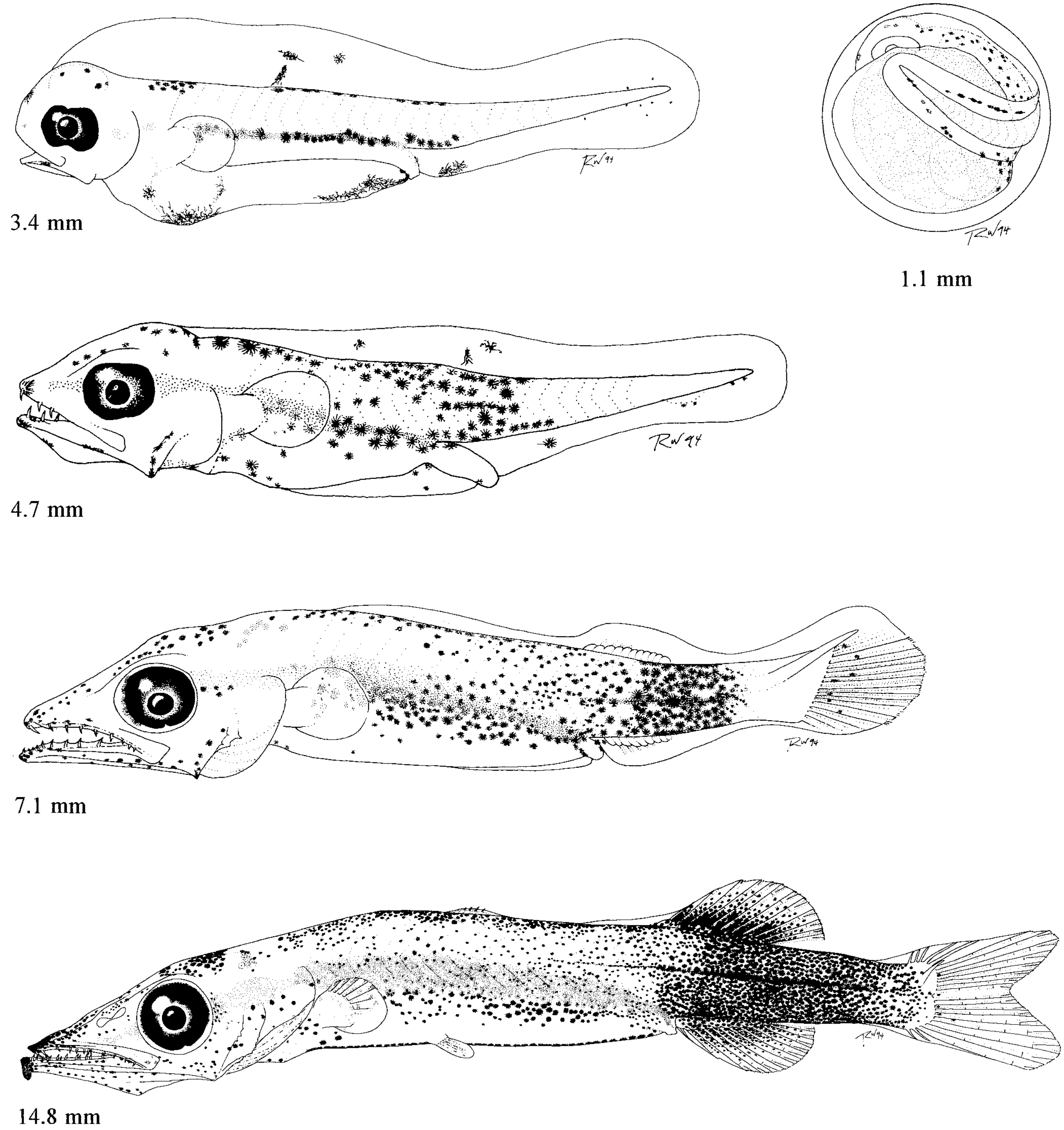


Figure Sphyraenidae 1. Egg, 1.1 mm (CalCOFI 7807, station 97.32); yolk-sac larva, 3.4 mm (CalCOFI 9204, station 90.30); preflexion larva, 4.7 mm (CalCOFI 9207, station 90.30); flexion larva, 7.1 mm (CalCOFI 9207, station 90.30); postflexion larva, 14.8 mm (CalCOFI 7808, station 97.29).

MERISTICS

	Range	Mode
Vertebrae:		
Total	24	24
Precaudal	12	12
Caudal	12	12
Fins:		
Dorsal spines	V+I	V+I
Dorsal rays	9	9
Anal spines	II	II
Anal rays	8	8
Pelvic	I,5	I,5
Pectoral	13	13
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10	10
Lower	9–10	10
Gill rakers:		
Upper	0	0
Lower	0	0
Branchiostegals	7	7

LIFE HISTORY

Range: Gulf of California to Peru

Habitat: Coastal waters

Spawning season: Larvae collected spring through autumn with June maximum

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.4 mm (R. C. Walker)
Flexion larva, 5.5 mm (R. C. Walker)
Postflexion larva, 8.8 mm (R. C. Walker)

* The eye is oval, becoming round or nearly so by the postflexion stage; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

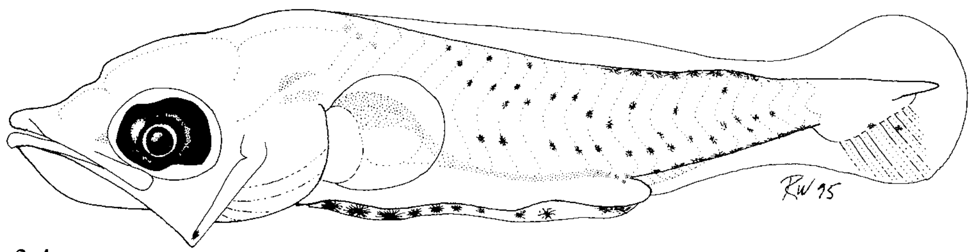
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diaguostic features:

LARVAE

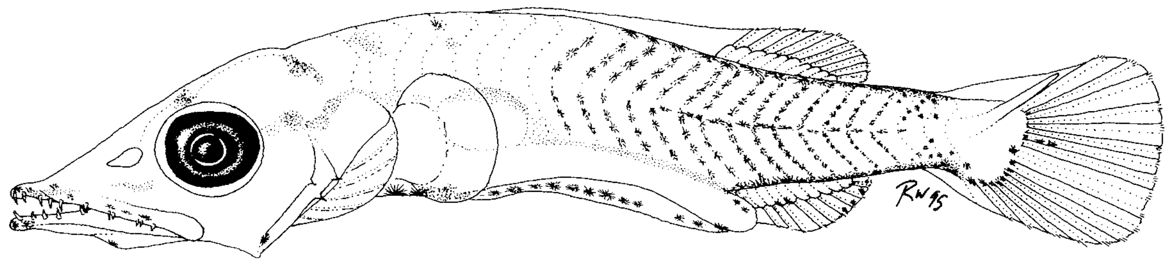
Hatching length: ca. 1.6 mm
Flexion length: ca. 4.2–6.3 mm
Transformation length: ca. 17.0 mm to <30.7 mm
Fin development sequence: C_1, 2D & A, C_2, P_1, 1D, P_2
Pigmentation: *Late yolk-sac*—Heavy dorsally on gut; several ventrally on yolk sac; series distally on preanal finfold; double rows on dorsal margin at ca. myomeres 5–8 & 12–15; series on lateral midline at myomeres 5–12; series on ventral margin of tail. *Preflexion*—1 at angular by 3 mm; by 4 mm, pair posteriorly on midbrain, 1 in otic capsule, series on isthmus, 2 rows on dorsum; few on epaxial myosepta at ca. myomeres 6–8 by 3 mm, to myomere 20 by 4 mm; on hypaxial myosepta of myomeres 10–20 by 4 mm; few on hypural margin; internally proximally on lower hypurals by 4 mm. *Flexion*—Few anteriorly on both jaws; posteriorly on premaxillae by 5.8 mm; 2–4 on vomer; 1 on palatine by 5.5 mm; 1 on gular area after 5.2 mm; anterior pair on midbrain; increasing posteriorly on midbrain, in otic capsule & under hindbrain; internal patch at nape; increasing dorsally on gut; few on anterior A ray bases. *Postflexion*—1–2 on snout by 7.3 mm, spreading as medial row to forebrain by ca. 9 mm, covering midbrain by 12.3 mm; on lower preopercular margin by 12.3 mm; pair of dense patches between 1D & 2D by 9 mm; broad bar between 2D & A by 8 mm & on caudal peduncle by 9 mm; midlateral stripe on tail by 8 mm; few on 2D & A bases. *Transformation*—Increasing on all areas, (saddle, bars, & midlateral stripe remain distinct).
Diagnostic features: P_2 only a little behind P_1 (apparent by ca. 7.3 mm); no dorsal pigment over midbrain before ca. 8 mm; ventral melanophores extend full length (or nearly so) of gut & preanal finfold; trunk & tail pigment primarily myoseptal.

MORPHOMETRICS (range & mean in %)

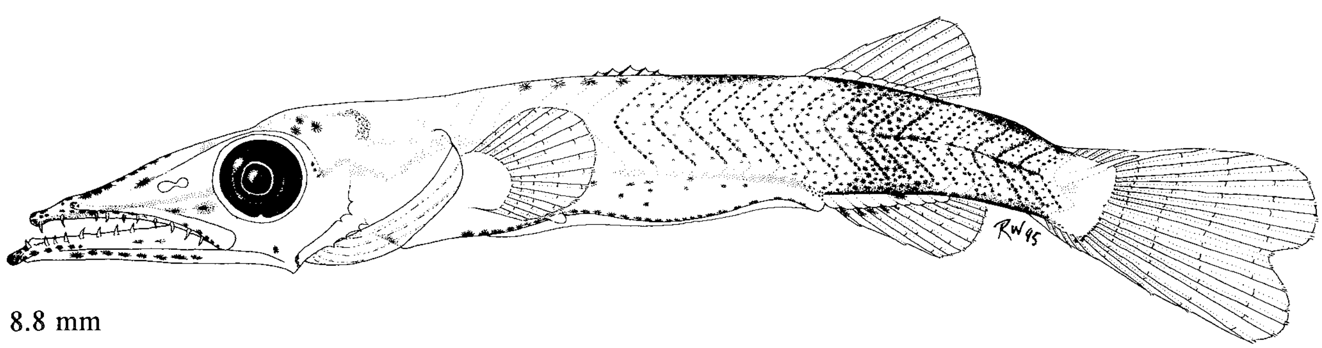
	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		66–70	58–74	71–75		70–71
	62	68	70	73	75	71
BD/BL		19–21	15–18	14–16		10–12
	20	20	17	15	14	11
HL/BL		32–36	30–41	37–40		32–38
	25	34	36	39	40	35
HW/HL		42–57	33–51	24–36		24–25
	75	48	41	30	29	25
SnL/HL		26–35	33–41	40–47		44–47
	20	31	38	44	49	46
ED/HL*		27–33× 22–26	22–26× 17–21	19–22		18–20
	50×45	30×24	21×20	20	20	19
P_1L/BL		4–7	4–7	4–9		10–11
	7	6	5	6	10	10
P_2L/BL		0–0	0–0	0–4		7–9
	0	0	0	1	5	8



3.4 mm



5.5 mm



8.8 mm

Figure Sphyraenidae 2. Preflexion larva, 3.4 mm (TO 58–1, station 71); flexion larva, 5.5 mm (IATTC 90019, station MSH2 #1 Red); postflexion larva, 8.8 mm (IATTC 90019, station MSH2 #2 Grn).

SCOMBROIDEI

D. A. AMBROSE

The suborder Scombroidei is among the most extensively studied and taxonomically best known of the perciform suborders. The generally accepted modern definition of this suborder was established by Regan (1909b) who included six families: Gempylidae, Trichiuridae, Scombridae, Istiophoridae, Xiphiidae and Luvaridae. Leis and Richards (1984) and Tyler et al. (1989) demonstrated that the monotypic Luvaridae is not a scombroid but an acanthuroid. Collette et al. (1984b) and Collette and Russo (1986) proposed a revised classification which included gempylids, trichiurids, scombrids, istiophorids and xiphiids in the Scombroidei but excluded the scombrolabracids. Johnson (1986) proposed an alternative classification with only three families included in the Scombroidei: Sphyraenidae, Gempylidae and Scombridae. Carpenter et al. (1995) reviewed all of these classifications and concluded that the Scombroidei should include 4 superfamilies: Sphyraenoidea, Trichiuroidea, Scombroidea, and Xiphioidea. Recent work utilizing genetic evidence makes a strong case for excluding Xiphioidea (billfishes) from the Scombroidei (Finnerty and Block 1995) which had been suggested by several earlier works (Potthoff and Kelley 1982; Collette et al. 1984b). For this identification guide, we follow the classification of Collette et al. (1984b), also used by Eschmeyer (1990), in which six families are recognized: Scombrolabracidae, Gempylidae, Trichiuridae, Xiphiidae, Istiophoridae and Scombridae. According to Gosline (1968) and Johnson (1975, 1986), this suborder may have its origins near the Pomatomidae. Scombroids, among the world's most highly evolved and fastest swimming predaceous fishes, have great ecological and commercial value.

The scombroids are oviparous, spawning spherical, pelagic eggs, 0.8–1.8 mm in diameter, which usually contain a single oil globule. Larvae hatch with a large yolk sac and unpigmented eyes. Usually, the larvae possess head spination and initially have a deep body, large mouth, and a short gut that becomes more elongate with development. Larval pigmentation is quite variable, ranging from very light to nearly complete, but often is largely restricted to the head and gut. Development is direct.

At least 32 species, representing five scombroid families, occur in the CalCOFI study area, primarily in the warmer waters south of Point Conception, California. Larvae of twelve of these species have been identified in CalCOFI ichthyoplankton collections. Adults of five species of istiophorids and the monotypic *Xiphias gladius* occur in our study area (Eschmeyer et al. 1983); however, their larvae have been collected only in CalCOFI ichthyoplankton tows from the Gulf of California and they are not included in this identification guide. Ueyangi (1963), Collette at al. (1984b), Richards (1989b), and Richards et al. (1990) discuss identification of larval billfishes.

Families included: Gempylidae
Scombridae
Trichiuridae

GEMPYLIDAE: Snake mackerels

D. A. AMBROSE

Five gempylidae species occur in the CalCOFI area and adjacent Equatorial and Central water masses (Table Gempylidae 1) but larvae of only two, *Diplospinus multistriatus* and *Gempylus serpens*, occur regularly in CalCOFI ichthyoplankton samples. *Nealotus tripes* larvae are widely distributed in the eastern tropical Pacific (Ahlstrom 1972b) but are rare in CalCOFI collections. Larvae of *Ruvettus pretiosus* have not been identified in CalCOFI ichthyoplankton samples and we have found only a single larva of *Lepidocybium flavobrunneum*. Adults of these two species are rarely captured in the California Current.

Gempylids are closely related to the trichiurids, whose larvae are more common in CalCOFI collections from 1951 to 1984 (102 vs. 586 occurrences). Adult gempylids are medium (*D. multistriatus* and *N. tripes* reach 30 cm) to large (*G. serpens* reach 1 m; *L. flavobrunneum* and *R. pretiosus* reach >2 m) swift predators found in all warm oceans, usually in the mesopelagic zone (200–1,000 m) or deeper, but often migrating to the surface at night. None is an important component of recreational or commercial fisheries in the California Current area.

Gempylids are oviparous, with planktonic larvae. Eggs and yolk-sac larvae have not been described, and none has been identified in CalCOFI ichthyoplankton samples. Larvae and early juveniles (3–30 mm) are distributed in the upper 50 m and young *L. flavobrunneum* and *G. serpens* have the greatest densities in the upper 1.5 m (Nishikawa 1987).

Early larval gempylids typically have deep, short, compressed bodies and large heads. In preflexion larvae, body depth is ca. 22–33% BL and head length is ca. 31–40% BL. Preopercular spines are prominent, and dorsal and pelvic fin spines are extremely well developed and finely serrated along their entire lengths; pelvic spine length is ca. 20–27% BL in flexion larvae. Preanal distance is ca. 52–63% BL in preflexion larvae. Mouth size is moderate, with the maxilla anterior to mid-eye throughout development. Other characters change markedly during ontogeny; e.g., the gut extends more posteriad (Sn-A is 71–75% BL in postflexion larvae), and spines of the preoperculum and the fins regress. Body elongation is more extreme in juveniles of the more oceanic species (BD is ca. 8% BL for *G. serpens* and *D. multistriatus*; ca. 13% for *N. tripes*) than in the more coastal species (*L. flavobrunneum* and *R. pretiosus*, ca. 26%).

Larval pigment typically is on the forebrain, midbrain, dorsal surface of the gut, first dorsal fin membrane, and along the body margin under the first dorsal fin. Development of lateral body pigment in juveniles is gradual. Pigment is diagnostic for individual species. *D. multistriatus* larvae are unique in having a pigmented area on the branchiostegal membrane. Only *G. serpens* larvae possess a row of melanophores along the midlateral line of the body. *L. flavobrunneum* larvae have the heaviest pigment on the dorsal and ventral gut margin. *R. pretiosus* larvae have diagnostic pigment in the gular region. By the postflexion stage, *N. tripes* larvae have a distinctive caudal peduncle pigment patch.

Early life history studies of gempylids are well summarized by Collette et al. (1984b) and Ozawa (1986e). Recently, Nishikawa (1987) filled many voids in our knowledge of the group and his work and that of Richards (1989a) were utilized extensively in preparation of this chapter. The following species accounts are based on the literature (*L. flavobrunneum* and *R. pretiosus*) and on detailed examinations of 36 specimens of *D. multistriatus*, 33 *G. serpens*, 6 *L. flavobrunneum*, and 35 *N. tripes* (Table Gempylidae 2). Meristic data were obtained from the literature (Fitch and Gotshall 1972; Fitch and Schultz 1978; Nakamura 1984b, 1986) and from counts made during this study. Ecological information was obtained from Miller and Lea (1972), Eschmeyer et al. (1983), and Nakamura and Parin (1993).

Table Gempylidae 1. Selected meristic characters for the gempylid species that occur in the vicinity of the California Current. Diagnostic counts are indicated by an asterisk.

	Vertebrae			Fin spines and rays						
				Dorsal			Anal			
Species	PrCV	CV	Total	D_1	D_2	Finlets	Fin	Finlets	P_1	P_2
Diplospinus multistriatus	22–28	30–37	57–61*	XXX–XXXVI	I,35–41*	0*	II,26–35	0*	11–14	I,0*
Gempylus serpens	26–29	23–26	49–55*	XXV–XXXII	I–II,10–14*	5–7	II+I,10–13	5–7	12–16	I,3–4*
Lepidocybium flavobrunneum	16–17	15	31–32	VIII–XII*	16–20	4–6	II,10–15	4–5	15–17*	I,5
Nealotus tripes	20–22	14–17	36–39*	XIX–XXI*	I,16–20	2	II,14–19*	2	12–14	I,1–2*
Ruvettus pretiosus	16	16	32	XIII–XV*	15–20	2–3	II–III,12–18*	1–3	13–15	I,5

Table Gempylidae 2. Number of specimens (above) and size ranges (in mm, below) used in preparation of the gempylid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Diplospinus multistriatus	0	0	10 3.9–8.5	6 8.2–15.2	10 11.8–20.1	5 21.7–31.5	5 36.1–56.4
Gempylus serpens	0	0	10 3.4–6.8	6 6.4–8.8	10 10.0–16.6	3 17.2–23.5	4 45.0–87.0
Lepidocybium flavobrunneum	0	0	L[a], 1 5.5	L[a]	L[a], 1 10.0	L[a]	L[a], 4 23.0–27.0
Nealotus tripes	0	0	10 2.3–5.4	6 6.0–11.0	10 10.5–17.2	4 17.5–30.5	5 8.4–12.1
Ruvettus pretiosus	0	0	L[a]	L[a]	L[a]	0	L[a]

[a] Nishikawa 1987

MERISTICS

	Range	Mode
Vertebrae:		
Total	57–61	
Precaudal	22–28	
Caudal	30–37	
Fins:		
Dorsal spines	XXX–XXXVI+I	
Dorsal rays	35–42	
Dorsal finlets	0	
Anal spines	II	
Anal rays	26–35	
Anal finlets	0	
Pelvic	I,0	
Pectoral	11–14	
Caudal:		
Total	26–29	
Principal	9+8	
Procurrent:		
Upper	4–6	
Lower	5–6	
Gill rakers:		
Upper	6–11 (1 large in angle)	
Lower	9–17	
Branchiostegals	7	

LIFE HISTORY

Range: Worldwide in warm seas; in the eastern Pacific to at least 35° N (CalCOFI station 60.140)

Habitat: Epi- & mesopelagic from continental slope to mid-ocean; migrates upward at night to 100–200 m depth, probably forming schools during daytime

Spawning season: Early-stage larvae occur mainly from April–August in CalCOFI area; reproduction reported throughout the year

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Collette et al. 1984b
Ozawa 1986e
Nishikawa 1987, 1988b
Richards 1989a

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 8.0 mm through ca. 12–15 mm
Transformation length: ca. 21–32 mm, gradual
Fin development sequence: 1D & P_2, P_1, C_1 & A, 2D, C_2
Pigmentation: *Preflexion*—On nasal region, lower jaw tip, & anterior & posterior peritoneum; by 5 mm, on cheek, 1D membrane, & lateral abdomen; by 6.5 mm, on branchiostegal membrane, occiput, & posterior to eye. *Flexion*—By 7–8 mm, heavy on forebrain & midbrain, & dorsal & ventral margins of trunk; by 10.6 mm, on both jaws, gular membrane, snout, & ventral margin between posterior tip of pelvic bone & anus. *Postflexion*—Mainly on head, 1D membrane, & dorsal body margin.
Diagnostic features: Pigment on tip of lower jaw; by 6.5 mm, larvae have pigment on branchiostegal membrane & markedly developed pelvic bone causing distension of belly; total vertebrae 57–61, 2D rays 35–42, A rays 26–35; P_2 rays & dorsal & anal finlets are absent.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		49–64 57	59–69 66	68–75 71	64–70 67	56–61 59
BD/BL		22–27 24	16–21 19	14–19 17	10–13 12	7–10 9
HL/BL		31–37 35	34–37 36	33–40 36	26–32 30	20–25 24
HW/HL		27–41 30	22–30 27	19–26 23	18–23 21	17–19 18
SnL/HL		37–45 41	36–40 37	34–41 37	35–38 37	38–42 40
ED/HL		25–30 27	22–28 24	18–24 22	18–21 20	15–18 17
P_1L/BL		4–7 7	5–9 8	9–11 10	8–10 9	6–7 7
P_2SpL/BL		13–36 26	21–31 27	16–25 21	11–14 13	7–9 8

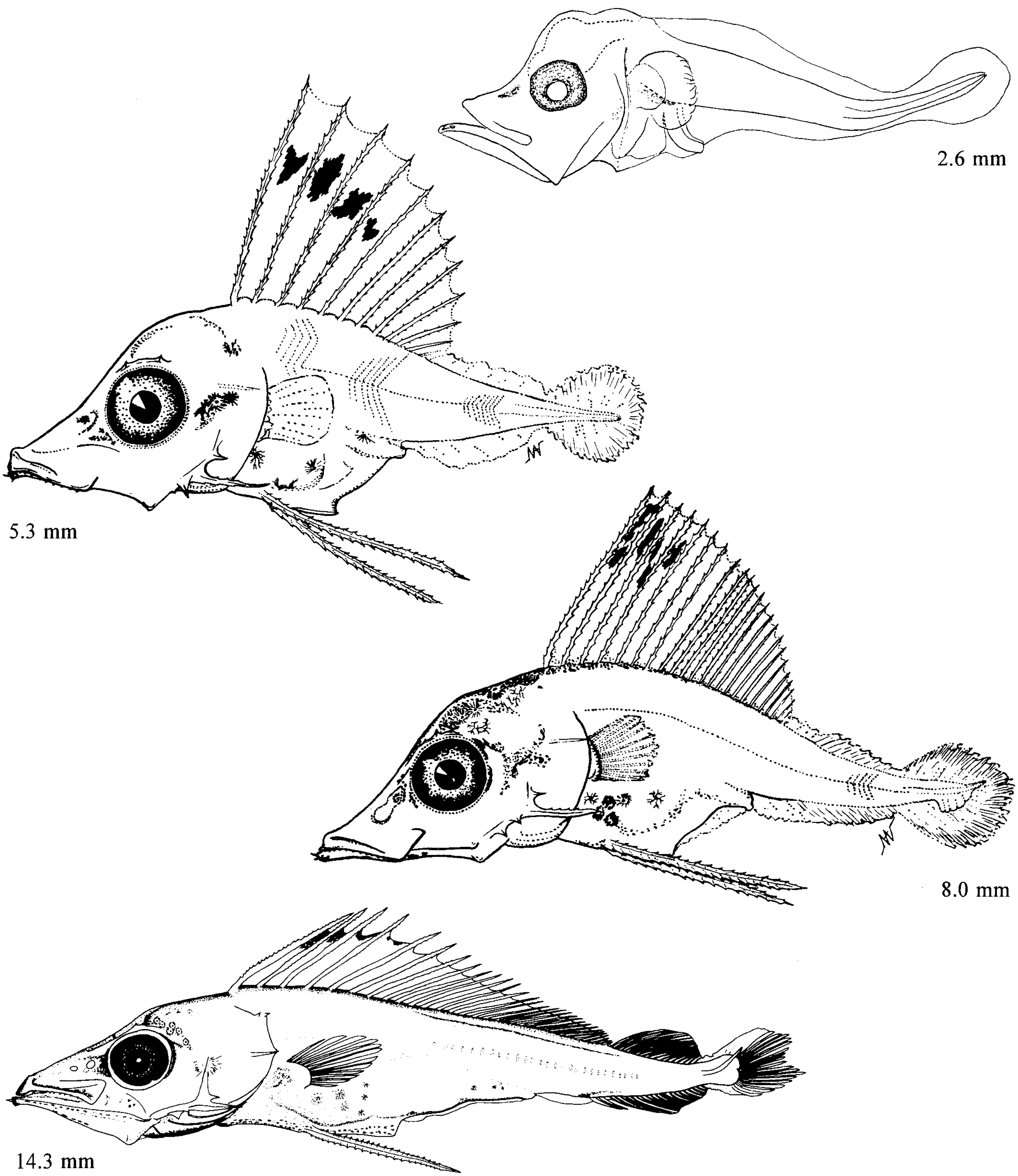


Figure Gempylidae 1. Preflexion larva, 2.6 mm (Ozawa 1986e); preflexion larva, 5.3 mm; flexion larva, 8.0 mm (Voss 1954); postflexion larva, 14.3 mm (Nishikawa 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	49–55	
Precaudal	26–29	
Caudal	23–26	
Fins:		
Dorsal spines	XXV–XXXII+I–II	
Dorsal rays	10–14	
Dorsal finlets	5–7	
Anal spines	II+I	
Anal rays	10–13	
Anal finlets	5–7	
Pelvic	I, 3–4	
Pectoral	12–16	
Caudal:		
Total	33–37	
Principal	9+8	
Procurrent:		
Upper	8–10	
Lower	8–10	
Gill rakers:		
Upper	1 (large) at angle	
Lower	5–6 emerging from tooth patches	
Branchiostegals	7	

LIFE HISTORY

Range: Worldwide in warm seas; in eastern Pacific from southern California to Chile

Habitat: Epi-, meso-, & perhaps bathypelagic from continental slope to mid-ocean; usually solitary; adults migrate to surface at night

Spawning season: Early larvae occur from February–November in CalCOFI area; reportedly spawns in tropical waters throughout the year.

ELH pattern: Oviparous; eggs and larvae planktonic; larvae & juveniles stay near surface only during the day

LITERATURE

Collette et al. 1984b
Nishikawa 1988b
Ozawa 1986e
Richards 1989a

* Damaged.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.5 mm
Flexion length: ca. 6–7 mm through ca. 10 mm
Transformation length: ca. 17 mm, gradual
Fin development sequence: P_2, 1D, C_1 & P_1 & 2D, A, C_2
Pigmentation: *Preflexion*—On jaw tips, forebrain, & midbrain; anterior to eye; over gut; on cheek & anterior 1D membrane; 3 rows at midbody (lateral midline, dorsal & ventral body margins). *Flexion–postflexion*—On most of 1D membrane; on dorsal margin of head; below 1D; laterally on gut.
Diagnostic features: Lateral pigment at midbody; total vertebrae 49–55, 2D rays 10–12, P_2 rays 3–4.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		59–66 63	64–74 69	72–78 75	72–74 73	66–75 72
BD/BL		18–26 22	23–27 25	14–21 18	11–15 14	7–9 8
HL/BL		27–36 32	36–40 38	35–39 37	32–34 33	19–23 22
HW/HL		32–44 37	31–34 33	23–33 26	18–26 22	20–28 24
SnL/HL		19–37 31	31–37 33	32–38 36	38–39 38	36–40 38
ED/HL		26–34 30	24–32 29	20–29 24	19–22 20	20–23 21
P_1L/BL		4–8 7	7–13 9	11–13 12	10–12 10	*
P_2L/BL		0.3–9 4	8–13 10	4–9 7	3–5 4	*
P_2SpL/BL		6–24 15	19–26 23	13–21 17	8–11 9	*

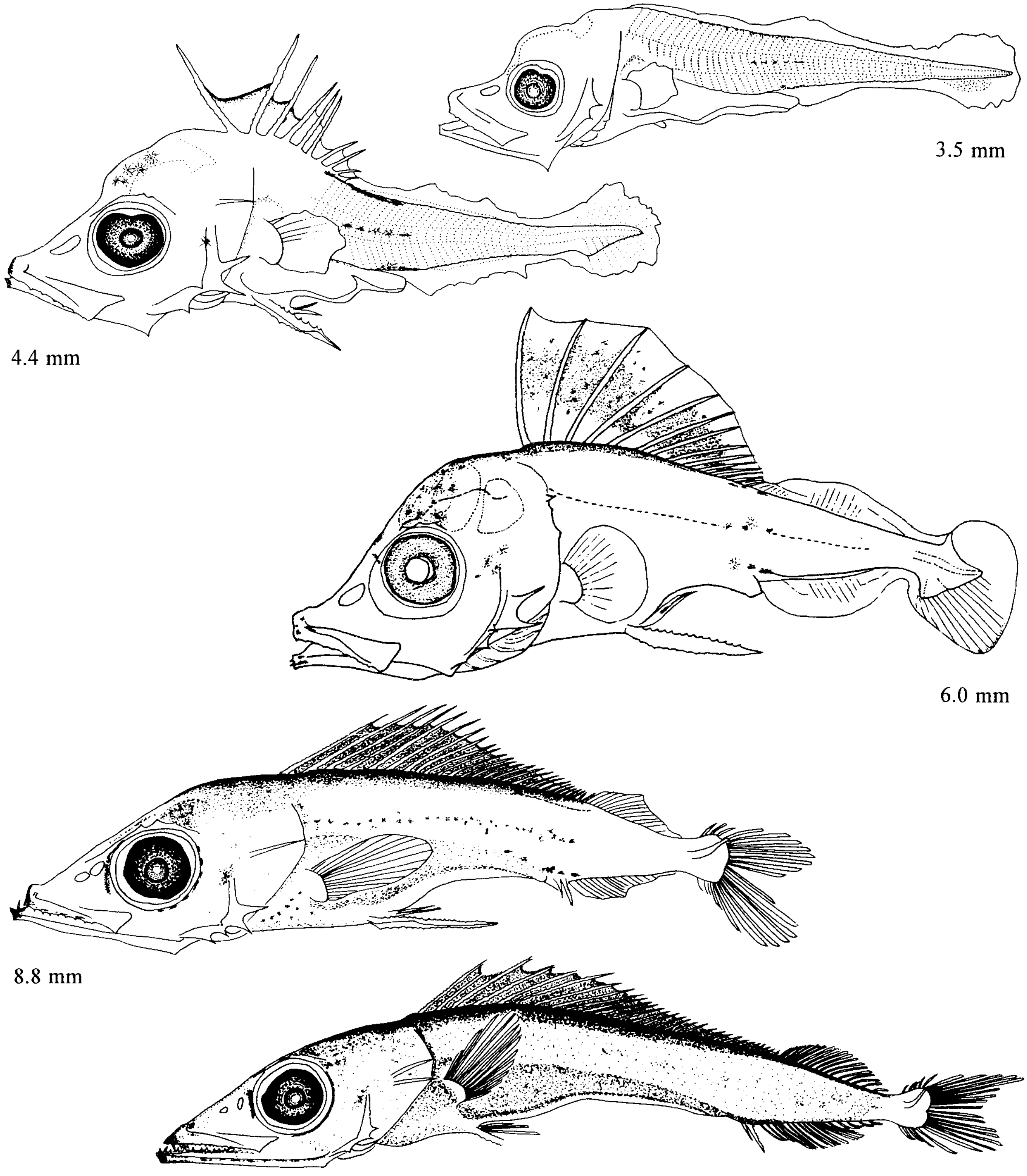


Figure Gempylidae 2. Preflexion larvae, 3.5 mm, 4.4 mm (Nishikawa 1987); flexion larva, 6.0 mm (Ozawa 1986e); postflexion larvae, 8.8 mm, 14.0 mm (Nishikawa 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31–32	
Precaudal	16–17	
Caudal	15	
Fins:		
Dorsal spines	VII–XII	
Dorsal rays	16–20	
Dorsal finlets	4–6	
Anal spines	II	
Anal rays	10–15	
Anal finlets	4–5	
Pelvic	I, 5	
Pectoral	15–17	
Caudal:		
Total	37	
Principal	9+8	
Procurrent:		
Upper	10	
Lower	10	
Gill rakers:		
Upper	none or minute spines	
Lower	none or minute spines	
Branchiostegals	7	

LIFE HISTORY

Range: Worldwide in warm seas; in eastern Pacific from southern California to Peru

Habitat: Epi- & mesopelagic usually over continental slope; often migrate upward at night

Spawning season:

ELH pattern: Oviparous; eggs and larvae planktonic

LITERATURE

Collette et al. 1984b
Nishikawa 1982, 1987, 1988b
Richards 1989a

* Damaged.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: ca. 5–6 mm
Transformation length: ca. 16 mm, gradual
Fin development sequence: D_1 & P_2, P_1 & C_1, A & D_2, C_2
Pigmentation: *Preflexion–flexion*—On gut; below D; distally on 1D membrane. *Postflexion*—Added on forebrain, midbrain, & nuchal region. *Transformation*—By 16 mm, caudal peduncle patch extending onto C.
Diagnostic features: Frontal bone layering in larvae; midlateral caudal peduncle pigment in juveniles; 1D spines 8–12, P_1 rays 15–17.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–58		67–76		67–74
		54	61	71	68	70
BD/BL		29–36		32–39		24–26
		31	37	36	29	26
HL/BL		29–33		40–42		32–37
		31	39	41	39	36
HW/HL						34–40
		44		37		37
SnL/HL		31–44		24–28		26–34
		37	29	26	21	28
ED/HL						23–24
		37		31		23
P_1L/BL						18–19
		6		21		19
P_2L/BL						17–19
		6		18		18
P_2SpL/BL						*
		14		29		

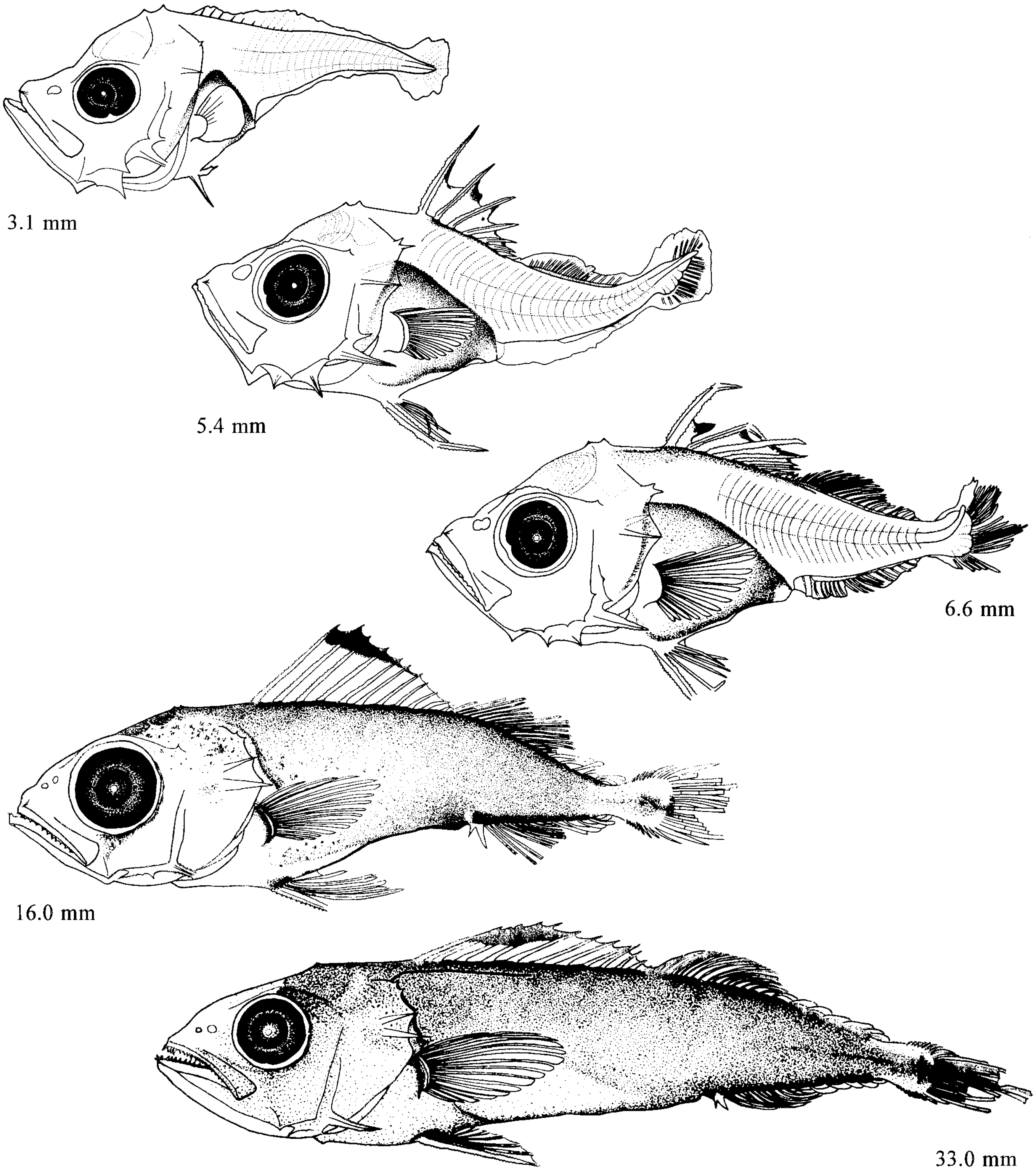


Figure Gempylidae 3. Preflexion larva, 3.1 mm; flexion larva, 5.4 mm; postflexion larva, 6.6 mm; transformation specimen, 16.0 mm; juvenile, 33.0 mm (Nishikawa 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–39	
Precaudal	20–22	
Caudal	14–17	
Fins:		
Dorsal spines	XIX–XXI+I	
Dorsal rays	16–21	
Dorsal finlets	2	
Anal spines	II	
Anal rays	14–19	
Anal finlets	2	
Pelvic	I, 1–2	
Pectoral	12–14	
Caudal:		
Total	34–38	
Principal	9+8	
Procurrent:		
Upper	8–10	
Lower	8–10	
Gill rakers:		
Upper	1 in angle	
Lower	0–5 emerging from tooth patches	
Branchiostegals	7	

LIFE HISTORY

Range: Worldwide in warm seas; in the eastern Pacific to at least 26° N

Habitat: Epi- & mesopelagic, oceanic; migrate to surface at night

Spawning season:

ELH pattern: Oviparous; eggs and larvae planktonic

LITERATURE

Collette et al. 1984b
Nakamura 1984b
Nishikawa 1987, 1988b
Richards 1989a

* Damaged.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.3 mm
Flexion length: ca. 6 mm through ca. 10–11 mm
Transformation leugth: ca. 17–31 mm, gradual
Fin development sequence: 1D, P_2 & P_1, C_1, A & 2D, C_2
Pigmentation: *Preflexion*—On distal 1D membrane, forebrain, midbrain, & behind eye. *Flexion-postflexion*—Caudal peduncle & jaw tips.
Diagnostic features: Midlateral pigment on caudal peduncle in larvae larger than ca. 8 mm; total vertebrae 36–39, D spines 19–21, A rays 14–19, P_2 rays 1–2.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		41–59 52	63–77 71	74–78 77	73–75 74	70–75 73
BD/BL		27–35 31	23–34 28	18–26 21	14–19 16	13–14 13
HL/BL		26–39 35	37–43 41	36–42 39	30–37 33	27–29 28
HW/HL		37–60 45	27–40 34	24–30 26	21–27 24	25–27 26
SnL/HL		18–43 34	31–38 34	33–38 35	37–38 38	34–39 37
ED/HL		31–43 36	27–32 29	21–27 24	18–24 21	20–23 21
P_1L/BL		6–11 8	10–14 12	11–15 13	12–15 13	11–11 11
P_2L/BL		0–10 6	6–15 10	6–19 9	8	*
P_2SpL/BL		0–23 10	24–28 26	19–27 23	14–19 17	8–12 11

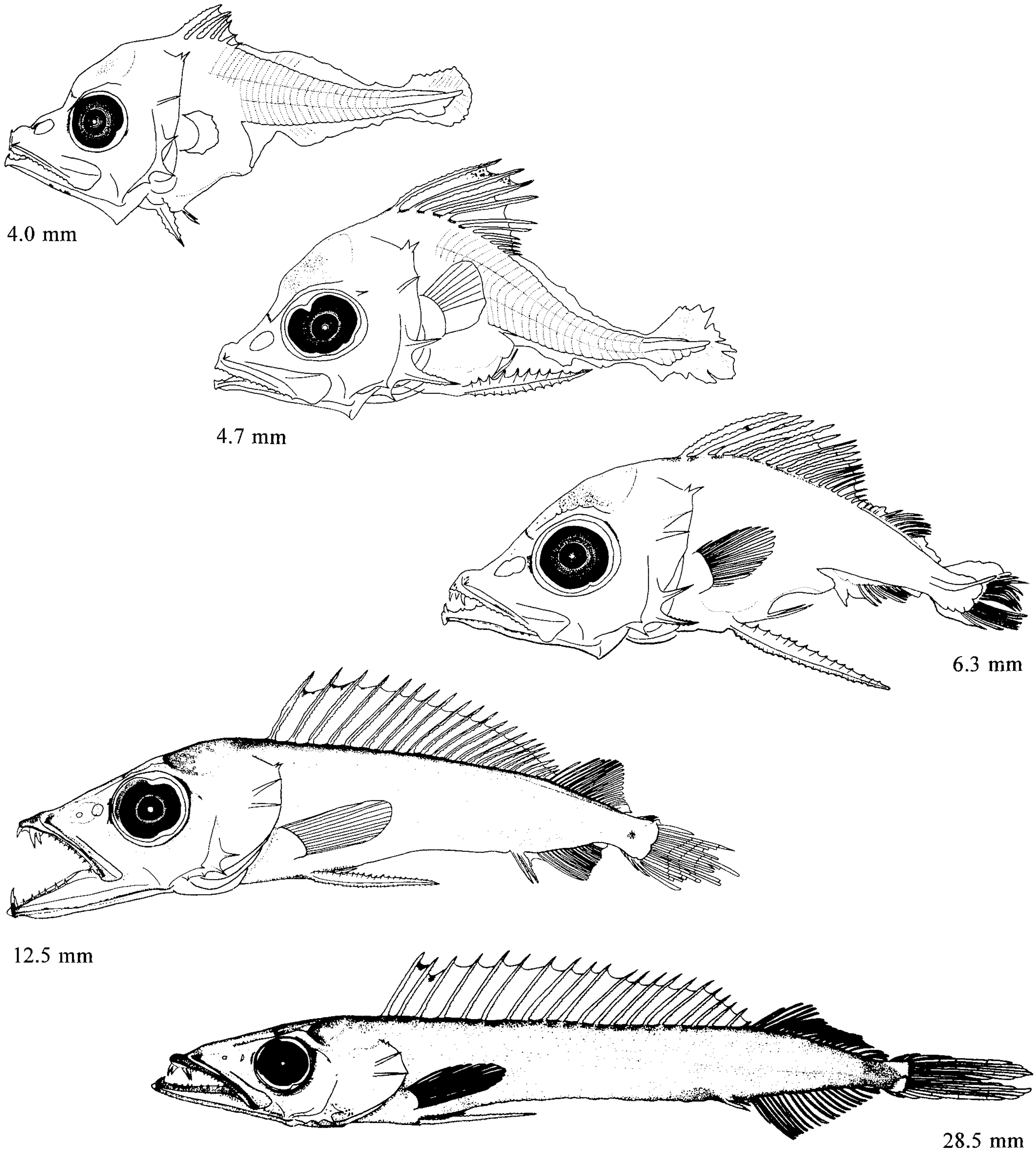


Figure Gempylidae 4. Preflexion larvae, 4.0 mm, 4.7 mm; flexion larva, 6.3 mm; postflexion larva 12.5 mm; juvenile, 28.5 mm (Nishikawa 1987).

MERISTICS

	Range	Mode
Vertebrae:		
Total	32	
Precaudal	16	
Caudal	16	
Fins:		
Dorsal spines	XIII–XV	
Dorsal rays	15–20	
Dorsal finlets	2–3	
Anal spines	II–III	
Anal rays	12–18	
Anal finlets	1–3	
Pelvic	I, 5	
Pectoral	13–15	
Caudal:		
Total	36–37	
Principal	9+8	
Procurrent:		
Upper	10	
Lower	9–10	
Gill rakers:		
Upper	1 in angle	
Lower	6–8 emerging from tooth patches	
Branchiostegals	7	

LIFE HISTORY

Range: Worldwide in warm seas; in the eastern Pacific from southern California to Peru

Habitat: Epi-, meso-, & benthopelagic usually over continental slope or sea rises; usually solitary or in pairs near bottom

Spawning season:

ELH pattern: Oviparous; eggs and larvae planktonic

LITERATURE

Collette et al. 1984b
Nishikawa 1987, 1988b
Richards 1989a

* Damaged

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <3.0 mm
Flexion length: ca. 4–6 mm
Transformation length:
Fin development sequence: 1D & P_2, P_1 & C_1, A & 2D & C_2
Pigmentation: *Preflexion*—On snout & over gut. *Flexion*—On 1D membrane, forebrain, & midbrain; below 2D; on gular region; near top of preopercle. *Postflexion*—On jaw tips; midlaterally on caudal peduncle.
Diagnostic features: Longitudinal pigment row in gular region; 1D spines 13–15, A spines 3.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL			55–56	67–77		69–76
		55	55	73		72
BD/BL			30–32	38–40		22–27
		33	32	39		25
HL/BL			37–41	43–47		29–34
		40	39	45		32
SnL/HL			30–31	28–31		29–31
		36	31	30		30
ED/HL			29–29	25–30		19–20
		29	29	27		20
P_2SpL/BL			11–28	38–40		*
		0	20	39		

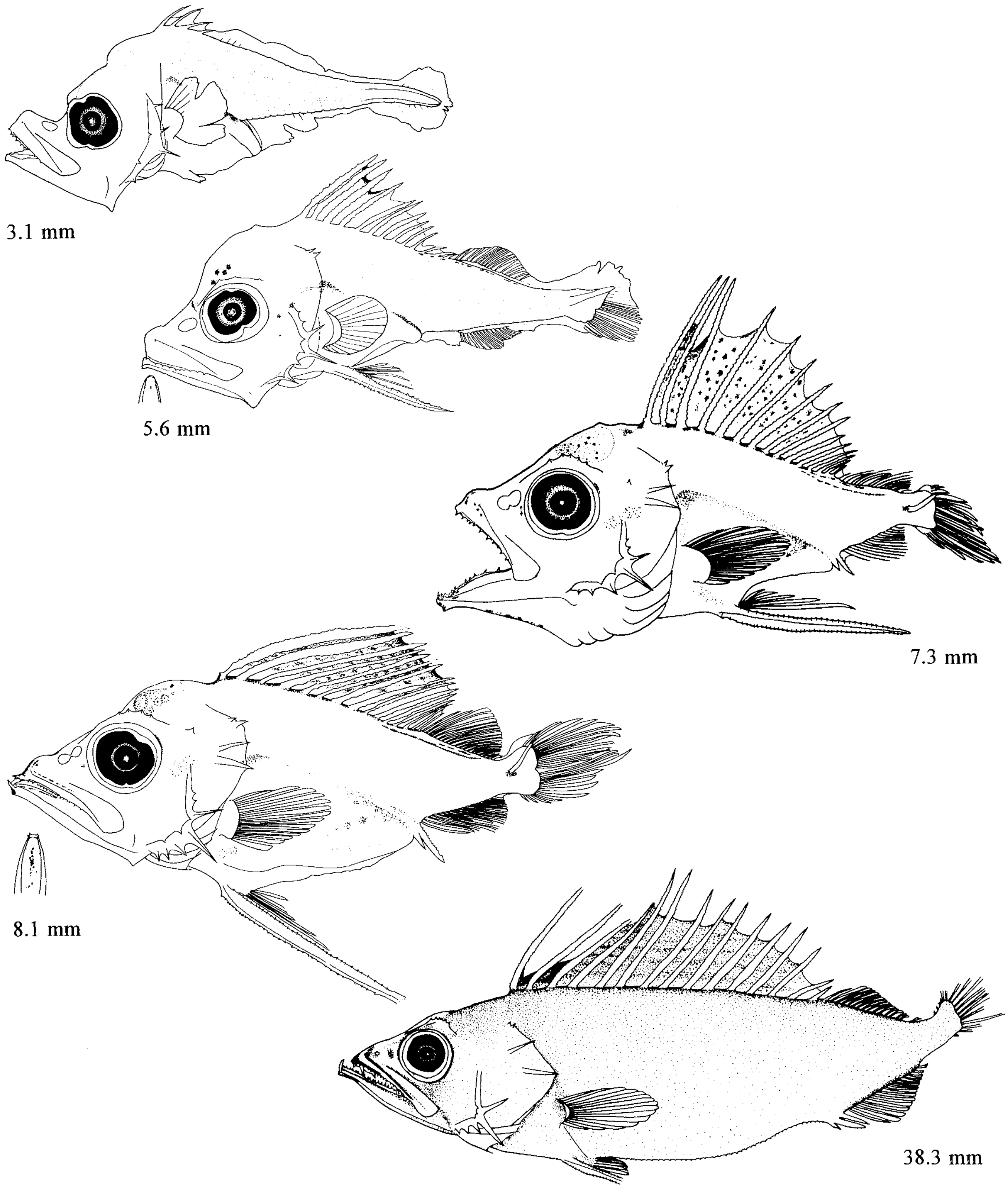


Figure Gempylidae 5. Preflexion larva, 3.1 mm; flexion larva, 5.6 mm, with ventral view of gular region; postflexion larvae, 7.3 mm, 8.1 mm (with ventral view of gular region); juvenile, 38.3 mm (Nishikawa 1987).

SCOMBRIDAE: Mackerels and tunas

D. A. AMBROSE

Scombridae includes 15 genera and 49 species (Collette and Nauen 1983). At least 16 species may occur in the CalCOFI study area (Table Scombridae 1), although larvae of only 6 taxa have been identified in CalCOFI ichthyoplankton collections, primarily from the southern portion of the pattern off Baja California. These are, in decreasing order of larval abundance: *Scomber japonicus*, *Sarda chiliensis*, *Auxis* spp., *Scomberomorus sierra*, *Thunnus albacares*, and *Euthynnus lineatus*.

Scombrids (mackerels, Spanish mackerels, bonitos, and tunas) are medium to large (30–430 cm), mostly epipelagic marine predators in coastal and oceanic habitats. They have an elongate, fusiform body, a pointed snout with a beak-like premaxillary, gill membranes free from the isthmus, two dorsal fins (the first depressible into a groove), 5–12 finlets behind the dorsal and anal fins, a first dorsal fin that originates well behind the head, pectoral fins inserted high on the body, pelvic fins (I,5) located beneath the pectoral fins, at least 2 small keels on each side of the caudal peduncle, and a caudal fin that is deeply forked with supporting rays completely covering the hypural plate (Collette 1986; Nelson 1994). Most species are silvery, with iridescent blue-green tints (Eschmeyer et al. 1983). Many species form large schools and most have great sport and commercial value. Johnson (1986) hypothesized that *Sphyraena* is a sister group of all scombroids and, that within the Scombroidei, Gempylidae is the sister group of the scombrids plus billfishes. Finnerty and Block (1995) have excluded the billfishes.

An extensive literature exists on the early life history of scombrids (e.g., Richards and Klawe 1972; Fritzsche 1978a; Collette et al. 1984b). Scombrids are oviparous, spawning planktonic eggs characterized by a smooth, spherical, transparent chorion 0.8–1.9 mm in diameter, usually with a single oil globule, a narrow perivitelline space and homogeneous yolk. Larvae hatch at ca. 2–4 mm with a large yolk sac, unpigmented eyes, and a non-functional mouth. Larval scombrids typically are deep-bodied, with a large head, mouth, and eyes. Most possess well developed preopercular spines as early as the preflexion stage. The preanal length is short, but the gut becomes relatively longer during development and the anus is located past midbody by the beginning of the postflexion stage. Development is direct with a gradual transition between larvae and juveniles. In this study, the transformation stage is considered to begin when all the pectoral fin rays have formed. Larval pigmentation typically is light, occurring primarily on the dorsal surfaces of the head and gut, and ventrally along the tail of most species. Most larvae can be identified using a combination of characters, principally the number of myomeres, the head spination, the body shape, and the distribution of melanophores. Young *Thunnus albacares* and *T. obesus* may be indistinguishable using these characters, but can be separated by the electrophoretic pattern of the muscle isozyme of glycerol–3–phosphate dehydrognease (Graves et al. 1988). All *Auxis* larvae smaller than ca. 7 mm examined in CalCOFI collections lacked midlateral caudal pigment similar to those described as *Auxis* type II by Matsumoto (1959) and *A. rochei* in Richards (1989b); however, for all *Auxis* measured in this study, the body depth and preanal length as a function of body length were more similar to those attributed to *A. thazard* by Gorbunova (1969). Thunnini includes the genera *Auxis*, *Euthynnus*, *Katsuwonus*, and *Thunnus*.

The following descriptions are based on literature and on detailed examinations of 5–40 specimens of each species (Table Scombridae 2). Early larval stages of *Sarda chiliensis* and *Scomberomorus sierra* are described for the first time. Larval *Katsuwonus pelamis* are also included in this chapter because adults may occasionally spawn near the southern end of the CalCOFI pattern (Klawe 1963). Meristic data were obtained from literature sources (Miller and Lea 1972; Collette and Chao 1975; Yoshida 1979, 1980; Uchida 1981; Collette and Nauen 1983; Collette and Russo 1984; Matsumoto et al. 1984; Nakamura 1984a; Matarese et al. 1989; Richards 1989b) and from counts made during this study. Ecological information was obtained primarily from Collette and Nauen (1983).

Table Scombridae 1. Meristic characters for the scombrid species in the California Current vicinity. All have 9+8 principal caudal rays and I,5 pelvic fin elements.

Species	Vertebrae			Fin rays and spines					GR
				D				Finlets	
	PrCV	CV	Total	1st	2nd	A	P_1	D+A	U+L
Acanthocybium solandri	30–32	31–34	62–66	23–27	11–16	11–14	22–26	7–10+7–10	0+0
Allothunnus fallai	20	19	39	15–18	12–13	12–14	24–26	6–8+6–7	21–25+49–53
Auxis rochei	20	19	39	10–12	10–12	11–14	22–25	7–9+7–8	8–12+32–37
A. thazard	20	19	39	10–12	10–12	9–14	22–25	7–9+7–8	8–12+29–37
Euthynnus affinis			39	14–15	11–14	12–15	24–28	7–9+6–8	7–10+22–26
E. lineatus	19–20	15–17	36–38	13–15	11–12	11–13	24–26	8–9+7–8	7–11+24–30
Katsuwonus pelamis	20	21	41	14–17	12–16	13–18	24–32	7–10+6–8	16–22+33–43
Sarda chiliensis	22–24	20–23	42–46	17–20	13–17	11–15	22–27	7–9+6–8	7–10+11–19
S. orientalis	23–25	20–22	44–45	17–19	15–16	14–16	22–26	7–9+6	3–4+5–10
Scomber japonicus	13–15	16–18	30–32	8–13	10–15	10–15	19–22	4–6+4–6	10–14+26–34
Scomberomorus concolor	18–20	27–29	46–48	15–18	16–20	19–23	19–22	6–9+6–8	4–9+15–21
S. sierra	19–21	26–29	46–49	15–18	16–19	16–21	20–24	7–10+7–10	2–5+9–14
Thunnus alalunga	18	21	39	9–14	12–16	11–16	30–36	7–10+7–10	7–11+18–24
T. albacares	18	21	39	11–14	12–16	11–16	30–36	7–10+7–10	8–11+19–24
T. obesus	18	21	39	11–14	12–16	11–16	30–36	7–10+7–10	7–13+18–25
T. thynnus orientalis	18	21	39	12–15	13–15	13–16	30–38	7–10+7–9	9–16+21–28

Table Scombridae 2. Number of specimens (above) and size range (in mm, below) used in preparation of the scombrid species descriptions. An "L" indicates literature used in the description.

Species	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Auxis spp.	L[a]	10 2.5–4.7	6 5.0–6.4	14 6.4–15.3	3 18.7–28.5	5 34.8–67.3
Euthynnus lineatus	0	9 3.7–5.4	5 4.8–5.7	10 5.8–12.2	5 13.2–24.5	5 34.0–38.0
Katsuwonus pelamis	L[b]	L[b], 8 2.8–5.6	L[c], 3 5.8–6.3	L[d], 3 7.8–13.2	L[e]	L[f]
Sarda chiliensis	5 3.4–3.7	10 5.2–7.8	4 7.7–8.8	L[g], 1 18.3	L[g], 1 30.2	2 87.2–94.1
Scomber japonicus	L[h]	L[h]	L[h]	L[h]	L[h]	5 30.0–86.1
Scomberomorus sierra	5 2.3–2.5	9 2.4–3.9	6 4.5–7.1	10 9.9–17.0	8 18.5–35.0	2 70.2–98.5
Thunnus albacares	L[i]	10 2.6–5.2	5 4.7–6.1	14 6.1–13.8	L[e]	L[f]

[a] Mito 1961b
[b] Ueyanagi et al. 1974
[c] Collette et al. 1984b
[d] Matsumoto 1958
[e] Schaefer and Marr 1948a
[f] Matsumoto 1961
[g] Pinkas 1961
[h] Kramer 1960
[i] Mori et al. 1971

MERISTICS

	Range	Mode
Vertebrae:		
Total	39	39
Precaudal	20	20
Caudal	19	19
Fins:		
Dorsal spines	X–XII	
Dorsal rays	10–12	
Dorsal finlets	7–9	
Anal spines	0	0
Anal rays	9–14	
Anal finlets	7–8	7
Pelvic	I,5	I,5
Pectoral	22–25	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	15	15
Lower	16	16
Gill rakers:		
Upper	8–12	
Lower	29–37	
Branchiostegals	7	7

LIFE HISTORY

Range: Two species, *A. rochei* & *A. thazard*, are cosmopolitan in warm seas; in eastern Pacific from Santa Catalina Island, California to Peru, including Gulf of California & Galapagos Islands

Habitat: Epipelagic; neritic & oceanic

Spawning season: In eastern Pacific, throughout the year; heaviest spawning off Costa Rica from December–April; larvae collected off Baja California primarily in August & September.

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Fitch & Roedel 1963
Mito 1961b
Uchida 1981

* Two species: *A. rochei* & *A. thazard*.
† Eye initially oval, becoming round by postflexion; horizontal axis is given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.84–0.92 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.24–0.29 mm
Shell surface: Oval, smooth, transparent
Pigment: On OG; scattered dorsolaterally on embryo
Diagnostic features:

LARVAE

Hatching length: ca. 2.3 mm
Flexion length: ca. 5–6.4 mm
Transformation length: ca. 18 mm
Fin development sequence: C, 1D, 2D, A, P_2, P_1
Pigmentation: *Yolk-sac*—On head; scattered dorsolaterally on body, migrating ventrally to tail margin; dorsally at notochord tip. *Preflexion*—On midbrain & nape; 1 anterior to anus & 1 at cleithral symphysis; anteriorly & dorsally on gut; ca. 20 ventrally on tail margin, decreasing in number with growth. *Flexion*—On hindbrain; ca. 4–9 on ventral margin of tail; 1 dorsally in caudal peduncle region. *Postflexion*—By 7 mm, on tip of lower jaw; midlaterally on tail; on forebrain; increasing at base of 2D; by ca. 10 mm, on snout & under 1D. *Transformation–juvenile*—At base of C; a few distally on 1D; prominent on upper & lower jaws, above snout, & posteroventral margin of orbit; body darker dorsally than ventrally.
Diagnostic features: 39 total vertebrae; head profile rounded & blunt with short jaws; forebrain pigment absent until postflexion stage; melanophore at cleithral symphysis & anterior to anus; by ca. 7 mm, 3 rows of melanophores on dorsal margin, midlaterally, & on ventral margin on the posterior half of the tail; 1D lightly pigmented or unpigmented; distinct gap between 1D & 2D; 7–8 anal finlets.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	35–48 41	38–47 43	42–47 44	52–65 60	65–67 66	64–68 65
BD/BL		17–28 25	26–28 27	24–36 29	21–24 23	18–20 19
HL/BL	17–24 19	21–29 26	29–32 31	36–42 39	31–37 34	27–30 28
HW/HL		55–71 60	46–57 50	36–46 40	36–40 39	35–42 38
SnL/HL	11–22 19	15–32 25	26–35 31	31–39 35	28–31 30	25–28 26
ED/HL†	36–43× 26–39	32–43× 27–37	31–35× 28–32	27–33	28–30	21–26
	40×34	36×32	32×30	30	29	24
P_1L/BL	0–7 4	5–6 6	5–6 6	5–11 8	9–11 10	9–11 10
P_2L/BL	0–0 0	0–0 0	0.4–2 1	5–15 10	11–14 12	10–12 11

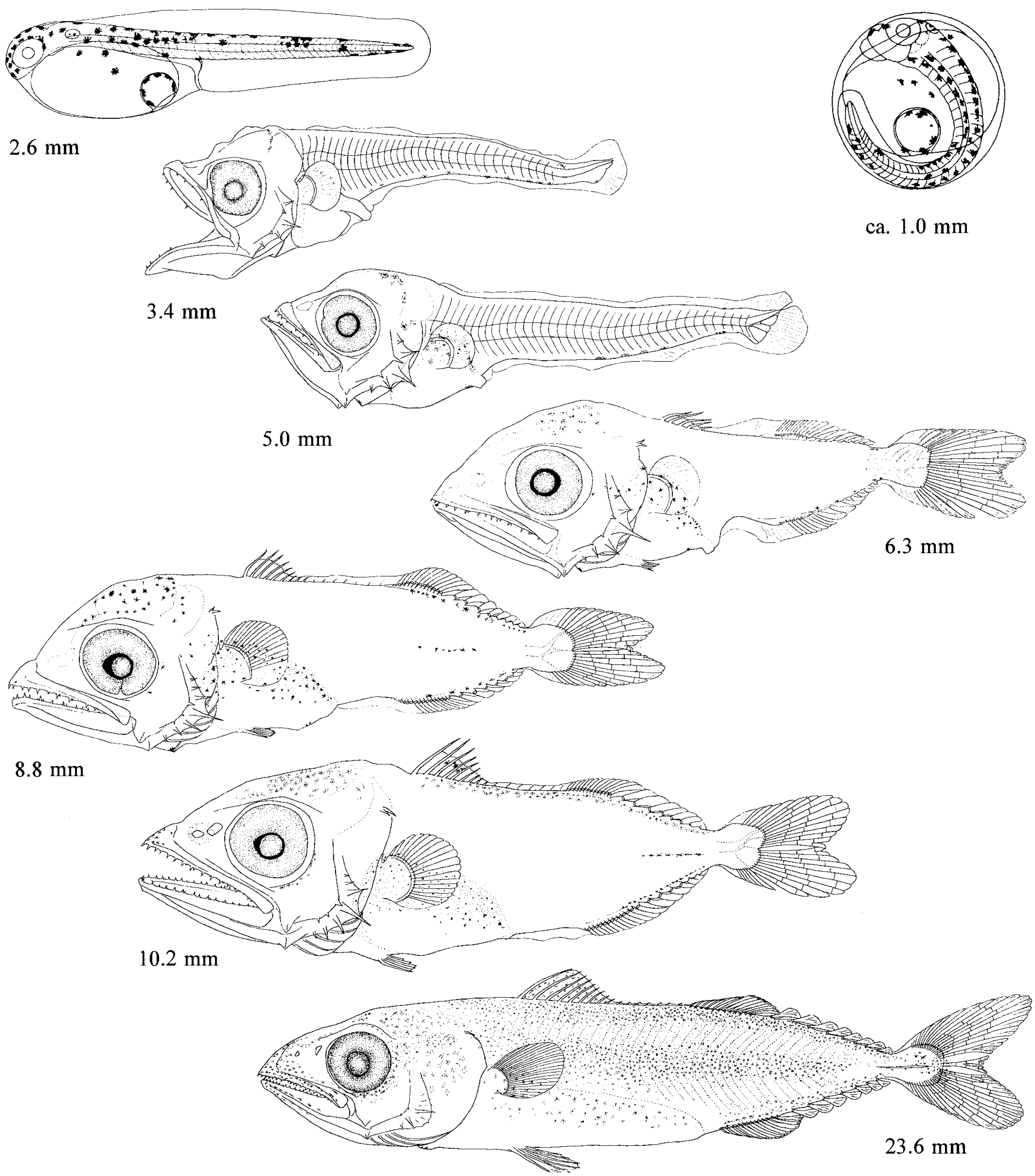


Figure Scombridae 1. Egg, ca. 1.0 mm; yolk-sac larva, 2.6 mm (Mito 1961b); preflexion larva, 3.4 mm; flexion larva, 5.0 mm; postflexion larvae, 6.3 mm, 8.8 mm, 10.2 mm; transformation specimen, 23.6 mm (Matsumoto 1959). Lengths converted from total length to notochord length in preflexion and flexion larvae, and from total length to standard length in later stages.

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	37
Precaudal	19–20	20
Caudal	15–17	17
Fins:		
Dorsal spines	XIII–XV	XIV–XV
Dorsal rays	11–12	11
Dorsal finlets	8–9	8
Anal spines	III	III
Anal rays	8–10	8–9
Anal finlets	7–8	7
Pelvic	I,5	I,5
Pectoral	24–26	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	7–11	9–10
Lower	24–30	27–28
Branchiostegals	7	7

LIFE HISTORY

Range: Tropical coastal eastern Pacific from central California to Peru (ca. 35° N – 12° S), including Gulf of California; strays also reported from Hawaii

Habitat: Epipelagic; neritic & oceanic; usually within 240 miles of mainland in waters with a shallow thermocline (10–50 m depth); frequently schools with skipjack & yellowfin tuna of similar size

Spawning season: Off outer coast of Baja California in summer; peak in October–December at mouth of Gulf of California; throughout the year off Costa Rica with peaks from April–March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Calkins & Klawe 1963
Klawe 1963
Matsumoto 1958, 1959
Mead 1951
Schaefer & Marr 1948a
Yoshida 1979

EARLY LIFE HISTORY DESCRIPTION

EGGS (Late-stage ovarian)
Shell diam.: 0.90–0.95 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.23–0.26 mm
Shell surface: Smooth
Pigment:
Diagnostic features:

LARVAE
Hatching length: ca. 2–3 mm
Flexion length: 4.3–5.7 mm
Transformation length: ca. 13 mm – >25 mm
Fin development sequence: C, 1D, 2D, A, P_2, P_1
Pigmentation: *Preflexion*—By 3.7 mm, on forebrain, anteriorly & dorsally on gut, 1 at cleithral symphysis; 1 anterior to anus; ca. 8–13 ventrally along tail margin; 1 ventrally on C. *Flexion*—By ca. 4.7 mm, on midbrain & snout, & decreasing ventrally along tail margin; by 5.3 mm, on lower jaw & opercle. *Postflexion*—By ca. 7 mm, heavy on 1D & at base of A; by 10.6 mm, at base of D; by ca. 12 mm, at base of 2D. *Transformation–juvenile*—By ca. 13 mm, along lateral midline; by ca. 19 mm, spreading over dorsal half of body; by ca. 45 mm, extending entire body depth to A, lighter ventrally; by 45–60 mm, some with 8–9 faint vertical bars dorsally.
Diagnostic features: Usually 37 vertebrae; by ca. 7 mm, pigment on forebrain, midbrain, cleithral symphysis, jaw tips, preanal region, ventral edge of tail, & 1D; snout slightly longer than in larvae of other Thunnini.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		47–61 52	54–62 56	58–69 64	66–70 68	69–73 70
BD/BL		24–38 29	23–36 31	29–37 34	25–31 29	23–24 23
HL/BL		28–40 34	36–44 41	38–47 44	36–47 42	31–34 32
HW/HL		40–62 52	40–47 43	36–48 41	35–40 37	36–41 38
SnL/HL		28–41 36	38–44 42	38–44 41	33–37 35	31–35 33
ED/HL		28–37 32	27–34 29	26–33 29	26–29 28	25–27 26
P_1L/BL		6–9 7	6–8 7	6–11 8	8–11 9	10–11 10
P_2L/BL		0–2 0.9	1–5 3	4–22 13	13–17 15	12–14 13

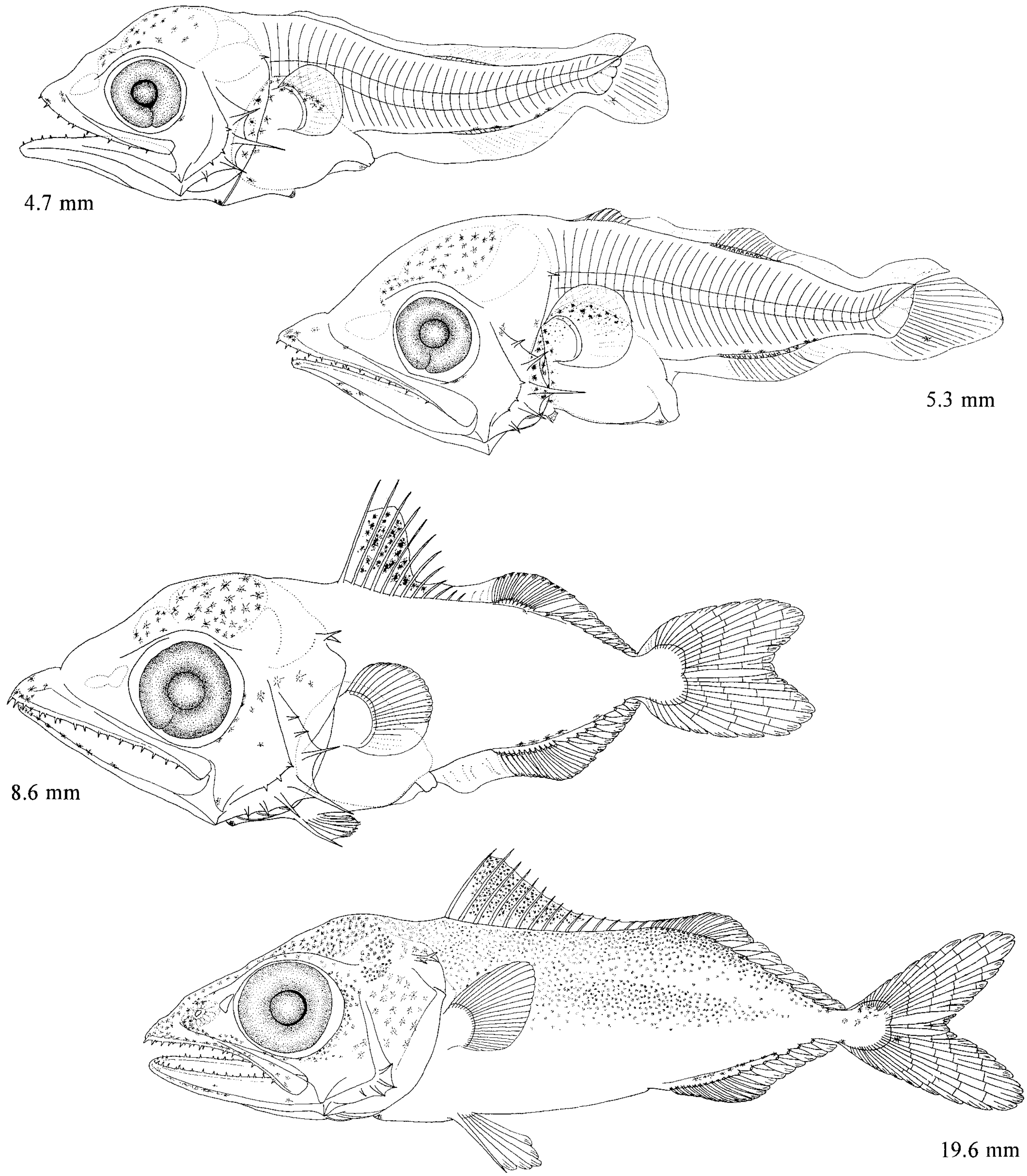


Figure Scombridae 2. Flexion larvae, 4.7 mm, 5.3 mm; postflexion larva, 8.6 mm; transformation specimen, 19.6 mm (Matsumoto 1959; lengths converted as in Figure Scombridae 1).

MERISTICS

	Range	Mode
Vertebrae:		
Total	41	41
Precaudal	20	20
Caudal	21	21
Fins:		
Dorsal spines	XIV–XVII	XV–XVI
Dorsal rays	12–16	14–15
Dorsal finlets	7–10	8
Anal spines	0–II	0
Anal rays	13–17	14–15
Anal finlets	6–8	7
Pelvic	I,5	I,5
Pectoral	24–32	26–30
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	16–17	
Lower	17–18	
Gill rakers:		
Upper	16–22	18–20
Lower	33–43	38–41
Branchiostegals	7	7

LIFE HISTORY

Range: Cosmopolitan in seas warmer than 15 °C; in eastern Pacific from Vancouver Island, British Columbia to Chile (ca. 27° S); rare north of Point Conception, California (ca. 34° N)

Habitat: Epipelagic in large schools, often with yellowfin tuna; neritic & oceanic; from surface to 260 m depth during the day but limited to upper 75 m at night; larvae generally in upper 50 m of water, perhaps migrating to surface at night

Spawning season: Throughout the year in equatorial regions & spring to early fall in subtropical waters; usually in water with surface temperature at least 24 °C

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Collette et al. 1984b
Matsumoto et al. 1984
Nishikawa & Rimmer 1987
Richards 1989b
Richards & Klawe 1972
Schaefer & Marr 1948b
Ueyanagi et al. 1974
Wild & Hampton 1994

* Eye initially oval, becoming round by preflexion; for yolk-sac stage, horizontal axis given first, vertical second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.80–1.17 mm **Yolk:** Homogeneous
No. of OG: Usually 1 **Diam. of OG:** 0.22–0.45 mm
Shell surface: Spherical, smooth, & transparent
Pigment: On OG, dorsolaterally on embryo
Diagnostic featnres: Golden OG; similar in size & appearance to eggs of other species of scombrids whose eggs have been artificially fertilized & reared

LARVAE

Hatching length: ca. 2.3–3.0 mm
Flexion length: ca. 5.0–7.0 mm
Transformation length: ca. 18 mm
Fin development sequence: C_1, 1D, 2D, A, C_2, P_2, P_1
Pigmentation: *Yolk-sac*—On midbrain & snout; dorsally on body, migrating ventrally & converging in caudal peduncle region. *Preflexion–flexion*—On midbrain; lower jaw tip; anteriorly & dorsally on gut; 1 ventrally on tail edge at ca. myomere 34; 1 in hypural region; by 4 mm, on forebrain. *Postflexion*—At dorsal end of preopercle; by 7–8 mm, at distal edge of 1D & 1 at midlength of mandible; on posteroventral edge of orbit; along 1D & A bases; by ca. 10 mm, on tips of jaws, extending dorsally from head, lighter toward dorsal finlets, & a few midlaterally on tail; by 13 mm, increasing in all areas. *Transformation*—By ca. 19 mm, extending dorsolaterally on body to base of C rays. *Juveniles*—No lateral bars on body; blotches mainly distally on 1D & absent from 2D.
Diagnostic features: Total vertebrae 41; by ca. 4 mm, pigment on forebrain & a melanophore on ventral edge of tail at about myomere 34; pigment absent from cleithral symphysis & anterior to anus; pigment on lower jaw tip; at ca. 7–8 mm, pigment at edge of 1D & rarely on dorsal edge of caudal peduncle; snout sharply pointed & beyond lower jaw in postflexion larvae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	37–46	33–49	46–55	53–68		
	42	43	51	63	69	64
BD/BL		23–30	26–32	32–36		
		26	29	33	26	21
HL/BL	21–26	19–36	34–39	42–46		
	23	30	37	44	38	29
HW/HL		45–67	43–46	42–45		
		52	45	43		
SnL/HL	12–20	31–39	38–42	34–40		
	14	35	40	37	38	34
ED/HL*	29–39× 20–35	33–48	31–35	28–36		
	33×26	38	33	32	26	24
P_1L/BL	0–3	4–7	4–7	7–10		
	2	6	6	8	9	9
P_2L/BL	0–0	0–2	1–2	9–17		
	0	0.2	2	13	12	8

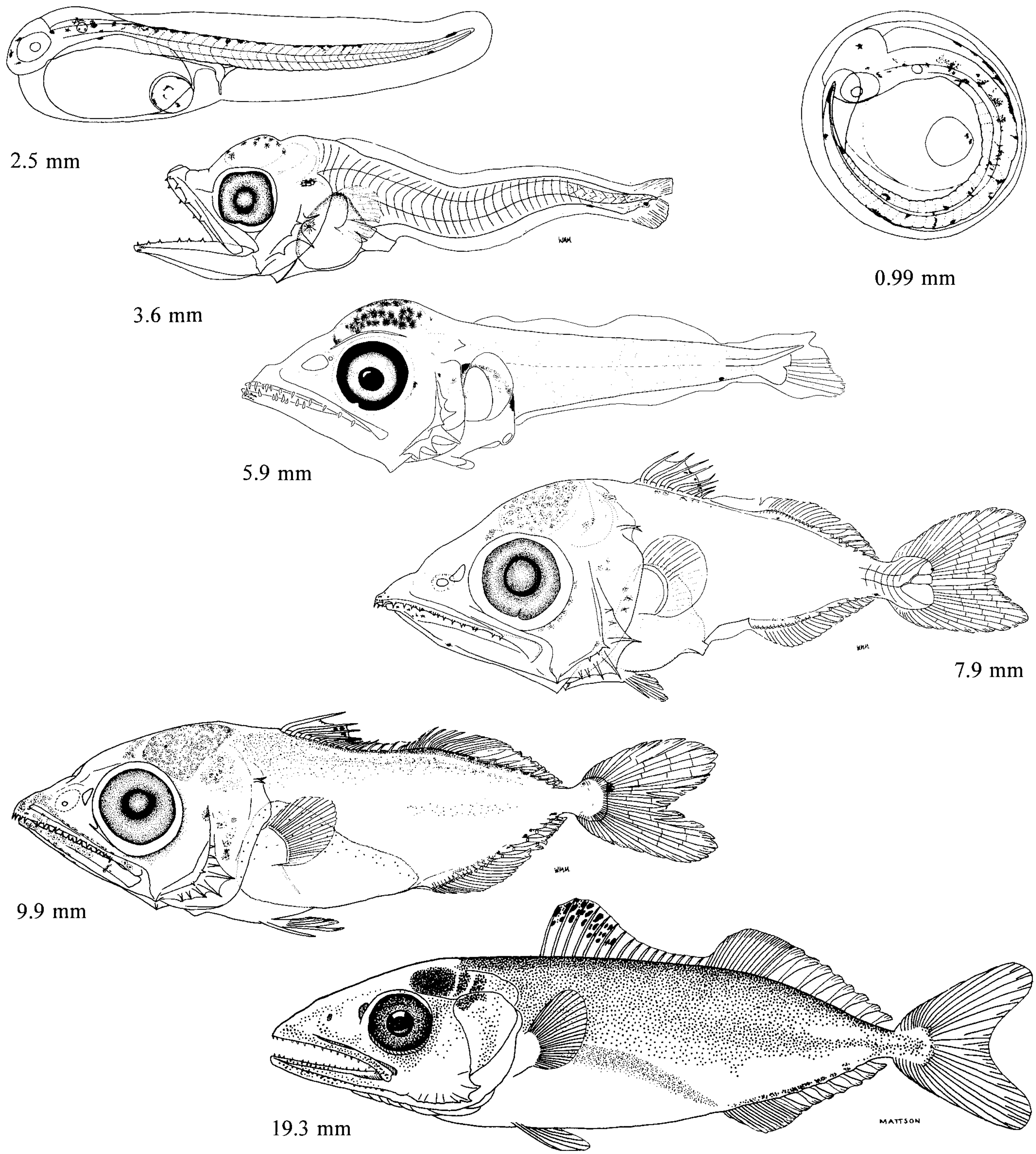


Figure Scombridae 3. Egg, 0.99 mm; yolk-sac larva, 2.5 mm (Ueyanagi et al. 1974); preflexion larva, 3.6 mm (Matsumoto 1958); flexion larva, 5.9 mm (Collette et al. 1984b); postflexion larvae, 7.9 mm, 9.9 mm (Matsumoto 1958); transformation specimen, 19.3 mm (Schaefer and Marr 1948b). Lengths converted as in Figure Scombridae 1.

MERISTICS

	Range	Mode
Vertebrae:		
Total	42–46	44–46
Precaudal	22–24	23
Caudal	20–23	21–22
Fins:		
Dorsal spines	XVII–XX	XVIII
Dorsal rays	13–17	15
Dorsal finlets	7–9	8
Anal spines	0–II	0
Anal rays & spines	11–15	14
Anal finlets	6–8	7
Pelvic	I,5	I,5
Pectoral	22–27	24–25
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper		
Lower		
Gill rakers:		
Total	23–27	24–25
Upper	7–10	
Lower	11–19	
Branchiostegals	7	7

LIFE HISTORY

Range: Restricted to eastern Pacific; northern population from Alaska (ca. 60° N) to Cabo San Lucas (ca. 22° N) & Islas de Revillagigedo, uncommon north of Point Conception, California; southern population from Peru (ca. 4° S) to Chile (ca. 37° S); intervening tropics occupied by *Sarda orientalis*

Habitat: Epipelagic; neritic; schooling

Spawning season: In northern hemisphere, begins in early March at southern end of range, spreading north with increasing water temperature

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Barnhart 1927
Klawe 1961
Orton 1953a,b
Pinkas 1961
Sokolovskii 1971

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.6 mm (B. Sumida MacCall)
Yolk-sac larva, 5.0 mm (B. Sumida MacCall)
Preflexion larvae, 5.2 mm, 6.3 mm (B. Sumida MacCall)
Flexion larva, 8.0 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.52–1.68 mm **Yolk:** Homogeneous; 1.08–1.36 mm diam.
No. of OG: 1 **Diam. of OG:** 0.28–0.44 mm
Shell surface: Smooth, clear, pinkish
Pigment: Specks scattered dorsally on head & dorsolaterally on body; ventral row near end of tail
Diagnostic features: Egg & OG size; pinkish chorion; pigment row ventrally near end of tail in late-stage embryos; homogeneous yolk

LARVAE

Hatching length: ca. 3.75 mm
Flexion length: ca. 7.5–9 mm
Transformation length: ca. 20–32 mm
Fin development sequence: C, 1D, 2D, A, P_2, P_1
Pigmentation: *Yolk-sac*—Fine specks scattered dorsally on midbrain & trunk; row along ventral body margin. *Preflexion–flexion*—On snout, lip, & lower jaw; on fore- & midbrain, ventrally on hindbrain; posterior to eye; dorsolaterally on gut; at nape & cleithral symphysis; 5–6 in A region & 2 ventrally in caudal region. *Postflexion*—On P_1 base; heavy on P_2 & anteriorly on 1D; patches in hypural region & dorsally & ventrally at C base; reduced above A; spreading dorsolaterally under D. *Transformation–juvenile*—Spreading over body, lighter ventrally; 7 to 12 vertical dusky bars dorsolaterally on body.
Diagnostic features: Vertebrae usually 44 or 45; large size at notochord flexion; moderately large head & snout; embedded melanophores along ventral margin of tail; pigment heavy on 1D & P_2; forebrain pigment present, preanal melanophore absent; by at least 15.6 mm, pigment patch laterally near end of tail; by ca. 24 mm, 14–25 acute, conical teeth irregularly spaced on lower jaw & 19–27 GR forming on first arch.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	35–45 41	35–44 40	49–53 51	62–63 63	68–69 68	67–69 68
BD/BL	12–21 15	17–26 21	25–27 27	28–31 30	23–25 24	14–20 17
HL/BL	11–20 14	19–31 24	28–34 32	41–41 41	34–36 35	28–29 28
HW/HL	66–115 94	43–68 56	39–50 44	42	36	29–31 30
SnL/HL	20–25 23	24–40 32	42–46 43	36–42 39	37–40 39	35–37 36
ED/HL	45–68 59	26–40 32	28–32 30	26–30 28	23–26 25	17–17 17
P_1L/BL	2–4 3	4–6 5	6–8 7	6–10 8	8–14 11	8–10 9
P_2L/BL	0–0 0	0–6 2	4–9 7	17–18 18	5–13 9	9–9 9

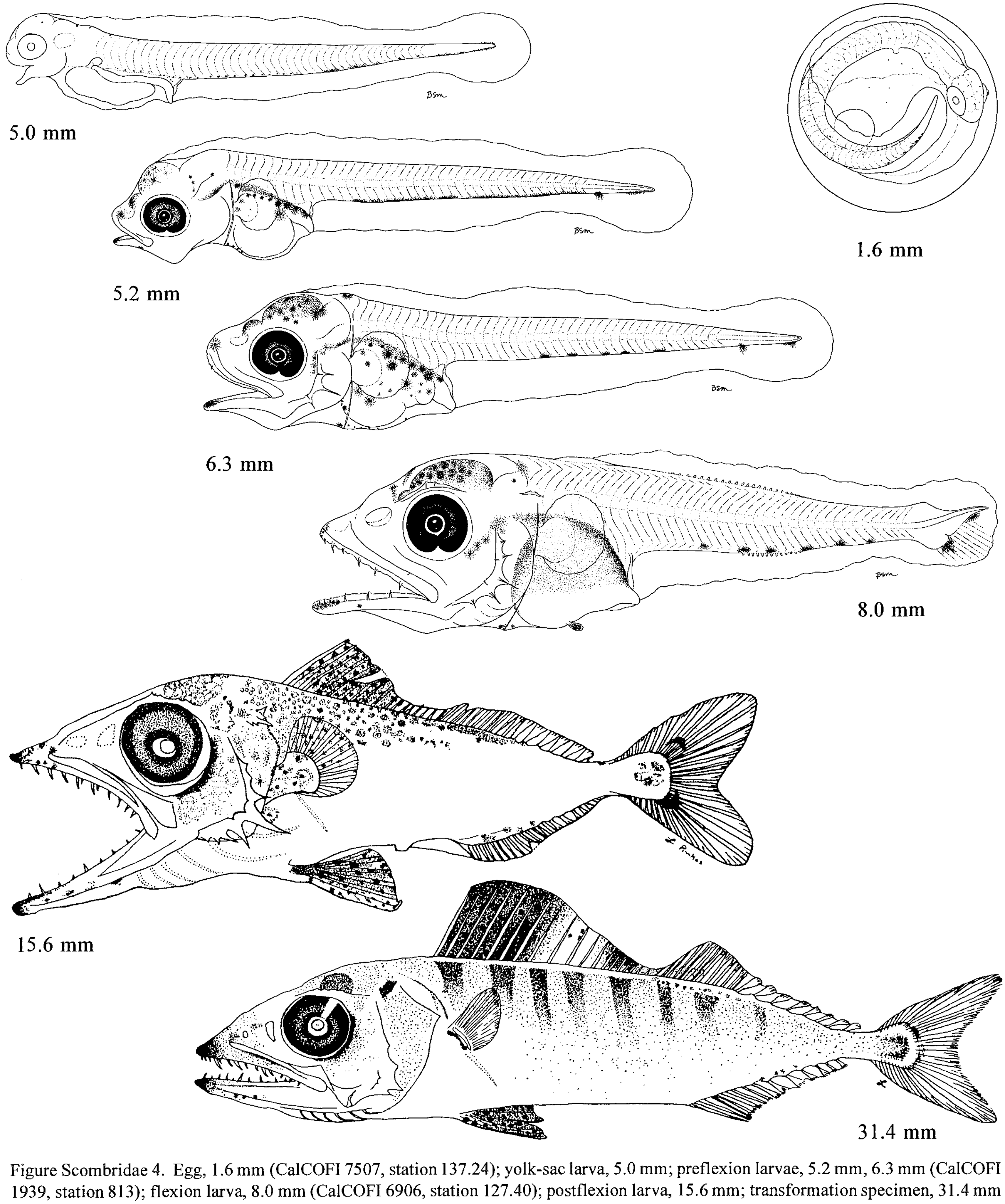


Figure Scombridae 4. Egg, 1.6 mm (CalCOFI 7507, station 137.24); yolk-sac larva, 5.0 mm; preflexion larvae, 5.2 mm, 6.3 mm (CalCOFI 1939, station 813); flexion larva, 8.0 mm (CalCOFI 6906, station 127.40); postflexion larva, 15.6 mm; transformation specimen, 31.4 mm (Pinkas 1961; lengths converted to standard length).

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–32	31
Precaudal	13–15	14
Caudal	16–18	17
Fins:		
Dorsal spines	VIII–XIII+I	X+I
Dorsal rays	9–14	11
Dorsal finlets	4–6	5
Anal spines	I–II	I
Anal rays	9–14	11
Anal finlets	4–6	5
Pelvic	I,5	I,5
Pectoral	19–22	17–18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	10–11	
Lower	10–12	
Gill rakers:		
Upper	10–14	13
Lower	26–34	28
Branchiostegals	7	7

LIFE HISTORY

Range: Cosmopolitan in warm & temperate waters; in the northeastern Pacific from southeast Alaska to Bahía Banderas, Mexico (ca. 21° N) & the Gulf of California

Habitat: Coastal pelagic, also to a lesser extent epi- & mesopelagic over continental slope from surface to about 300 m depth

Spawning season: Off California & Baja California, from March through October with peaks in April & August; usually at water temperatures 15–21 °C

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Berrien 1978
Collette et al. 1984b
Hunter & Kimbrell 1980
Kramer 1960, 1969
Ozawa 1988f
Richards & Klawe 1972

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.80–1.35 mm (in CalCOFI, 1.06–1.14 mm)

Yolk: Homogeneous; 1.04–1.12 mm diam.

No. of OG: 1

Diam. of OG: 0.22–0.31 mm (in CalCOFI, 0.26–0.28 mm)

Shell surface: Smooth, clear

Pigment: On yolk near P_1 region; on dorsum from head to tail, migrates ventrally; on OG in late-stage eggs

Diagnostic features: Egg size; OG size; tiny vacuoles in homogeneous yolk; pigment anterior to eyes

LARVAE

Hatching length: ca. 2–3 mm; yolk sac persists to ca. 4.0 mm

Flexion length: ca. 6.0–6.8 mm

Transformation length: ca. 12–19 mm

Fin development sequence: C_1, C_2, P_1, 2D & A, 1D, P_2

Pigmentation: *Yolk-sac*—Over brain; forming on eyes; on & under snout; dorsolaterally on yolk sac; on OG; migrating ventrally on body. *Preflexion*—On mid- & hindbrain; dorsolaterally on gut; row along ventral margin of tail. *Flexion*—Large circular blotches on occipital region; at C. *Postflexion*—Spreading over top of head, snout, & gut; on mandible & operculum; forming dorsally along body margin & along lateral midline posterior to anus; at caudal peduncle. *Transformation–juvenile*—Spreading laterally over body & onto C.

Diagnostic features: Low number of vertebrae (31); 2D & A form before 1D; wide gap between 1D & 2D; HL <33% BL; rounded dorsal profile of head & snout; preopercular spines absent; pigment along ventral margin of tail & lateral midline.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	41–47 45	42–54 49	42–57 50	52–61 58	60–67 63	64–68 65
BD/BL		22–28 25	21–27 25	23–28 26	20–25 23	18–21 19
HL/BL	22–26 24	22–28 26	24–27 25	27–31 28	28–31 29	29–32 31
HW/HL						31–39 34
SnL/HL						30–32 32
ED/HL	42–55 47	42–51 46	39–47 44	36–43 39	31–39 34	20–25 22
P_1L/BL						10–12 11
P_2L/BL						11–13 11

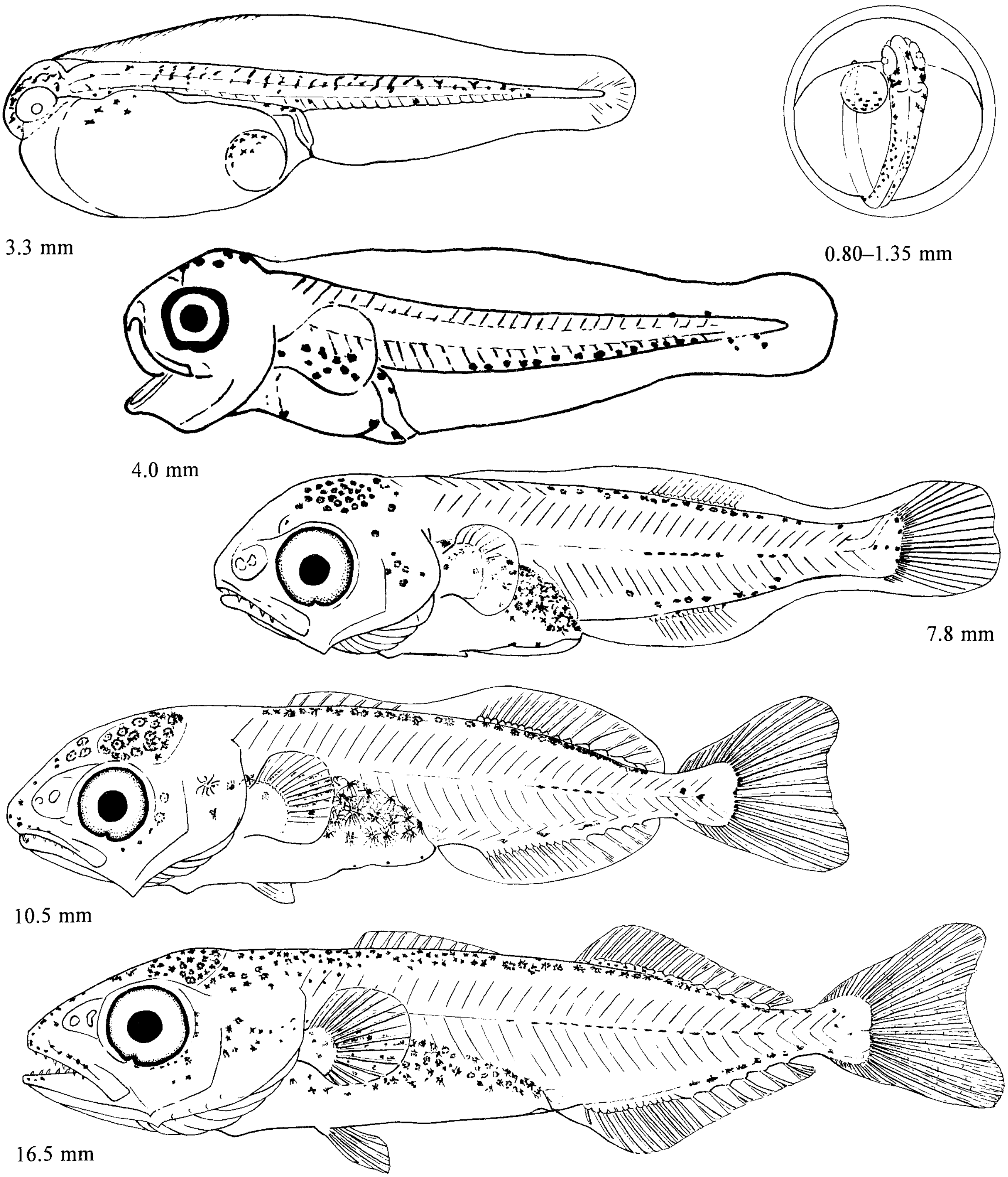


Figure Scombridae 5. Egg, 0.80–1.35 mm; yolk-sac larva, 3.3 mm; preflexion larva, 4.0 mm; postflexion larvae, 7.8 mm, 10.5 mm, 16.5 mm (modified from Kramer 1969).

MERISTICS

	Range	Mode
Vertebrae:		
Total	46–49	48
Precaudal	19–21	20
Caudal	26–29	28
Fins:		
Dorsal spines	XV–XVIII	XVIII
Dorsal rays	16–19	18
Dorsal finlets	7–10	8
Anal spines	0–II	0
Anal rays & spines	16–21	19
Anal finlets	7–10	8
Pelvic	I,5	I,5
Pectoral	20–24	21
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–5	2–4
Lower	9–14	12–13
Branchiostegals	7	7

LIFE HISTORY

Range: Southern California (ca. 32° N) to Chile (ca. 24° S), & the Galapagos Islands; rare north of Baja California

Habitat: Schooling; epipelagic; neritic

Spawning season: Off Mexico, July–September; Costa Rica, August–November; Colombia, November–April

ELH pattern: Oviparous; eggs and larvae planktonic

LITERATURE

Clemens 1956
Eckles 1949
Klawe 1966
Matsumoto 1967

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 2.3 mm (B. Sumida MacCall)
Preflexion larvae, 2.7 mm, 3.6 mm (B. Sumida MacCall)
Flexion larvae, 5.4 mm, 7.1 mm (B. Sumida MacCall)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.0–2.5 mm
Flexion length: ca. 4.5–7.5 mm
Transformation length: ca. 18 mm
Fin development sequence: C, 1D, 2D, A, P_2, P_1
Pigmentation: *Yolk-sac*—On fore- & midbrain; at nape; on OG; at angle of gut above anus; series (fine) ventrally along tail. *Preflexion–flexion*—On hindbrain; anteriorly & dorsally on gut; at cleithral symphysis; preanal spot; fewer (larger) ventrally along tail in A region. *Postflexion*—On jaw tips; along lower jaw; top of head between orbits; spreading laterally on peritoneum; on opercle; oblique line near end of maxilla; between first & fifth D spines; at bases of 1D & 2D; scattered mid-laterally on body; at C base. *Transformation*—Heavy on snout; distally on 1D & 2D; spreading laterally on body, lighter ventrally. *Juvenile*—Heavy dorsally, light ventrally on body; heavy between first & fifth D spines.
Diagnostic features: Vertebrae 46–49; A rays 16–21; supraoccipital crest well developed; large head & mouth; elongate snout; preopercular spines well developed; pigment at tips of jaws; melanophore at cleithral symphysis & anterior to anus; stellate melanophores on ventral margin of tail.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	40–43 42	43–50 46	46–59 51	58–64 61	61–71 64	58–63 61
BD/BL	14–17 16	21–29 26	24–35 28	21–25 23	22–24 22	18–19 19
HL/BL	18–20 18	21–28 25	25–38 34	37–41 39	31–40 34	25–27 26
HW/HL	73–91 85	57–82 67	39–60 47	32–39 35	32–40 38	31–32 31
SnL/HL	9–21 17	17–33 23	40–46 41	40–46 43	38–44 41	33–35 34
ED/HL	48–57 52	37–48 43	26–40 31	26–29 28	23–27 25	20–21 20
P_1L/BL	3–4 3	4–10 8	6–8 7	7–9 8	7–10 9	8–10 9
P_2L/BL	0–0 0	0–0 0	0–3 0.7	8–10 9	7–9 8	6–6 6

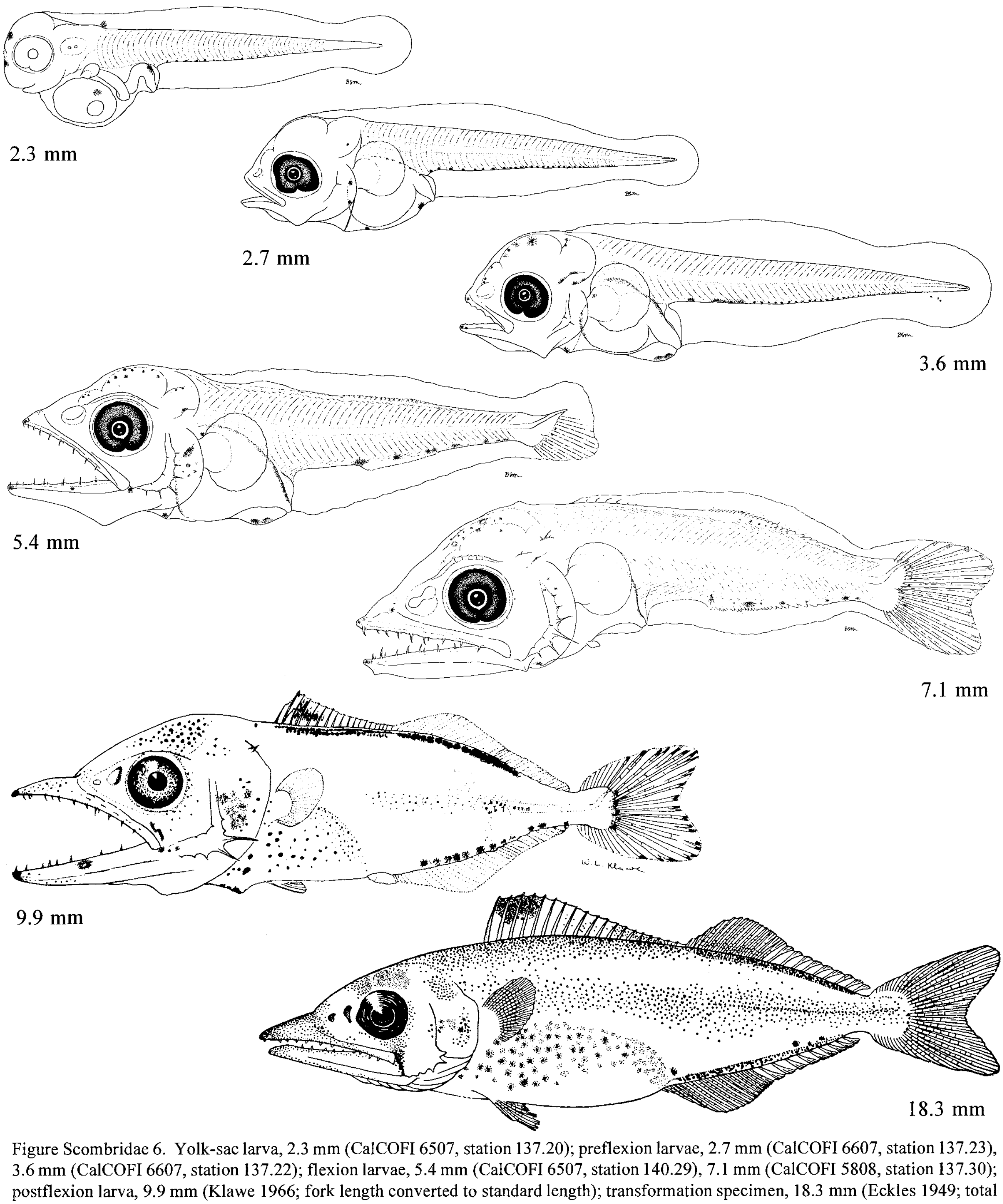


Figure Scombridae 6. Yolk-sac larva, 2.3 mm (CalCOFI 6507, station 137.20); preflexion larvae, 2.7 mm (CalCOFI 6607, station 137.23), 3.6 mm (CalCOFI 6607, station 137.22); flexion larvae, 5.4 mm (CalCOFI 6507, station 140.29), 7.1 mm (CalCOFI 5808, station 137.30); postflexion larva, 9.9 mm (Klawe 1966; fork length converted to standard length); transformation specimen, 18.3 mm (Eckles 1949; total length converted to standard length).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39	39
Precaudal	18	18
Caudal	21	21
Fins:		
Dorsal spines	XI–XIV	XIV
Dorsal rays	12–16	15
Dorsal finlets	7–10	8
Anal spines	0	0
Anal rays	11–16	14
Anal finlets	7–10	7
Pelvic	I,5	I,5
Pectoral	30–36	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	15–17	
Lower	15–17	
Gill rakers:		
Upper	8–11	
Lower	19–24	
Branchiostegals	7	7

LIFE HISTORY

Range: Worldwide in warm seas, absent from the Mediterranean Sea; in the eastern Pacific from Pt. Conception, California to Peru

Habitat: Epipelagic (usually upper 100 m depth); open sea in schools

Spawning season: Throughout the year with peak in April–June off Central America

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Mori et al. 1971
Nishikawa 1988a
Wild 1994

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.90–1.04 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.18–0.28 mm
Shell surface: Smooth, clear
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 2.7 mm
Flexion length: ca. 4.5–6.1 mm
Transformation length: ca. 18 mm
Fin development sequence: C, 1D, 2D, A, P_2, P_1
Pigmentation: *Yolk-sac*—On brain; scattered on yolk; dorsally on gut; patch ventrally near end of tail. *Preflexion*—On lower lip; over midbrain; internally on posterior margin of brain; dorsally on angle of gut above anus; occasionally 1 ventrally in hypural region. *Flexion–postflexion*—On snout tip; near dorsal margin of preopercle; dorsolaterally on peritoneum; by ca. 5 mm, distally on 1D membrane; posteroventrally on brain; posterior edge of orbit. *Transformation*—Scattered posteriorly over head & a saddle extending posteriorly to beneath 2D insertion; spreading laterally on dorsal half of body; occasionally a row above posterior half of A. *Juvenile*—Heavy on entire 1D, proximally on 2D; dorsally & midlaterally on body; 5 vertical bars on upper half of body; on hypurals & C base.
Diagnostic features: Total vertebrae 39; pigment absent from forebrain, cleithral symphysis, anterior to anus, & along tail until ca. 14 mm; by ca. 4 mm, usually one small melanophore on underside of jaw; pigment on 1D present by ca. 6 mm, becoming heavy by postflexion.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	34–49 40	40–62 49	43–53 50	53–71 61	64	60
BD/BL		25–31 27	25–31 27	29–36 32	29	26
HL/BL	17–18 18	27–37 33	33–40 38	37–47 42	38	32
HW/HL		41–60 49	40–51 48	36–48 43		
SnL/HL	8–21 14	19–44 31	32–43 38	33–44 37	35	27
ED/HL	36–45 40	33–43 37	32–37 35	30–38 32	32	32
P_1L/BL	0–3 1	4–7 6	7–8 8	5–10 8	10	9
P_2L/BL	0–0 0	0–5 0.6	2–6 3	7–20 13	16	12

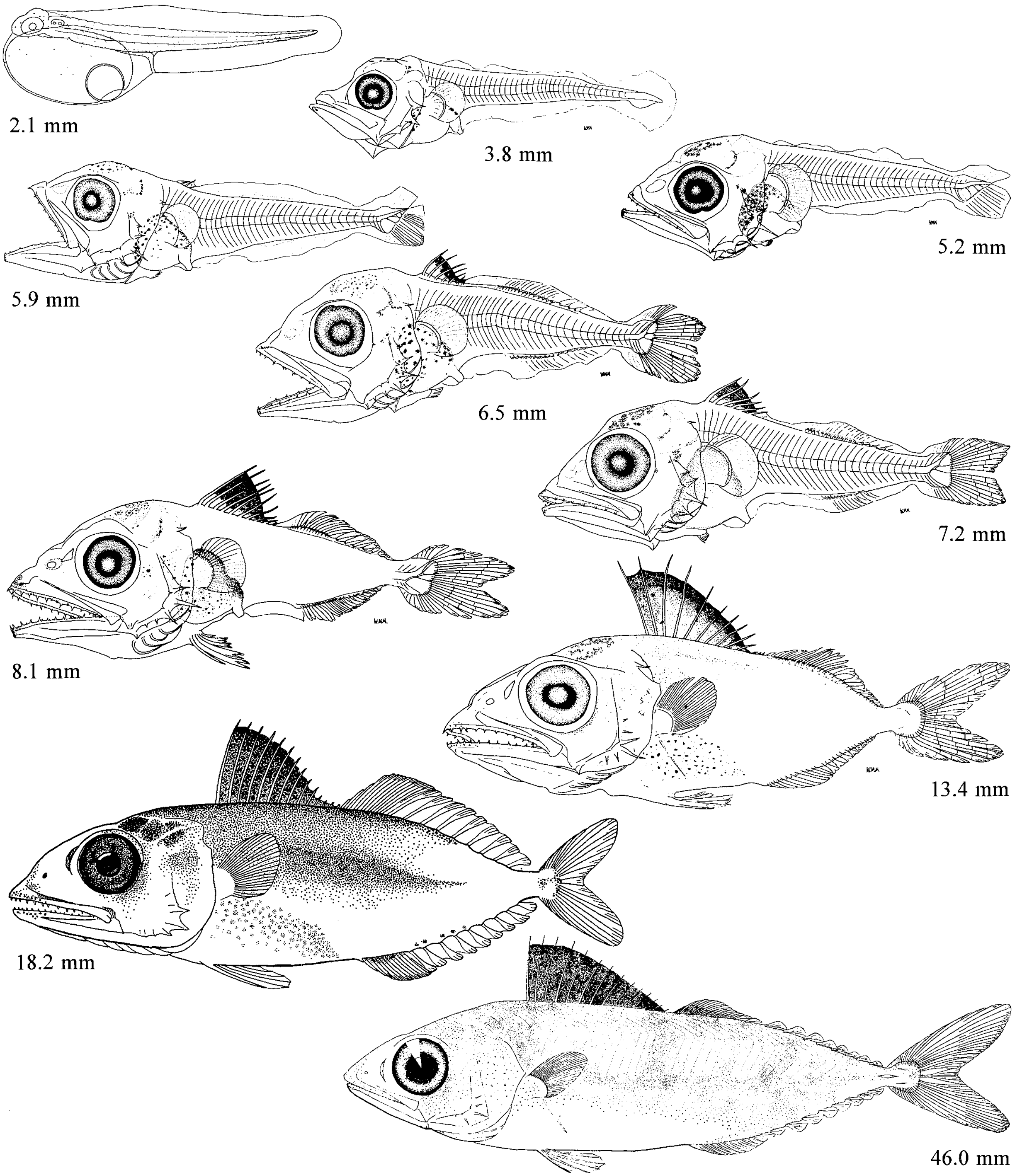


Figure Scombridae 7. Reared yolk-sac larva, 2.1 mm (Mori et al. 1971); preflexion larva, 3.8 mm; flexion larvae, 5.2 mm, 5.9 mm; postflexion larvae, 6.5 mm, 7.2 mm, 8.1 mm, 13.4 mm (Matsumoto 1958; lengths converted as in Figure Scombridae 1); transformation specimen, 18.2 mm (Schaefer and Marr 1948b; length converted from total to standard length); juvenile, 46.0 mm (Matsumoto 1961).

TRICHIURIDAE: Cutlassfishes

E. M. SANDKNOP AND W. WATSON

Five of the 35 trichiurid species range into the California Current vicinity (Table Trichiuridae 1; Nakamura and Parin 1993; Parin 1995b). In the eastern North Pacific *Aphanopus arigato* ranges from British Columbia to southern California and *Lepidopus fitchi* from northern Oregon to the Gulf of California, *Benthodesmus pacificus* occurs in the Straits of Juan de Fuca and off California, *Assurger anzac* occurs off southern California and northern Baja California, and *Trichiurus nitens* ranges southward from southern California. Nakamura and Parin (1993) consider *T. nitens* a synonym of *T. lepturus*; however, because of larval pigmentation differences between CalCOFI specimens and *T. lepturus* elsewhere (Tsukahara 1961; Ozawa 1988g; J. Gago, Los Angeles County Museum of Natural History, pers. comm., August 1995), we provisionally retain *T. nitens* for the eastern Pacific (CalCOFI) material. Eggs and larvae of *L. fitchi* and *T. nitens* have been taken in moderate numbers during CalCOFI ichthyoplankton surveys: *L. fitchi* primarily during summer and autumn at stations off the outer coast of central Baja California and *T. nitens* primarily during summer at stations within the Gulf of California. Neither eggs nor larvae of the other species have been identified in CalCOFI collections.

Trichiurids are medium-size to large (most species ≤1 m, largest species to >2 m long), primarily benthopelagic, ambush predators over continental and insular shelves and slopes, seamounts, and submarine ridges in tropical and temperate waters. They are very elongate and compressed, with preanal length about half of body length. The snout is elongate and the mouth large, with large fang-like teeth anteriorly in the upper jaw. The continuous dorsal fin extends nearly the full length of the body and is unnotched to deeply notched between the spinous and soft-rayed portions. The caudal fin is small and forked, greatly reduced, or absent. Pelvic fins are reduced or absent. The first anal fin spine is greatly reduced. Scales are lacking. Trichiurids typically are darkly pigmented, usually brown to black, often with a silvery sheen. Some species support important commercial fisheries and some are exploited in artisanal fisheries (Nakamura and Parin 1993).

Trichiurids are oviparous, with planktonic eggs and larvae (Nakamura and Parin 1993). *Lepidopus* and *Trichiurus* spawn spherical eggs ca. 1.6–2.5 mm in diameter that have an unsculptured, colorless to pink or amber chorion, a homogeneous yolk, and a single colorless to yellowish or pinkish oil globule ca. 0.4–0.7 mm in diameter (Raffaele 1888; Delsman 1927; Padoa 1956a; Mito 1961b; Tsukahara 1961; Olivar and Fortuño 1991; this study). Larvae hatch with unpigmented eyes, an unformed mouth, pectoral fin buds forming, and a moderately large yolk sac containing the oil globule posteriorly. Larvae are elongate and compressed, becoming more so with growth. Preanal length initially is ca. one-quarter to one-third of body length, lengthening to the vicinity of 50% BL by midway through the postflexion stage (or by the time dorsal and anal fin ray complements are ≥50% complete in species that do not undergo notochord flexion). The snout initially is short and rounded, but becomes long and pointed. Spination of the head is largely limited to a few small to moderate spines along the preopercular margin; older larvae of some species may develop small spines or serrations along the upper opercular margin and some species may acquire a few small supraocular spines or serrations. The first dorsal spine is the first fin element to form, just before to just after completion of yolk absorption. This spine may become rather long or strongly serrate. The next fins to begin developing rays are the pectorals, followed by pelvic and caudal rays in species that have those fins. Anal fin rays are the last to begin developing. Larval pigmentation typically is rather light, initially consisting primarily of a few small melanophores on the oil globule and dorsally on the head and/or gut, and one to four large blotches on the margins of the tail and adjacent finfold. These blotches commonly diminish and disappear during development. Concurrently, melanophores commonly form along the dorsal margin and increase on the head and gut.

Larval trichiurids are easily recognized and are unlikely to be confused with the larvae of other fishes in the CalCOFI study area. Key characters are the elongate, slender shape; short preanal length in young larvae; the long, pointed snout; high myomere counts (ca. 84–93 in *L. fitchi*, >100 in the others); and the long-based dorsal and anal fins with elongate or serrate spines anteriorly. Early larval *L. fitchi* resemble young larval *Chiasmodon niger* in both pigmentation and shape, but are easily distinguished by a number of characters including myomere counts (<50 in *C. niger*, >80 in *L. fitchi*), lack of the elongate first dorsal spine in *C. niger* (present by 6.2 mm in *L. fitchi*), and the lack of body spinules in *L. fitchi* (present by 5.5 mm in *C. niger*). Myomere counts distinguish *L. fitchi* from the larvae of the other trichiurid species in the CalCOFI study area (e.g., Table Trichiuridae 1); pigmentation likewise distinguishes larval *L. fitchi* from *Aphanopus arigato*, *Assurger anzac*, *B. pacificus*, and *T. nitens* (c.f. Figures Trichiuridae 1–3). Young larvae of *Assurger*, *Benthodesmus*, and *Lepidopus* have an elongate first dorsal spine, while that of *Trichiurus* is not particularly long.

The following descriptions are based on examination of 22 eggs and 27 larvae of *L. fitchi* and 43 eggs and 23 larvae of *T. nitens* (Table Trichiuridae 2). The other species are not described separately since their eggs and larvae were not found in CalCOFI ichthyoplankton collections, but larval *Aphanopus arigato*, *Assurger anzac* and *B. pacificus* are shown in Figure Trichiuridae 1. Refer to Gorbunova (1977), Ozawa (1986f, 1988g) and Evseyenko et al. (1994) for additional illustrations and descriptions. Meristic data were obtained from Mikhaylin (1982), Rosenblatt and Wilson (1987), Nakamura and Parin (1993), J. Gago (Los Angeles County Museum of Natural History, pers. comm., July 1995), and counts made during this study. Ecological information is from Eschmeyer et al. (1983) and Nakamura and Parin 1993).

Table Trichiuridae 1. Meristic characters for the trichiurid species in the California Current vicinity.

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	P_1	P_2
Aphanopus arigato	43–46	57–62	103–108	XXXIX–XLIII,54–59	II,47–50	12	0–I[a]
Assurger anzac	41–43	83–86	125–129	XXXIV–XXXV,85–86	II,72–85	12	I,2
Benthodesmus pacificus			149–153	XLIV–XLVI,99–104	II,90–94	12	I,1
Lepidopus fitchi	32–37	48–57	84–93	IX–XII,68–77	II,41–49	12	I,1–2
Trichiurus nitens	34–36	112–124	141–158	III,116–128	I,95–105	12–14	0

[a] P_2 consists of a single thoracic spine in juveniles, absent in adults.

Table Trichiuridae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the trichiurid species descriptions. *Trichiurus nitens* does not undergo notochord flexion; larvae are partitioned into "less developed" and "more developed" categories (defined by absence and presence, respectively, of the anal fin spine) and are listed under the headings "Preflexion" and "Postflexion," respectively, only as a convenience.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation
Lepidopus fitchi	22 1.6–1.8	5 4.1–5.9	8 5.8–9.5	6 10.0–13.2	5 14.2–15.7	3 21.8–27.8
Trichiurus nitens	43 1.6–1.9	4 5.6–6.5	7 5.6–9.4	0	12 9.8–20.2	0

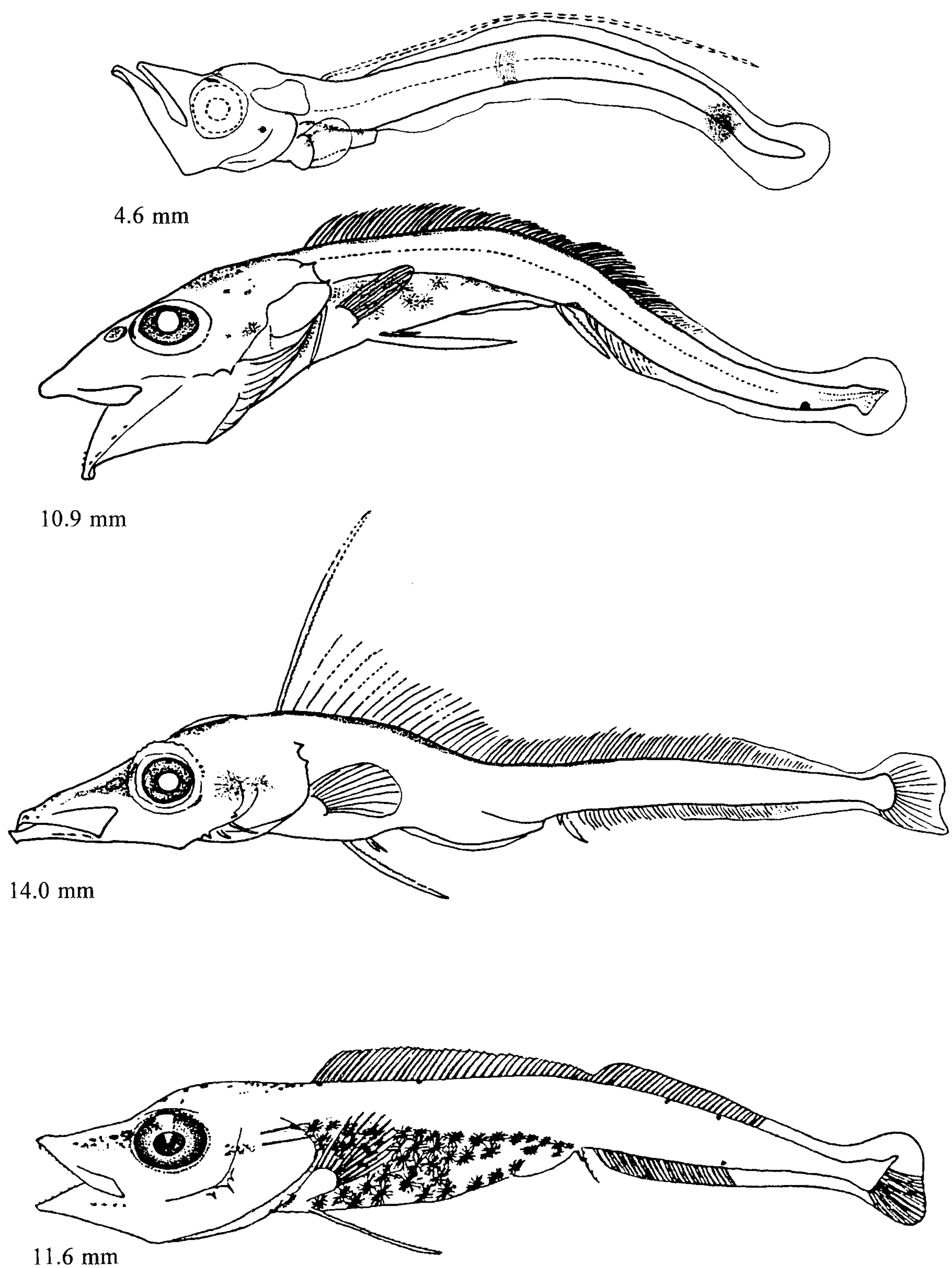


Figure Trichiuridae 1. *Benthodesmus pacificus*,4.6 mm preflexion larva and 10.9 mm flexion larva; *Assurger anzac*, 14.0 mm postflexion larva (Ozawa 1986f); *Aphanopus arigato*, 11.6 mm flexion larva (Evseyenko et al. 1994).

MERISTICS

	Range	Mode
Vertebrae:		
Total	84–93	87–92*
Precaudal	32–37	35
Caudal	48–57	53
Fins:		
Dorsal spines	IX–XII	X
Dorsal rays	68–77	70–74*
Anal spines	II	II
Anal rays	41–49	44–47*
Pelvic	I,1–2	I,1
Pectoral	12	12
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	6–8	
Lower	6–7	
Gill rakers:		
Total	12–17	17
Upper	7	7
Lower	10	10
Branchiostegals	7	7

LIFE HISTORY

Range: Northern, Oregon (45°12′ N, 123°57′ W) to Gulf of California, & from 5° N to southern Peru

Habitat: Benthopelagic, over deep continental shelf & upper slope between 175 & 500 m depth; young epipelagic in upper 150 m

Spawning season: Eggs & larvae collected primarily from June–October with August larval peak in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.7 mm (M. T. Vona)
Yolk-sac larva, 4.1 mm (M. T. Vona)
Preflexion larva, 6.2 mm (M. T. Vona)
Flexion larvae, 10.0 mm, 15.0 mm (M. T. Vona)
Transformation specimen, 21.8 mm (M. T. Vona)

* Mean counts for eastern North Pacific specimens are 87 total vertebrae, 80 total D elements, & 44 A rays; respective means for eastern South Pacific specimens are 92, 84, & 46.5 (Rosenblatt & Wilson 1987).
† Only one specimen with P_2 intact.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.6–1.8 mm **Yolk:** Homogeneous; 1.4–1.7 mm diam.
No. of OG: 1 **Diam. of OG:** 0.34–0.62 mm
Shell surface: Smooth
Pigment: Chorion amber to dark pink; advanced embryo with melanophores over brain; on snout; 2 dendritic patches each on dorsal & ventral margins, extending onto finfold; 1 dendritic patch each dorsally & ventrally near distal margin of caudal finfold; few on yolk sac & OG
Diagnostic features: Diameter; pigmentation of advanced embryo

LARVAE

Hatching length: ca. 4.1–4.8 mm
Flexion length: ca. 10–14 mm
Transformation length: ca. 22–28 mm
Fin development sequence: 1D, P_1, C_1, P_2, 2D, A, C_2
Pigmentation: *Yolk-sac*—In addition to pigmentation of late embryo (see above): on otic capsule; under hindbrain by end of stage; over gut. *Preflexion*—On snout; on ethmoid cartilage; 0–few anteriorly on forebrain; 0–few over midbrain; under mid- & hindbrain; in otic capsule; under upper preopercle by 6–7 mm; on upper 30–50% of gut & to near ventrum anteriorly; dorsal & ventral patches contract from finfold & begin to move internally; caudal finfold patches diminish & usually absent after 8–10 mm. *Flexion–postflexion*—Increasing on head & gut; on lateral ethmoid by 10 mm, spreading posteriorly around orbit; on isthmus by ca. 13 mm; on dentary & articular by ca. 14 mm; on bases of D spines by 11 mm, spreading forward to meet head pigment & posteriorly to D insertion by ca. 22 mm; dorsal & ventral patches usually internal by 14 mm; series over notochord by ca. 22 mm.
Diagnostic features: Prominent pigment patches alternating on dorsal & ventral margins, 2 patches on each margin; 2 prominent caudal pigment patches in yolk-sac & preflexion stages; myomeres 11–13+76–77 in preflexion stage, 31–37+48–57 in postflexion stage; caudal fin present.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	26–35 29	25–35 33	36–46 40	44–59 51	58–61 59	
BD/BL	13–20 15	13–17 15	13–15 14	11–16 14	10–11 11	
HL/BL	12–17 13	16–25 22	24–29 26	27–32 29	28–29 28	
HW/HL	48–68 58	30–58 38	23–32 28	20–27 24	16–20 18	
SnL/HL	9–23 18	31–51 42	41–44 43	37–42 39	33–54 41	
ED/HL	38–49 42	25–32 29	23–25 24	21–23 22	18–20 19	
P_1L/BL	0–3 2	2–6 4	4–7 6	7–10 8	9–11 10	
P_2L/BL	0–0 0	0–2 0.4	3–12 7	15–17 16	12†	

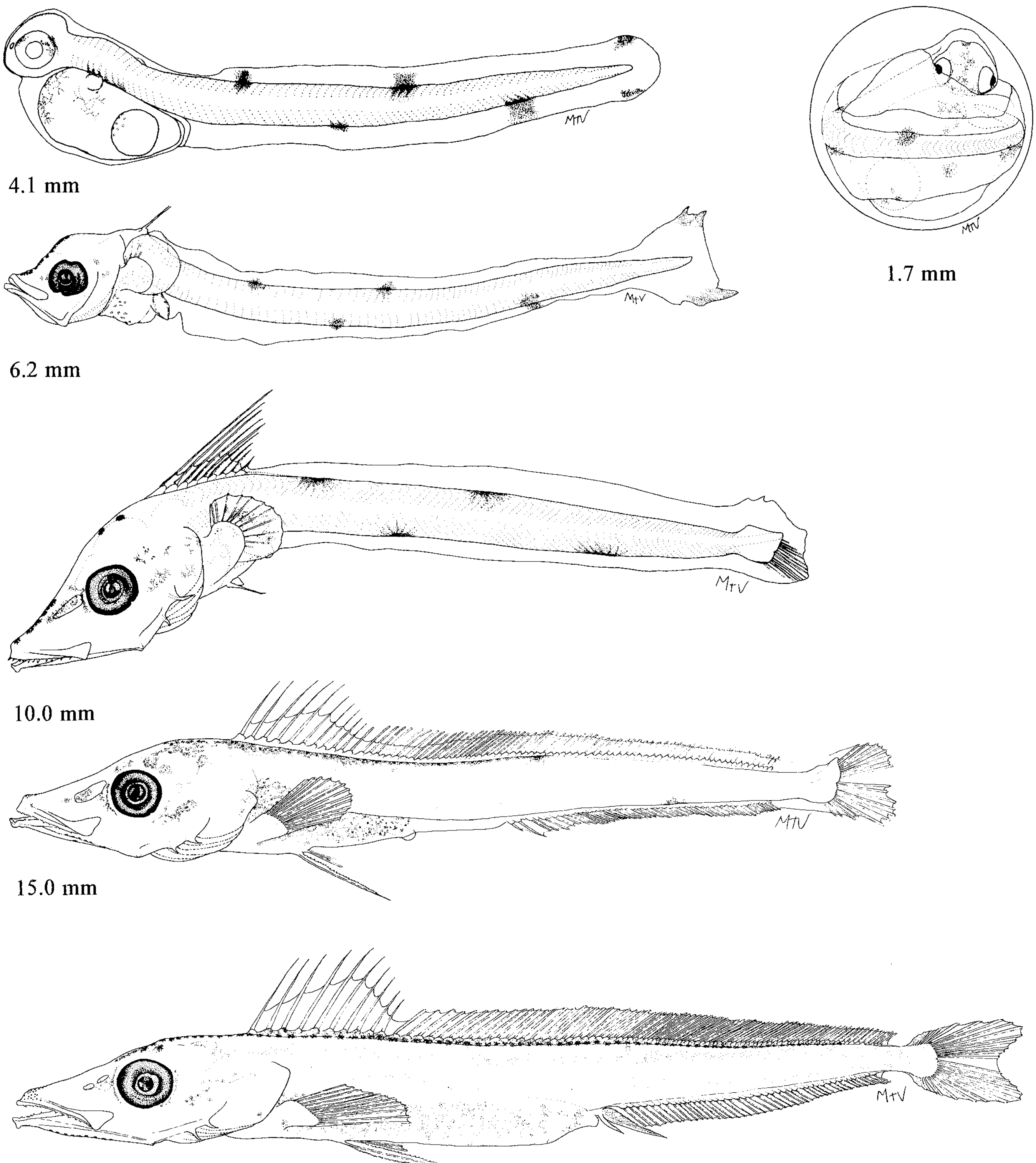


Figure Trichiuridae 2. Egg, 1.7 mm (CalCOFI 7510, station 97.55); yolk-sac larva, 4.1 mm (CalCOFI 7510, station 123.30); preflexion larva, 6.2 mm (CalCOFI 7210, station 110.45); early flexion larva, 10.0 mm (CalCOFI 6910, station 107.70); late flexion larva, 15.0 mm (CalCOFI 7808, station 117.60); transformation specimen, 21.8 mm (CalCOFI 5706, station 138G.20).

MERISTICS

	Range	Mode
Vertebrae:		
Total	141–158	
Precaudal	34–36	
Caudal	112–124	
Fins:		
Dorsal spines	III	III
Dorsal rays	116–128	
Anal spines	I	I
Anal rays	95–105	
Pelvic	0	0
Pectoral	12–14	
Caudal:		
Principal	0	0
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper	7–11	
Lower	12–24	
Branchiostegals	7	7

LIFE HISTORY

Range: Worldwide in tropical & temperate seas; in eastern Pacific from southern California, to Peru, including Gulf of California & Galapagos Islands

Habitat: Benthopelagic on continental shelf & slope, primarily between 55–385 m depth; young may feed near surface at night & large adults may do so during the day

Spawning season: Eggs & larvae collected during summer in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 1.7 mm (M. T. Vona)
Yolk-sac larva, 5.5 mm (M. T. Vona)
Larvae, 6.5 mm, 9.5 mm, 16.8 mm (M. T. Vona)

* Notochord flexion does not occur. Two post-yolk absorption developmental stanzas were defined: "less developed" larvae (≤9.4 mm) lacking the A spine, & "more developed" larvae (≥9.8 mm) with the A spine formed.

† Eyes initially somewhat oval, becoming round after 9.4 mm; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.6–1.9 mm **Yolk:** Homogeneous; 1.3–1.6 mm diam.
No. of OG: 1 **Diam. of OG:** 0.36–0.48 mm
Shell surface: Smooth
Pigment: Chorion amber; advanced embryo with few melanophores scattered on head & OG, large ventral patch posteriorly on tail
Diagnostic features: Diameter; pigmentation of advanced embryo.

LARVAE

Hatching length: ca. 5.5 mm
Flexion length:*
Transformation length: >20.2 mm
Fin development sequence: D, P_1, A
Pigmentation: *Yolk-sac*—Few scattered from tip of snout to above midbrain, decreasing; few dorsally from above middle of hindbrain to middle of gut, decreasing; few on gut to level of P_1 buds; few on OG & yolk; large ventral patch posteriorly on tail, extends well onto finfold. *Post-yolk absorption*—Initially little or none on snout & over midbrain, increasing over midbrain after 9 mm; over forebrain after 16 mm; ventrally on mid- & hindbrain & ventrolaterally on midbrain; 1 in nasal capsule after 9 mm; series around lower rim of orbit, beginning posteroventrally at ca. 9.4 mm; 0–few at tip of lower jaw after 9 mm & at tip of upper jaw after 16 mm; series on dentary & articular after 16 mm; 1–2 ventrally on basihyal; anteriorly on gut; occasionally 1–2 over mid- or hindgut after 9 mm; dorsal series beginning at D origin by 6.5 mm, spreading anteriad above hindbrain by 7.4 mm & caudad to ca. 90% BL by 20 mm; ventral tail patch diminishes, usually is absent after 8 mm.
Diagnostic features: Single ventral pigment patch on tail to ca. 8 mm, usually no ventral pigment thereafter; series of melanophores along dorsal margin beginning anteriorly just after yolk absorption, slowly spreading caudad, reaching nearly full length of body by ca. 20 mm; postanal myomeres >100; notochord flexion does not occur.

MORPHOMETRICS (range & mean in %)*

	Y-S	5.6–9.4 mm	9.8–20.2 mm
Sn-A/BL	32–38 35	31–44 38	52–57 54
BD/BL	5–7 6	13–15 14	9–14 11
HL/BL	14–17 16	18–26 23	24–30 26
HW/HL	46–55 50	23–42 33	18–26 22
SnL/HL	16–25 19	32–49 40	35–41 38
ED/HL†	30–39× 23–30	23–33× 19–24	17–22
	34×26	28×21	20
P_1L/BL	0–5 2	4–6 5	6–9 8

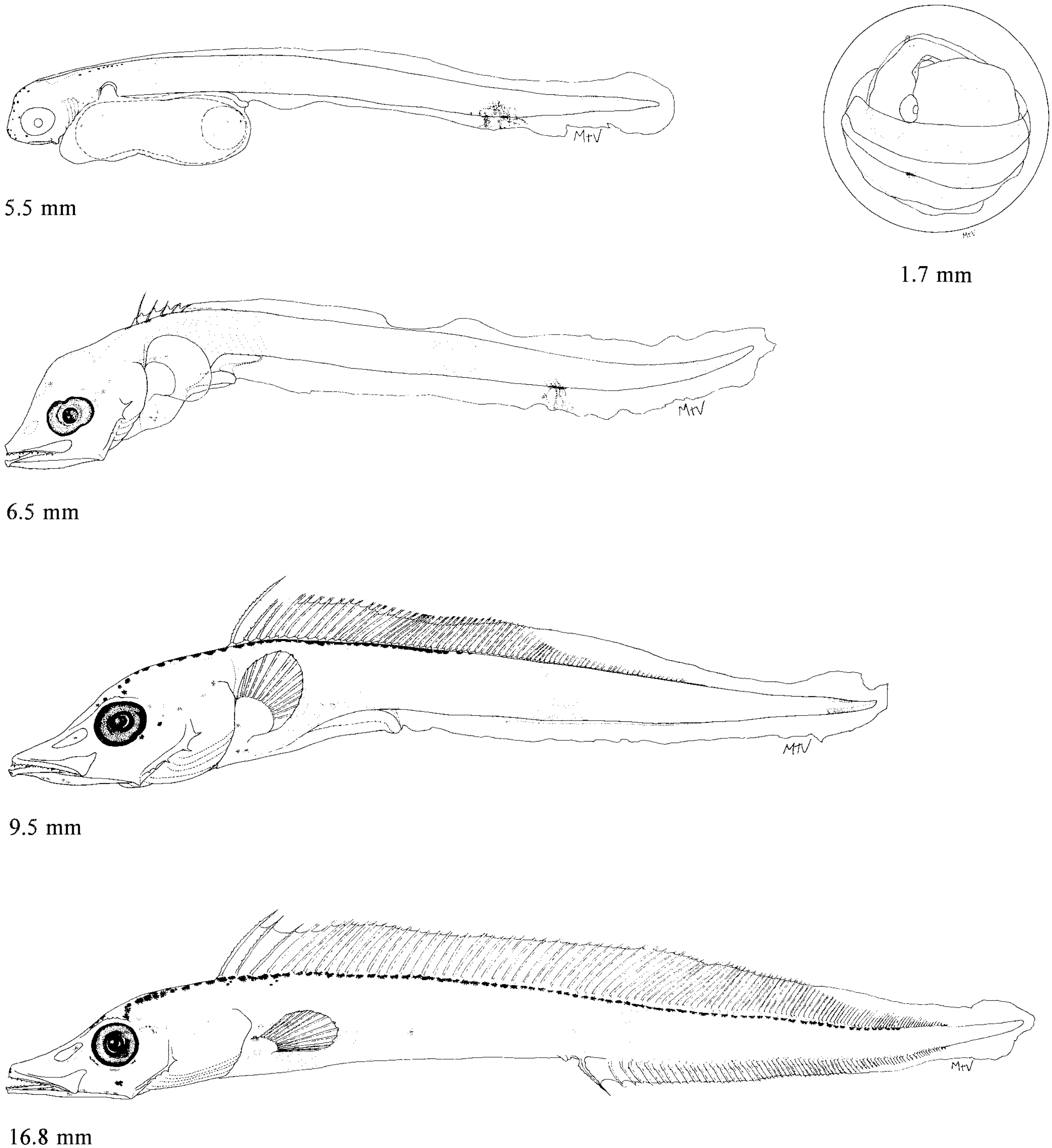


Figure Trichiuridae 3. Egg, 1.7 mm (CalCOFI 5706, station 103G.70); yolk-sac larva, 5.5 mm (CalCOFI 5706, station 109G.68); larvae, 6.5 mm (CalCOFI 5706, station 109G.68), 9.5 mm (CalCOFI 5706, station 109G.66), 16.8 mm (CalCOFI 5706, station 129G.89).

STROMATEOIDEI

W. WATSON

Stromateoidei is characterized by the presence of toothed pharyngeal pouches (except in Amarsipidae, which has strong pharyngeal teeth but lacks the saccular pharyngeal outgrowths) (Haedrich 1967, 1969), an arrangement of the ramus lateralis accessorius facial nerve complex (RLA pattern 10) shared with only a few percoid families (Freihofer 1963; Johnson and Fritzsche 1989), and other more widely distributed features (e.g., mainly small, uniserial teeth in jaws, weak to moderate spines in fins, cycloid or weakly ctenoid scales). Haedrich (1967) speculated that stromateoid affinities are with the RLA pattern 10 percoid families Pomatomidae (Johnson and Fritzsche [1989] subsequently stated that Freihofer's observation of pattern 10 in *Pomatomus* was in error), Kyphosidae, and Scorpididae, and noted a strong general resemblance between kyphosids and Centrolophidae, which he considered the most primitive stromateoid family. Johnson and Fritzsche (1989) concurred that RLA pattern 10 is a synapomorphy uniting the stromateoids and the pattern 10 percoid families.

Relationships of families within the Stromateoidei and the composition of some families are more uncertain. Haedrich (1967) proposed two lineages, one containing Centrolophidae and its derivative Stromateidae, and the other containing Nomeidae as the primitive member with ariommids and tetragonurids derived from it. He later suggested (Haedrich 1969) that Amarsipidae is a third stromateoid lineage distantly related to Nomeidae through a common ancestor. In contrast, Horn (1984) suggested that the ariommids and tetragonurids are more closely related to the stromateids than to the nomeids, that the ariommids and tetragonurids should not be considered distinct families, and that only the amarsipids, nomeids and stromateids form monophyletic groups. However, he cautioned that further study would be required before any such changes could be made. Haedrich (1986) and Johnson (1993) likewise noted that work remains to be done before relationships within the stromateoids can be resolved. Here, we follow Eschmeyer (1990) in retaining all six stromateoid families as outlined by Haedrich (1967, 1969).

The six stromateoid families contain about 65 species in 16 genera (Nelson 1994). Eleven species representing six of the genera and four of the families occur within the CalCOFI study area (Table Stromateoidei 1). As far as is presently known, all are oviparous, with planktonic eggs and larvae (Ahlstrom et al. 1976; D'Vincent et al. 1980).

Family included: Centrolophidae
Nomeidae
Tetragonuridae
Stromateidae

Table Stromateoidei 1. Meristic characters for the stromateoid species in the California Current vicinity. All have I,5 pelvic fin rays except *Peprilus*, in which the pelvic fins are reduced to a single minute spine, all have 9+8 principal caudal fin rays, and all have 6 branchiostegal rays except *Icichthys lockingtoni* with 7, and *Tetragonurus cuvieri* which may have 5.

	Vertebrae			Fin rays				
Taxon	PrCV	CV	Total	D	A	P_1	C_2	Gill rakers
Centrolophidae								
Icichthys lockingtoni	23–25	34–37	58–61	III,36–43	III,24–29	18–21	11–13+10–13	4–6+8–14
Nomeidae								
Cubiceps baxteri	12	19	31	XI–XIII,20–24	III,20–22	20–23	7–10+7–10	6–10+16–18
C. paradoxus	12	19	31	XII,19–20	III,20	22	11–12+12	
C. pauciradiatus	13–14	17–18	30–31	XI–XIII,15–18	II,14–16	16–20	8–10+8–10	7–9+16–19
Nomeus gronovii	14–15	26–27	40–41	X–XIII,24–28	I–II,24–29	19–24	8–9+8–9	6–9+15–19
Psenes pellucidus	13–15	26–29	40–42	X–XII+I–II,26–32	III,26–31	18–20	8–10+8–10	8–9+15–17
P. sio	12–13	24–26	36–38	X–XII+I,22–26	II,23–26	17–19	7–10+8–10	7–8+15–18
Tetragonuridae								
Tetragonurus atlanticus	23–24	20–22	44–51	XIV–XVII,10–13	I,9–12	14–18	9–10+9–10	4–6+9–11
T. cuvieri	25–29	24–28	51–58	XV–XXI,10–17	I–II,9–15	14–21	9–13+9–12	5–6+7–14
Stromateidae								
Peprillus simillimus	11–14	17–19	29–31	II–IV,41–48	II–III,35–44	19–23	6–9+6–8	3+11–13
P. snyderi	13–14	22–23	35–37	II–III,43–49	II–III,40–44	21–23	7–8+7	

CENTROLOPHIDAE: Medusafishes

W. WATSON

Centrolophidae contains about 27 species in seven genera (Nelson 1994); only one, *Icichthys lockingtoni*, occurs in the California Current region, where it ranges south to about Punta Eugenia, Baja California Sur. Its eggs and larvae occur commonly off the coast of California and northern Baja California. Larval abundance and frequency of occurrence are highest from spring through mid-summer, and lowest in autumn and early winter.

Medusafishes are small to large (ca. 10–120 cm) epipelagic to epibenthic residents of all temperate and subtropical seas. Juveniles often are associated with medusae. Medusafishes are compressed, slightly to moderately elongate, with preanal length about half of body length. The snout is rounded or squared. The dorsal fin is long-based and continuous, with 5–9 stout spines that are shorter than the soft rays, or fewer, weak spines that grade into the soft rays. The long-based anal fin typically contains three spines. The caudal fin is forked to rounded. Most are covered with small cycloid scales, except the head typically is unscaled. Medusafishes are evenly dark to mottled or weakly barred; browns and greys predominate.

Medusafishes are oviparous, with planktonic eggs and larvae (Ahlstrom et al. 1976; Horn 1984). Eggs are spherical, ca. 1.1–2.1 mm in diameter, with a smooth chorion and a single oil globule ca. 0.3–0.6 mm in diameter (Sanzo 1932; Ahlstrom et al. 1976; Grimes and Robertson 1981). The yolk may be segmented (*Centrolophus*—Sanzo 1932) or not (e.g., *Ichichthys*—Ahlstrom et al. 1976; *Seriolella*—Grimes and Robertson 1981). Larvae hatch with unpigmented eyes, unformed mouth, pectoral fins lacking or present as buds, and moderate to large yolk sac with posterior oil globule. Larvae initially are slightly to moderately elongate and compressed, with a short, rounded snout and straight gut extending to about mid-body. As they grow they become more compressed and deeper-bodied or more elongate, depending on genus. The small, anterior gas bladder regresses during the juvenile stage and is absent in adults (Horn 1975). The snout elongates but remains rounded to bluntly acute, and during the preflexion or flexion stage, the gut coils. Small spines may form on the preopercular, interopercular, and subopercular bones during the postflexion stage (*Hyperoglyphe* and *Psenopsis*—Kimura 1988; *Icichthys*—this study; *Schedophilus*—John and Karrer 1985), or head spination may be lacking (*Centrolophus*—Sanzo 1932). The order of fin development differs between genera: the caudal rays are first in *Centrolophus*, while pectoral rays are first in *Icichthys*. Larval medusafishes are lightly to moderately pigmented through the preflexion stage, with melanophores primarily dorsally on the head, and in discrete patches dorsally on the trunk and/or tail, dorsally along the gut, and ventrally on the tail. The median finfolds may be pigmented as well. Melanophores are added laterally during the flexion or postflexion stage and increase on all areas during the postflexion stage.

Eggs of *I. lockingtoni* are easily identified by the following characters: large diameter (1.5–1.8 mm), large oil globule (0.3–0.4 mm), homogeneous yolk, unsculptured chorion, and embryonic pigmentation in later stages. Larvae resemble larval *Tetragonurus cuvieri* during the yolk-sac and preflexion stages, but are distinguished from them by myomere counts (58–61 vs. 51–54, respectively), preanal length (50–58% BL vs. 57–64% BL, respectively), dorsal pigmentation (several melanophores or patches along much of the tail vs. melanophores restricted to the last few myomeres and notochord tip), and ventral pigmentation on the tail (continuous pigment condensing into well separated melanophore clusters vs. continuous pigment condensing into only slightly separated melanophores or not condensing at all). Fin ray counts also distinguish the two species (Table Stromateioidei 1).

The following description of *I. lockingtoni* is based on Ahlstrom et al. (1976), supplemented with measurements of three more yolk-sac larvae (5.2–5.8 mm), one more flexion larva (11.7 mm), and additional measurements on the specimens used by Ahlstrom et al. (1976). Two of their preflexion stage larvae (4.3, 5.2 mm) were reclassified as yolk-sac stage, and four postflexion larvae were reclassified as flexion (11.7, 12.5, 13.5 mm) and transformation (19.4 mm) stages.

MERISTICS

	Range	Mode
Vertebrae:		
Total	58–61	59
Precaudal	23–25	23–24
Caudal	34–37	35–36
Fins:		
Dorsal spines	III	III
Dorsal rays	36–43	39–40
Anal spines	III	III
Anal rays	24–29	26–27
Pelvic	I,5	I,5
Pectoral	18–21	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	11–13	12
Lower	10–13	12
Gill rakers:		
Upper	4–6	
Lower	8–14	
Branchiostegals	7	7

LIFE HISTORY

Range: North Pacific Ocean; in eastern Pacific from Gulf of Alaska (ca. 60° N) to southern Baja California Sur

Habitat: Epipelagic

Spawning season: Eggs & larvae collected throughout the year; larvae most abundant in spring & summer with March & June–July maxima, September minimum

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Haedrich 1966
Kimura 1988b
Matarese et al. 1989

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.52–1.80 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.30–0.44 mm
Shell surface: Smooth
Pigment: Melanophores scattered on embryo & adjacent areas of yolk & on OG beginning shortly after blastopore closure; concentrated along dorsum of gut & ventrum of tail with few scattered dorsally by late stages
Diagnostic features: Diameter; large OG; embryonic pigmentation

LARVAE

Hatching length: ca. 4 mm
Flexion length: ca. 9.0 mm through 12.5–13.5 mm
Transformation length: ca. 19–20 mm
Fin development sequence: P_1, C_1, D & A & P_2, C_2
Pigmentation: *Yolk-sac*—Eyes unpigmented initially; few scattered laterally around eyes; few scattered on yolk sac, mostly around OG; series over gut, continues posteriorly along ventral margin of tail to notochord tip; irregularly spaced series on dorsal margin of tail. *Preflexion*—Scattered dorsally on head, spreading ventrolaterally; internally in roof of mouth & under hindbrain; ventral series forming on isthmus & anteriorly on gut; dorsal gut & ventral tail series melanophores become more distinctly separated; dorsal margin series augmented cephalad. *Flexion*—At tips of upper & lower jaws; increasing dorsally & laterally on head; increasing on gut; few dorsolaterally on trunk & tail & series on lateral midline of tail by mid-stage; scattered ventrolaterally on tail by end of stage; scattered over hypural region & proximally on C rays. *Postflexion*—Developing on all fins & increasing on all area. *Transformation*—Completely pigmented, darkest ventrally on head & on P_2, D & A.
Diagnostic features: Elongate, slender, with preanal length ca. 50–58% BL; myomeres 58–61 (usually 25 preanal); continuous pigment band over gut & along ventral margin of tail, separating into discrete melanophores late in yolk-sac stage or during preflexion stage; dorsal blotches on tail, spreading cephalad during flexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	52–54 53	50–58 54	53–57 55	51–55 53	 54	53–58 56
BD/BL	6–10 8	12–15 14	15–20 17	23–29 27	 32	34–36 35
HL/BL	12–14 13	18–24 21	23–26 25	27–32 29	 32	32–35 34
HW/HL	67–77 72	47–51 49	45–49 47	52–59 55	 64	 71
SnL/HL	9–14 12	18–32 25	23–27 25	21–26 23	 21	20–25 23
ED/HL	33–53 45	24–37 31	29–32 30	31–41 36	 35	31–36 34
P_1L/BL	0–1 0.4	6–6 6	5–7 6	12–17 14	 16	 19
P_2L/BL	0–0 0	0–0 0	0–5 3	10–13 11	 15	 19

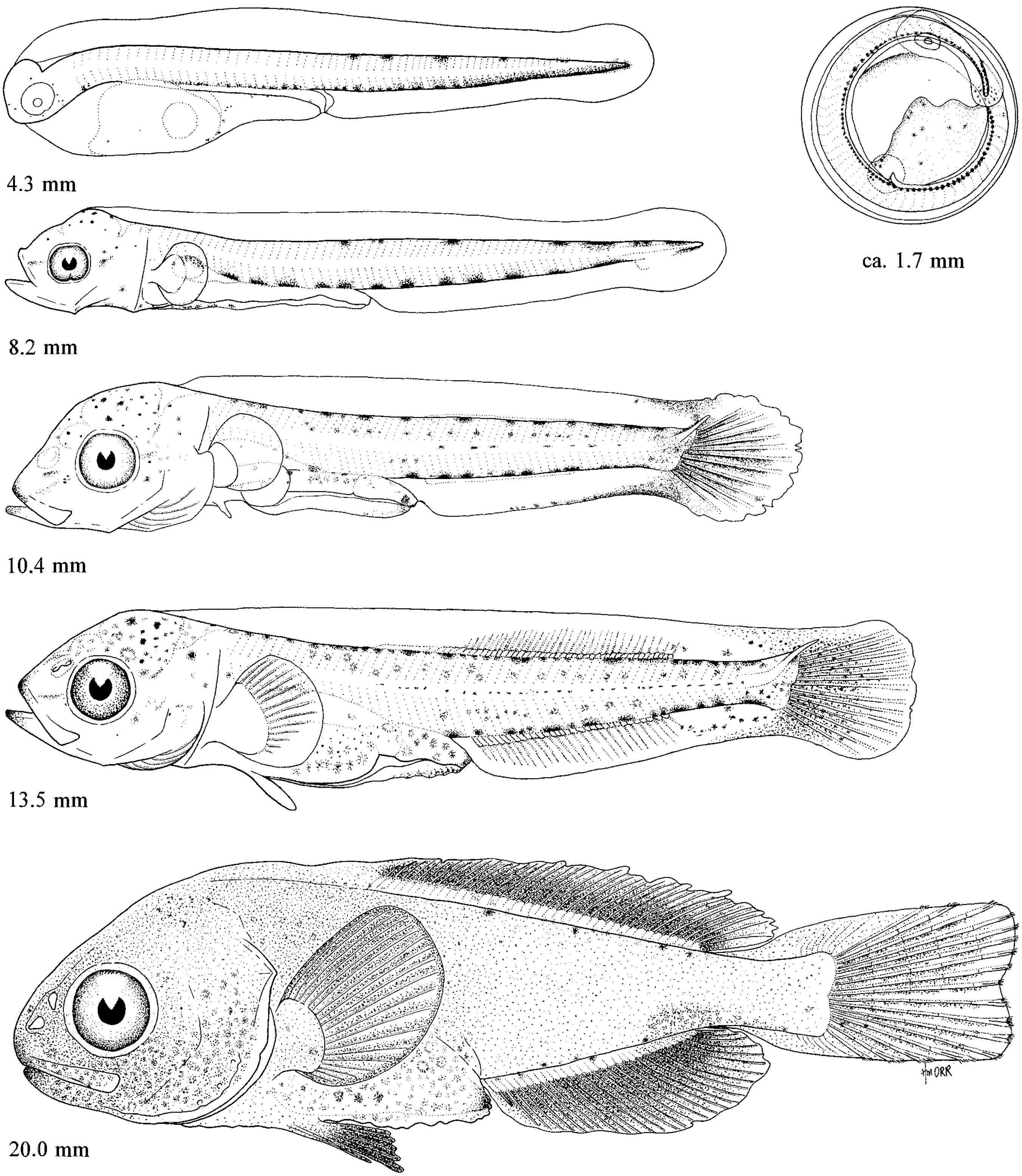


Figure Centrolophidae 1. Late stage egg, ca. 1.7 mm; yolk-sac larva, 4.3 mm; preflexion larva, 8.2 mm; flexion larvae, 10.4 mm, 13.5 mm; early juvenile, 20.0 mm (Ahlstrom et al. 1976).

NOMEIDAE: Driftfishes

W. WATSON

There are about 15 nomeid species in three genera (Nelson 1994); six species representing all three genera are known from the California Current region (Table Stromateioidei 1). *Cubiceps paradoxus* apparently is restricted to the temperate North Pacific Ocean, *Psenes sio* is endemic to the tropical and subtropical eastern Pacific (Horn and Haedrich 1973), and the other four species are widely distributed in warm waters of the Pacific, Indian and Atlantic Oceans (Haedrich 1967, 1970; Ahlstrom et al. 1976; Butler 1979). Larvae of all except *C. paradoxus* have been collected during CalCOFI surveys, primarily at stations 185 km or farther from shore, between May and February.

Nomeids are medium-size (commonly 20–30 cm; largest species to ca. 1 m) high seas inhabitants. Juveniles are epipelagic, usually associated with medusae or floating objects, while adults occur deeper in the water column; some are meso- or bathypelagic (Haedrich 1967; Horn 1975). Juveniles of most *Psenes* species are moderately deep-bodied and compressed (juvenile *Cubiceps* and *Nomeus* also are compressed, but more elongate than *Psenes*) while adults of all three genera (adults are not known for all species) are more elongate and rounded. The dorsal fin may be continuous but deeply notched, or the spinous portion may be slightly separated from the soft-rayed portion of the fin. The spinous dorsal folds into a shallow groove. The long-based anal and second dorsal fins are opposite one another. The caudal fin is emarginate or forked. Pectoral fins may be long and tapered (*Cubiceps*) or shorter and more rounded (*Nomeus*, *Psenes*). Pelvic fins are enlarged in the pelagic juveniles of *Nomeus* and *Psenes*, presumably to enhance maneuverability in these medusae- or flotsam-associated fishes (e.g., Mansueti 1963). The pelvic fins fold into shallow grooves. Epipelagic juveniles of the medusae- and flotsam-associated species commonly are spotted, mottled or barred in shades of brown (dark blue on a silvery white background in *Nomeus*), while the deeper-living adults are more evenly pigmented in shades of blue-gray to brown, often darker dorsally.

Nomeids are oviparous, with planktonic eggs and larvae (Ahlstrom et al. 1976). The single, spherical eggs are 0.7–1.3 mm in diameter, have a smooth, straw to pinkish tinted chorion, and contain a homogeneous yolk with one oil globule 0.1–0.3 mm in diameter. Melanophores form on the oil globule and in characteristic patterns on the embryo beginning shortly after blastopore closure (Ahlstrom et al. 1976). Recently hatched yolk-sac stage larvae (known for few species) are 1.5–3.0 mm long, with unpigmented eyes, unformed mouth, unformed pectoral fin buds, moderate yolk sac with posterior oil globule, and pigmentation like that of the advanced embryo (Ahlstrom et al. 1976; this study). Larval nomeids are elongate initially, with preanal length about half of body length. As the gut coils early in the preflexion stage, PAL may shorten or change little; it typically increases somewhat during or after notochord flexion. The gas bladder is small and anterior; it regresses and is lost by the adult stage, except perhaps in *Nomeus* (Horn 1975). Body depth increases throughout larval development, usually more so in *Psenes* (except *P. sio*) than in *Nomeus* or *Cubiceps*. The initially small, rounded head becomes large and the snout lengthens, but remains blunt. A few small preopercular spines form during the preflexion (*Psenes*) or postflexion stage (*Cubiceps*, *Nomeus*) and usually are overgrown or lost by the juvenile stage. In *Cubiceps* the principal caudal fin rays are first to form, followed by simultaneous development of dorsal and anal soft rays and pectoral fin rays. Dorsal spines, pelvic fin rays and procurrent caudal fin rays are next, forming simultaneously, or nearly so with the pelvic fins last. In contrast, both *Nomeus* and *Psenes* acquire full complements of pelvic fin rays before rays begin to form in any other fin. Nomeids are lightly to moderately pigmented through notochord flexion, usually with relatively little (but increasing) pigmentation on the head, melanophores dorsally on the gas bladder and gut (and ventrally on the gut in some species), melanophores ventrally on some to most postanal myomeres, and often at least some pigment on the lateral midline and dorsal margin in the vicinity of midtail. Larvae become heavily pigmented during postflexion and transformation stages, with characteristic barred patterns forming in *Nomeus* and *Psenes* (Ahlstrom et al. 1976).

Larval *Cubiceps* superficially resemble larval carangids (many of the Carangini), while *Nomeus* and

Psenes look something like pomacentrids (some Pomacentrinae). In both cases the nomeids are readily recognized by their higher myomere counts: 30–31 for *Cubiceps* vs. 24–25 for the carangins and 36–42 for *Nomeus* and the *Psenes* species in the CalCOFI study area vs. 25–28 for the pomacentrids. Spination of the head and pectoral girdle and fin ray counts, as well as species-specific pigmentation patterns provide additional means for distinguishing the larvae of these families (see Carangidae and Pomacentridae, this volume). Larvae of the nomeid species within the CalCOFI study area can be identified through a combination of meristic (especially myomere counts), morphometric (particular preanal length and body depth), and pigment characters (Ahlstrom et al. 1976).

The following descriptions are taken from Ahlstrom et al. (1976), with the following additions and modifications: *Cubiceps pauciradiatus*, 2.1 mm specimen reassigned from preflexion to yolk-sac stage, 12.4 mm and 13.5 mm specimens reassigned from juvenile to transformation stage, and three additional yolk-sac larvae (1.8–2.0 mm) measured; *Nomeus gronovii*, three preflexion stage larvae (3.8–4.6 mm) measured; *Psenes pellucidus*, 13.4–18.2 mm specimens reassigned from juvenile to postflexion stage and 21.2–26.7 mm specimens reassigned from juvenile to transformation stage; *P. sio*, three yolk-sac larvae (2.6–3.0 mm) measured and 11.0–13.5 mm postflexion larvae plus 14.4 mm and 15.0 mm juveniles reassigned to transformation stage. *Cubiceps paradoxus* is not described since none was collected during CalCOFI surveys; see Ahlstrom et al. (1976) for description and illustration of juveniles. Meristic data were obtained from Haedrich (1967, 1970, 1972, 1986), Ahlstrom et al. (1976), and Butler (1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	31	31
Precaudal	12	12
Caudal	19	19
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	20–24	21
Anal spines	III	III
Anal rays	20–22	20–21
Pelvic	I,5	I,5
Pectoral	20–23	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–10	8–9
Lower	7–10	8–9
Gill rakers:		
Upper	6–10	
Lower	16–18	
Branchiostegals	6	6

LIFE HISTORY

Range: Widely distributed in warm waters of the Pacific, Indian & Atlantic Oceans; in eastern Pacific from ca. 32° N – 10° S except not in O_2 minimum waters off Mexico & Central America

Habitat: Epipelagic

Spawning season: Larvae collected May–October in eastern Pacific

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Kimura 1988b
Olivar & Fortuño 1991

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.84–0.96 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.16–0.22 mm
Shell surface: Smooth
Pigment: Chorion light tan; late embryo with melanophores outlining brain & continuing posteriorly as band along dorsum; OG pigmented on side opposite embryo
Diagnostic features: Diameter; pigmentation of late embryo

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 4.5–5.0 mm
Transformation length: >10.1 mm, <10.7 mm
Fin development sequence: C_1, 2D & A & P_1, 1D & P_2 & C_2
Pigmentation: *Preflexion*—Over & internally laterally around midbrain; at tips of jaws; in roof of mouth & along ventrum of skull, appearing as stripe through eye; anteriorly & dorsally over gut, spreading ventrad; series of ca. 1/myomere on ventral margin of tail beginning at postanal myomere 4–6; few under notochord tip. *Flexion*—Increasing on head & gut; stripe through eye becomes less conspicuous; decreasing ventrally on tail. *Postflexion*—Spreading from head onto trunk & increasing; stripe through eye absent by 6.2 mm; surrounding gut; lateral patch at midtail by 6.6 mm, spreads anteriorly & posteriorly; none on ventral margin of tail by 6.2 mm; body nearly covered by end of stage, except little or none on caudal peduncle, ventrally on head, & ventrolaterally on first few postanal myomeres. *Juvenile*—Becoming completely pigmented by 15 mm, lighter ventrally on head, anteroventrally on gut, & ventrolaterally just behind gut.
Diagnostic features: D usually XII, 21 & A usually III,20–21 (countable by 6.5 mm); myomeres usually 31; large eyes; short preanal length; ventral tail pigment present until ca. 6 mm; no dorsal, midlateral, & ventral pigment streaks at midtail (as in *C. pauciradiatus*).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		32–43 37	43–54 48	48–62 55		55–59 57
BD/BL		21–36 28	35–41 38	38–45 43		37–44 40
HL/BL		18–27 23	27–35 30	31–37 34		32–35 33
HW/HL						
SnL/HL		24–28 26	23–32 26	18–28 23		20–26 23
ED/HL		41–45 43	40–45 43	39–43 41		38–48 42
P_1L/BL						
P_2L/BL						

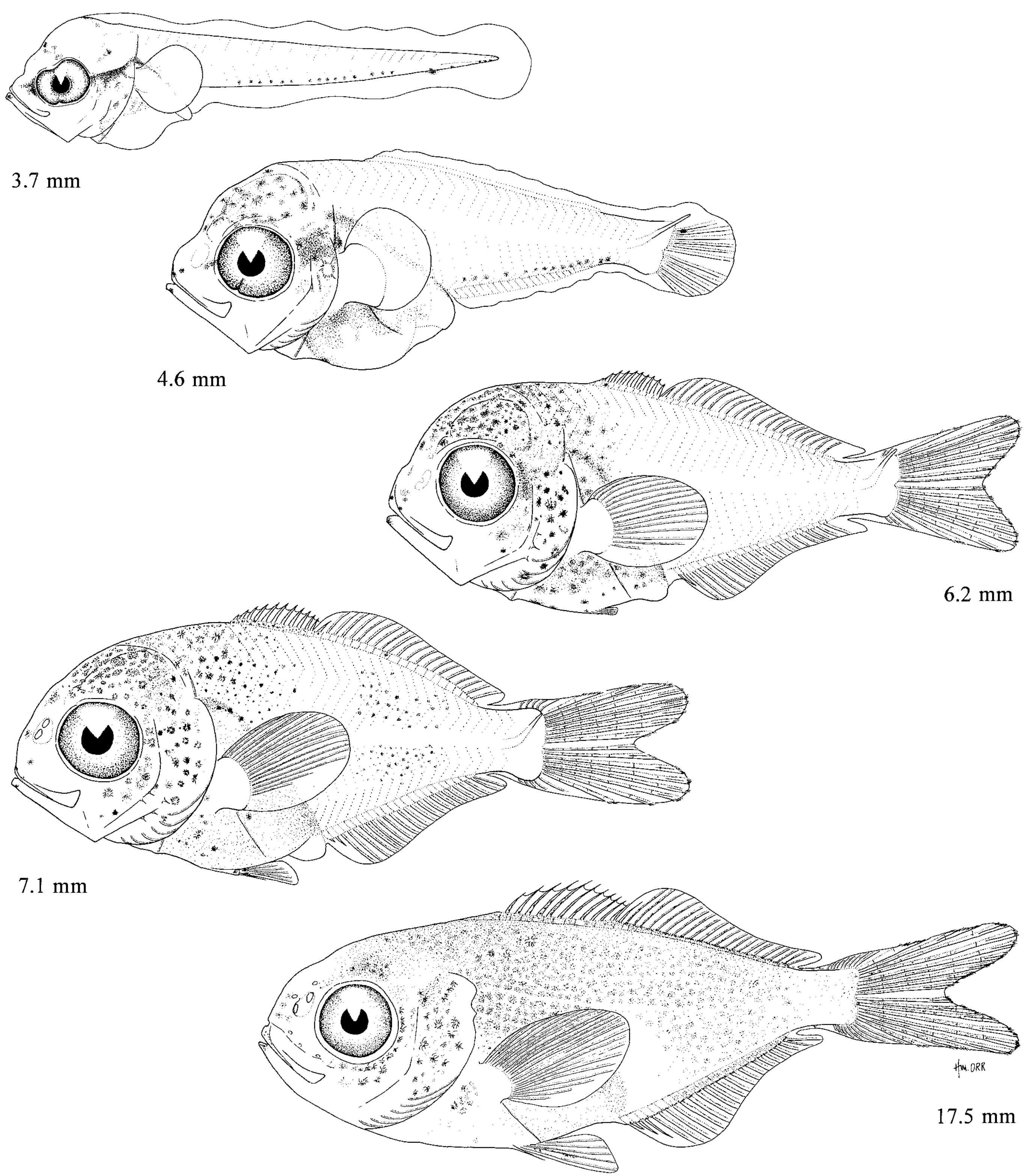


Figure Nomeidae 1. Preflexion larva, 3.7 mm; flexion larva, 4.6 mm; postflexion larvae, 6.2 mm, 7.1 mm; juvenile, 17.5 mm (Ahlstrom et al. 1976).

MERISTICS

	Range	Mode
Vertebrae:		
Total	30–31	31
Precaudal	13–14	13
Caudal	17–18	18
Fins:		
Dorsal spines	XI–XIII	XII
Dorsal rays	15–18	16–17
Anal spines	II	II
Anal rays	14–16	15
Pelvic	I,5	I,5
Pectoral	16–20	18
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	9
Lower	8–10	9
Gill rakers:		
Upper	7–9	8
Lower	16–19	17
Branchiostegals	6	6

LIFE HISTORY

Range: Cosmopolitan in tropical & subtropical waters of the Atlantic, Indian & Pacific Oceans; in eastern Pacific from lower Gulf of California to Peru

Habitat: Epipelagic

Spawning season: Larvae collected in November in CalCOFI area, year-round in eastern tropical Pacific

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Fahay 1983
Horn 1984
Kimura 1988b
Olivar & Fortuño 1991

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.70–0.80 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.14–0.20 mm
Shell surface: Smooth
Pigment: Chorion with pinkish tan tint; 2 melanophore patches on opposing sides of OG; late embryo with patch on snout, patch dorsally on head, & heavy band dorsally on trunk & tail
Diagnostic features: Chorion & OG diameters; embryonic pigmentation

LARVAE

Hatching length: ca. 1.5–2.0 mm
Flexion length: ca. 3.7–4.3 mm
Transformation length: ca. 12.4 mm through 14.0–14.7 mm
Fin development sequence: C_1, 2D & A & P_1 & C_2, 1D, P_2
Pigmentation: *Yolk-sac*—Pigmented like advanced embryo initially; dorsal pigment migrates ventrally, forming band over gut & along ventral margin of tail to near notochord tip; ventrally on head & gut by end of stage. *Preflexion*—Few dorsally over midbrain; at tips of jaws; 1 on isthmus by end of stage; pigment ventrally on gut coalesces to 1–2 by 3 mm, then disappears; ventral tail series coalesces to patch at postanal myomeres 3 to 6–10 & 2–5 (small) posteriorly; on lateral midline above ventral patch at 2–2.5 mm; on dorsal margin above ventral patch by 3 mm. *Flexion*—Increasing on head. *Postflexion*—On snout & opercle, increasing on jaws, spreading over entire brain, on nape, series along D & A bases, & laterally on tail by 5.1 mm; spreading over gut & dorsum to cover upper half of gut & body except caudal peduncle by 8.6 mm. *Transformation*—Spreading ventrad & onto caudal peduncle.
Diagnostic features: 15–17 D rays & 14–16 A rays (present by 5 mm); long preanal length; dorsal, midlateral, & ventral pigment streaks at ca. myomeres 20–23, little or no other ventral tail pigment after yolk-sac stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	48–54 51	52–58 56	58–62 60	60–65 63	62–63 63	59–65 62
BD/BL	10–17 13	18–32 27	35–37 36	33–38 35	33–35 34	28–34 32
HL/BL	19–22 21	18–29 25	33–35 33	33–36 34	34–35 35	31–35 33
HW/HL	53–58 55					
SnL/HL	11–25 17	33–38 35	25–27 26	21–27 25	22–25 23	19–25 22
ED/HL	32–45 40	37–46 41	32–34 33	33–37 35	34–37 36	33–37 35
P_1L/BL	0–0 0					
P_2L/BL	0–0 0					

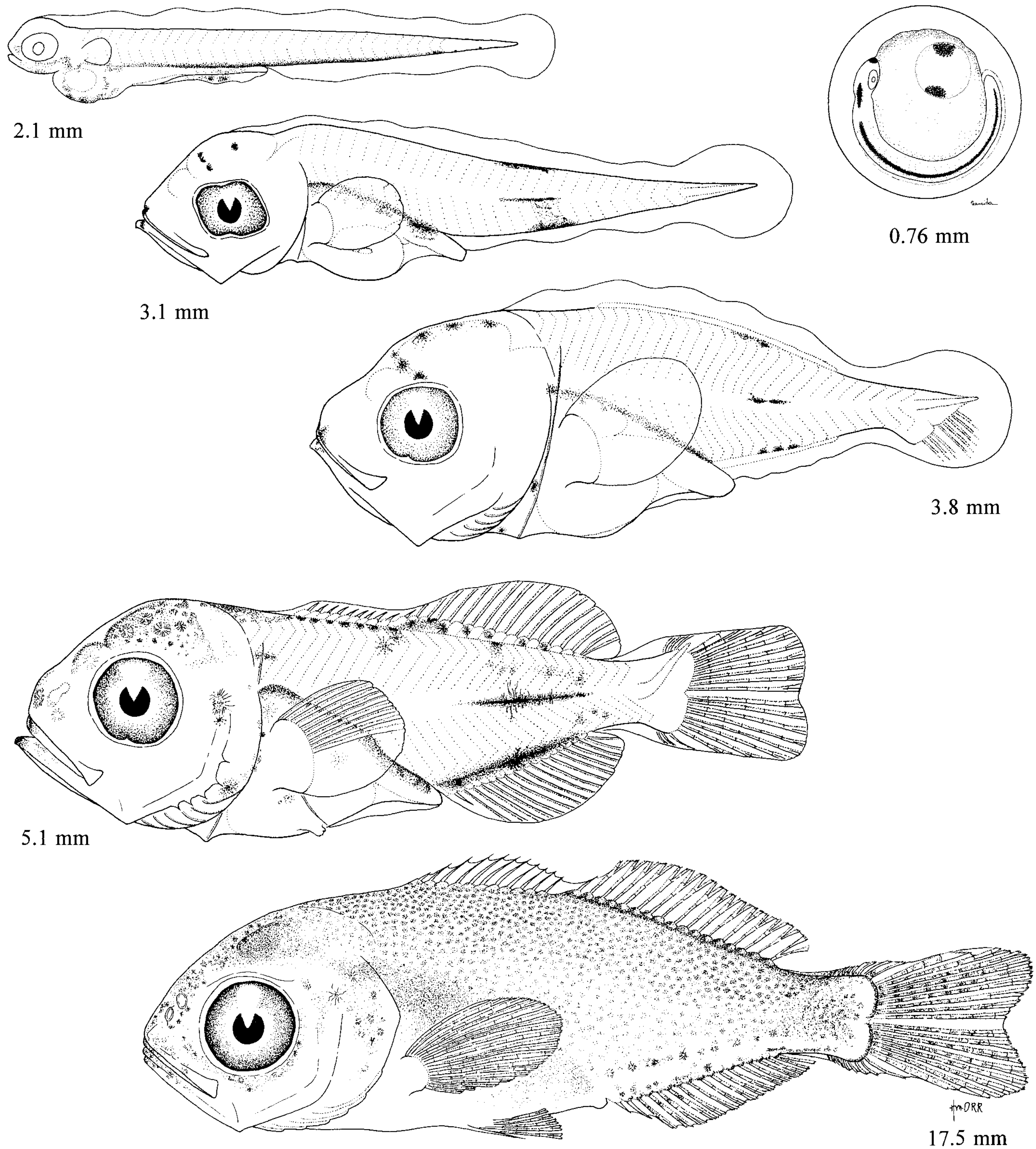


Figure Nomeidae 2. Egg, 0.76 mm; yolk-sac larva, 2.1 mm (note that the oil globule normally is located posteriorly in the yolk sac, not anteriorly as it appears to be in this illustration); preflexion larva, 3.1 mm; early flexion larva, 3.8 mm; early postflexion larva, 5.1 mm; early juvenile, 17.5 mm (Ahlstrom et al. 1976).

MERISTICS

	Range	Mode
Vertebrae:		
Total	40–41	41
Precaudal	14–15	14
Caudal	26–27	27
Fins:		
Dorsal spines	X–XIII	XII
Dorsal rays	24–28	26
Anal spines	I–II	II
Anal rays	24–29	25–27
Pelvic	I,5	I,5
Pectoral	19–24	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–9	9
Lower	8–9	8–9
Gill rakers:		
Upper	6–9	
Lower	15–19	
Branchiostegals	6	6

LIFE HISTORY

Range: Widely distributed in tropical to temperate waters of Pacific, Indian & Atlantic Oceans

Habitat: Juveniles epipelagic, associated with *Physalia*; adults deeper, possibly benthopelagic

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Fahay 1983
Horn 1984
Kimura 1988b

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 4.4 mm (W. Watson)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: >4.6 mm; <7.3 mm
Transformation length: ca. 9 mm
Fin development sequence: P_2, D & A & P_1 & C
Pigmentation: *Preflexion*—Few dorsally over midbrain; anterolaterally on hindbrain; posterolaterally on midbrain by 4.6 mm; pair in roof of mouth; at tip of upper jaw; at tip of lower jaw by 4.4 mm; anteriorly on gular region by 4.6 mm; on floor of otic capsule, extending to margin of orbit by 4.6 mm; dorsally on gas bladder & gut, spreading ventrad; ventrally on gut between P_2 bases & on bases, contracting to abdominal wall just above & behind P_2 bases; heavy on P_2 membranes; 22–26 on ventral margin of tail to notochord tip; 1 on dorsal margin of tail at myomere 27–29. *Postflexion*—Moderate to heavy on midbrain area; on preopercle & opercle, increasing; heavy on abdominal area, extending dorsad onto spinous D; lateral & ventral streaks or patches near midtail; patch over hypural area. *Juvenile*—Increasing on head & trunk; increasing on midtail to form bar by 9.2 mm; increasing on hypural area; filling in posteriad on trunk of tail after 9.2 mm; 4 prominent bars at 22.7 mm.
Diagnostic features: Very large, heavily pigmented, early forming P_2 (<3.8 mm); 41–42 myomeres; higher D & A counts than *Cubiceps*; more elongate than *Psenes*; barred pigment pattern in juvenile.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		41–43 42		56–58 57		52–59 56
BD/BL		15–24 18		38–41 39		33–39 37
HL/BL		20–23 22		33–33 33		30–34 32
HW/HL		48–59 55				
SnL/HL		26–26 26		19–24 21		20–25 22
ED/HL		34–37 36		38–44 41		33–44 40
P_1L/BL		4–7 6				
P_2L/BL		16–31 24				

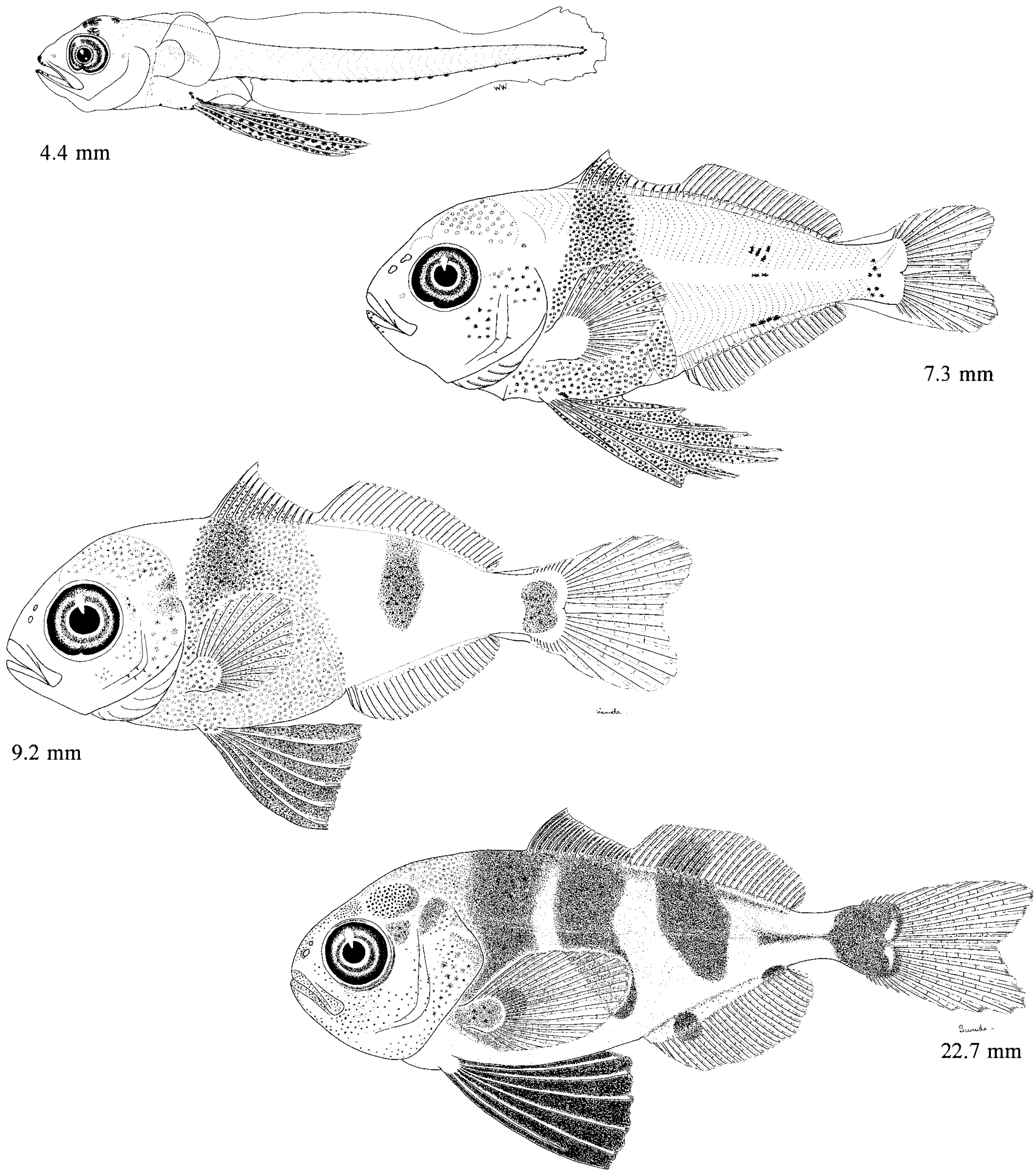


Figure Nomeidae 3. Preflexion larva, 4.4 mm (CFRD Ref. Coll., Mokapu, Hawaii, tow 63, 28 February 1976); postflexion larva, 7.3 mm (modified from Ahlstrom et al. 1976); early juveniles, 9.2 mm, 22.7 mm (Ahlstrom et al. 1976).

MERISTICS

	Range	Mode
Vertebrae:		
Total	40–42	41
Precaudal	13–15	13
Caudal	26–29	28
Fins:		
Dorsal spines	X–XII+I–II	XII+I
Dorsal rays	26–32	28–29
Anal spines	III	III
Anal rays	26–31	28–30
Pelvic	I,5	I,5
Pectoral	18–20	
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	8–10	9
Lower	8–10	9
Gill rakers:		
Upper	8–9	
Lower	15–17	
Branchiostegals	6	6

LIFE HISTORY

Range: Widely distributed in warm waters of the Pacific, Indian, & Atlantic Oceans; in the eastern Pacific from Catalina Island, California to southern end of Baja California Sur, & ca. 5° N – 5° S

Habitat: Juveniles epipelagic, commonly associated with floating objects; adults deeper, meso- & possibly bathypelagic

Spawning season: Larvae collected July–October & February in CalCOFI area, strong September peak

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Fahay 1983
Kimura 1988b
Olivar & Fortuño 1991

* Tentative identification (Ahlstrom et al. 1976).

EARLY LIFE HISTORY DESCRIPTION

EGGS*

Shell diam.: 1.1–1.3 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.24–0.28 mm
Shell surface: Smooth
Pigment: Chorion brownish with rose tint; late embryo with melanophores outlining brain lobes & ventrally on head, patches anteriorly & posteriorly over gut, anterolaterally on trunk, anterodorsally on tail, on dorsal & ventral margins at midtail, & posteriorly on tail; few on OG
Diagnostic features: Diameter; pigmentation of late embryo

LARVAE

Hatching length: <3.8 mm
Flexion length: ca. 5–6 mm
Transformation length: ca. 20.8–27.0 mm
Fin development sequence: P_2, 1D & 2D & P_1 & C_1, A, C_2
Pigmentation: *Preflexion*—Series in inverted Y-shape pattern on gular area; over gas bladder; dorsally on hindgut; ventrally just behind cleithral symphysis; on P_2, primarily on distal half; 6–13 on ventral margin of tail; dorsal, lateral & ventral blotches at myomeres 27–30; dorsal & ventral blotches near notochord tip. *Flexion*—Few above eye; few on anterior margin of upper jaw; few anteriorly on base of 1D; few on myosepta in vicinity of myomeres 27–31; ventral series on tail becomes internal; marginal blotches on notochord tip move to area over developing hypurals; on central C rays. *Postflexion*—Increasing dorsally on head & on upper jaw; on lower jaw by 12.4 mm; on snout by 13.4 mm; decreasing on gular area, absent by 12 mm; dorsolaterally on nape & first few myomeres by 13.4 mm, spreading ventrad & caudad; increasing on 1D; patches forming on 2D base, beginning near middle by 12.4 mm; increasing on gas bladder & gut; increasing on P_2; midlateral patch in vicinity of myomeres 18–22 by 12.4 mm; bar forming in vicinity of myomeres 28–31; patches on A base, beginning posteriorly by 9.7 mm; heavy on C_1 lobes. *Transformation*—Heavy on upper part of head & trunk, on 1D, distally on 2D & A, on C lobes, on P_2, & on upper part of P_1; 4 or 5 indistinct bars on tail.
Diagnostic features: 40–42 myomeres; early forming, pigmented P_2; gular pigment pattern (through flexion stage); dorsal, lateral & ventral streaks or blotches in vicinity of myomeres 27–31.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		39–45 42	46–47 47	46–51 48	49–53 51	
BD/BL		20–24 22	32–33 32	43–50 48	51–57 55	
HL/BL		24–24 24	29–29 29	27–32 29	32–33 32	
HW/HL						
SnL/HL		22–25 24	24–25 24	18–25 21	22–23 23	
ED/HL		37–40 38	37–38 37	39–44 41	35–35 35	
P_1L/BL						
P_2L/BL						

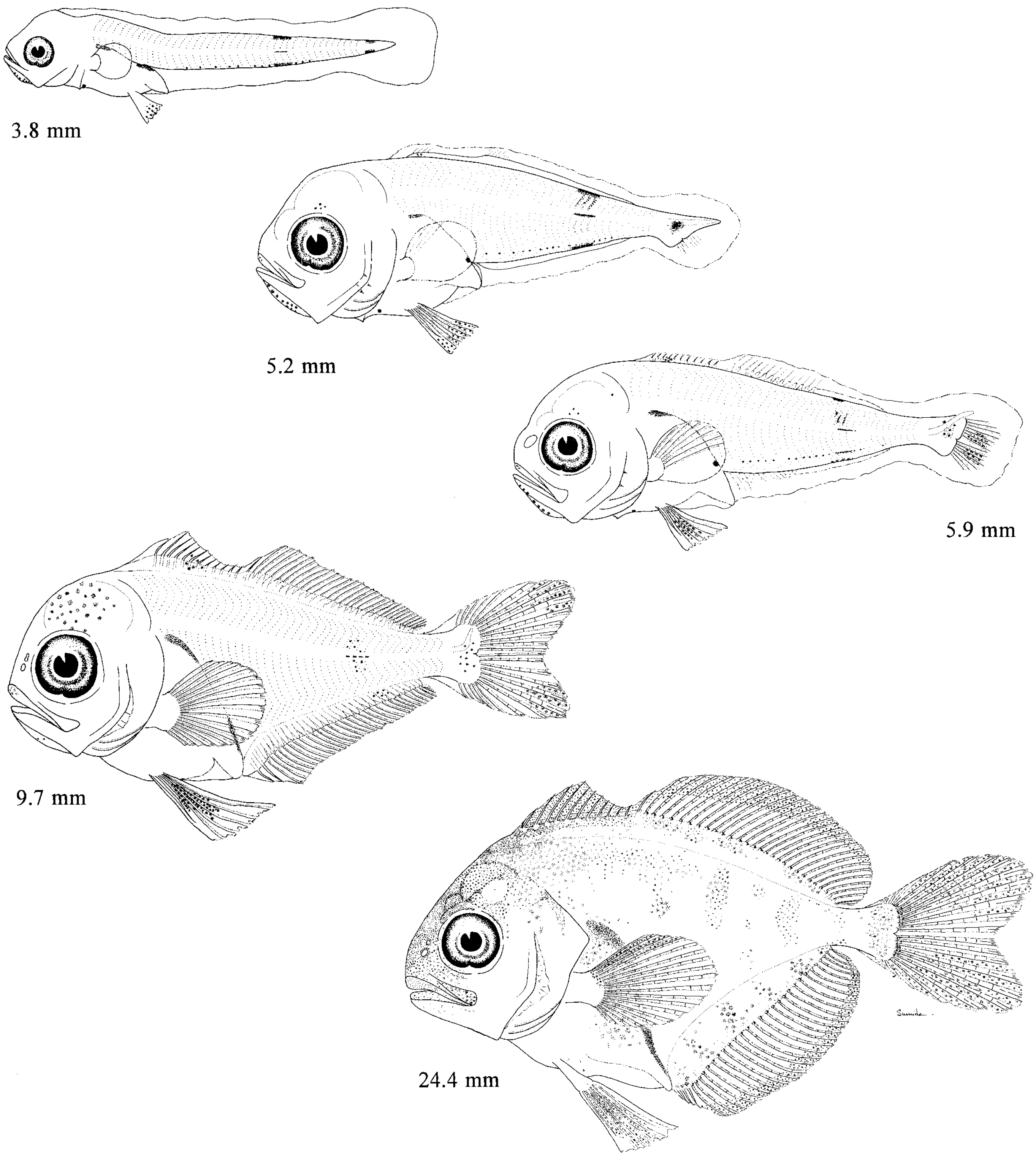


Figure Nomeidae 4. Preflexion larva, 3.8 mm; early flexion larva, 5.2 mm; flexion larva, 5.9 mm; postflexion larva, 9.7 mm; juvenile, 24.4 mm (Ahlstrom et al. 1976).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	37
Precaudal	12–13	12
Caudal	24–26	25
Fins:		
Dorsal spines	X–XII+I	XI+I
Dorsal rays	22–26	23–24
Anal spines	II	II
Anal rays	23–26	23–24
Pelvic	I,5	I,5
Pectoral	17–19	19
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	7–10	8–9
Lower	8–10	8–9
Gill rakers:		
Upper	7–8	8
Lower	15–18	
Branchiostegals	6	6

LIFE HISTORY

Range: Eastern Pacific, southern Baja California Sur to Peru, including Gulf of California

Habitat: Juveniles in upper part of water column

Spawning season: Larvae collected May–December in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.0–1.1 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.20–0.26 mm
Shell surface: Smooth
Pigment: Chorion pinkish straw color; on dorsum of embryo soon after blastopore closure, migrates ventrally; late embryo with pigment outlining brain lobes posteriorly, ventrally on head, anteriorly & posteriorly over gut; anterolaterally on trunk, anterodorsally on tail, on dorsal & ventral margins at midtail; few on OG
Diagnostic features: Diameter; embryonic pigmentation

LARVAE

Hatching length: <2.4 mm
Flexion length: ca. 4–6 mm
Transformation length: ca. 10.9–15.4 mm
Fin development sequence: P_2, 1D & P_1 & C_1, 2D & A, C_2
Pigmentation: *Yolk-sac*—Eyes unpigmented initially; on snout; at anterior & posterior margins of eyes; anterolaterally on trunk; anteriorly & posteriorly over gut; on yolk sac; dorsally at myomeres 13–15; dorsally, laterally & ventrally at myomeres 22–25. *Preflexion*—Y-shaped pattern on gular area; at cleithral symphysis; anterolateral trunk patch lost; discrete anterior & posterior patches or extending nearly full length dorsally on gut; 8–18 ventrally on tail, becoming internal; dorsally & ventrally near notochord tip; heavy on P_2. *Flexion*—Above eye, anteriorly on upper jaw, & on 1D by 5.6 mm; dorsal tail spots lost except near notochord tip; ventral notochord patch expands over hypural area. *Postflexion*—Increasing dorsally on head; anteriorly on hindbrain; on lower jaw at 7.6–9.6 mm; decreasing on gular area; distal patches near middles of 1D & 2D; proximal & distal bands forming on C. *Transformation*—Spreading ventrad on head, & caudad onto trunk; patches on D base forming 4–5 bars; increasing on gut; distal bands on D, A & C. *Juvenile*—Nearly completely covered by ca. 26 mm; lighter ventrally on head & abdomen.
Diagnostic features: Myomeres 36–38; A usually II, 23–24 (countable by ca. 6 mm); large, pigmented P_2 (complete by 3.4 mm); gular pigment; dorsal pigment at myomeres 12–15 through early flexion stage; dorsal, lateral & ventral pigment at myomeres 22–25.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	46–47 47	42–50 46	43–52 49	49–51 50	49–53 51	51–52 51
BD/BL	10–15 12	20–25 22	31–43 38	37–43 39	39–45 42	41–43 42
HL/BL	17–18 17	20–23 22	31–36 33	30–35 32	29–33 31	32–33 32
HW/HL	50–76 64					
SnL/HL	4–9 7	22–25 24	19–25 23	22–27 24	22–27 24	23–29 26
ED/HL	43–48 45	38–43 40	33–40 37	34–40 38	38–42 40	32–33 33
P_1L/BL	0–0 0					
P_2L/BL	0–0 0					

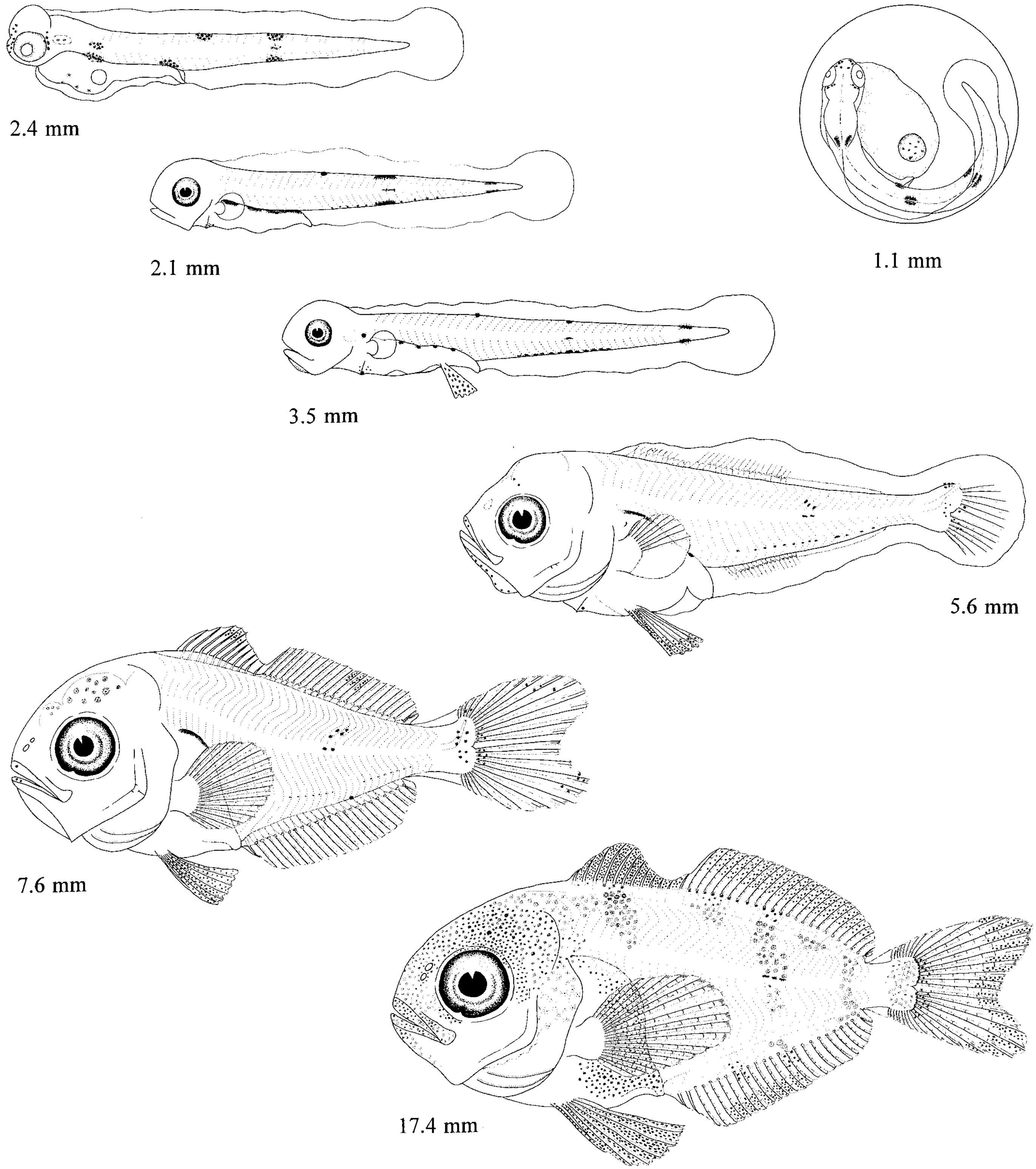


Figure Nomeidae 5. Egg, 1.1 mm; yolk-sac larva, 2.4 mm; preflexion larvae, 2.1 mm, 3.5 mm; flexion larva, 5.6 mm; postflexion larva, 7.6 mm; early juvenile, 17.4 mm (Ahlstrom et al. 1976).

TETRAGONURIDAE: Squaretails

W. WATSON

Tetragonuridae comprises three *Tetragonurus* species, two of which occur in the California Current vicinity. *T. atlanticus* is an essentially tropical species that ranges southward from the vicinity of Isla Cedros, Mexico (28° N) to northern Chile (20° S) in the eastern Pacific, and occurs in warm waters of the central and western Pacific, the Indian and Atlantic Oceans as well. *T. cuvieri* is a temperate species that ranges in the eastern Pacific from the Aleutian Islands to the vicinity of Cabo San Lazaro, Baja California Sur, and is cosmopolitan in all temperate seas. The third species, *T. pacificus*, ranges from the tropical Indian Ocean to the western margin of the eastern tropical Pacific. Eggs of *T. cuvieri* and moderate numbers of its larvae have been collected during CalCOFI surveys; larval *T. atlanticus* apparently rarely occur in the CalCOFI study area but a few were taken during the EASTROPAC eastern tropical Pacific expeditions (Ahlstrom 1971, 1972). Larval *T. cuvieri* occur throughout the year in the California Current vicinity, with an autumn peak and a spring minimum in abundance. Larvae are most abundant at CalCOFI stations seaward of about 280 km from shore.

Tetragonurids are medium-size (ca. 30–70 cm) oceanic salp predators in tropical and temperate seas. Juveniles commonly are found inside salps (Janssen and Harbison 1981). Tetragonurids are elongate, slightly compressed, with preanal length about 60% BL. The moderately long snout is blunt. The scoop-like lower jaw, armed with flattened teeth in a saw-like arrangement, closes inside the upper jaw. Janssen and Harbison (1981) discuss the functional significance of the jaws and dentition. The continuous dorsal fin consists of 10–21 low spines that fold into a groove and 10–17 longer soft rays. The short-based anal fin, containing 1 or 2 spines and 9–16 soft rays, is posterior, under the soft-rayed dorsal fin. Pectoral and pelvic fins are small and the pelvics fold into a groove. The scales are strongly adherent and arranged in curved oblique rows. Those on the caudal peduncle form a dorsolateral and ventrolateral ridge posteriorly on each side, resulting in a squarish appearance from which the common name derives. Tetragonurids are evenly pigmented, light grey or brown to nearly black. Juveniles are more lightly pigmented than adults. Tetragonurids are not utilized in fisheries and in some parts of the world their flesh is considered toxic.

Tetragonurids are oviparous, with planktonic eggs and larvae (Ahlstrom et al. 1976). Eggs are single, spherical, ca. 1.1–1.3 mm in diameter, with a homogeneous yolk and single oil globule 0.24–0.30 mm in diameter. The chorion is smooth, with a characteristic golden tint and pink highlights (Ahlstrom et al. 1976). Larval *T. cuvieri* hatch at a length of ca. 3–4 mm with unpigmented eyes, unformed mouth, pectoral fins present as small buds, and moderate yolk sac. Larvae initially are elongate and slender with a straight gut extending to about 60–70% BL. The gut begins to fold anteriorly during the latter part of the preflexion stage and coils during notochord flexion. Body depth concurrently increases but preanal length changes little. The small, anterior gas bladder inflates early in the preflexion stage and is visible until obscured by the increasing abdominal pigmentation in the postflexion stage; it regresses and is absent in adults (Horn 1975). The head initially is small, with a short, rounded snout and nearly rectangular (horizontally elongate) eyes. The head subsequently becomes relatively larger and the snout elongates and becomes deeply wedge-shaped through notochord flexion, then becomes increasingly blunt. The eyes become round late in the preflexion stage or during notochord flexion. A series of small spines forms along the preopercular margin during notochord flexion. The principal caudal fin rays are first to begin forming at about the beginning of notochord flexion, followed by simultaneous development of the soft rays of the dorsal, anal, and pectoral fins. Next, dorsal spines, the anal spine(s), and pelvic fin rays begin forming; concurrently, or just afterward, the procurrent caudal rays begin forming. Larval tetragonurids are lightly to moderately pigmented through the early part of the flexion stage, with melanophores forming a prominent band that originates internally at the snout (by late preflexion), extends dorsally over the gut, and continues along the ventral margin of the tail (*T. atlanticus* and *T. cuvieri*). This band does not form in *T. pacificus*, which is only lightly pigmented on the head and gut through notochord flexion (Grey 1955).

In *T. atlanticus* and *T. cuvieri*, melanophores form dorsally on the head during the preflexion stage, laterally on the tail late in preflexion or during notochord flexion, and on the trunk late in flexion or early in the postflexion stage. Melanophores subsequently increase on all areas so that by mid-way through the postflexion stage both species typically are heavily pigmented. Larval *T. pacificus* remain more lightly pigmented, with melanophores slowly spreading posteriorly from the head and dorsally and posteriorly from the abdominal area during the postflexion stage (Grey 1955; Ahlstrom et al. 1976).

Tetragonurid eggs often can be distinguished from others in the CalCOFI study area by a combination of characters including chorion diameter (1.1–1.3 mm), lack of sculpturing, and color (golden tint with pink highlights), presence of a single oil globule ca. 0.2–0.3 mm in diameter, and homogeneous yolk. Pigmentation of the late stage embryos is distinctive. Larvae also are distinctive and probably will not be confused with others in the CalCOFI study area except perhaps *Icichthys lockingtoni*, which they superficially resemble. The tetragonurids can be distinguished from *I. lockingtoni* by myomere counts (44–54 vs. 58–61, respectively), fin ray counts in postflexion larvae, and pigmentation patterns (see Centrolophidae, this volume). The two *Tetragonurus* species in the area are readily distinguished by myomere counts (*T. atlanticus*, 44–46; *T. cuvieri*, 51–54) and pigmentation. *T. atlanticus* lacks melanophores on the notochord tip following yolk absorption and is unpigmented posteriorly on the caudal peduncle while *T. cuvieri* has notochord tip and posterior caudal peduncle pigmentation. The melanophore series on the dorsal margin of the tail and along the lateral midline typically are shorter in *T. atlanticus* than in *T. cuvieri* of similar size through notochord flexion.

The following descriptions of *T. atlanticus* and *T. cuvieri* are taken from Ahlstrom et al. (1976) supplemented with measurements of additional specimens (*T. atlanticus*: three yolk-sac, 2.7–3.0 mm; *T. cuvieri*: three yolk-sac, 3.3–4.4 mm, and three juveniles 27.1–43.2 mm) and additional meristic counts. Ecological information is from Grey (1955), Ahlstrom et al. (1976), and Janssen and Harbison (1981).

MERISTICS

	Range	Mode*
Vertebrae:		
Total	44–51	44–45
Precaudal	23–24	23–24
Caudal	20–22	21
Fins:		
Dorsal spines	XIV–XVII	XIV
Dorsal rays	10–13	11
Anal spines	I	I
Anal rays	9–12	10
Pelvic	I,5	I,5
Pectoral	14–18	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–10	9
Lower	9–10	9
Gill rakers:		
Upper	4–6	
Lower	9–11	
Branchiostegals	6	6

LIFE HISTORY

Range: Widely distributed in warm waters of Atlantic, Indian, & Pacific Oceans; in eastern Pacific from ca. 28° N – 20° S

Habitat: Epipelagic, possibly deeper

Spawning season: Autumn in eastern & northern Atlantic, winter–spring in Caribbean & Sargasso Seas

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Grey 1955
Horn 1984
Kimura 1988b
Olivar & Fortuño 1991

* Modal counts are given for eastern Pacific specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.1 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.24 mm
Shell surface: Smooth
Pigment: Chorion golden with pink tint; late stage embryo with patch on snout, heavy band over gut & on ventral margin of tail to notochord tip, & short streak posteriorly on dorsal margin.
Diagnostic features: Diameter, OG, chorion color, embryonic pigmentation

LARVAE

Hatching length: ca. 2.7–2.9 mm
Flexion length: ca. 7.0–8.1 mm
Transformation length: ca. 17.0 mm to <19.7 mm
Fin development sequence: C_1, 2D & A & P_1, 1D & P_2 & C_2
Pigmentation: *Yolk-sac*–Few scattered around mouth; two continuous bands beginning under forebrain, extending over gut & ventrally on tail to notochord tip; scattered ventrally on yolk sac & gut; single row on dorsal margin from last 8–12 myomeres to notochord tip. *Preflexion*–On snout by 4.6 mm; scattered dorsally on head by 4.9 mm; dorsal series on tail becomes double, spreads forward. *Flexion*–Increasing on head, gut, & caudal peduncle; series begins posteriorly along lateral midline. *Postflexion*—Forming laterally on trunk & tail to mid-caudal peduncle; heavy on dorsal & ventral margins & lateral midline of tail; increasing on all areas to completely cover body except end of caudal peduncle by end of stage.
Diagnostic features: 44–46 myomeres; notochord tip unpigmented after yolk absorption; during postflexion stage body becomes entirely pigmented except none on posterior part of caudal peduncle or C.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	52–63 59	63–69 66	64–69 67	64–69 66	71	
BD/BL	9–12 11	13–20 17	18–23 21	24–28 26	26	
HL/BL	17–20 19	14–26 23	27–30 29	30–35 33	33	
HW/HL	33–43 38					
SnL/HL	11–13 12	24–29 26	22–29 27	27–29 28	29	
ED/HL	39–43 41	28–48 35	28–31 30	29–34 32	30	
P_1L/BL	0–3 2					
P_2L/BL	0–0 0					

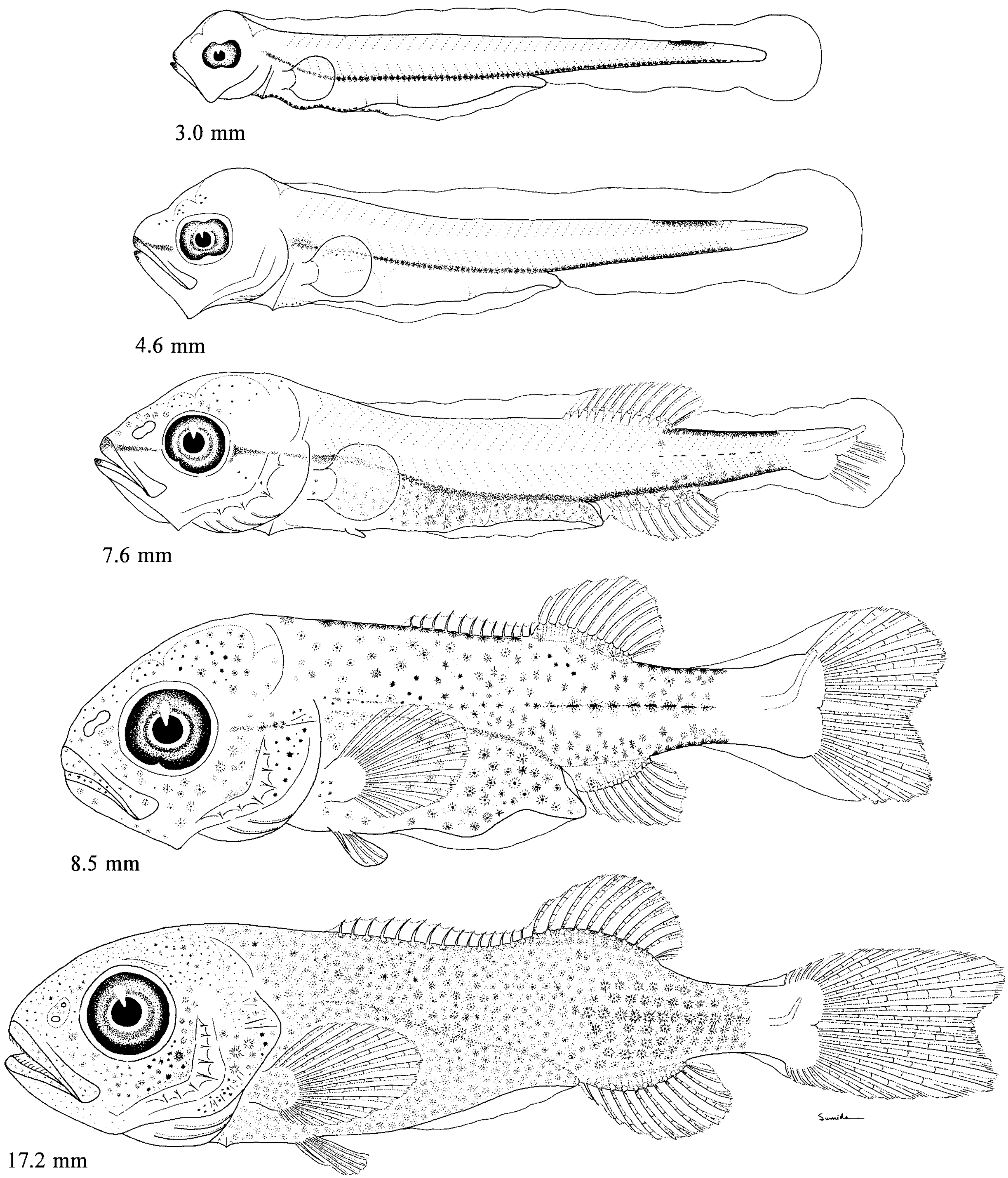


Figure Tetragonuridae 1. Preflexion larvae, 3.0 mm, 4.6 mm; early flexion larva, 7.6 mm; postflexion larva, 8.5 mm; transformation specimen, 17.2 mm (Ahlstrom et al. 1976).

MERISTICS

	Range	Mode*
Vertebrae:		
Total	51–58	51–53
Precaudal	25–29	26–27
Caudal	24–28	25–26
Fins:		
Dorsal spines	XV–XXI	XVII–XVIII
Dorsal rays	10–17	12
Anal spines	I–II	I
Anal rays	9–15	11–12
Pelvic	I,5	I,5
Pectoral	14–21	16
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	9–13	9–11
Lower	9–12	9–12
Gill rakers:		
Upper	5–6	
Lower	7–14	
Branchiostegals	5–6	6

LIFE HISTORY

Range: Cosmopolitan in temperate seas; in eastern Pacific from Aleutian Islands to Cabo San Lazaro, Baja California Sur

Habitat: Juveniles epipelagic, adults epi- & mesopelagic

Spawning season: Larvae collected throughout the year with autumn peak & spring minimum in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1976
Grey 1955
Kimura 1988b
Matarese et al. 1989
Olivar & Fortuño 1991
Sparta 1929b

* Modal counts are given for eastern Pacific specimens.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.1–1.3 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.25–0.30 mm
Shell surface: Smooth
Pigment: Chorion golden with pink tint; following blastopore closure, on OG & embryo with melanophores scattered on head & in rows along dorsal & ventral margins & over gut; most of dorsal margin pigment migrates to ventrum before hatching.
Diagnostic features: Diameter; OG; chorion color; embryonic pigment

LARVAE

Hatching length: 3.3–4.1 mm
Flexion length: ca. 7.6–10.1 mm
Transformation length: 17.7 mm to >21.4 mm
Fin development sequence: C_1, 2D & A & P_1, 1D & C_2, P_2
Pigmentation: *Yolk-sac*–Scattered on snout & ventrally on head; scattered on yolk sac; band over gut & continuing along ventral margin of tail; series on dorsal margin at last few myomeres & notochord tip. *Preflexion*–Ventrally on skull; gradually spreading forward on dorsal margin. *Flexion*–Scattered dorsally on head, increasing; on jaws; spreading ventrolaterally on gut; series on lateral midline beginning posteriorly & spreading forward; proximally on C rays. *Postflexion*–Forming laterally on trunk & tail; increasing on all areas.
Diagnostic features: 51–54 myomeres; melanophores at notochord tip & on caudal peduncle.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	56–72 62	57–64 60	56–62 59	58–67 62		60–66 64
BD/BL	9–11 10	10–18 12	18–20 19	20–25 22		22–22 22
HL/BL	15–19 18	11–23 17	24–27 25	25–32 28		27–32 29
HW/HL	47–63 53					44–51 47
SnL/HL	13–16 14	21–28 23	25–28 26	23–31 27		29–34 31
ED/HL	28–38 33	33–50 39	29–34 32	27–32 30		25–29 27
P_1L/BL	0–0 0					14–16 15
P_2L/BL	0–0 0					9–10 9

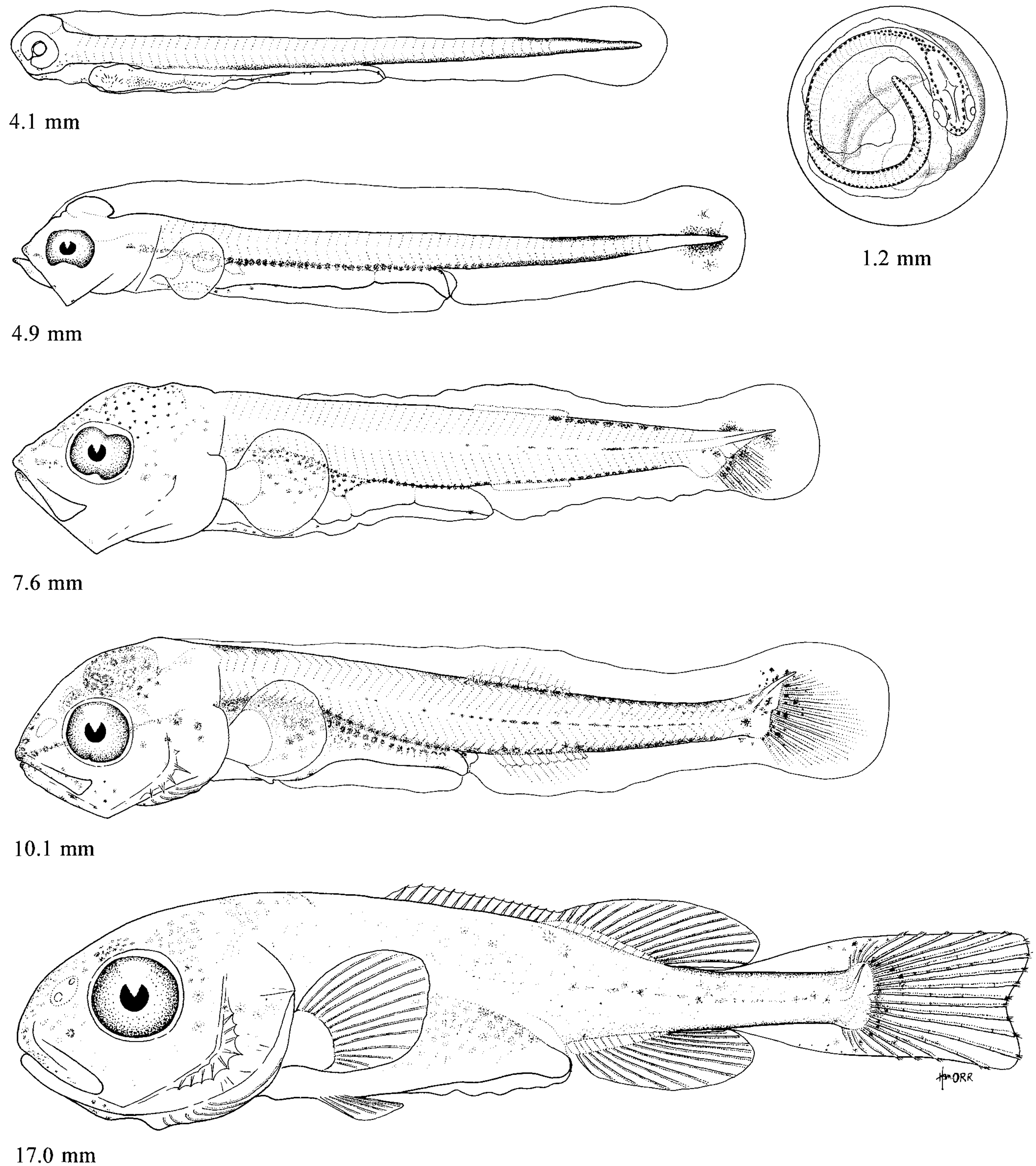


Figure Tetragonuridae 2. Egg, 1.2 mm; yolk-sac larva, 4.1 mm; preflexion larva, 4.9 mm; early flexion larva, 7.6 mm; late flexion larva, 10.1 mm; postflexion larva, 17.0 mm (Ahlstrom et al. 1976).

STROMATEIDAE: Butterfishes

W. WATSON

The butterfish family Stromateidae contains 13 species in three genera (Nelson 1994) and is represented in the eastern North Pacific by four *Peprilus* species (Horn 1970). Two of these occur in the CalCOFI study area and the other two occur near the study area. *Peprilus simillimus* ranges from British Columbia to Bahía Magdalena, Baja California Sur, and *P. snyderi* ranges southward from Bahía San Juanico, Baja California Sur and the Gulf of California to Panama. *P. medius* ranges along the Sinaloa coast of the lower Gulf of California to Peru, while *P. ovatus* is restricted to the northern Gulf of California. Larval *P. simillimus* are relatively common in CalCOFI ichthyoplankton collections, occurring primarily at inshore stations between about Point Conception, California, and Cabo San Lazaro, Baja California Sur. Larvae occur throughout the year, with highest abundance in June and lowest abundance between September and November. Larval *P. snyderi* have not been identified from CalCOFI collections.

Butterfishes are small to medium-size (ca. 30–50 cm) pelagic and epibenthic residents of tropical to temperate coastal seas. Juveniles commonly are associated with medusae. Butterfishes are compressed, moderately deep-bodied, with a rounded head. Preanal length typically is in the vicinity of 40% BL. The long-based, continuous dorsal fin contains 0–10 spines and about 33–50 soft rays. The anal fin also is long-based, with 0–7 spines and 31–47 soft rays (Horn 1984). The anterior soft rays commonly are longer than the more posterior rays and both fins are falcate in some species. Pectoral fins are long and tapered, the caudal fin is forked, and pelvic fins are absent. Scales are small, cycloid, and deciduous. Butterfishes typically are silvery on the flanks and grey to green or blue dorsally. Butterfishes are considered excellent eating and many species are utilized in commercial fisheries.

Butterfishes are oviparous, with planktonic eggs and larvae (*Pampus* and *Peprilus*: Colton and Honey 1963; Mito and Senta 1967; Martin and Drewry 1978; Pati 1979; D'Vincent et al. 1980; Ditty and Truesdale 1983; Kimura 1988b). Eggs are spherical, 0.75–1.35 mm in diameter, with a smooth chorion, a homogeneous to partially (coarsely) segmented yolk, and 1–3 oil globules 0.06–0.45 mm in diameter (usually 1, 0.17–0.45 mm). Larvae ca. 1.7–2.8 mm hatch with unpigmented eyes and unformed mouth, without pectoral fin buds, and with a large yolk sac containing the oil globule posteriorly (Colton and Honey 1963; Mito and Senta 1967; D'Vincent et al. 1980). Preanal length initially is somewhat more than half of body length but it shortens slightly as the gut coils early in the preflexion stage, and it typically continues to gradually shorten with further larval development. The gas bladder is small and anterior (lacking in *Pamprus*); it regresses and is absent by the adult stage (Horn 1975). Larvae are neither particularly compressed nor deep-bodied initially but become increasingly so with development. The snout initially is short and rounded and, although it subsequently lengthens, it remains blunt. A few small spines form along the preopercular margin during notochord flexion in *Peprilus* (D'Vincent et al. 1980; Ditty and Truesdale 1983) but none forms in *Pampus* (Kimura 1988b). Principal caudal fin rays are first to begin forming in *Peprilus*, followed by simultaneous development of dorsal, anal, and pectoral rays (D'Vincent et al. 1980; Ditty and Truesdale 1983). Yolk-sac stage larvae are lightly pigmented dorsally on the trunk and/or tail, on the gut, and anteriorly on the oil globule. Melanophores also may be located anteriorly on the yolk sac and ventrally on the tail; *Peprilus* lacks dorsal head pigment (Colton and Honey 1963; D'Vincent et al. 1980), while *Pampus* may have much dorsal head pigment (Mito and Senta 1967). *Peprilus* subsequently becomes rather heavily pigmented on the head while *Pampus* apparently loses most or all of its dorsal head pigmentation (D'Vincent et al. 1980; Ditty and Truesdale 1983; Kimura 1988b). Stromateid larvae commonly become moderately to heavily pigmented laterally on the trunk early in the preflexion stage, with the lateral pigment subsequently spreading caudad along the tail (Pearson 1941; Mito and Senta 1967; D'Vincent et al. 1980; Ditty and Truesdale 1983; Kimura 1988b).

Larval *Peprilus* in the CalCOFI study area superficially resemble larval carangins but are easily distinguished from them by myomere count (ca. 29–37 vs. 24–26, respectively), lack of a supraoccipital crest (developing in many carangin genera during the preflexion stage: see Carangidae, this volume; Laroche et al. 1984), presence of small preopercular spines that form during the flexion stage in contrast to the elongate preopercular spines that form during the preflexion stage in carangids, fin ray counts in postflexion stage larvae (c.f. Tables Stromateoidei 1 and Carangidae 1), and pigmentation patterns. Postflexion stage carangids also have well developed pelvic fins which *Peprilus* lacks, and they develop a clear separation between the first two and the third anal spine in contrast to the approximately uniform anal spine spacing in *Peprilus*. Yolk-sac stage *P. simillimus* resemble yolk-sac stage larvae of the croakers *Genyonemus lineatus* and *Roncador stearnsii* but have more myomeres (29–31 vs. 26–28, respectively) and lack melanophores dorsally on the head and on the tail posterior of about the second or third postanal myomere (melanophores present in both locations in both croaker species: see Sciaenidae, this volume). Larvae of the two *Peprilus* species in the CalCOFI study area can be distinguished by meristic characters (Table Stromateoidei 1); it is unknown whether there are differences in larval pigmentation.

The following description of *Peprilus simillimus* is taken from D'Vincent et al. (1980), supplemented with additional observations on some of the specimens used in that study and additional meristic counts made during this study.

MERISTICS

	Range	Mode
Vertebrae:		
Total	29–31	30
Precaudal	11–14	13
Caudal	17–19	17
Fins:		
Dorsal spines	II–IV	III
Dorsal rays	41–48	45
Anal spines	II–III	III
Anal rays	35–44	39
Pelvic*	0	0
Pectoral	19–23	21
Caudal:		
Principal	9+8	9+8
Procurrent:		
Upper	6–9	8
Lower	6–8	7
Gill rakers:		
Total	23–26†	
Upper	3‡	
Lower	11–13‡	
Branchiostegals	6	6

LIFE HISTORY

Range: Queen Charlotte Sound, British Columbia, to Bahía Magdalena, Baja California Sur

Habitat: Over soft bottom on continental shelf to ca. 90 m depth

Spawning season: Larvae collected year-round with summer peak in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

D'Vincent et al. 1980
Horn 1970
Matarese et al. 1989

* P_2 reduced to a single small spine.
† Horn (1970)
‡ Matarese et al. (1989)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.:
Yolk: Homogeneous
No. of OG: 1
Diam. of OG: 0.2 mm
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: 1.8–2.0 mm
Flexion length: 4.8–6.2 mm
Transformation length: 19 mm to ca. 28 mm
Fin development sequence: C_1, D & A & P_1 & C_2
Pigmentation: *Yolk-sac*—Scattered ventrally on head & tail, dorsally on gut, anteriorly on yolk sac & OG; few anteriorly on dorsal finfold; 1–6 on dorsal margin at about myomere 16; 0–1 ventrally on hindgut. *Preflexion*—Under forebrain; ventrolaterally on mid- & hindbrain, spreading dorsad; dorsally over brain by 4.7 mm; 0–1 (usually 1) at tip of lower jaw; 0–2 on gular region; series on isthmus & ventral margin of gut; spreading ventrolaterally & cephalad to cover most of trunk & anterior part of tail by end of stage; spreading ventrolaterally on gut. *Flexion–transformation*—Increasing on head, gut, & trunk; spreading caudad on tail; on P_1 base by 10 mm, extending onto upper rays by 12 mm; proximally on D & A beginning anteriorly by 10 mm, spreading caudad; proximally on C rays by 20 mm.
Diagnostic features: Moderately deep-bodied by late preflexion stage; Sn-A near half of BL; few, small preopercular spines forming during flexion stage; D & A counts (all elements present by ca. 10 mm); P_2 lacking; myomeres 12–14+16–20=30–32 (usually 13+18); lateral pigmentation of head, trunk, & gut.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–60	53–58	41–61	46–49	40–47
	53	55	55	51	47	44
BD/BL		22–23	28–34	39–50	47–51	44–53
	25	28	30	44	49	49
HL/BL		17–27	27–31	32–37	31–35	30–36
	14	23	28	35	32	34
HW/HL						
SnL/HL		18–31	19–23	20–28	22–28	16–23
	30	23	22	24	25	19
ED/HL		38–56	37–40	32–41	32–45	32–41
	67	44	38	38	39	36
P_1L/BL						
P_2L/BL						

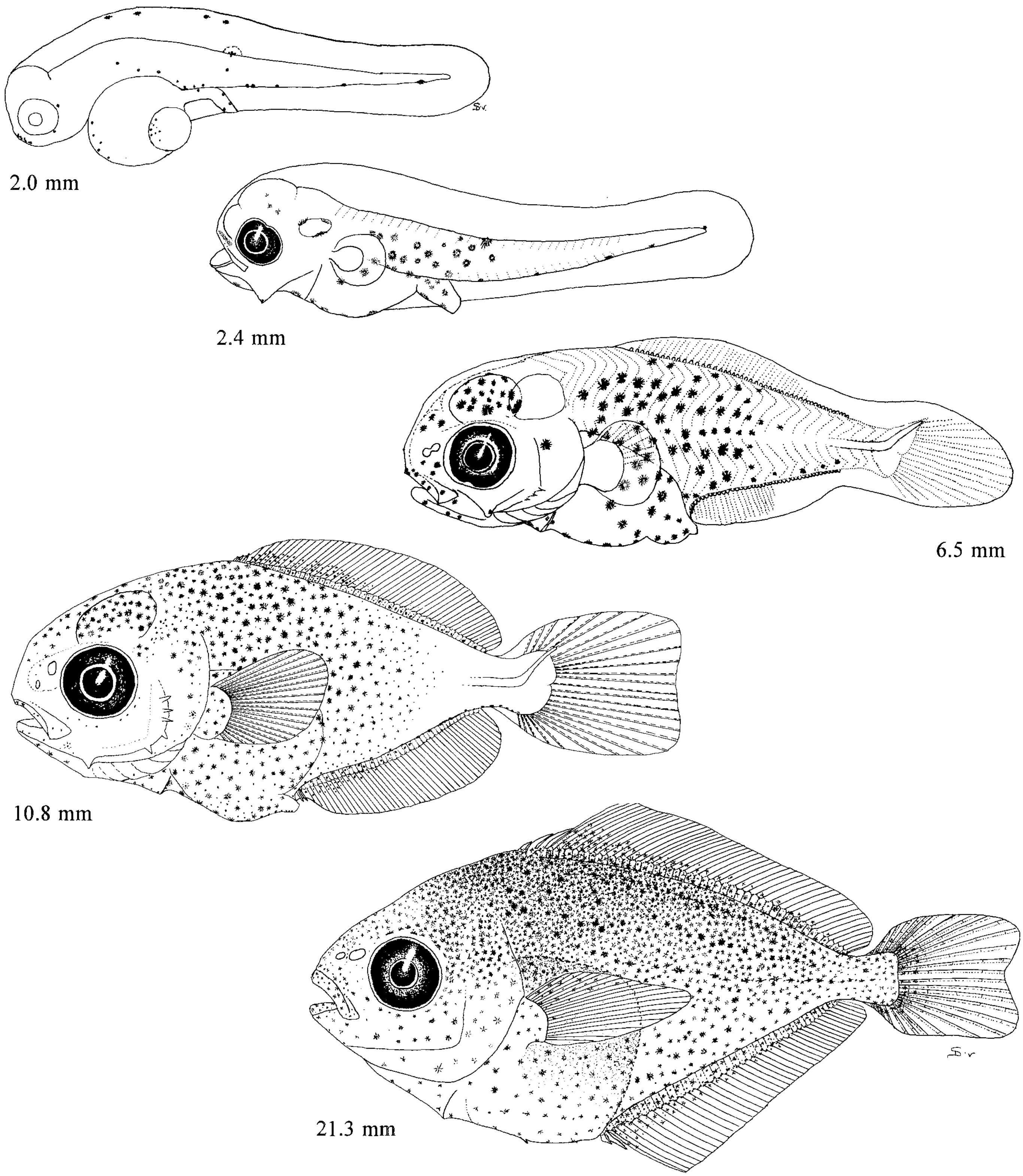


Figure Stromateidae 1. Yolk-sac larva, 2.0 mm; preflexion larva, 2.4 mm; flexion larva, 6.5 mm; postflexion larva, 10.8 mm; transformation specimen, 21.3 mm (D'Vincent et al. 1980).

PLEURONECTIFORMES

H. G. Moser

Pleuronectiformes, the flatfishes, is a large, highly specialized assemblage that includes ca. 570 species placed in approximately 123 genera and 11 families (Nelson 1994). Since Regan (1910), most workers have considered the flatfishes to be monophyletic. Chapleau (1993) listed three synapomorphies for the order: (1) the migration of one eye to the opposite side at the end of the larval period, resulting in an eyed and a blind side in juveniles and adults, (2) the dorsal fin origin far forward and overlapping the cranium, and (3) the presence of a specialized organ, the Recessus Orbitalis, that allows flatfish to protrude their eyes above the body surface and see while buried in the substrate. In his comprehensive monograph, Norman (1934) revised all pleuronectiform groups, except the soleoids, and discussed relationships within the order. This provided a foundation for more recent surveys of pleuronectiform relationships (Hensley and Ahlstrom 1984; Ahlstrom et al. 1984a; Sakamoto 1984b; Chapleau 1988, 1993; Chapleau and Keast 1988), which have clarified many of the problems surrounding flatfish relationships and have focused attention on those yet unresolved. According to Hensley and Ahlstrom (1984), there are three pleuronectiform suborders: Psettodoidei, Pleuronectoidei, and Soleoidei. Psettodoidei includes three species in the Indo-Pacific and eastern Atlantic genus *Psettodes*. *Psettodes* differs markedly from other flatfishes (e.g., it has spinous rays in the dorsal, anal, and pelvic fins and the dorsal fin origin is posteriad on the head) and has been hypothesized to have the closest relationship to a yet undefined perciform or preperciform flatfish ancestor (Chapleau 1993). Pleuronectoidei, the largest suborder, contains five (Hensley and Ahlstrom 1984) or seven (Nelson 1994) families and more than 400 species. Three families, Bothidae, Paralichthyidae, and Pleuronectidae, are represented in the California Current vicinity. Within Pleuronectidae, only the subfamily Pleuronectinae is represented in the CalCOFI area. Bothids and paralichthyids are tropical to temperate in distribution and pleuronectines are boreal to temperate. We include ELH descriptions of 4 bothid, 13 paralichthyid, and 15 pleuronectine species in this guide. The tropical to temperate families Achiridae, Cynoglossidae, and Soleidae comprise Soleoidei. Soleids are essentially absent from the eastern Pacific. A single species, *Aseraggodes herrei*, is reported from the Galápagos Islands and some other insular habitats in the tropical northeastern Pacific (Krupp 1995b). The other two families are well represented in tropical-subtropical waters of the eastern Pacific but only marginally in the CalCOFI sampling area; we include ELH descriptions of two species from each family.

Flatfishes are highly compressed fishes, with long-based dorsal and anal fins that usually are separate from the caudal fin (the median fins are continuous in cynoglossids and in some soleids). The eyes are on the right side (dextral) or left side (sinistral) according to family. Among the families included in this guide, pleuronectids and achirids are dextral whereas bothids, paralichthyids, and cynoglossids are sinistral. A proportion of individuals in species of some sinistral genera (e.g., *Paralichthys*) are dextral and the opposite is true for some dextral genera (e.g., *Platichthys*). Jaw size ranges from small to large and dentition from minute to strong and sharp. The pigment pattern of the ocular side typically matches the substrate and the blind side is usually white. Flatfishes bury themselves in the substrate to conceal themselves from predators or potential prey. Most are ambush predators, whereas many small-mouth species forage for worms or crustaceans in the substrate. Most are found on continental shelves but some species are found in shallow coastal waters, bays, and even fresh water, while others occur in the deepest waters of the continental slopes.

All flatfishes are oviparous and, with few exceptions, spawn large numbers of round, buoyant eggs (Ahlstrom et al. 1984a). Some pleuronectine species (in *Lepidopsetta* and *Limanda*) spawn demersal eggs. Typically, annual fecundity ranges from several thousand to several million eggs depending on the species. Egg diameter ranges from ca. 0.6 mm (some bothid species) to 4.5 mm (*Reinhardtius*) but most species fall within the range of 0.8–1.1 mm. The chorion is smooth in most species but may be striated, reticulated, rugose, adhesive (demersal eggs), or covered with a polygonal network (Ahlstrom et al. 1984a). The perivitelline space typically is narrow to moderate but is wide in some genera (e.g., *Hippoglossoides*, *Microstomus*). The yolk is homogeneous except in some soleids, where it is peripherally segmented. The presence or absence of oil globules and their arrangement provides an important suite of characters in flatfishes. Pleuronectines lack oil globules, except for three species. Paralichthyids, bothids, and scophthalmids have a single oil globule. Soleids, achirids, cynoglossids, achiropsettids, and rhombosoleids have multiple oil globules in a variety of sizes and arrangements (Ahlstrom et al. 1984a). In most species, late-stage embryos develop some melanistic pigmentation that often is helpful in identification.

In general, the degree of development of newly-hatched yolk-sac larvae is related to egg size; those hatching from small eggs have unpigmented eyes and an undeveloped mouth and lack pectoral fins whereas the opposite is true for species hatching from large eggs (Ahlstrom et al. 1984a). Preflexion flatfish larvae usually have a short, coiled gut, well developed finfold, and diagnostic melanophore patterns. In addition, a large array of morphological specializations (e.g., spination on the head and body, elongate rays in the dorsal and pelvic fins, unique shape of the head, body, and gut) are helpful in identification. Most flatfish species undergo transformation between 10 mm and 20 mm; however, some transform at extremely small sizes (e.g., <5.0 mm in achirids) and some attain large sizes (e.g., >50 mm in some *Cyclopsetta* species, >70 mm in *Glyptocephalus zachirus*, and >100 mm in *Chascanopsetta*). Size at settlement and duration of pelagic life usually are associated with depth of settlement and the depth of the habitat of adults; shallow water species have a short larval life and transform at small sizes whereas larvae of deeper-living species often attain large sizes during an extended pelagic life and settle at greater depths (Moser 1981).

Suborders and families included:

- Pleuronectoidei
  - Paralichthyidae
  - Bothidae
  - Pleuronectidae
- Soleoidei
  - Achiridae
  - Cynoglossidae

PARALICHTHYIDAE: Lefteye flounders and sanddabs

H. G. MOSER AND B. Y. SUMIDA[1]

Paralichthyidae consists of at least 85 species grouped in 16 genera (Nelson 1994). The family includes a diverse array of genera from the Atlantic, Pacific, and Indian Oceans and probably is polyphyletic (Hensley and Ahlstrom 1984; Chapleau 1993). Paralichthyids are represented in the California Current region by 8 genera and approximately 19 species (Table Paralichthyidae 1). Sanddabs (*Citharichthys*) rank among the 10 most abundant larval fish taxa in CalCOFI ichthyoplankton collections and larvae of 4 species (*C. fragilis*, *C. sordidus*, *C. stigmaeus*, and *C. xanthostigma*) are common in plankton tows seaward to 100 n.mi. Larvae of bigmouth sole, *Hippoglossina stomata*, are relatively common seaward to 100 n.mi., whereas those of California halibut (*Paralichthys californicus*) and fantail sole (*Xystreurys liolepis*) are rare in waters beyond ca. 20 n.mi. from the coast.

Paralichthyids are small to medium-sized (most species <50 cm) flatfishes with the eyes on the left side of the body. Some *Paralichthys* species attain a large size (e.g., *P. californicus* may reach 1.5 m). Dextral individuals are found in some genera (e.g., *Paralichthys*, *Xystreurys*) and, in some species, half the individuals may be dextral. Spinous rays are lacking. The pelvic fins are short and nearly symmetrical with 6 rays in almost all species. The dorsal fin originates above or in front of the superior eye and the mouth is large and armed with sharp teeth. Pectoral fins are usually somewhat better developed on the eyed side where they may be elongate in some species (e.g., *C. xanthostigma*, *X. liolepis*) and sexually dimorphic in others (e.g., elongate in males but not in females of *Syacium latifrons*). The caudal fin is rounded, to truncate, to somewhat wedge-shaped. Scales are small and cycloid in most species. The eyed side is light to dark brown, with many kinds of markings, while the blind side is white in most species. Hensley and Ahlstrom (1984) and Hensley (1995b) proposed three generic groupings for Paralichthyidae: the *Cyclopsetta*, *Paralichthys*, and *Pseudorhombus* groups. In the *Cyclopsetta* group (*Citharichthys*, *Cyclopsetta*, *Etropus*, and *Syacium*) the pelvic fin of the eyed side is on the midline, its origin slightly posteriad to that of the blind side fin, the urinary papilla is located on the blind side, and the lateral line is straight. In the *Paralichthys* group (*Ancylopsetta*, *Gastropsetta*, *Hippoglossina*, *Paralichthys*, *Verecundum*, and *Xystreurys*) the pelvic fins are symmetrically located on each side of the ventral midline, the urinary papilla is on the eyed side, and the lateral line is arched, extends below the inferior eye, and may have a dorsal branch. The *Pseudorhombus* group is primarily Indo-Pacific with no eastern Pacific representatives. Paralichthyids live in a variety of soft-bottom (usually sandy) habitats, primarily on the continental shelf; they are ambush predators feeding on invertebrates and fish. Some species are common in estuaries and coastal lagoons; species of *Citharichthys* and *Pseudorhombus* enter rivers in Africa. Paralichthyids are the focus of important commercial and recreational fisheries throughout the world.

Paralichthyids are oviparous and produce large numbers of eggs in multiple spawnings during a prolonged spawning period. Information on spawning seasonality and fecundity is scanty for most species; however, Topp and Hoff (1972) reported 155,000 eggs in a 99 mm female of *Etropus crossotus* and Caddell et al. (1990) reported a range of 313,000 to 589,000 eggs per spawning for captive *Paralichthys californicus*, a large member of the family. Caddell et al. (1990) estimated a total annual fecundity of 1.6 to 7.7 million eggs per female produced during 5–13 spawnings at weekly or biweekly intervals. Recent observations indicate that batch fecundity may reach 1.9 million eggs and spawning may occur every 2–3 days (Oda et al. 1995). Larval catches from ichthyoplankton surveys show that *P. californicus* spawns year-round with a peak in late winter-early spring and another in summer (Lavenberg et al. 1986; Walker et al. 1987; Moser and Watson 1990). CalCOFI larval data indicate broad spawning seasons for *Citharichthys* species, *Hippoglossina stomata*, and *Xystreurys liolepis*, with peaks in summer or fall.

Paralichthyid eggs are round, relatively small (<1.0 mm diam. for most species in the family), have

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a smooth chorion, homogeneous yolk, and a single oil globule. Scattered pigmentation develops on the head and body of late-stage embryos and on the yolk adjacent to the embryo and the finfold of some species. Eggs have been described for few paralichthyid species. Embryos of late-stage eggs of *P. californicus* are larger and more robust than in late-stage eggs of *Citharichthys*; also, the oil globule is larger (0.12–0.16 mm diam.) than in *Citharichthys* (maximum of 0.11 mm diam.). Eggs of *P. californicus* have a smaller oil globule than in *X. liolepis* (0.18–0.24 mm) and the late-stage embryos lack the notochord tip pigment present in *X. liolepis* (Oda, 1991). There is considerable overlap in shell and oil globule diameter in eggs of *Citharichthys* in the CalCOFI region; however, at the northern part of the survey region, only *C. sordidus* and *C. stigmaeus* are present and they have distinctly different egg and oil globule diameters (Table Paralichthyidae 2). In *C. sordidus*, ranges for shell and oil globule diameters are 0.78–0.84 mm and 0.08–0.11 mm, respectively, while in *C. stigmaeus* they are 0.62–0.66 mm and 0.06–0.08 mm, respectively. Ranges for egg and oil diameters of *C. fragilis* and *C. xanthostigma* have not been determined but probably overlap those of *C. sordidus* and *C. stigmaeus*, thus confounding identification where these species co-occur.

Larvae hatch at a relatively small size (most species <2.5 mm) with a large yolk sac, posteriorly placed oil globule, unpigmented eyes and undeveloped mouth. Yolk-sac and early preflexion larvae usually have distinct pigment patterns that permit identification to species (Table Paralichthyidae 2). Larvae of the *Paralichthys* group generally are heavily pigmented, have a crest formed from elongate anterior dorsal fin rays, and transform at a relatively small size (most species <12.0 mm). In the CalCOFI region, *Hippoglossina stomata*, *P. californicus*, and *X. liolepis* have distinctly different pigment patterns at all stages of development (Sumida et al. 1972; Ahlstrom et al. 1984a; Oda 1991). Larvae of the *Cyclopsetta* group, compared with the *Paralichthys* group, generally are less pigmented but have a partial or complete bar posteriorly on the tail, develop elongate dorsal and pelvic fin rays (eyed side only), and attain a larger size before transformation and settlement. Within this group, *Citharichthys-Etropus* and *Cyclopsetta-Syacium* form distinct subgroups (Table Paralichthyidae 2). Larvae of *Citharichthys* and *Etropus* have variously developed preopercular spines. Most species of *Citharichthys* have two early-developing, elongate dorsal fin rays and two elongate pelvic fin rays. Exceptions are *C. platophrys* with three elongate dorsal rays and *C. stigmaeus*, with no elongate fin rays. *E. crossotus* larvae have two elongate dorsal rays and one elongate pelvic ray. Larvae of *Cyclopsetta* and *Syacium* have a horn-like spine on each side of the head and highly developed preopercular spines; in *Syacium*, the preopercular spine at the angle becomes antler-like during the preflexion stage and, in *Cyclopsetta*, it becomes bifurcate. In *Cyclopsetta* larvae, a crest is formed from nine extremely elongate anterior dorsal fin rays and three of the pelvic fin rays on the eyed side become highly elongate. In *Syacium*, 5–8 anterior dorsal fin rays become elongate and the pelvic fins become only slightly elongate.

The larvae of all species of *Citharichthys* in the CalCOFI area, except *C. gilberti*, can be identified. *Citharichthys gordae* and *C. platophrys* are deep-bodied with highly distinctive pigment and morphology at all developmental stages. Among the other species, late yolk-sac and early preflexion larvae can be identified by the arrangement of pigment on the notochord tip and postanal ventral margin (Table Paralichthyidae 2). Additionally, in *C. xanthostigma*, the postanal pigment bar is more anteriad (at ca. midtail) during these stages compared with co-occurring species, where it is located at ca. 60% of tail length. The anlagen of the elongate dorsal rays appear at ca. 4.5 mm in *C. fragilis*, *C. sordidus*, and *C. xanthostigma*, separating larvae of these species from those of *C. stigmaeus* which do not develop elongate rays. Later stages of *C. fragilis*, *C. sordidus*, and *C. xanthostigma* can be separated by a combination of morphological, pigment, and meristic characters. Postflexion larvae of *Cyclopsetta panamensis* and *C. querna* are distinctly different; however, no differences were evident in flexion and preflexion larvae of this genus. Preflexion and flexion *Cyclopsetta* larvae are described as *C. panamensis* but may also represent specimens of *C. querna*. Additional material will be required to resolve this problem. It is clear from this study that the specimens described as a new genus, *Dorsopsetta*, by Nielsen (1963) are transformation specimens of *C. panamensis* on the basis of pigment characters and lateral line pore counts and are not *C. querna* as concluded by van der Heiden and Perez (1993). *Cyclopsetta querna* has an extended pelagic phase that reaches at least 50 mm before settlement. Large pelagic specimens of *C. querna* closely resemble the 220 mm pelagic flatfish ("Sally Rand fish") observed by Barham (1966) at 120 m depth from a research submarine. Since *C. querna* settle at ca. 50 mm, Barham's specimen may represent an undescribed deep-living species of *Cyclopsetta* or may possibly be an undescribed neotenic species. Most *Syacium* larvae from the CalCOFI area, the Gulf of California, and the adjacent eastern tropical Pacific appear to represent a single type. A few specimens in our collection are somewhat more slender than is typical and may be the larvae of *S. latifrons*. Since the distributions of *S. ovale* and *S. latifrons* overlap, our identification of the common *Syacium* larval form as *Syacium ovale* must be considered tentative, awaiting the collection of more complete larval series and critical transformation specimens.

The following descriptions of 13 species are based on detailed observations of 8–61 specimens of each species and literature where applicable (Table Paralichthyidae 3). Meristics were obtained from literature sources (Miller and Lea 1972; Ahlstrom et al. 1984a; van der Heiden and Perez 1993; Allen and Robertson 1994; Hensley 1995b) and from original counts made during this study. Ecological information is based primarily on Eschmeyer et al. (1983), Ahlstrom et al. (1984a), and Hensley (1995b).

Table Paralichthyidae 1. Meristic characters for the paralichthyid species in the California Current vicinity. All species have 6 pelvic rays on the eyed side. Counts of pectoral fin rays are from the eyed side. Small "splinter" rays in the caudal fin are indicated by "½".

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	Total C	Gill rakers
Ancylopsetta dendritica	9–11	27–28	36–39	76–84	59–67	11	½+17+½	2+5–7
Citharichthys fragilis	10	26–28	36–38	76–88	59–71	10–12	17	7–9+16–21
C. gilberti	10	22–26	32–36	77–89	56–68	9–11	17	4–7+12–17
C. gordae	10–11	25–26	35–36	72–79	57–62	11–12	17	7–9+16–19
C. platophrys	10	24–26	34–36	76–84	56–63	10–11	17	4–5+8–10
C. sordidus	11–12	27–29	38–40	86–102	67–81	11–13	17	6–9+11–16
C. stigmaeus	9–11	27–28	36–38	75–97	58–77	10–12	17	3–6+8–11
C. xanthostigma	11	26–27	37–38	79–89	61–69	10	17	6–8+10–12
Cyclopsetta panamensis	10	29	39	90–99	68–78	14–17	17	3–5+8–10
C. querna	10	27–30	37–40	82–95	69–76	14–17	17	4–7+7–10
Etropus crossotus	10	23–26	33–36	70–89	54–68	9–10	17	4–7+6–10
E. peruvianus	10	25–27	35–37	79–86	62–68	8–9	17	4–6+5–9
Hippoglossina bollmani	11	26–27	37–38	60–65	46–51	10–11	½+17+½	2–3+9–10
H. stomata	11	26–28	37–39	63–70	47–55	11–12	½+17+½	4–6+11–15
H. tetropthalma	10	27–28	37–38	74–85	54–63	10–11	½+17+½	2+9–10
Paralichthys aestuarius	10	27–28	37–38	72–85	57–67	9–11	½+17+½	6–9+18–23
P. californicus	10	23–26	33–36	66–76	49–59	10–13	½+17+½	7–11+18–23
P. woolmani	10	25	35	70–81	52–64	11–12	½+17+½	4–6+11–15
Syacium latifrons	9–10	23–24	33–34	81–83	63–74	11	16–17	3–4+7–8
S. ovale	10	24–25	34–35	82–91	64–72	9–12	16–17	2–4+7–9
Xystreurys liolepis	11–12	25–28	36–39	73–80	57–62	11–13	½+17+½	2–4+6–7

Table Paralichthyidae 2. Summary of some larval features of paralichthyid species described in this guide. Based on literature and original observations (see Table Paralichthyidae 3). Sizes at hatching, flexion, and transformation are approximate (see species descriptions).

Taxon	Size at hatching (mm)	Size at flexion (mm)	Size at transformation (mm)	Head spines	Elongate D rays	Elongate P_2 rays	Notochord tip pigment (early preflexion)	Postanal ventral margin pigment (early preflexion)*
Cyclopsetta Group								
Citharichthys fragilis	<3.6	7.6–8.5	16.0–19.0	preopercular (2 rows)	2	2	2–4 below	series coalesces to 2 blotches
C. gordae		7	>10.0	preopercular (wide patch)	2	2	1 below	2 series coalesce to 2 blotches
C. platophrys	<3.4	6.1–6.6	15.0–20.0	preopercular (3 rows)	3	2	none	series coalesces to 1 blotch
C. sordidus	<2.6	9.3–11.2	25–40	preopercular (2 rows)	2	2	4–6 above & below	series coalesces to 2 blotches
C. stigmaeus	1.3	9.3–10.5	25–38	preopercular (2 rows)	none	none	blotch above & below becoming a series of 2–6 (usually 3–4) above & below	initially 1 blotch then series; both persist
C. xanthostigma	<2.3	7.8–10.0	23–30	preopercular (2 rows)	2	2	cluster at extreme tip	short series becoming a blotch
Cyclopsetta panamensis	<3.3	6.0–9.0	33–36	horn-like pair; preopercular, strong with spine at angle becoming bifurcate	5 increasing to 9	3	none	none
C. querna		<16.2	ca. 50	same as *C. panamensis*	9 in postflexion	3		
Etropus crossotus	<3.0	4.8–7.1	ca. 10	preopercular (2 rows)	2	1	several below	series persists
Syacium ovale	<2.2	5.1–5.9	14–18	horn-like pair; preopercular, strong with spine at angle becoming antler-like	5 increasing to 8–9	3 slightly elongate	ca. 3 below	ca. 15 in series coalescing to ca. 6–8
Paralichthys Group								
Hippoglossina stomata	<2.8	4.5–5.2	9–11	preopercular (1 row)	5	none	several above & below	most of tail covered
Paralichthys californicus	1.6–2.1	5.0–7.0	7.5–9.4	preopercular (1 row); several on sphenotic (small)	5	none	series (minute) below, 1–2 above (some specimens)	double row anteriorly
Xystreurys liolepis	1.8–2.3	5.5–7.0	7.5–<9.0	preopercular (1 row)	5–6	none	several above & below	double row anteriorly

* In *Cyclopsetta* group, refers to ventral margin melanophores anterior to tail bar.

Table Paralichthyidae 3. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the paralichthyid species descriptions. An "L" indicates literature used in the description.

Taxon	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Cyclopsetta Group	0	0					
Citharichthys fragilis			6 3.5–6.4	3 7.6–8.5	7 8.9–15.7	3 16.6–18.9	3 19.2–22.6
C. gordae	0	0	4 5.0–5.6	1 7.1	3 8.6–10.6	0	0
C. platophrys	0	0	5 3.4–5.6	3 6.1–6.6	L[a,e], 4 6.9–13.2	3 14.9–19.9	3 16.4–21.2
C. sordidus	L[b], 16 0.78–0.84	2 2.6–2.7	L[b], 12 3.0–9.8	L[b,c,d,e], 3 9.3–11.2	L[b,c,d,e], 8 9.7–23.9	4 25.3–39.9	2 47.3–51.3
C. stigmaeus	L[b], 27 0.62–0.65	4 1.3–3.0	9 3.2–10.6	L[b,c,d,e], 4 9.3–10.5	L[b,c,d,e], 10 9.4–24.4	4 26.4–38.2	3 23.4–28.7
C. xanthostigma	0	0	10 2.3–7.8	L[c], 4 7.8–10.0	L[c], 8 9.6–21.8	2 23.4–30.5	2 24.5–25.1
Cyclopsetta panamensis	0	0	6 3.3–6.1	2 6.6–8.2	4 9.4–32.5	L[f]	0
C. querna	0	0	0	0	6 14.7–44.0	2 52.5–57	2 49.0–49.2
Etropus crossotus	0	0	L[g], 7 3.0–4.8	L[g], 7 4.8–7.1	L[g], 5 7.1–8.9	L[g]	0
Syacium ovale	0	0	9 2.2–5.0	3 5.1–5.8	L[a,e], 10 6.1–11.8	3 14.2–18.1	0
Paralichthys Group							
Hippoglossina stomata	L[h]	L[h]	L[h]	L[h]	L[h]	L[h]	L[h]
Paralichthys californicus	L[i]	L[i]	L[i]	L[i]	L[i]	L[i]	L[i]
Xystreurys liolepis	L[i]	L[i]	L[i]	L[i]	L[i]	L[i]	L[i]

[a] Moser 1981
[b] Matarese et al. 1989
[c] Ahlstrom 1965
[d] Ahlstrom and Moser 1975
[e] Ahlstrom et al. 1984a
[f] Nielsen 1963
[g] Tucker 1982
[h] Sumida et al. 1979
[i] Oda 1991

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	36–37
Precaudal	26–28	26–27
Caudal	10	10
Fins:		
Dorsal spines	0	0
Dorsal rays	76–88	84
Anal spines	0	0
Anal rays	59–71	67
Pelvic	6	6
Pectoral	10–12	11
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	7–9	8–9
Lower	16–21	17–18
Branchiostegals		

LIFE HISTORY

Range: Southern California to Cabo San Lucas, Baja California Sur & Gulf of California

Habitat: Sandy bottom to ca. 350 m depth

Spawning season: Larvae captured year-round in CalCOFI area, with peak abundance in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.6 mm, 5.2 mm, 6.3 mm (B. Sumida MacCall)
Flexion larvae, 7.6 mm, 8.5 mm (B. Sumida MacCall)
Postflexion larva, 10.0 mm (B. Sumida MacCall)

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* Eye initially oval; horizontal axis is given first, vertical axis second.
† Rays broken.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.6 mm
Flexion length: ca. 7.6–8.5 mm
Transformation length: ca. 16.0–19.0 mm
Fin development sequence: Elongate D, C & P_2, D & A, P_1
Pigmentation: *Preflexion*—By 3.5 mm, on angular, on ventral margin of gut, a patch above gut (later covers gas bladder), on margin of ventral finfold, a series on ventral margin of tail, a bar centered at ca. 55% of tail length, & 2–4 (usually 3) ventrally on notochord tip; by 5.0 mm, on isthmus, ventral tail series beginning to coalesce; by end of stage, bar centered at ca. 67% of tail length, on tips of elongate D rays, blotch on urohyal, & none on notochord tip. *Flexion*—Tail bar incomplete, lateral & apposing dorsal & ventral blotches at ca. 72% of tail length (only lateral blotch in some specimens); ventral series coalesced to 2 pairs of blotches; apposing blotches distally on D & A rays at ca. midtail. *Postflexion*—4 pairs of blotches on dorsum & 3 ventrally on tail, spreading to pterygiophores. *Transformation*—On upper jaw; 5th pair of blotches added anteriorly on dorsum. *Juvenile*—Dorsal & ventral patches expand to form chevron-like bars.
Diagnostic features: Generally fewer total myomeres & D rays than in *C. sordidus* (36–38 & 78–88 vs. 38–40 & 86–102); 2 elongate, early-forming D & P_2 (left side) rays; 2–4 (usually 3) melanophores ventrally at notochord tip in early preflexion larvae; urohyal blotch; transforms at smaller size (16–19 mm) than *C. sordidus* (25–40 mm) or *C. xanthostigma* (23–30 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		35–41 38	40–44 42	36–44 41	32–35 34	31–33 32
BD/BL		17–23 19	25–32 28	32–39 35	34–36 35	31–32 32
HL/BL		17–22 20	22–25 23	25–28 26	25–26 25	25–27 26
HW/HL		42–61 52	43–51 46	39–50 44	35–39 38	35–37 36
SnL/HL		17–20 19	20–22 21	18–26 22	21–23 22	19–21 20
ED/HL*		25–33× 24–33	25–28× 25–28	24–27× 26–30	25–27× 25–29	29–30× 21–25
		29×28	27×27	26×28	26×27	29×24
P_1L/BL		6–7 6	7–8 7	7–9 8	7–7 7	7–11 9
P_2L/BL		0–1 0.4	10–21 15	21–26 23	†	7–8 7

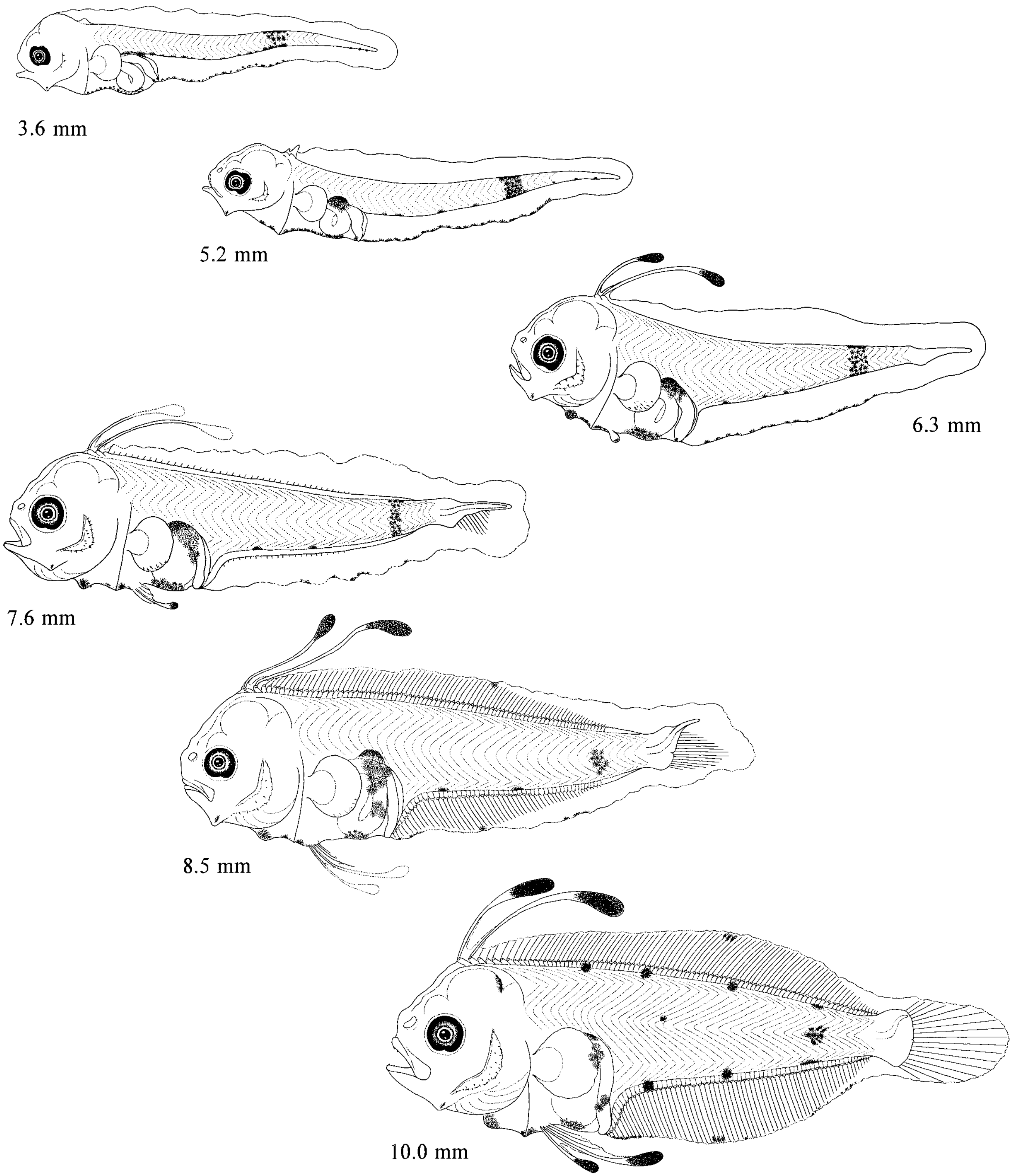

Figure Paralichthyidae 1. Preflexion larvae, 3.6 mm, 5.2 mm, 6.3 mm; flexion larvae, 7.6 mm, 8.5 mm; postflexion larva, 10.0 mm (CalCOFI 6706, station 119.33).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–36	35
Precaudal	10–11	10
Caudal	25–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	72–79	75–76
Anal spines	0	0
Anal rays	57–62	58–59
Pelvic	6	6
Pectoral	11–12	12
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	7–9	8
Lower	16–19	17
Branchiostegals		

LIFE HISTORY

Range: Extreme southern region of Baja California peninsula, on outer coast as far north as Punta Lobos (off Todo Santos); coast of Sinaloa, Mexico; may range to Bay of Panama

Habitat: Sand bottom to >100 m depth

Spawning season: Larvae captured from January to June

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 5.0 mm (B. Sumida MacCall)
Flexion larva, 6.9 mm (B. Sumida MacCall)
Postflexion larva, 8.5 mm (B. Sumida MacCall)

* Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: ca. 7 mm
Transformation length: >10 mm
Fin development sequence: Elongate D, C & D & A & P_2, P_1
Pigmentation: *Preflexion*—Embedded in snout; laterally & ventrolaterally on hindbrain; medially in branchial region; blotch in gular region, series on isthmus; above gas bladder; on ventral surface of gut & laterally on terminal section of gut; dorsolateral patches at midtrunk, apposing dorso- and ventrolateral patches anteriorly on tail; elongate dorso- and ventrolateral patches at midtail, separate into 2 pairs of apposing patches by end of stage; ventrally at notochord tip. *Flexion–postflexion*—4 dorsolateral & 3 ventrolateral patches extending to pterygiophores & to adjacent myosepta; posteriormost apposing dorsal & ventral patches expanded to form partial bar with streaks lateral to (& embedded above) spinal column; conspicuous blotch on urohyal.
Diagnostic features: Low D ray count (72–79); extremely deep-bodied (BD 38–50% BL in flexion & postflexion stages); broad arc-like patch of preopercular spines; 2 elongate, early-forming D & P_2 (left side) rays; distinctive pattern of large pigment patches.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		46–47 46	52	52–55 53		
BD/BL		20–30 26	38	41–50 46		
HL/BL		22–25 23	27	30–34 32		
HW/HL		49–60 54	48	35–41 38		
SnL/HL		22–29 24	25	24–27 25		
ED/HL*		25–29× 23–28 27×25	27×28	26–28× 22–26 27×24		
P_1L/BL		6–9 7	5	7–9 8		
P_2L/BL		0–8 2	9	26–28 27		

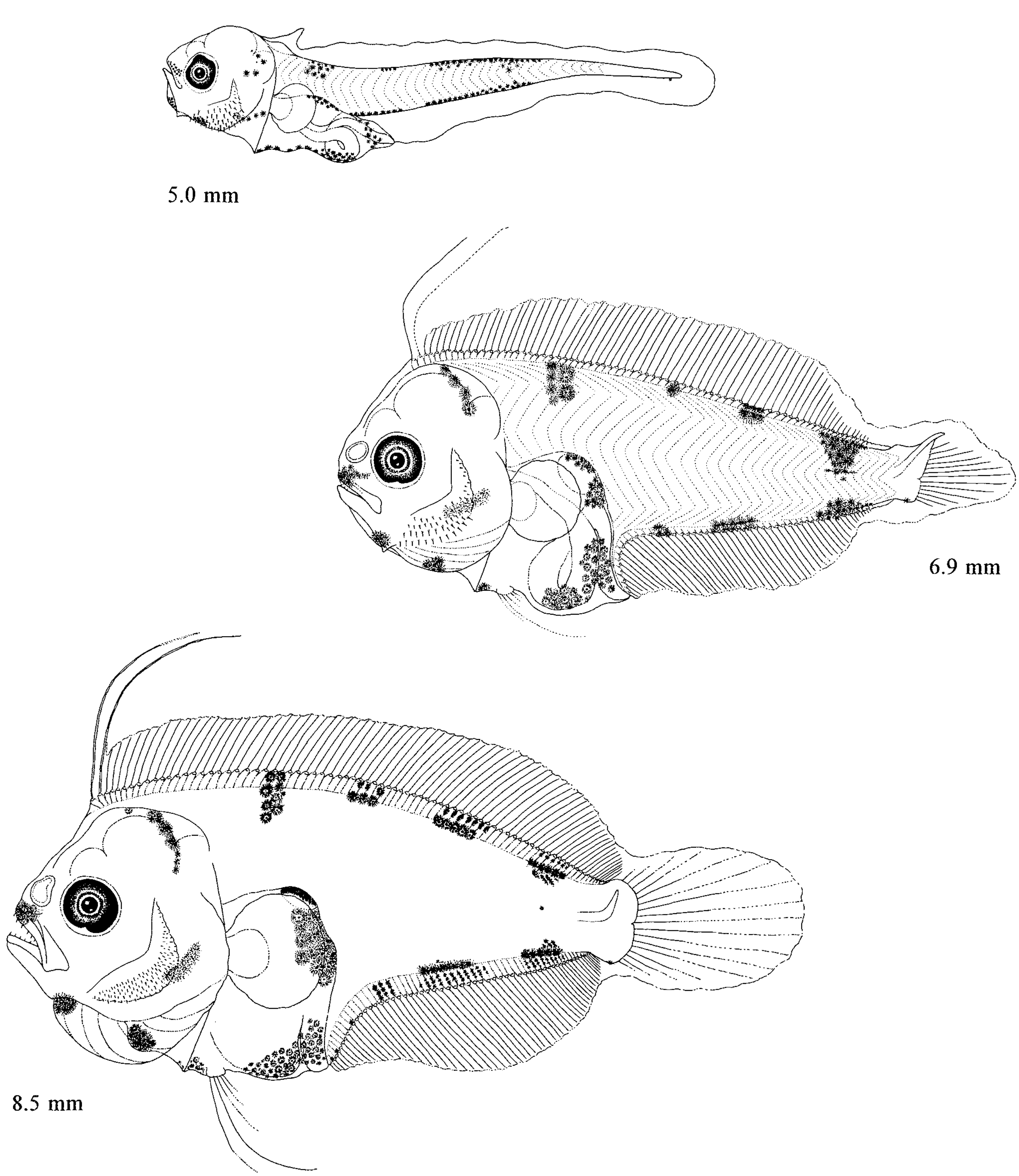

Figure Paralichthyidae 2. Preflexion larva, 5.0 mm (CalCOFI 6101, station 120.70); flexion larva, 6.9 mm (CalCOFI 7205, station 150.25); postflexion larva, 8.5 mm (CFRD Ref. Coll., UNAM, midwater trawl, Bahia de La Paz, Baja California Sur).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	35
Precaudal	10	10
Caudal	24–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	76–84	80
Anal spines	0	0
Anal rays	56–63	60–62
Pelvic	6	6
Pectoral	10–11	10
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	4–5	4
Lower	8–10	9
Branchiostegals		

LIFE HISTORY

Range: Southernmost region of Baja California Sur; Gulf of California to Peru

Habitat: Soft bottom & ca. 50 m depth

Spawning season: Probably year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser 1981
Ahlstrom et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.5 mm, 5.2 mm (B. Sumida MacCall)

* Eye initially oval; horizontal axis is given first, vertical axis second.
† Rays broken.
‡ Rays broken.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.4 mm
Flexion length: ca. 6.1–6.6 mm
Transformation length: 14.9–16.4 through 19.9 mm
Fin development sequence: Elongate D, D & A & P_2, C, P_1
Pigmentation: *Preflexion*—Series on ventral midline from isthmus to hindgut; large patch above gas bladder; patch lateral to terminal gut section; 6–7 (minute) on ventral margin of tail; bar at ca. midtail, including lateral streak & streak embedded above notochord; on dorsal & ventral finfold adjacent to bar; by 5.0 mm, medially in branchial region, pair on each side of dorsal midline just posterior to anus, pair of small patches (diagonal to dorsal pair) on each side of ventral midline of tail, & on spatulate tips of 1st & 2nd elongate D rays & 2nd elongate P_2 ray. *Flexion–postflexion*—On lower jaw & angular; apposing (diagonal) patches spread to pterygiophores & myosepta; ventral gut series consolidated posterior to cleithrum & below gut loop. *Transformation*—On hindbrain; tail bar widens. *Juvenile*—Series on lateral midline; 3 epaxial & 2 hypaxial chevron patches anterior to tail bar.
Diagnostic features: Only *Citharichthys* larva in area with 3 elongate D rays; 2 elongate, early-forming P_2 (left side) rays; distinctive tail bar & apposing (diagonal) patches dorsally & ventrally on tail; narrow arc-like band of preopercular spines; extremely deep-bodied (BD 36–53% BL in flexion & postflexion stages).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		43–48 44	42–48 45	43–52 47	36–38 37	38–39 38
BD/BL		21–33 28	36–39 37	39–53 44	41–44 42	38–40 39
HL/BL		21–25 23	24–26 25	26–30 28	28–31 30	31–34 33
HW/HL		37–51 43	41–43 42	40–47 43	36–45 41	28–29 29
SnL/HL		20–26 23	17–21 19	17–24 21	18–21 19	18–20 19
ED/HL*		17–28× 20–32 24×28	27–31× 28–30 29×29	28–29× 28–30 29×29	25–30× 25–30 28×28	26–27× 16–18 27×18
P_1L/BL		6–8 7	6–9 8	8–9 8	†	15–19 17
P_2L/BL		0–0 0	26–36 30	47–48 47	‡	10–13 11

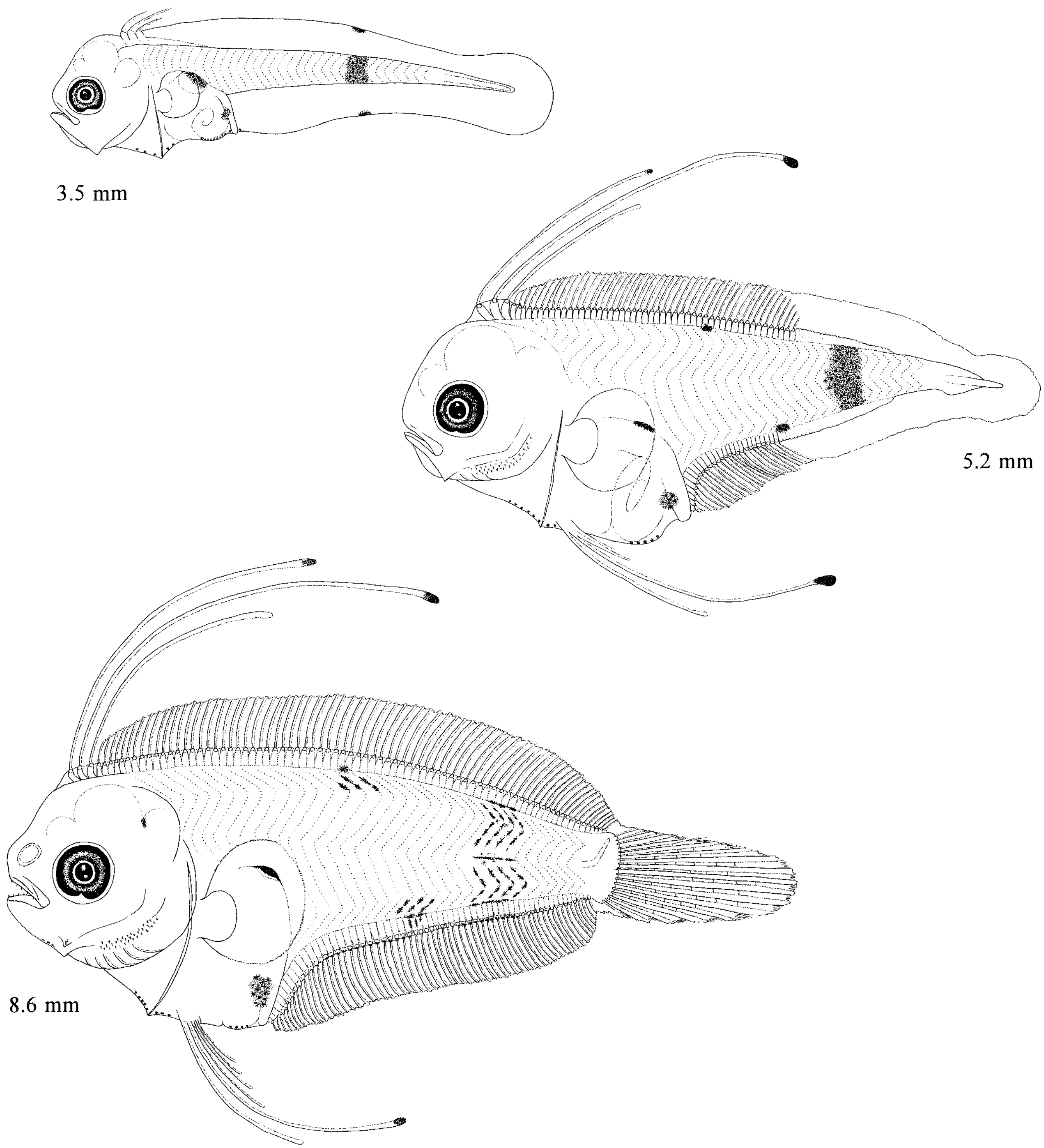

Figure Paralichthyidae 3. Preflexion larvae, 3.5 mm (EASTROPAC II, station 47.258), 5.2 mm (EASTROPAC I, station 14.323); postflexion larva, 8.6 mm (Ahlstrom et al 1984a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–40	39
Precaudal	11–12	11
Caudal	27–29	28
Fins:		
Dorsal spines	0	0
Dorsal rays	86–102	93–94
Anal spines	0	0
Anal rays	67–81	75
Pelvic	6	6
Pectoral	11–13	12
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	6–9	7–8
Lower	11–16	13–14
Branchiostegals		

LIFE HISTORY

Range: Bering Sea to southern Baja California

Habitat: Sandy bottom to >500 m depth

Spawning season: Larvae captured year-round in CalCOFI area, with abundance peaks in January–February & August–October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.6 mm, 6.6 mm, 9.0 mm (B. Sumida MacCall)
Flexion larvae, 9.1 mm, 10.9 mm (B. Sumida MacCall)

* Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.78–0.84 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.08–0.11 mm
Shell surface: Smooth
Pigment: Evenly distributed on late-stage embryos; only dorsally on posterior tail, except some under notochord tip; none on OG
Diagnostic features: Shell & OG diam.; pigment pattern

LARVAE

Hatching length: <2.6 mm
Flexion length: 9.3–9.8 mm through 9.7–11.2 mm
Transformation length: ca. 25–40 mm
Fin development sequence: Elongate D, P_2, D & A & C, P_1
Pigmentation: *Late yolk-sac–early preflexion*—On ventral margin of yolk sac or anterior section of gut; double row above gut extending posteriad on ventral margin of tail; series of 4–6 (usually) above & below notochord tip; short series dorsally on tail centered at ca. 60% of tail length. *Preflexion*—By ca. 6.0 mm, bar forming on tail & ventral series coalescing; 1 on angular; by end of stage, on isthmus, medially in branchial region, ventral to P_1 base (transitory), blotch above gas bladder, posterior to cleithral junction, lateral & ventral to gut coil, on tips of elongate D & P_2 rays, 2 patches forming on ventral margin of tail between bar and anus, & fewer at notochord tip. *Flexion*—Back of cerebellum; 3 blotches on dorsum anterior to tail bar & 2 ventrally on tail anterior to bar; a blotch distally on D & on A at ca. midtail. *Postflexion*—1 or series of several (widely spaced) above spinal column; by ca. 15.0 mm, blotches spreading to pterygiophores; laterally on hypural & on hypural margin. *Transformation*—Additional patches form between patches on D & A pterygiophores; 6 chevron-like patches form on body; series of blotches along entire D & A; series on lateral midline of blind side.
Diagnostic features: Total myomere, D, & A counts higher than *C. fragilis* & *C. xanthostigma* (some overlap); also more slender than these species; 2 early-forming, elongate D & P_2 rays; series of 4–6 (usually) melanophores above & below notochord tip (lacking after flexion stage); larger at flexion stage & settlement than *C. fragilis* & *C. xanthostigma*; 2 rows of preopercular spines.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	37–41 39	36–41 39	40–42 41	37–46 42	21–35 29	
BD/BL	10–12 11	9–23 15	21–23 22	30–38 33	32–33 33	
HL/BL	15–16 16	15–21 18	20–22 21	25–29 26	24–27 25	
HW/HL	50–53 51	40–58 46	33–45 38	33–47 41	31–44 39	
SnL/HL	14–21 17	13–29 20	20–24 22	24–31 28	20–24 23	
ED/HL	41–42× 32–37 42×34	25–39× 23–32 30×29	23–29× 24–29 25×26	24–30× 24–30 26×26	19–27× 20–27 25×23	
P_1L/BL	 2	4–6 5	6–7 7	6–8 7	6–9 7	
P_2L/BL	0–0 0	0–22 4	 31	26–44 35	8–25 16	

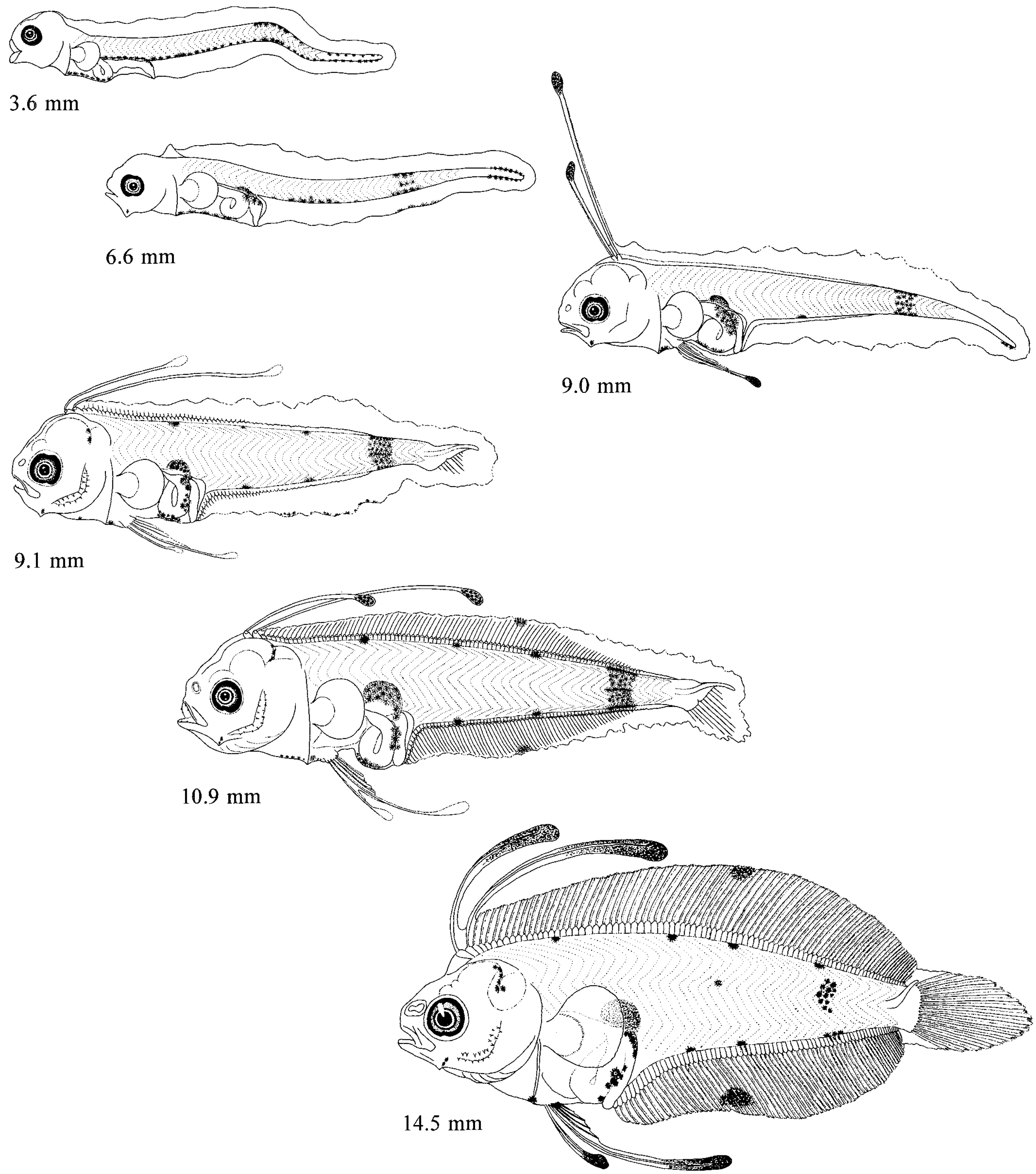

Figure Paralichthyidae 4. Preflexion larvae, 3.6 mm (CalCOFI 6401, station 73.50), 6.6 mm, 9.0 mm (CalCOFI 7512, station 91.5.30); flexion larvae, 9.1 mm, 10.9 mm (CalCOFI 7807, station 83.60); postflexion larva, 14.5 mm (Ahlstrom 1965).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	38
Precaudal	9–11	10
Caudal	27–28	28
Fins:		
Dorsal spines	0	0
Dorsal rays	75–97	88–90
Anal spines	0	0
Anal rays	58–77	70
Pelvic	6	6
Pectoral	10–12	11
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	3–6	4
Lower	8–11	9
Branchiostegals		

LIFE HISTORY

Range: Southeast Alaska to southern Baja California

Habitat: Sandy bottom on shelf & slope to 366 m depth, usually shallower than ca. 90 m; in bays & estuaries

Spawning season: Larvae captured year-round in CalCOFI area, with highest abundance in August–December & peak in October

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.8 mm (B. Sumida MacCall)
Preflexion larvae, 3.0 mm, 3.7 mm, 7.7 mm (B. Sumida MacCall)
Flexion larva, 10.4 mm (B. Sumida MacCall)
Postflexion larva, 13.7 mm (B. Sumida MacCall)

* Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.62–0.66 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.06–0.08 mm
Shell surface: Smooth
Pigment: Sparsely, & evenly distributed on head & trunk & dorsally on tail; heavier above & below notochord tip
Diagnostic features: Small shell & OG diam.; pigment on late-stage embryos

LARVAE

Hatching length: ca. 1.3 mm
Flexion length: ca. 9.3–10.5 mm
Transformation length: ca. 24–38 mm
Fin development sequence: C & D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Ventrad migration & coalescence; above mid- & terminal sections of gut & ventrally on yolk sac; bar centered at ca. 60% of tail length; blotch on ventral margin midway between bar & anus; blotch above & below notochord tip. *Preflexion*—By 3.5 mm, irregular series on ventral margin of tail, series dorsally on terminal gut section, on margin of ventral finfold, 2–6 (usually 3–4) in series above & below notochord tip, & a blotch above gas bladder; by 6.5 mm, on angular & isthmus. *Flexion*—Blotch on urohyal; blotch distally on C rays; tail bar & notochord tip series diminishing. *Postflexion*—By 14.0 mm, tail bar lacking, patches dorsally & ventrally on C, posterior apposing patches on margins of D & A, elongate patch anteriorly on margin of D, on hypural margin, the series on ventral margin of tail now in pterygiophore zone, & on back of cerebellum & lateral to midbrain (in some); by end of stage, on snout. *Transformation*–On entire margin of D & A; body margin outlined (visible on blind side); series on lateral midline on blind side; on tip of P_2. *Juvenile*—5 indistinct chevron-like bars on body; D, A, & P_1 mottled.
Diagnostic features: No elongate D or P_2 rays; blotches above & below notochord tip in yolk-sac larvae, become series in preflexion stage, then lacking after flexion stage; irregular series on ventral margin of tail persists to transformation; tail bar lost in early postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	33–54 43	32–41 36	36–38 36	32–44 38	24–35 28	30–32 31
BD/BL	7–37 19	10–19 13	19–24 22	26–35 32	31–38 33	30–32 31
HL/BL	15–29 20	13–18 16	18–20 19	20–26 23	21–27 23	23–26 25
HW/HL	53–65 57	35–62 45	35–40 37	34–42 37	31–35 33	47–50 48
SnL/HL	5–20 15	16–27 19	17–23 19	13–24 19	15–21 19	18–20 19
ED/HL*	37–45× 30–35 41×32	23–35× 25–36 28×30	22–31× 26–29 27×27	23–28× 23–30 25×27	22–27× 21–25 25×22	27–29× 22–24 28×23
P_1L/BL	 2	4–6 5	6–7 6	7–8 7	4–6 5	6–8 7
P_2L/BL	0–0 0	0–0 0	0–0 0	0.6–9 5	7–8 8	7–8 7

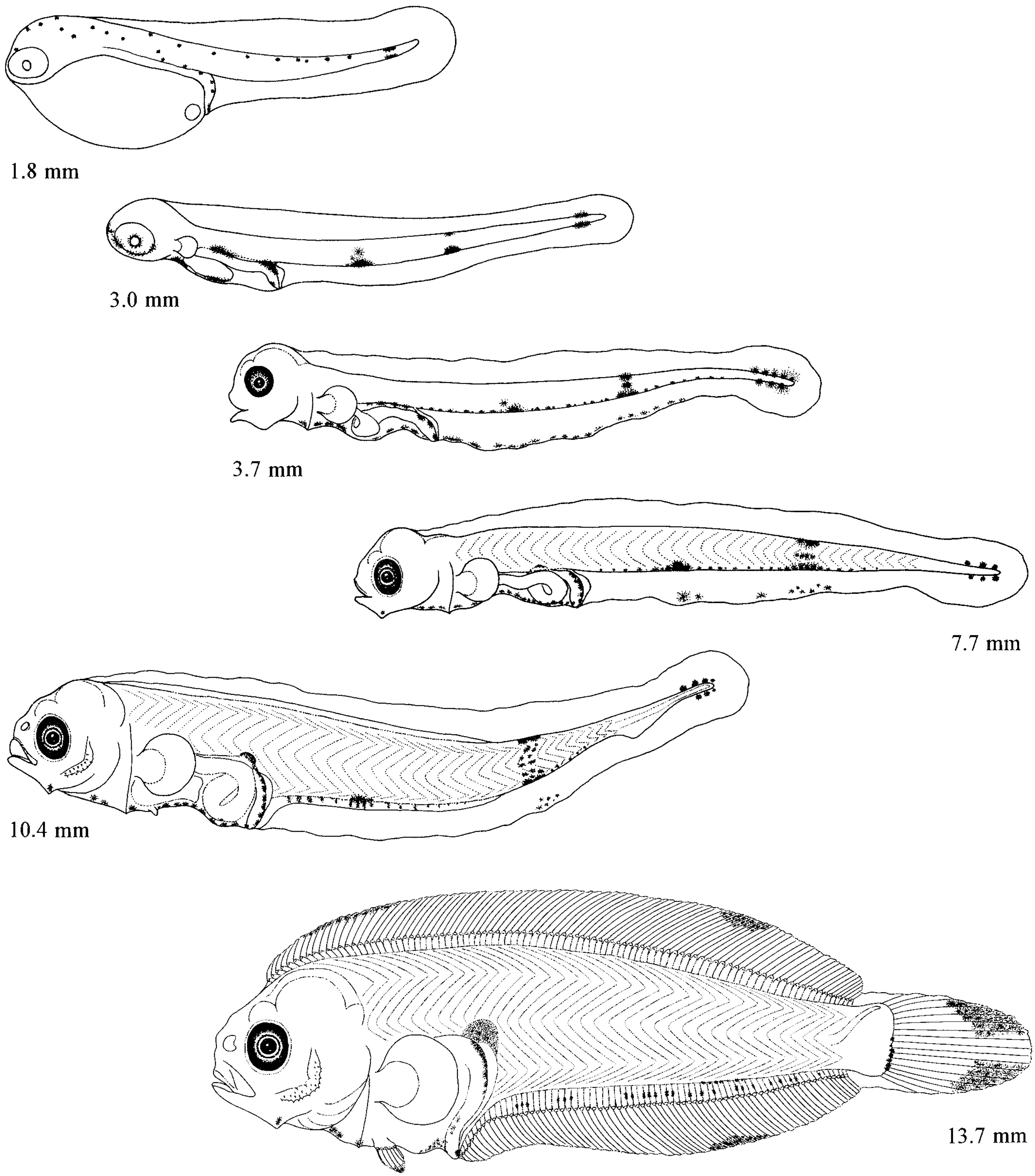

Figure Paralichthyidae 5. Yolk-sac larva, 1.8 mm (CFRD Ref. Coll., reared at SWFSC, March 16, 1979); preflexion larvae, 3.0 mm (CFRD Ref. Coll., reared at SWFSC, March 19, 1979), 3.7 mm (CalCOFI 5207, station 87.35), 7.7 mm; flexion larva, 10.4 mm (CalCOFI 6607, station 110.41); postflexion larva, 13.7 mm (CalCOFI 5204, station 85.75).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–38	37
Precaudal	11	11
Caudal	26–27	26
Fins:		
Dorsal spines	0	0
Dorsal rays	79–89	83–85
Anal spines	0	0
Anal rays	61–69	65–66
Pelvic	6	6
Pectoral	10	10
Caudal:		
Total	17	17
Procurrent:		
Upper	6–8	7
Lower	10–12	11
Gill rakers:		
Upper	6–8	7
Lower	10–12	11
Branchiostegals		

LIFE HISTORY

Range: Monterey Bay, California to Costa Rica

Habitat: Sandy bottom to ca. 200 m depth

Spawning season: Larvae captured year-round in CalCOFI area, with peak abundance in July–August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom 1965
Ahlstrom & Moser 1975
Ahlstrom et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 3.0 mm, 4.9 mm, 7.1 mm (B. Sumida MacCall)
Postflexion larva, 11.7 mm (B. Sumida MacCall)

* Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.3 mm
Flexion length: 7.8 mm through 9.6–10.0 mm
Transformation length: ca. 23 through 25–31 mm
Fin development sequence: Elongate D, P_2, D & A & C, P_1
Pigmentation: *Preflexion*—Initially, above gut, on ventral margin of foregut, a bar centered at ca. 52% of tail length, a short series between bar & anus, & a cluster at extreme tip of notochord; by 5.0 mm, blotch above gas bladder, on ventral margin of gut, on margin of ventral finfold, blotch on ventral margin between anus & tail bar, series of 1 to several on ventral midline of tail anterior to bar with 1 or more posterior to bar (in some). *Late-preflexion–flexion*—On tips of elongate D & A rays; on isthmus; a blotch laterally on gut; bar centered at ca. 60% of tail length. *Postflexion*—By 12.0 mm, 3 dorsal & 2 ventral blotches at body margin (& pterygiophores) anterior to tail bar, on back of cerebellum, & embedded in snout; by late stage, on gular & medial branchial regions, scattered laterally on head, ventrolaterally on hindbrain, & on posterior margin of hypural. *Transformation*—4 epaxial & 2 hypaxial chevron-like patches anterior to tail bar & 1 pair posterior to bar; series on lateral midline of blind side; short series posteriorly on lateral midline of ocular side. *Juvenile*—5 epaxial patches.
Diagnostic features: Tail bar at ca. midtail in early preflexion stage (more posteriad in *C. fragilis* & *C. stigmaeus*); a single blotch on ventral margin anterior to tail bar (usually 2 in above species); cluster of melanophores at extreme tip of notochord appear as large blotch when expanded; 2 elongate, early-forming D & P_2 (left side) rays; 2 irregular rows of relatively large preopercular spines.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		31–41 37	41–44 43	33–48 41	32–35 33	31–32 31
BD/BL		12–22 16	23–33 30	34–43 39	33–37 35	33–36 34
HL/BL		15–21 18	22–25 24	26–27 27	26–26 26	27–28 28
HW/HL		40–61 48	44–46 45	38–48 43	41–41 41	26–28 27
SnL/HL		12–26 20	15–24 20	17–25 22	18–21 20	20–21 21
ED/HL*		26–43× 26–39	27–30× 27–32	25–36× 27–33	25–27× 25–27	27–28× 23–24
		32×33	28×31	30×30	26×26	28×23
P_1L/BL		4–6 6	6–9 8	7–9 8	6–7 7	8
P_2L/BL		0–10 1	28	22–31 26	18	9–11 10

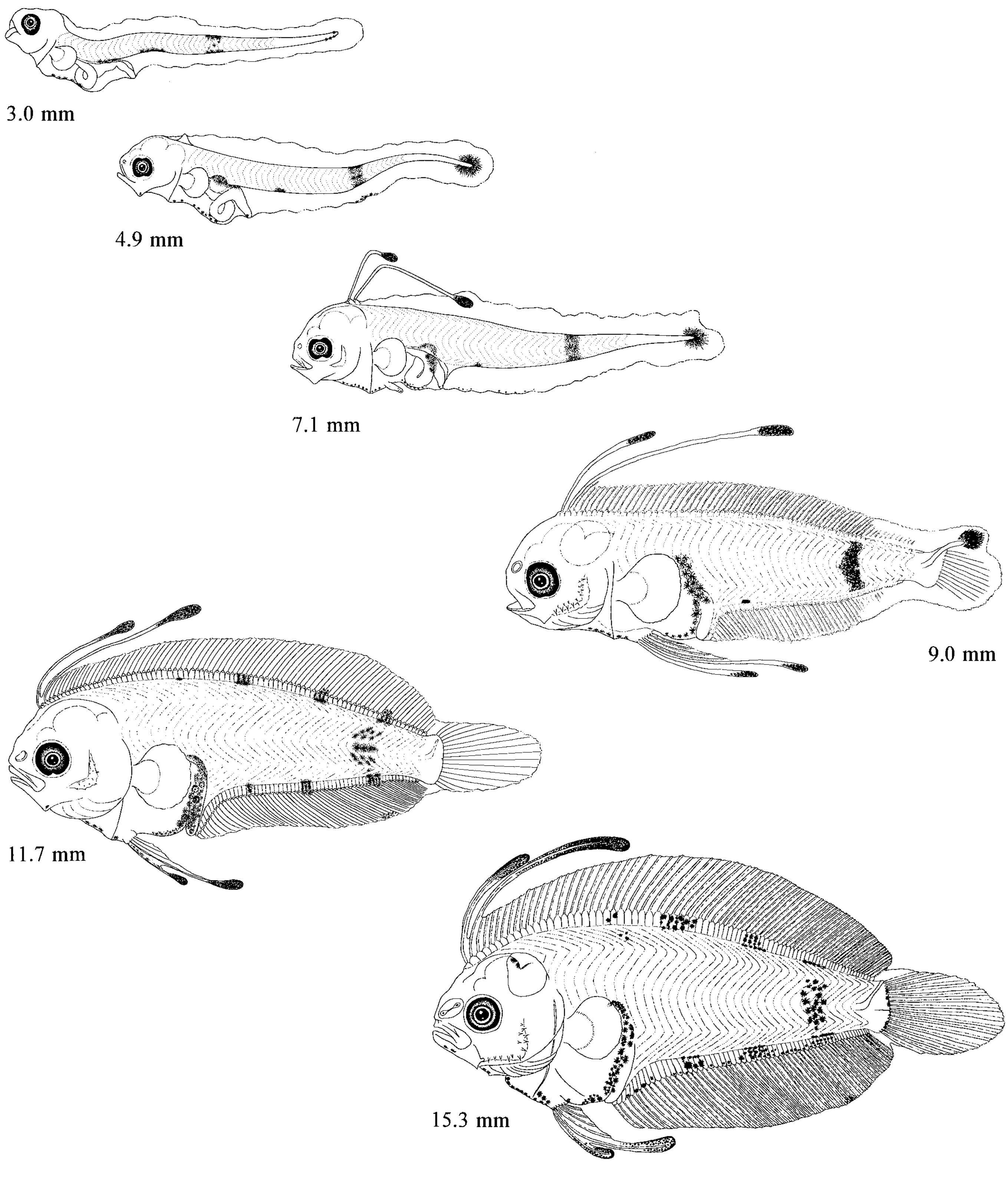

Figure Paralichthyidae 6. Preflexion larvae, 3.0 mm (CalCOFI 7510, station 120.40), 4.9 mm, 7.1 mm (CalCOFI 5707, station 120.35); flexion larva, 9.0 mm (Ahlstrom 1965); postflexion larvae, 11.7 mm (CalCOFI 5707, station 123.50), 15.3 mm (Ahlstrom 1965).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39	39
Precaudal	10	10
Caudal	29	29
Fins:		
Dorsal spines	0	0
Dorsal rays	90–99	
Anal spines	0	0
Anal rays	68–78	
Pelvic	6	6
Pectoral	14–17	
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	3–5	
Lower	8–10	
Branchiostegals		

LIFE HISTORY

Range: Southernmost region of Baja California to Peru, including Gulf of California

Habitat: Soft bottom to 44 m depth; common in estuaries

Spawning season: Possibly year-round

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 4.2 mm, 6.1 mm (R. C. Walker)
Postflexion larvae, 9.4 mm, 17.8 mm (R. C. Walker)

* Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.3 mm
Flexion length: ca. 6.0–9.0 mm
Transformation length: ca. 33–36 mm
Fin development sequence: Elongate D, P_2, D & A & C, P_1
Pigmentation: *Preflexion*—By 3.4 mm, on ventral midline from gular membrane to anus, above gas bladder, & on tips of elongate D rays; by 5.3 mm, 2 blotches medially on branchial region, paired short series on dorsal & ventral margins with lateral streak (on surface & above notochord) forming a partial bar, a blotch on margin of dorsal & ventral finfold (slightly anterior to bar), & some on tips of elongate P_2 rays; by 6.1 mm, patch forming on ventral surface of gut coil, apposing dorsal & ventral margin blotches between anus & bar, & patches on tabs that are forming on elongate D rays. *Flexion*—Apposing blotches on dorsum & ventrum anterior to original ones & 1 on dorsum at midtrunk; another lateral streak (on surface & embedded above notochord) on tail anterior to bar; blotch embedded above gut coil. *Postflexion*—By 12.0 mm, 5 streaks on dorsum & 3 on ventral margin (blotches extend distally from streaks to D & A pterygiophores & rays), 4 lateral streaks on tail, above midbrain, ventrolateral to hindbrain, on upper & lower jaws, at base of gular region, on branchiostegal membrane, at P_2 base, & 2 blotches ventrolaterally on gut; by 18.0 mm, on fleshy tab at isthmus, on preopercle, & on tabs on elongate P_2 rays. *Transformation*—6 ocelli on D & A fins, the 4th & 5th ones the largest.
Diagnostic features: Horn-like spines & prominent preopercular spines with bifid spine at angle; early-forming elongate D rays (eventually 9) & left P_2 rays (3) with pigmented tabs; pigment pattern with dorsal, ventral, & lateral streaks; pattern similar on left & right sides.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		42–49 44	41–48 44	31–47 41		
BD/BL		31–36 35	39–41 40	42–44 43		
HL/BL		25–26 26	24–27 26	27–34 30		
HW/HL		38–50 45	41	31–37 34		
SnL/HL		20–30 26	25–26 25	22–25 23		
ED/HL*		24–30× 26–33 27×29	23–25× 24–28 24×26	17–22× 16–24 19×19		
P_1L/BL		6–8 7	7–8 7	5–8 7		
P_2L/BL		0–41 9	45	48–68 55		

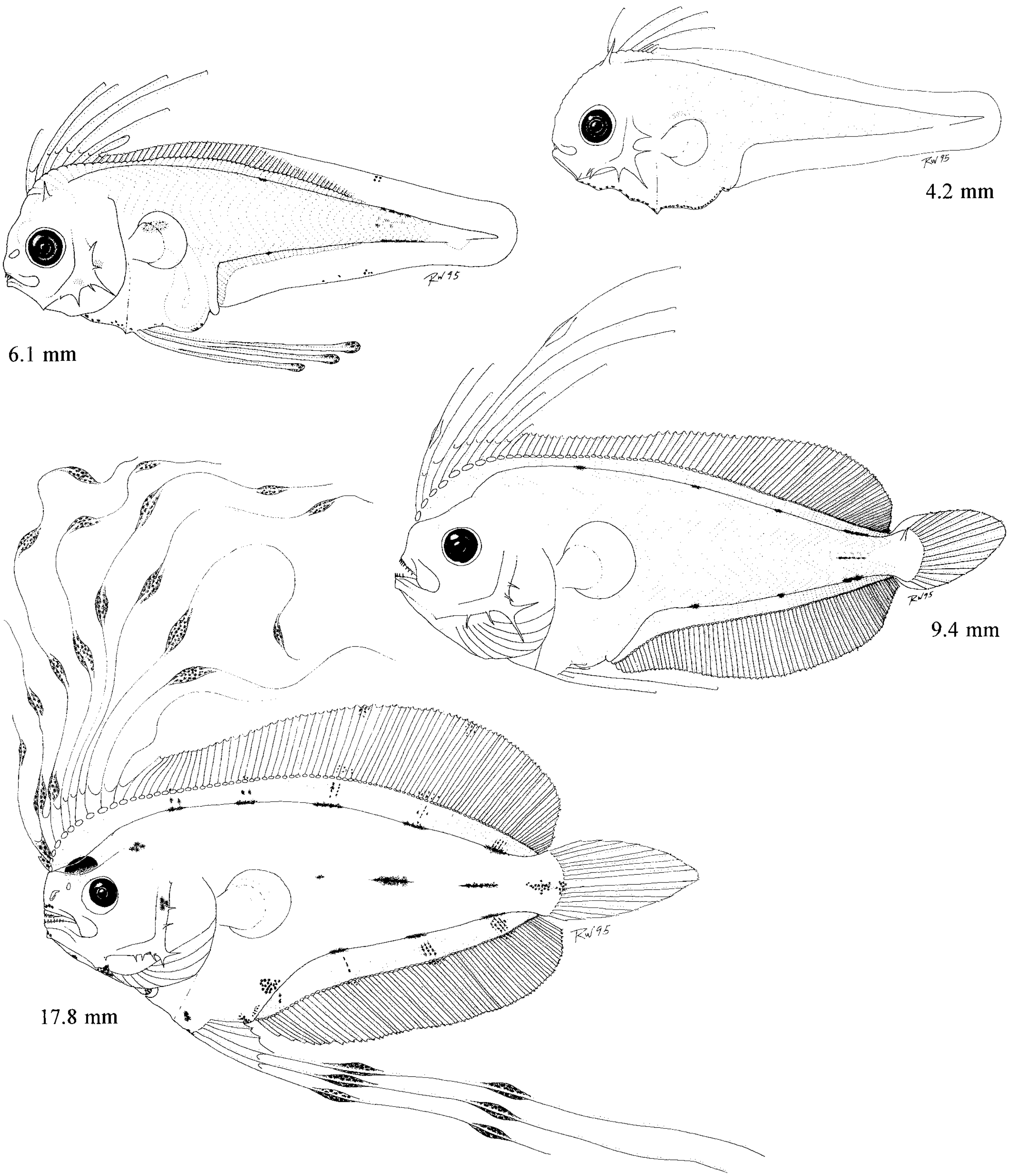

Figure Paralichthyidae 7. Preflexion larvae, 4.2 mm, 6.1 mm (EASTROPAC II, station 46.135); postflexion larvae, 9.4 mm (EASTROPAC I, station 13.042), 17.8 mm (TO 61–1, station 32).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–40	39
Precaudal	10	10
Caudal	27–30	29
Fins:		
Dorsal spines	0	0
Dorsal rays	82–95	89–91
Anal spines	0	0
Anal rays	69–76	72
Pelvic	6	6
Pectoral	14–17	16
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	4–7	6
Lower	7–10	9
Branchiostegals		

LIFE HISTORY

Range: Gulf of California to Peru

Habitat: Soft bottom to ca. 30 m depth; enters estuaries & lagoons

Spawning season:

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 14.9 mm (R. C. Walker)
Transformation specimen, 52.5 mm (R. C. Walker)

* Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: <16.2 mm
Transformation length: ca. 50 mm
Fin development sequence:
Pigmentation: *Postflexion*—By 16.2 mm, dorsal & ventrolateral to midbrain, ventrolateral to hindbrain, ventral margin of head, medially in branchial region, blotch above gut & 2 blotches on ventrolateral surface of gut, 5 streaks on dorsal body margin & 3 on ventral margin of tail (spreading to pterygiophores & myosepta), & evenly distributed on fleshy part of elongate D & P_2 rays; by 25.0 mm, distributed over entire surface of head & gut (heavier ventrally), 6 vague bars (including 1 on C base) beginning to form, D & A mottled, right side completely peppered, & myosepta, pterygiophores, & lateral midline of blind side outlined. *Transformation (pelagic juvenile)*—6 bars formed by groups of ocelli; numerous ocelli of various sizes on D & A; blind side as in late postflexion stage; elongate D & P_2 rays covered evenly.
Diagnostic features: Horn-like spines; prominent preopercular spines with spine at angle bifid; body more oval & eye smaller than in *C. panamensis*; streaks at body margin in early postflexion stage replaced by 5 vague bars which become clusters of ocelli in pelagic juvenile; numerous ocelli develop on D & A; 9 D & 3 A rays become extremely elongate & evenly pigmented.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				26–40 34	26–28 27	26–29 27
BD/BL				36–52 45	35–37 36	35–37 36
HL/BL				25–37 32	25–27 26	28–29 28
HW/HL				24–32 28	24–32 28	20–22 21
SnL/HL				19–25 23	21–23 22	22–23 22
ED/HL*				12–15× 12–16	12–12× 10–11	16–23× 12–12
				14×14	12×10	19×12
P_1L/BL				3–7 5	4–5 5	7–11 9
P_2L/BL				79–92 86	80	9–14 12

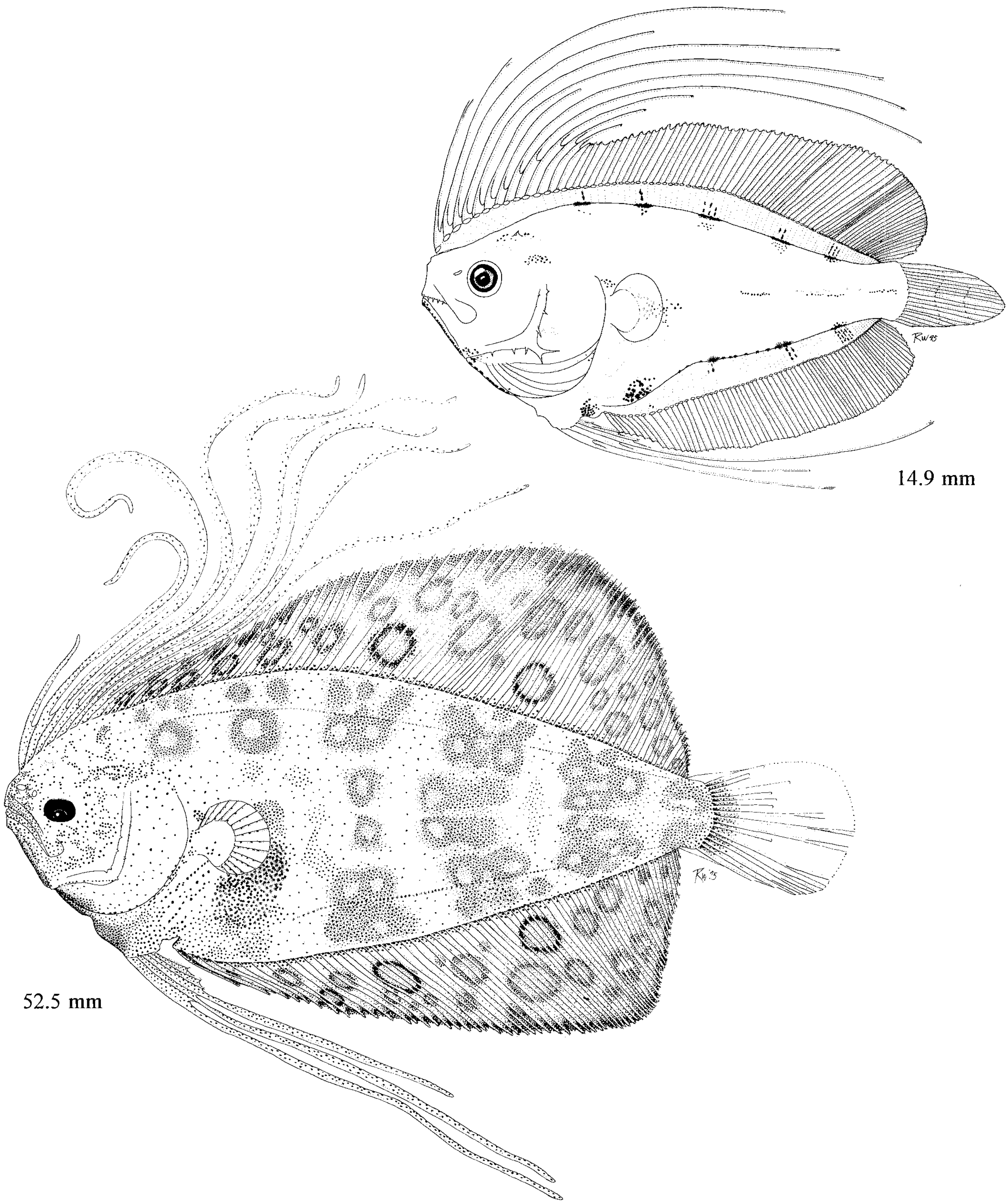

Figure Paralichthyidae 8. Postflexion larva, 14.9 mm (TO 61–1, station 32); transformation specimen, 52.5 mm (SIO 89–134).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–36	34
Precaudal	10	10
Caudal	23–26	24
Fins:		
Dorsal spines	0	0
Dorsal rays	70–89	72–74
Anal spines	0	0
Anal rays	54–68	56–66
Pelvic	6	6
Pectoral	9–10	10
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	4–7	4–5
Lower	6–10	7
Branchiostegals		

LIFE HISTORY

Range: Central Baja California to Peru, including Gulf of California; western Atlantic from Chesapeake Bay to Brazil, including Gulf of Mexico & Caribbean Sea

Habitat: Soft bottom to ca. 30 m depth; common in estuaries & coastal lagoons

Spawning season: Larvae are captured during January–March & June–October in CalCOFI area, with peak abundance in September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Tucker 1982
Ahlstrom et al. 1984a

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.9 mm, 4.8 mm (B. Sumida MacCall)
Flexion larva, 5.8 mm (B. Sumida MacCall)
Postflexion larva, 7.5 mm (B. Sumida MacCall)

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* All *Etropus* larvae appear to be a single type similar to larval *E. crossotus* from the Atlantic Ocean described by Tucker (1982); *E. peruvianus* occurs as far north as Bahía Magdalena, Baja California Sur; larvae of *E. peruvianus* are unknown.

† Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.0 mm
Flexion length: 4.8–7.1 mm
Transformation length: ca. 10.0 mm
Fin development sequence: Elongate D, C, P_2, D & A, P_1
Pigmentation: *Preflexion*—By 3.0 mm, on angular, at base of gular region, ventrally on P_1 base at axilla, a series on ventral surface of foregut, an elongate patch below gut coil, apposing dorsal & ventral blotches at midtail, double series on ventral margin of tail between anus & blotch, a single series posterior to blotch, several melanophores ventral to notochord tip, 1 to several blotches on margin of dorsal finfold, & 1 on margin of ventral finfold; by 3.3 mm, lateral streak between dorsal & ventral tail blotches (partial bar), double series on ventral margin of tail posterior to bar, & dorsal & ventral blotches now are short paired series on each side of midline; by 4.0 mm, on lower jaw & on tips of elongate D rays; by end of stage, 2 paired streaks on dorsum anterior to bar (some specimens) & notochord series has migrated to hypural margin. *Flexion*—On tip of elongate P_2 ray; paired series on ventral margin of tail intensified, some coalesced into streaks opposite streaks on dorsum; blotch on urohyal; ventral midline series (minute) forming on A base, 1 at each distal pterygiophore; above midbrain (in some). *Postflexion*—Additional pair of blotches on dorsum at nape (in some); several patches on margin of D & A.
Diagnostic features: 2 elongate D rays & 1 elongate P_2 ray; double row of melanophores ventrally on tail persists throughout larval period; partial bar at ca. midtail reduced to dorsal, ventral, & lateral streaks; up to 5 dorsal blotches & 3 ventral blotches in postflexion stage; several minute melanophores ventral to notochord tip in preflexion stage; series of melanophores on A pterygiophores; 2 rows of preopercular spines.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		40–44 42	40–45 43	38–43 42		
BD/BL		21–30 26	29–35 32	37–38 38		
HL/BL		20–22 21	23–25 23	25–27 26		
HW/HL		52–58 55	46–53 49	42–45 44		
SnL/HL		18–26 21	17–23 20	22–26 24		
ED/HL†		23–29× 28–33 26×30	23–26× 23–27 24×25	21–25× 22–27 23×24		
P_1L/BL		6–8 7	7–8 7	7–8 7		
P_2L/BL		0–0 0	0.4–15 7	8–26 17		

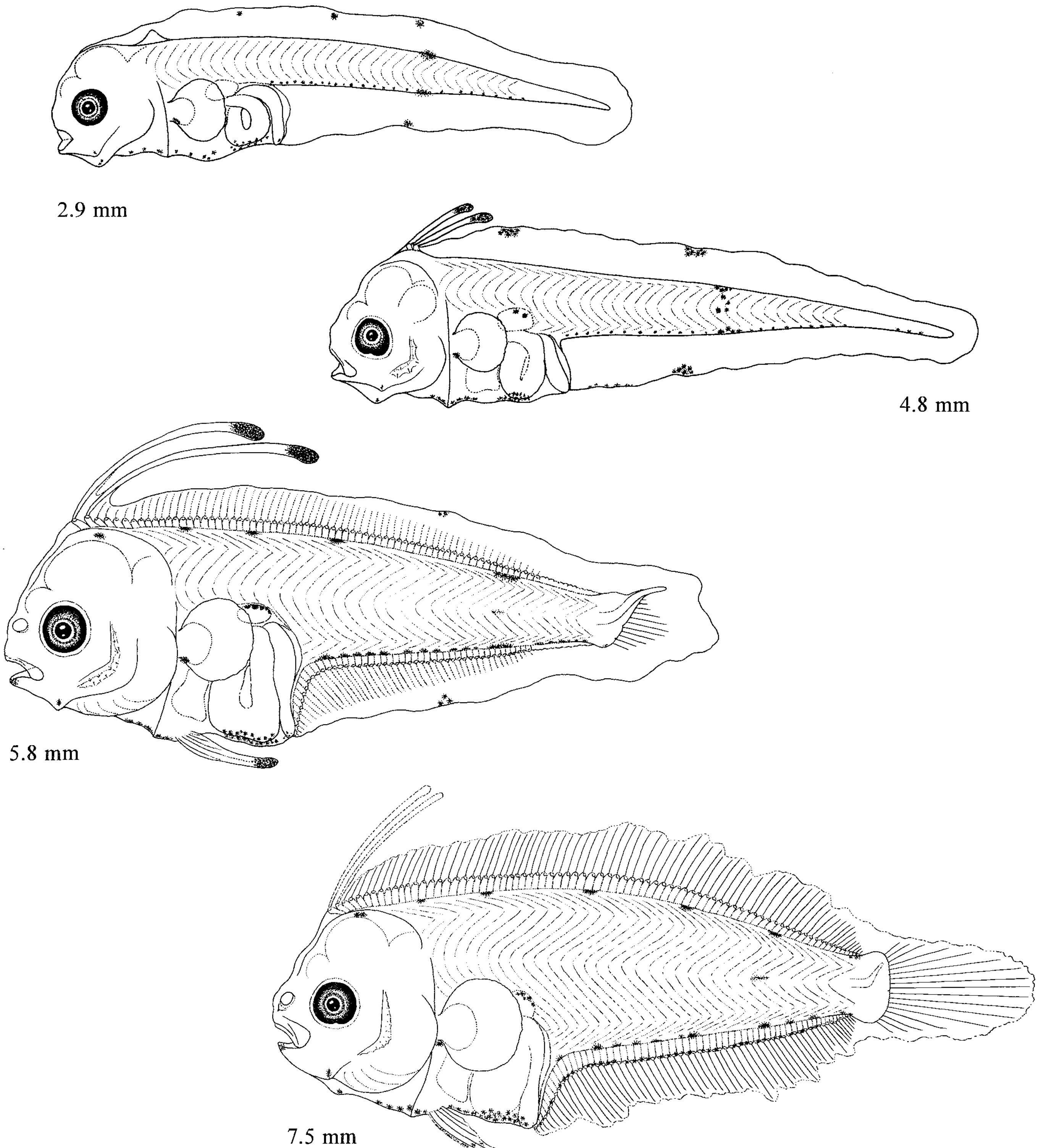


Figure Paralichthyidae 9. Preflexion larvae, 2.9 mm (CalCOFI 6507, station 130.50), 4.8 mm (CalCOFI 6207, station 127.50); flexion larva, 5.8 mm (CalCOFI 5708, station "Punta Eugenia"); postflexion larva, 7.5 mm (CalCOFI 6706, station 119.36).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–35	35
Precaudal	10	10
Caudal	24–25	25
Fins:		
Dorsal spines	0	0
Dorsal rays	82–91	85
Anal spines	0	0
Anal rays	64–72	67
Pelvic	6	6
Pectoral	9–12	11
Caudal:		
Total	16–17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–4	3
Lower	7–9	8
Branchiostegals		

LIFE HISTORY

Range: Pacific Coast of southern Baja California to Peru, including Gulf of California

Habitat: Soft bottom to 40 m depth

Spawning season: Larvae occur from June to January in CalCOFI area

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Guzman & Ayon 1995

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.7 mm, 2.9 mm, 4.9 mm (R. C. Walker)
Transformation specimen, 14.7 (R. C. Walker)

* *Syacium ovale* & *S. latifrons* have overlapping distributions from the northern Gulf of California to Peru; *S. ovale* is reported from the outer coast of Baja California as far north as Bahía Magdalena whereas *S. latifrons* is not known from the outer coast of Baja California. The larval *Syacium* series described in this guide is tentatively identified as *S. ovale*; see introduction to family for further discussion of *Syacium* larvae.

† Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 5.1–5.9 mm
Transformation length: ca. 14–18 mm
Fin development sequence: Elongate D, D & A & C, P_2, P_1
Pigmentation: *Preflexion*—Initially, at angle of lower jaw, blotch above gas bladder, on ventral margin of gut (heavier below gut coil), ca. 15 in series on ventral midline of tail, & ca. 3 below notochord tip; by 2.7 mm, on gular midline, ca. 9 in ventral tail series, & 1 below notochord tip; by 3.0 mm, on tips of elongate D rays, series on isthmus, 6–8 in ventral tail series, & none below notochord tip; by end of stage, series above gut coil & short series forming a streak on ventral margin posteriad on tail. *Flexion*—Above midbrain; on tip of P_2; 4 streaks on dorsum. *Postflexion*—By 6.1 mm, apposing streaks on dorsal & ventral margins posteriad on tail with lateral streak between them forming a partial bar & a series on ventral margin of tail between anus & bar; by 8.0 mm, some above hindbrain, some on ventral margin of branchiostegal membrane, streak on ventral margin of tail & another on lateral midline anterior to partial bar, & series (blind side) outline dorsal margin of body & ventral margin of tail; by end of stage, 3 streaks on ventral margin of tail & blotch ventrolaterally on gut. *Transformation*—5 streaks on dorsal margin & 4 on ventral margin of tail extend to pterygiophores, rays, & myosepta.
Diagnostic features: Horn-like spines; prominent preopercular spines with the one at angle becoming antler-like by 4.5 mm; initially 5 & later 8–9 elongate D rays; 3 slightly elongate P_2 rays; distinct pigment pattern; transforms at smaller size than *Cyclopsetta*.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		36–44 40	39–47 42	39–48 43	34–39 36	
BD/BL		18–40 32	39–45 41	44–52 48	42–47 44	
HL/BL		23–29 25	26–29 27	29–33 31	28–32 30	
HW/HL		40–60 51	41–51 47	38–48 43	33–44 37	
SnL/HL		26–32 30	29–39 33	26–34 29	25–26 26	
ED/HL†		23–32× 28–36 27×30	22–26× 26–29 25×28	23–28× 25–30 25×27	24–25× 23–24 24×24	
P_1L/BL		5–9 7	7–8 8	6–9 8	6–7 6	
P_2L/BL		0–2 0.4	4–14 8	14–19 17	22–23 23	

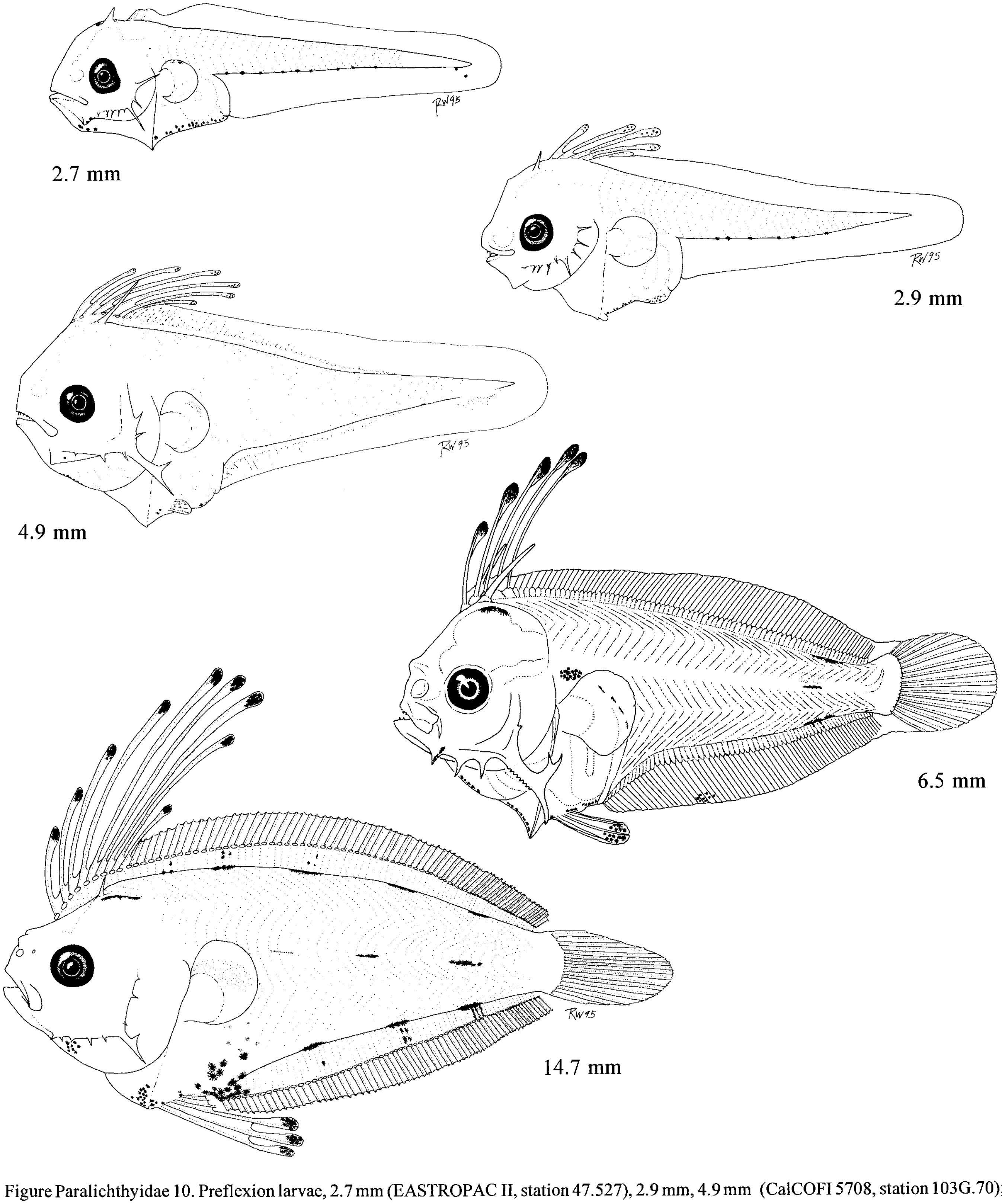


Figure Paralichthyidae 10. Preflexion larvae, 2.7 mm (EASTROPAC II, station 47.527), 2.9 mm, 4.9 mm (CalCOFI 5708, station 103G.70); postflexion larva, 6.5 mm (Ahlstrom et al. 1984a); transformation specimen, 14.7 mm (SIO 73–247).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–39	38
Precaudal	11	11
Caudal	26–28	27
Fins:		
Dorsal spines	0	0
Dorsal rays	63–70	67
Anal spines	0	0
Anal rays	47–55	51
Pelvic	6	6
Pectoral	11–12	11
Caudal:		
Total†	½+17+½	½+17+½
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	4–6	4
Lower	11–15	13
Branchiostegals		

LIFE HISTORY

Range: Monterey Bay, California to Gulf of California

Habitat: Soft bottom at 37–137 m depth

Spawning season: Larvae present year-round in CalCOFI area, with highest abundance in July–October & a peak in August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Sumida et al. 1979

ORIGINAL ILLUSTRATIONS (Illustrator)

Transformation specimen, 11.7 mm (G. Mattson)

* *Hippoglossina tetropthalma* & *H. bollmani* occur on the outer coast of Baja California, *H. tetropthalma* to as far north as Bahía Asuncion & *H. bollmani* to Bahía Magdalena. Larvae of these species are unknown.

† Small, splinter ray indicated by "½".

‡ Calculated from data in Sumida et al. (1972); specimens undergoing eye migration included, in postflexion stage by Sumida et al. (1972), were considered to be transformation specimens for our calculations.

§ Eye initially oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.22–1.38 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.20–0.26 mm
Shell surface: Smooth
Pigment: Late-stage embryo covered, except on caudal region; yolk peppered; on finfold
Diagnostic features: Size; pigment

LARVAE

Hatching length: <2.8 mm
Flexion length: ca. 4.5–5.2 mm
Transformation length: ca. 9–11 mm
Fin development sequence: Elongate D & C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Heavy on trunk & tail (except tip); short series above & below notochord tip; scattered on head & gut; embedded from snout to otic region, forming streak through eye; upper & lower jaws; median gular region & isthmus by end of stage; both sides of P_1 base; small rounded patch distally on dorsal finfold opposite broad patch proximally on ventral finfold. *Preflexion*—Augmented on gut & dorsally & laterally on head; more on P_1 base, some scattered on fin blade; late in stage, concentrated on head above fore- & midbrain, blotches on finfolds enlarge to include pterygiophore zones of D & A, series above notochord tip lacking, & ventral notochord series spreading to C rays. *Flexion–postflexion*—Reduced dorsally on head & body; lacking on hypural region.
Diagnostic features: Early larvae heavily pigmented with streak through eye, patch distally in dorsal finfold & proximally in ventral finfold, & pigment on both sides of P_1 base (early larvae of *Pleuronichthys coenosus* lack eye streak & P_1 base pigment & have a smaller dorsal finfold patch, proximal in position); 5 elongate D rays form crest; short series of preopercular spines develop in preflexion stage (lacking in *Pleuronichthys*).

MORPHOMETRICS (range & mean in %)‡

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		34–44 39	37–41 39	39–44 42	36–42 39	32–35 33
BD/BL		12–30 20	28–33 31	36–38 37	36–41 39	37–37 37
HL/BL		17–26 21	22–28 26	29–31 30	32–34 33	34–35 35
HW/HL						
SnL/HL		10–24 18	18–24 21	19–27 22	23–26 24	19–20 19
ED/HL§		28–44× 23–33 35×29	26–37× 30–34 31×32	28–36× 30–35 32×32	24–31× 27–32 27×30	31–35 33
P_1L/BL						
P_2L/BL						

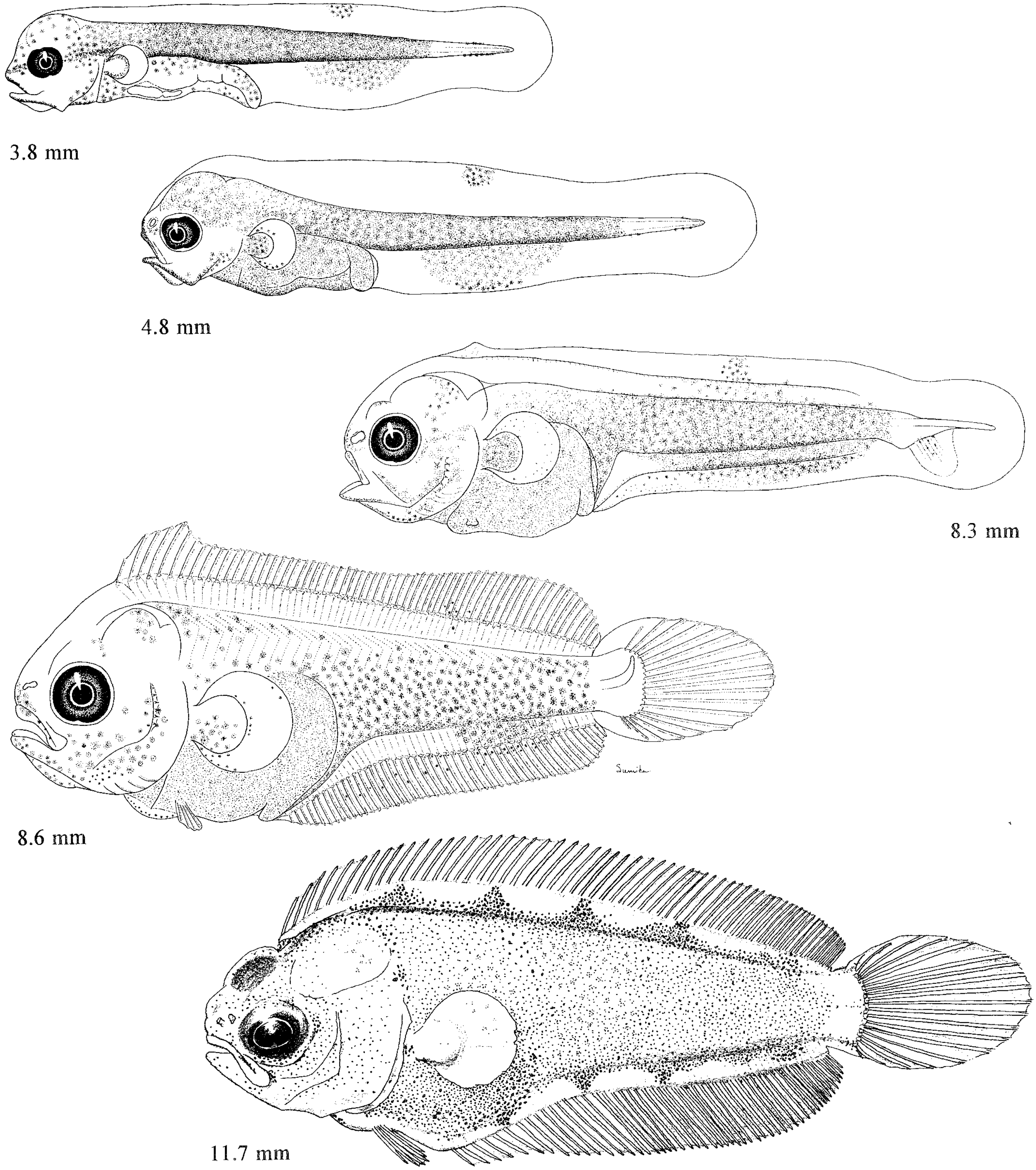


Figure Paralichthyidae 11. Preflexion larvae, 3.8 mm, 4.8 mm, 8.3 mm; postflexion larva, 8.6 mm (Sumida et al. 1979); transformation specimen, 11.7 mm (CalCOFI 5005, station 123.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	33–36	34
Precaudal	10	10
Caudal	23–26	24
Fins:		
Dorsal spines	0	0
Dorsal rays	66–76	69
Anal spines	0	0
Anal rays	49–59	53
Pelvic	6	6
Pectoral	10–13	12
Caudal:		
Total†	½+17+½	½+17+½
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	7–11	8–10
Lower	18–23	21
Branchiostegals		

LIFE HISTORY

Range: Northern Washington to Bahía Magdalena, Baja California Sur

Habitat: Soft, usually sandy, bottom to 183 m depth; common in surf zone, bays, & estuaries

Spawning season: Larvae captured year-round in CalCOFI area, with highest abundance during January–April & June–August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Moser & Watson 1990
Oda 1991

EARLY LIFE HISTORY DESCRIPTION‡

EGGS

Shell diam.: 0.68–0.83 mm **Yolk:** Homogeneous; 0.60–0.70 diam.
No. of OG: 1 **Diam. of OG:** 0.12–0.16 mm
Shell surface: Smooth
Pigment: On late-stage embryos, dorsally on head & body, laterally on trunk, laterally & ventrally on tail (none at tip), some on yolk near embryo, proximally on OG, widespread in dorsal finfold, & some in ventral finfold
Diagnostic features: Shell & OG diam. typically smaller than eggs of *Xystreurys liolepis*; pigment widespread in dorsal finfold in late-stage embryo, lacking at notochord tip

LARVAE

Hatching length: ca. 1.6–2.1 mm
Flexion length: ca. 5.0–7.0 mm
Transformation length: ca. 7.5–9.4 mm
Fin development sequence: Elongate D, C, D, A, P_2, P_1
Pigmentation: *Late yolk-sac*—Varies in dorsal finfold from widespread to a patch above trunk & another at midtail opposite patch in ventral finfold; on midbrain & snout; ventral & posterior to eye; on lower jaw; series on dorsum from nape to anterior region of tail; series above gut continuous with double row on postanal ventral margin, extending to midtail; some laterally on mid region of tail; series (minute) below tip of tail; laterally & ventrally on gut; embedded series beginning to form above notochord. *Preflexion*—Series becomes complete above notochord; double row on postanal ventral margin extends to tail tip; additional postanal ventrolateral rows; series on dorsum patchy in some specimens, becoming continuous by late in stage; increased in dorsal & ventral finfolds; throughout ventral finfold & most of dorsal finfold by end of stage; ventrally & laterally on isthmus; heavier anteriorly & laterally on gut; on preopercle & opercle. *Flexion*—On elongate D rays, developing P_2, C rays, & A pterygiophores; on branchiostegal membrane; diffuse bar posteriorly on tail. *Postflexion*—Increased on lateral trunk & tail & on D & A late in stage.
Diagnostic features: Sphenotic & preopercular spines present (no sphenotic spines in *Xystreurys liolepis*); slender & narrow body compared to *X. liolepis* & finfold pigment not as patchy in early preflexion stage; series embedded above notochord (not visible in *X. liolepis*); 2nd through 6th D rays early-forming & elongate; pattern and sequence of formation of lateral body pigment differs from that of *X. liolepis*.

MORPHOMETRICS (range in %)§

	Y-S	PrF	F	PoF & Tr	Juv
Sn-A/BL	43–46	41–57	39–52	31–47	
BD/BL		16–32	26–39	33–43	
HL/BL		18–28	21–28	26–32	
HW/HL	8–10	11–19	13–15	11–15	
SnL/HL					
ED/HL					
P_1L/BL					

* *Paralichthys woolmani* occurs as far north as Bahía Magdalena on the outer coast of Baja California & there is an unconfirmed occurrence of *P. aestuarius* from Bahía Magdalena. We have not identified larvae of these species in CalCOFI samples.
† Small, "splinter" rays are indicated by "½".
‡ Based on Oda (1991).
§ From Oda (1991); the range is given for each stage; only values from formalin-preserved specimens are listed.

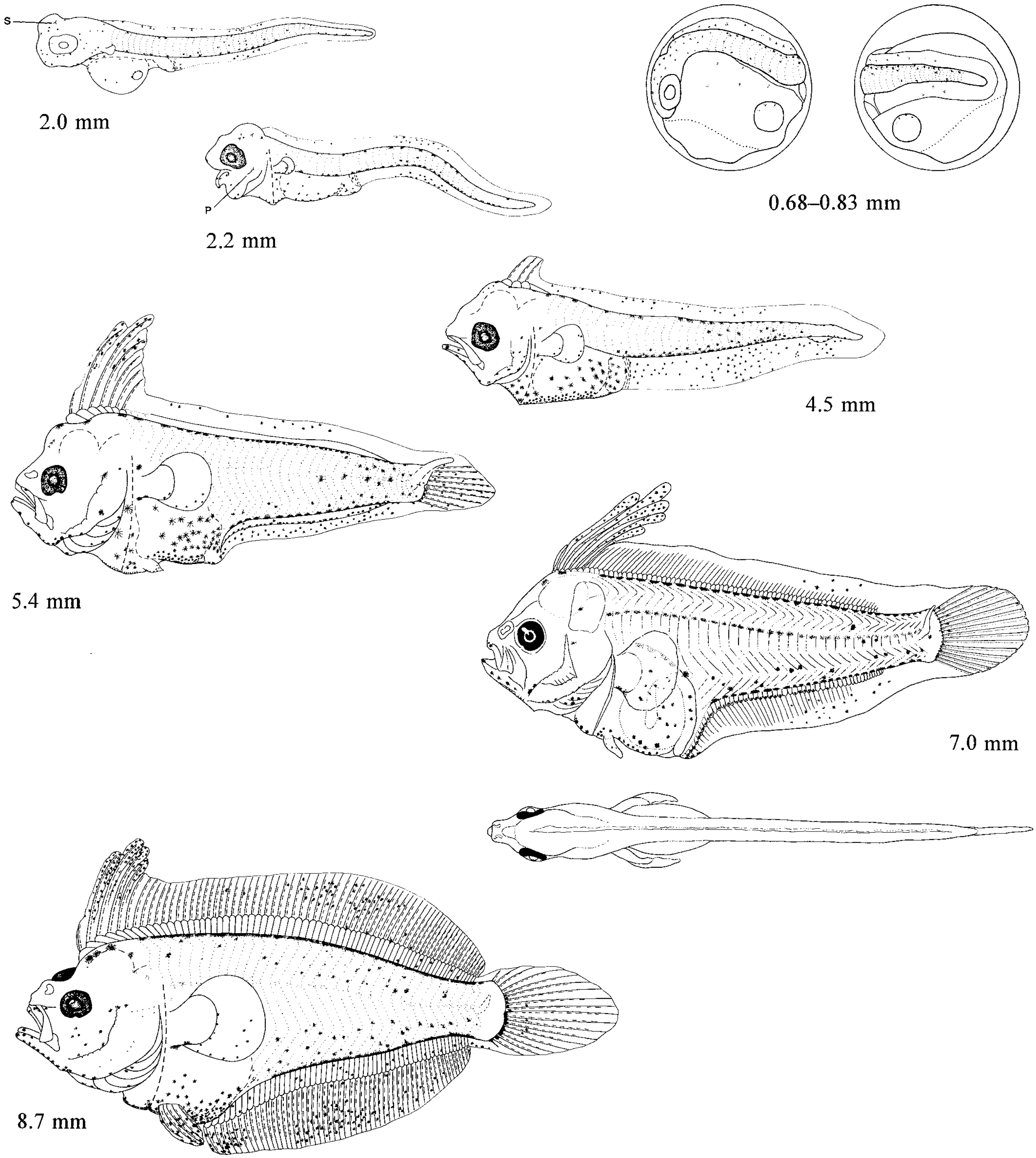


Figure Paralichthyidae 12. Late-stage egg, 0.68–0.83 mm, views of head and tail regions; yolk-sac larva, 2.0 mm (s = sphenotic spine); preflexion larvae, 2.2 mm (p = preopercular spine), 4.5 mm; flexion larva, 5.4 mm (Oda 1991); postflexion larva, 7.0, lateral and dorsal views (Ahlstrom et al. 1984a); transformation specimen, 8.7 mm (Oda 1991).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–39	37
Precaudal	11–12	11
Caudal	25–28	26
Fins:		
Dorsal spines	0	0
Dorsal rays	73–80	
Anal spines	0	0
Anal rays	57–62	
Pelvic	6	6
Pectoral	11–13	11
Caudal:		
Total*	½+17+½	½+17+½
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–4	3
Lower	6–7	7
Branchiostegals		

LIFE HISTORY

Range: Monterey Bay, California to Gulf of California

Habitat: Sand or mud bottom to 79 m depth

Spawning season: Larvae captured year-round in CalCOFI area; highest abundance in summer & autumn with peak in August; larvae captured in July–December in nearshore zone

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Moser & Watson 1990
Oda 1991

* Small, splinter rays are indicated by "½".
† Based on Oda (1991).
‡ From Oda (1991); the range is given for each stage; only values for formalin-preserved specimens are listed.

EARLY LIFE HISTORY DESCRIPTION†

EGGS

Shell diam.: 0.82–0.92 mm **Yolk:** Homogeneous; 0.65–0.74 mm diam.
No. of OG: 1 **Diam. of OG:** 0.18–0.24 mm
Shell surface: Smooth
Pigment: On late-stage embryos, dorsally on head & body, above & below notochord tip, some on yolk near embryo, proximally on OG, patch in dorsal finfold at trunk & tail, & patch in ventral finfold
Diagnostic features: Shell & OG diam. typically greater than in *Paralichthys californicus*; pigment present at notochord tip & patchy in dorsal finfold in late-stage embryos.

LARVAE

Hatching length: ca. 1.8–2.3 mm
Flexion length: ca. 5.5–7.0 mm
Transformation length: ca. 7.5 – >9.0 mm
Fin development sequence: Elongate D, C, D, A, P_2, P_1
Pigmentation: *Late yolk-sac*—Patches on margin of dorsal finfold at trunk & midtail with apposing patch in ventral finfold; above & below tip of tail; above midbrain; dorsally & ventrally on gut; series forms on postanal ventral margin to about midtail. *Preflexion*—On dorsal & ventral finfolds; some on lower jaw & opercle; heavier laterally & ventrally on gut; dorso- & ventrolaterally on trunk & tail; double rows on dorsum & on ventral margin of tail by end of stage; series embedded above notochord but obscured by muscle. *Flexion*—On elongate D rays; irregular rows laterally on trunk & tail, except for hypural region; concentrated on finfold & pterygiophores of developing D & A; on upper & lower jaws. *Postflexion*—More laterally on trunk & tail except on posteriormost region; on all fins; series of streaks on lateral midline posteriorly on tail; on isthmus.
Diagnostic features: Deeper-bodied & more robust than *Paralichthys californicus*; gut more saccular; only preopercular spines (no sphenotic spines as in *P. californicus*); concentrated distal pigment patches on finfolds & scant pigment on postanal ventral margin in yolk-sac & early preflexion larvae; finfold pigment widespread in late preflexion stage, becoming restricted in flexion larvae; heavier on dorsal & ventral midlines & laterally than in *P. californicus*, except none dorsally & laterally on posteriormost region of tail.

MORPHOMETRICS (range in %)‡

	Y-S	PrF	F	PoF & Tr	Juv
Sn-A/BL	38–42	39–55	46–52	39–52	
BD/BL		19–37	30–42	41–54	
HL/BL		20–30	25–34	29–36	
HW/HL	9–13	13–21	15–21	15–19	
SnL/HL					
ED/HL					
P_1L/BL					
P_2L/BL					

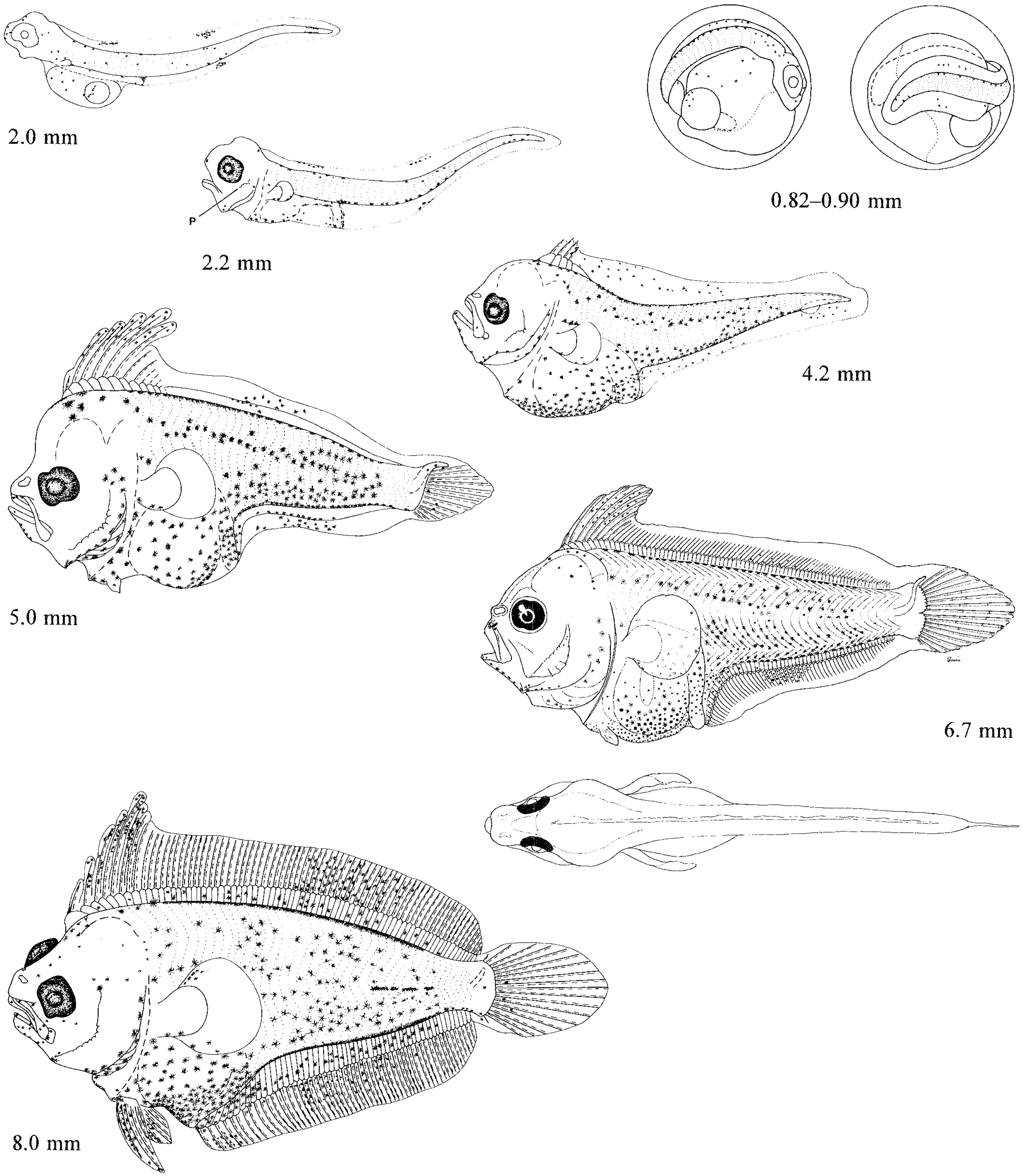


Figure Paralichthyidae 13. Late-stage egg, 0.82–0.90 mm, views of head and tail regions; yolk-sac larva, 2.0 mm; preflexion larvae, 2.2 mm (p = preopercular spine), 4.2 mm; flexion larva, 5.0 mm (Oda 1991); postflexion larva, 6.7 mm, lateral and dorsal views (Ahlstrom et al. 1984a); transformation specimen, 8.0 mm (Oda 1991).

BOTHIDAE: Lefteye flounders

H. G. MOSER AND S. R. CHARTER

Bothidae consists of at least 115 species, grouped in ca. 20 genera, found primarily in tropical and subtropical regions of the Atlantic, Pacific, and Indian Oceans. Hensley and Ahlstrom (1984) proposed monophyly for the family based on the presence of at least two series of intermuscular bones (myorhabdoi), loss of the preorbital bone on the blind side, and a high degree of pelvic fin asymmetry. Chapleau (1993) expressed some doubt about these characters as indicators of monophyly for the family and Patterson and Johnson (1995) have shown that myorhabdoi occur outside of the pleuronectiforms. The family is represented in the California Current region by four species, *Bothus leopardinus*, *Engyophrys sanctilaurentia*, *Monolene asaedai*, and *Perissias taeniopterus* (Table Bothidae 1). Bothid larvae are uncommon in CalCOFI collections and only those of *B. leopardinus* are captured as far north as Punta Eugenia, Baja California Sur. Larvae of the other three species are rarely collected off southernmost Baja California; most specimens are from the Gulf of California and from waters off mainland Mexico and Central America.

The taxonomic status of some species is unsettled. Norman (1934) distinguished *B. constellatus* from *B. leopardinus* on the basis of a wider interorbital distance and this is recognized by some recent workers (e.g., Allen and Robertson 1994); however, variation in interorbital space is attributable to sexual dimorphism, with the males of *Bothus* having a relatively wider interorbital space (R. J. Lavenberg, pers. comm.). We can distinguish only one kind of *Bothus* larva, *B. leopardinus*, in samples from the CalCOFI area and from other regions of the eastern Pacific. Another species, *B. mancus*, is widely distributed throughout the Indo-Pacific and has been recorded from the Galápagos Islands and from other insular habitats in the eastern Pacific. We have not identified its distinctive larvae (Ahlstrom et al. 1984a; Ozawa and Fukui 1986) in eastern Pacific samples. Except for a single 39 mm larva of *Monolene maculipinna*, easily identified by high dorsal and anal fin-ray counts, we find only a single kind of *Monolene* larva in samples from the eastern Pacific and refer it to *M. asaedai*. Another species, *M. dubiosa*, known only from the type locality off Acapulco, Mexico, is probably synonymous with *M. asaedai*, since the principal differentiating character, relative eye size, changes with growth after settlement (pers. obs.). If additional specimens become available and the two species prove to be synonymous, the name *M. dubiosa* has priority.

Bothids are small to medium-sized (most species <20 cm) flatfishes with the eyes on the left side of the body. Dextral individuals are extremely rare. Spinous rays are lacking. The pelvic fins are short and asymmetrical, with 6 rays in almost all species. The left pelvic fin is on the ventral midline, has a longer base than the fin on the right side, and originates anterior to the origin of the right fin. In taeniopsettine genera (*Engyophrys*, *Perissias*, *Taeniopsetta*, and *Trichopsetta*) ca. 2 rays of the left fin are anterior to the origin of the right fin, while in Bothinae (all other bothid genera), 3 to 4 rays of the left fin are forward of the right fin (Hensley and Ahlstrom 1984; Hensley 1995a). The dorsal fin originates in front of the superior eye; in some species one or more of the anterior rays may be elongate. The mouth is relatively small. The ocular pectoral fin is always present and is elongate in some species (e.g., *B. mancus*), whereas the fin on the blind side may be reduced or absent in some species. The caudal fin usually is rounded or is slightly wedge-shaped in some species. The lateral line is strongly arched over the pectoral fin on the ocular side and may be weakly developed or absent on the blind side. Scales are small and cycloid or feebly ctenoid. The urinary papilla is on the blind side. Sexual dimorphism is widespread in the family (e.g., males of some species may have a wider interorbital space, elongate pectoral and/or pelvic fin rays, eye ornamentation, or distinct color patterns (Norman 1934). Bothids live in a variety of soft-bottom habitats (sand, mud, shell), primarily on the continental shelf; they are ambush predators feeding on invertebrates and fish. Some species are common in estuaries and coastal lagoons. They have some commercial importance and are commonly taken in bottom-trawl fisheries.

Bothids are oviparous; information on fecundity and spawning frequency and seasonality is scanty or nonexistent for most species. *Bothus* species in the western Atlantic have prolonged spawning seasons (Martin and Drewry 1978) and, in the CalCOFI region, *B. leopardinus* larvae are present during most of the year, with highest abundance in the fall. The few described bothid eggs (*Arnoglossus* species) are small (0.59–0.88 mm diam.), round, have a smooth chorion, homogeneous yolk, narrow perivitelline space, and a single oil globule, 0.10–0.13 mm in diameter (Russell 1976; Ahlstrom et al. 1984a). Information on size at hatching is scanty since yolk-sac larvae are rarely collected in good condition; those of *A. laterna* are ca. 2.6 mm while those of *A. thori* are ca. 2.0 mm (Russell 1976). The oil globule is located posteriorly in the yolk sac and the mouth has not yet formed. Melanistic pigment is sparse or lacking in eggs and larval stages of bothids but some genera (e.g., *Arnoglossus*, *Grammatobothus*, *Laeops*, *Psettina*, *Trichopsetta*) have extensive melanistic pigmentation. Red and yellow chromatophore patterns have been reported in live eggs and larvae of some species (Russell 1976; Ozawa and Fukui 1986). Typically, preflexion larvae of *Bothus* species have pigment at the tip of the notochord. Early preflexion bothid larvae are relatively slender, have an elongate foregut with the thin elongate liver lying below it, a coiled hindgut, and a tentacle-like anterior dorsal fin ray. In the few available intact specimens of *Arnoglossus*, the elongate ray terminates in a pigmented bulb (Russell 1976) and such a structure may be present in other bothid larvae, but is destroyed during capture. In some species of *Arnoglossus*, the ray is pigmented and ornamented with a series of streamers and, in *Monolene*, the ray has a fleshy pigmented vane (Futch 1971; Ahlstrom et al. 1984a; Ozawa and Fukui 1986). Bothid larvae become compressed and deep-bodied, range in profile from oval to almost round, and develop a rich array of specialized features that aid in identification and systematic analyses (Ahlstrom et al. 1984a). Taeniopsettine larvae have spines on the urohyal bone, basipterygium, and cleithrum and have a cluster of three spines in the otic region. Bothine larvae may have urohyal, basipterygial, and cleithral spines present in various combinations or may lack spination entirely. Most bothid larvae transform and settle at <30 mm; however, some species of *Chascanopsetta* and *Laeops* may exceed 80 mm before transformation (Ahlstrom et al. 1984a).

Bothid larvae in the CalCOFI area can be identified by a combination of morphological and pigment characters; our identification of *P. taeniopterus* larvae must be considered tentative until transformation specimens become available. Early preflexion larvae of *P. taeniopterus* have several melanophores along the ventral margin of the gut but lack pigment on the gut coil or terminal section. Those of *B. leopardinus* have a series of melanophores between the gut coil and the terminal gut section and are the only bothid in the region with pigment on the notochord tip. Gut pigment is absent in larvae larger than ca. 5 mm and notochord pigment is lost in late flexion or early postflexion larvae. The smallest available preflexion larva of *M. asaedai* (3.8 mm) has a cluster of melanophores above the gut coil and minute melanophores on the ventral margin from the anus to the isthmus. The smallest *E. sanctilaurentia* larvae (1.9–2.2 mm) have one or two melanophores on each side of the terminal section of the gut where it diverges from the trunk, a sparse series on the ventral margin from the anus to the isthmus, and some on the lower jaw. By ca. 4.0 mm, the only remaining pigment is a pair of melanophores proximally on the terminal gut section and a few ventral margin melanophores between the isthmus and the anus. Later larval stages are deeper-bodied than the oval-shaped *P. taeniopterus*, and have a blunter anterior profile. By 5.0 mm, otic spines are present on both taeniopsettine species, clearly separating them from the bothines *B. leopardinus* and *M. asaedai*, which lack otic spines. Flexion and postflexion *M. asaedai* larvae are more slender compared with the other species and develop a fleshy vane on the prominent, pigmented anterior dorsal ray. Melanistic blotches develop on the trunk, tail, gut, and fins of late postflexion larvae of *E. sanctilaurentia* but postflexion larvae of the other bothid species in the region are unpigmented. Transforming *E. sanctilaurentia* develop optic papillae similar to those in *E. senta* (Hensley 1977).

The following descriptions are based on detailed observations of 7–24 specimens of each species and literature where applicable (Table Bothidae 2). Meristics were obtained from several literature sources (Ahlstrom et al. 1984a; Allen and Robertson 1994; Hensley 1995a) and from original counts made during this study. Ecological information is based primarily on Martin and Drewry (1978), Ahlstrom et al. (1984a), Allen and Robertson (1994), and Hensley (1995a).

Table Bothidae 1. Meristic characters for the bothid species in the California Current vicinity. All species have 6 pelvic rays. Pectoral fin-ray counts are from the ocular side.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	C	Gill rakers
Bothus leopardinus	10	28–29	38–39	86–92	64–70	10–12	17	5–6+9–10
Engyophrys sanctilaurentia	10	30–31	40–41	81–89	66–71	10–13	17	3–4+6
Monolene asaedai	10–11	28–30	38–40	75–85	58–66	9–12	16–18	5–6+8–10
M. maculipinna	10	36	46	98–102	78–85	15–16	17	+8–9
Perissias taeniopterus	10	28–30	38–40	81–88	61–70	10–11	17	2–4+7–9

Table Bothidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the bothid species descriptions.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Bothus leopardinus	0	0	7 1.7–7.3	4 7.7–8.5	10 9.9–29.2	0	3 23.3–28.4
Engyophrys sanctilaurentia	0	0	3 2.0–4.0	1 6.1	11 7.1–36.2	2 26.7–32.0	3 37.7–39.2
Monolene asaedai	0	0	1 3.8	0	4 11.6–29.2	0	2 54.1–54.8
Perissias taeniopterus	0	0	10 2.8–6.8	3 7.4–8.1	6 8.7–23.7	0	3 34.1–41.4

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–39	38
Precaudal	10	10
Caudal	28–29	28
Fins:		
Dorsal spines	0	0
Dorsal rays	86–92	90–91
Anal spines	0	0
Anal rays	64–70	68
Pelvic	6	6
Pectoral	10–12	11
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	5–6	6
Lower	9–10	10
Branchiostegals		

LIFE HISTORY

Range: Bahía Sebastián Viscaíno, Baja California to Peru, including Gulf of California

Habitat: Sandy bottom at 55–120 m depth

Spawning season: Larvae present from June to February in CalCOFI area, with peak abundance in October–November

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Moser 1981

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 1.9 mm (R. C. Walker)
Preflexion larva, 4.5 mm (G. Mattson/R.C. Walker)
Flexion larva, 8.5 mm (R. C. Walker)
Postflexion larva, 27.1 mm (G. Mattson/R.C. Walker)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.:
Yolk:
No. of OG:
Diam. of OG:
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <1.7 mm
Flexion length: ca. 7.7–8.5 mm
Transformation length: ca. 23–29 mm
Fin development sequence: Elongate D, D & A, C, P_2, P_1
Pigmentation: *Preflexion*—Initially, vertical series between gut coil & terminal gut section, 1 on dorsum above gut coil, sparse series on ventral margin from anus to isthmus, & pair on lower jaw; elongate blotch above & below notochord tip; by 3.2 mm, only on notochord tip; blotches expand onto finfold in some specimens. *Flexion–transformation*—Lacking on notochord tip in late flexion to early postflexion stages. *Juvenile*—Small spots cover head & body; series of vertical bars on D & A fins.
Diagnostic features: Early preflexion larvae have blotches above & below notochord tip, vertical series between gut coil & terminal gut section, & series on ventral margin from anus to isthmus; notochord blotches present through, at least, flexion stage; elongate D ray present by ca. 2.2 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–53 41	30–33 31	19–33 26		24–29 27
BD/BL		17–43 31	42–52 46	66–78 71		46–50 48
HL/BL		16–23 21	21–24 23	20–27 24		28–31 29
HW/HL		27–69 43	29–32 31	23–39 30		25–37 30
SnL/HL		23–34 28	32–34 33	24–35 28		21–24 23
ED/HL*		20–39× 20–54 28×30	20–23× 21–25 22×24	16–22× 17–23 19×20		21–24× 16–17 22×17
P_1L/BL		5–10 7	6–8 7	2–10 7		14–19 16
P_2L/BL		0–0 0	0–0 0	2–7 6		8–8 8
BDA/BL		18–50 35	52–65 56	64–80 72		43–46 44

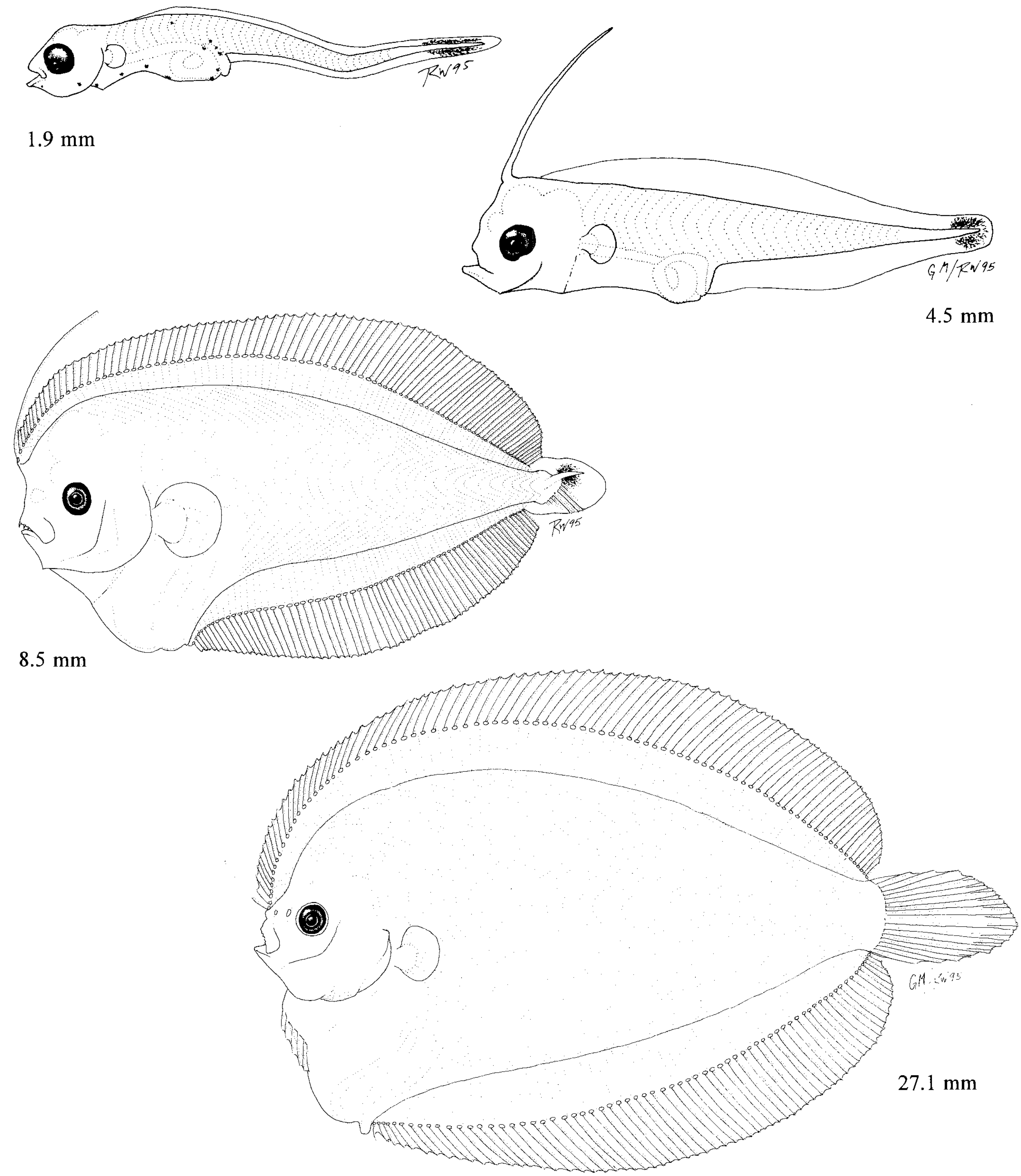


Figure Bothidae 1. Preflexion larvae, 1.9 mm, (EASTROPAC II, station 47.527), 4.5 mm (CalCOFI 5109, station 137.50); late flexion larva, 8.5 mm (EASTROPAC II, station 46.112); postflexion larva, 27.1 mm (CalCOFI 5202, station 137.40).

MERISTICS

	Range	Mode
Vertebrae:		
Total	40–41	40
Precaudal	10	10
Caudal	30–31	30
Fins:		
Dorsal spines	0	0
Dorsal rays	81–89	83
Anal spines	0	0
Anal rays	66–71	67
Pelvic	6	6
Pectoral	10–13	11
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	3–4	4
Lower	6	6
Branchiostegals		

LIFE HISTORY

Range: Bahía Sebastián Viscaíno, Baja California to Panama, including the Gulf of California

Habitat: On soft bottom of mud & shell between 46 & 157 m depth

Spawning season: Larvae collected year-round

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.0 mm, 4.2 mm (R. C. Walker)
Late flexion larva, 6.1 mm (R.C. Walker)
Postflexion larva, 28.9 mm (R. C. Walker)
Transformation larva, 32.0 mm (R. C. Walker)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.0 mm
Flexion length: >4.0 mm, <7.1 mm
Transformation length: ca. 27–37 mm
Fin development sequence: Elongate D, D & A, C, P_2, P_1
Pigmentation: *Preflexion*—Initially, 1 or 2 on each side of terminal section of gut at point of deflection from trunk, sparse series on ventral margin from anus to isthmus, & series on lower jaw (at slightly later stage); at ca. 4.2 mm, a pair proximally on terminal section of gut & more on ventral margin of gut & isthmus. *Flexion–early postflexion*—None. *Late postflexion*—Larvae ca. >18.0 mm have large blotches (3 midlaterally on body, 3 over gut coil, 1 over liver, 5 on D pterygiophores, 3 on A pterygiophores, ca. 8 on D rays, & ca. 6 on A rays).
Diagnostic features: Early preflexion larvae have pair of melanophores proximally on terminal gut section, some on ventral margin of gut, & lack notochord tip pigment; blotches in late postflexion stage; elongate D ray forms at ca. 2.0 mm; deeper-bodied than *Perissias taeniopterus* & forehead higher & steeper; margin of urohyal more vertical than in *P. taeniopterus*; basipterygial, urohyal, cleithral, & 3 otic spines.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		48–52 50	 36	16–39 28	19–26 23	26–27 26
BD/BL		13–36 22	 61	55–71 67	50–58 54	44–48 45
HL/BL		18–21 20	 28	22–25 23	25–28 26	29–29 29
HW/HL		44–55 50	 37	24–44 33	23–23 23	24–26 25
SnL/HL		20–44 29	 34	23–36 30	22–23 22	15–18 16
ED/HL*		38–41× 36–50		23–32	22–23× 20–22	25–28× 16–17
		40×42	28×28	27	22×21	27×16
P_1L/BL		5–10 7	 9	5–11 7	4–5 5	13–17 15
P_2L/BL		0–0 0	0–0 0	4–11 7	11–12 11	12–13 13
BDA/BL		13–41 25	 57	54–72 66	50–58 54	44–48 45

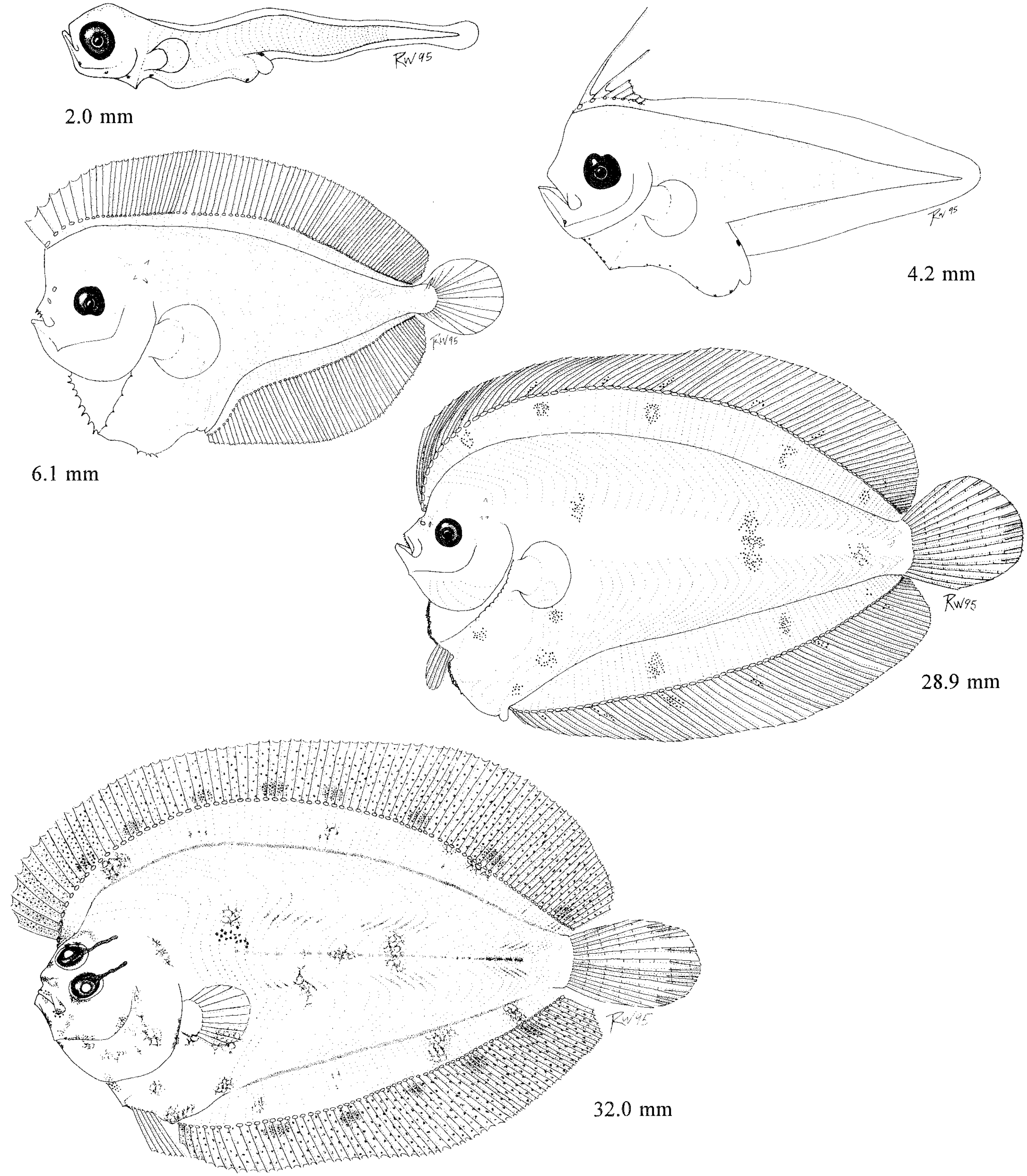


Figure Bothidae 2. Preflexion larvae, 2.0 mm (EASTROPAC II, station 47.527), 4.2 mm (CalCOFI 5210, station 133.30); late flexion larva, 6.1 mm (SIO 65–244); postflexion larva, 28.9 mm (CalCOFI 7210, station 157G.70); transformation specimen, 32.0 mm (SIO 62–76).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–40	39
Precaudal	10–11	10
Caudal	28–30	29
Fins:		
Dorsal spines	0	0
Dorsal rays	75–85	79–80
Anal spines	0	0
Anal rays	58–66	59
Pelvic	6	6
Pectoral	9–12	11
Caudal:		
Total	16–18	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	5–6	6
Lower	8–10	9–10
Branchiostegals		

LIFE HISTORY

Range: Mouth of Gulf of California to Panama

Habitat: Soft bottom on shelf to >100 m depth

Spawning season:

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 3.8 mm (R. C. Walker)
Postflexion larvae, 11.6 mm, 29.2 mm (R.C. Walker)
Juvenile, 54.1 mm (R. C. Walker)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <3.8 mm
Flexion length: <11.3 mm
Transformation length: >29 mm, <54 mm
Fin development sequence: Elongate D, D & A & C, P_2, P_1
Pigmentation: *Preflexion–postflexion*—At 3.8 mm, a cluster above gut coil & sparse series on ventral margin of gut to isthmus; nearly lacking on later stages except on elongate D ray; series (minute) basally along the D & A pterygiophores, & patches distally on D & A rays late in postflexion stage.
Diagnostic features: Cluster of melanophores above gut in early preflexion stage; pigment on elongate D ray in postflexion larvae; elongate ray stouter than in other genera & develops vane of tissue; more slender-bodied than other genera; ventral loop of gut coil spreads to form an inverted T-shaped structure.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL				36–47		24–26
		55		41		25
BD/BL				35–39		39–40
		20		37		40
HL/BL				21–23		28–29
		20		22		28
HW/HL				22–29		23–23
		49		25		23
SnL/HL				25–29		15–15
		60		28		15
ED/HL*				12–18× 13–21		16–17× 14–14
		35×35		16×18		16×14
P_1L/BL				5–6		11–11
		7		6		11
P_2L/BL				0–5		7–9
		0		1		8
BDA/BL				38–50		39–40
		17		43		40

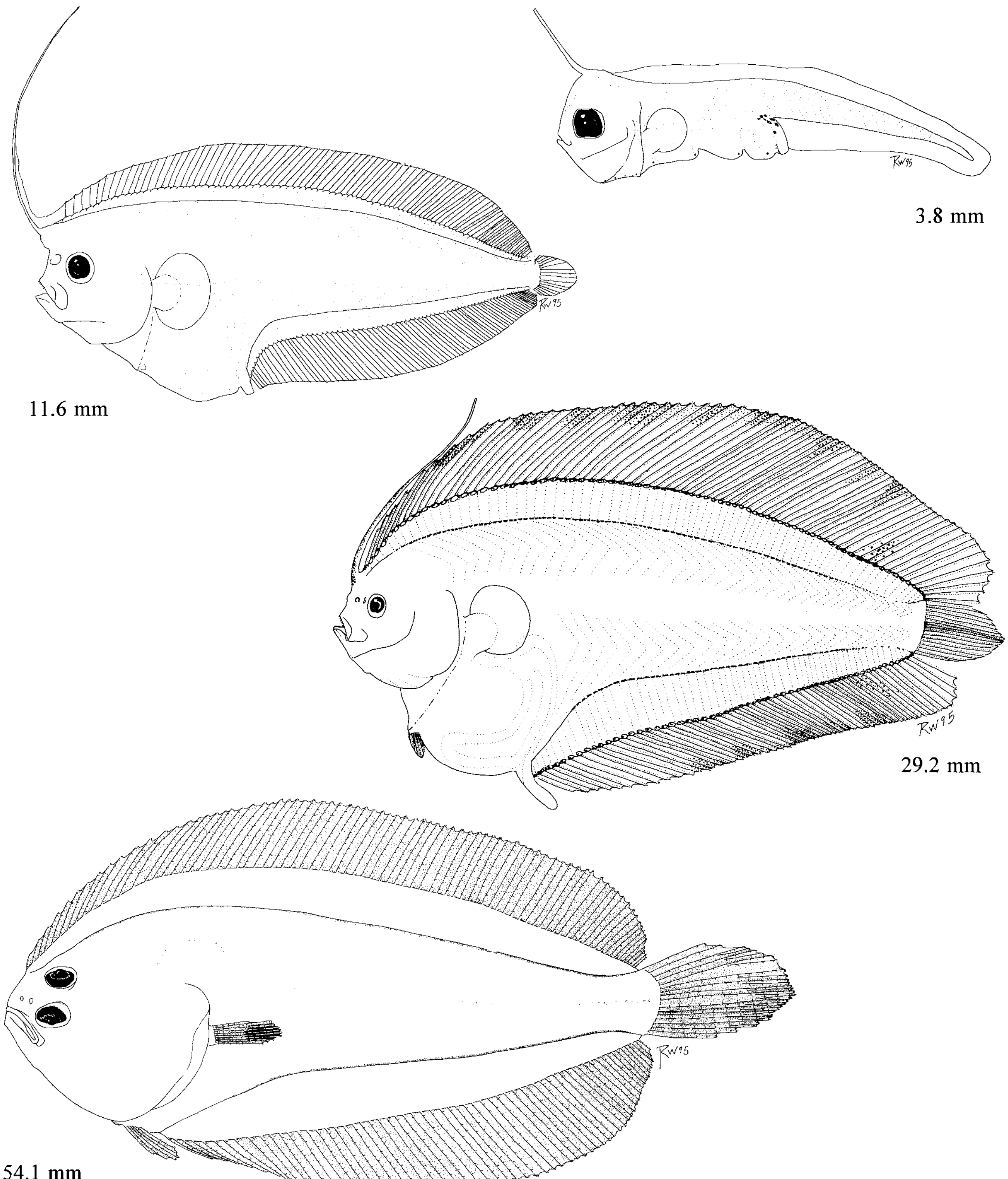


Figure Bothidae 3. Preflexion larva, 3.8 mm (CalCOFI 7210, station, 150.25); postflexion larvae, 11.6 mm (TO 58–2), 29.2 mm (CFRD Ref. Coll., FB 62–189); juvenile, 54.1 mm (SIO 70–157).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–40	39
Precaudal	10	10
Caudal	28–30	29
Fins:		
Dorsal spines	0	0
Dorsal rays	81–88	83
Anal spines	0	0
Anal rays	61–70	62
Pelvic	6	6
Pectoral	10–11	11
Caudal:		
Total	17	17
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper	2–4	3
Lower	7–9	8
Branchiostegals		

LIFE HISTORY

Range: Bahía Sebastián Viscaíno, Baja California to Panama, including the Gulf of California

Habitat: Soft bottom at 46–157 m depth

Spawning season: Most larvae collected in summer–fall

ELH pattern: Oviparous; eggs & larvae planktonic

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 2.8 mm (R. C. Walker)
Preflexion larva, 6.2 mm (B. Sumida MacCall)
Postflexion larva, 23.7 mm (R. C. Walker)

* Eye slightly oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS
Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE
Hatching length: <2.8 mm
Flexion length: ca. 7.4–8.1 mm
Transformation length: >23.7 mm
Fin development sequence: Elongate D, D & A, C, P_2, P_1
Pigmentation: *Preflexion*—Initially, none to several on ventral margin of gut; none in specimens >3.0 mm. *Flexion–postflexion*—None.
Diagnostic features: Early preflexion larvae lack pigment except a few melanophores on ventral margin of gut & have flatter gut coil than *Engyophrys sanctilaurentia*; later preflexion larvae more slender & have lower forehead than *E. sanctilaurentia*; postflexion larvae oval-shaped with relatively large eye, & lack pigment; basipterygial, urohyal, cleithral, & 3 otic spines.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		38–58 48	36–41 38	20–46 31		27–32 29
BD/BL		19–38 29	38–46 41	48–62 57		36–40 37
HL/BL		18–25 21	22–23 23	24–28 26		25–26 26
HW/HL		39–54 45	39–45 43	36–46 42		29–34 32
SnL/HL		10–33 25	31–40 36	22–32 28		18–21 20
ED/HL*		25–39× 25–39	25–28× 26–29	26–31× 26–34		29–31× 21–21
		30×31	27×28	28×29		30×21
P_1L/BL		3–12 7	5–9 7	6–9 8		13–16 14
P_2L/BL		0–0 0	0–0 0	2–7 5		8–9 9
BDA/BL		14–40 29	40–47 43	52–79 62		36–40 37

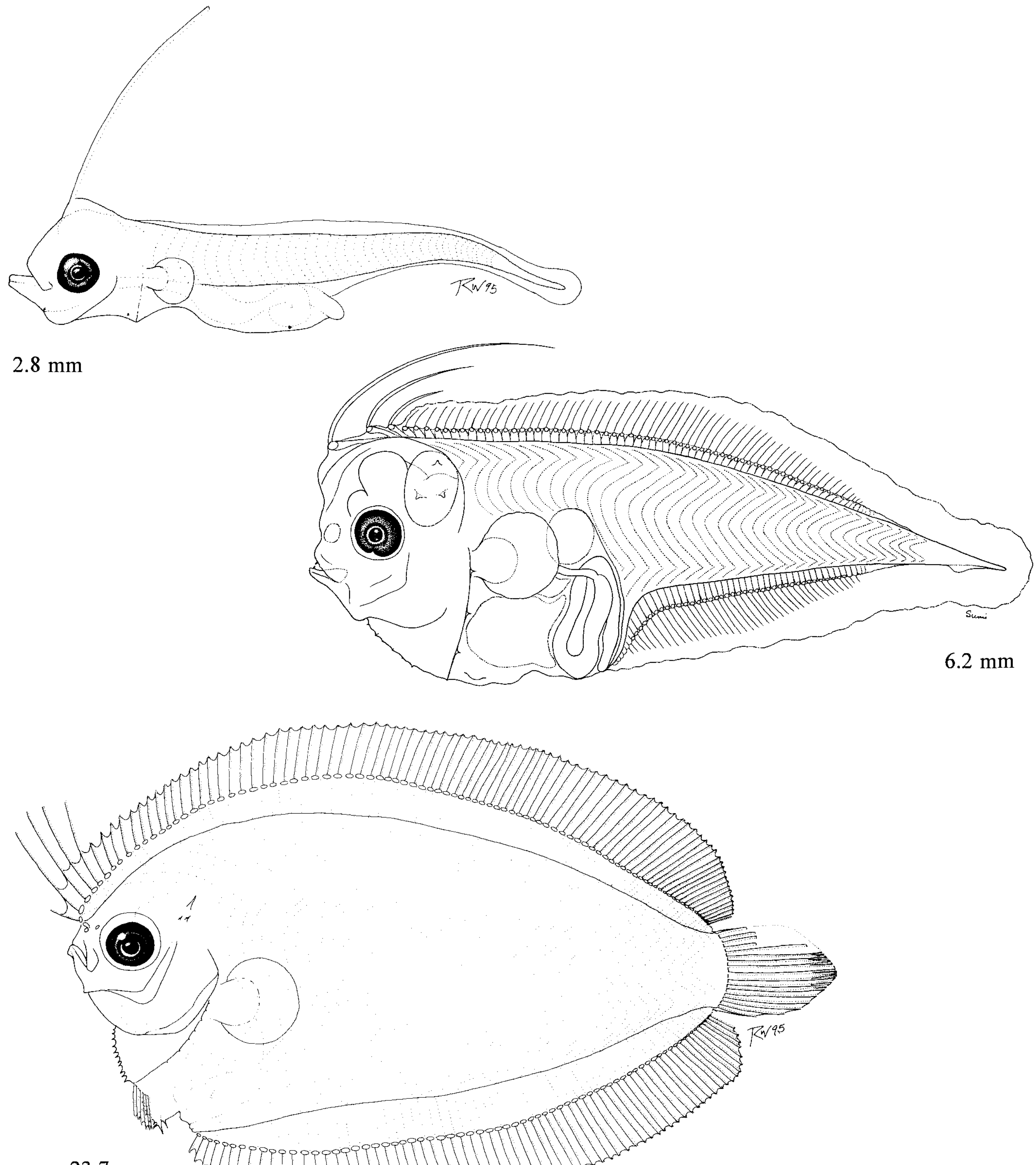


Figure Bothidae 4. Preflexion larvae, 2.8 mm (EASTROPAC II, station 47.527), 6.2 mm (CalCOFI 5310, station 130.35); postflexion larva, 23.7 mm (TO 58–1, station 75).

PLEURONECTIDAE: Righteye flounders

S. R. CHARTER AND H. G. MOSER

Pleuronectids inhabit all oceans, occasionally are found in brackish water, and rarely enter freshwater. There are 39 genera with approximately 93 species presently placed in four subfamilies (Nelson 1994). All 19 species that occur in the CalCOFI study area (Table Pleuronectidae 1) belong to the subfamily Pleuronectinae. *Atheresthes stomias, Hippoglossoides elassodon, Hippoglossus stenolepis* and *Reinhardtius hippoglossoides* are northern species whose eggs and larvae are not found in CalCOFI ichthyoplankton samples. *Embassichthys bathybius* inhabits the continental slope from Alaska to southern California and its eggs and larvae are rarely collected on CalCOFI surveys. Adults of the other 14 species are common in the California Current region; eggs and larvae of some (e.g., *Parophrys vetulus, Lyopsetta exilis, Pleuronichthys verticalis, Microstomus pacificus,* and *Glyptocephalus zachirus*) occur frequently in CalCOFI plankton tows, while those of others (e.g., *Lepidopsetta bilineata, Isopsetta isolepis,* and *Eopsetta jordani*) are relatively rare.

The systematic status of several groups traditionally placed in Pleuronectidae (e.g., poecilopsettines, rhombosoleines, paralichthodines) is unsettled (Hensley and Ahlstrom 1984). The subfamilly Samarinae has been elevated to family (Nelson 1994) based on cladistic analyses (Chapleau and Keast 1988; Chapleau 1993; Nelson 1994). Sakamoto (1984b) revised the family on the basis of a phenetic study and proposed numerous changes in generic limits that Nelson (1994) has chosen to ignore, pending a cladistic analysis. We use the generic names that have been used in other identification guides to Pacific coast fishes (e.g., Miller and Lea 1972; Eschmeyer et. al. 1983; Matarese et. al. 1989).

The subfamily Pleuronectinae includes 59 species (26 genera) of benthic carnivores that occupy shelf and slope habitats in arctic and northern seas (Nelson 1994). Adults are moderate to large (most species are <60 cm, the largest may reach 3 m), bilaterally asymmetrical, highly compressed, and lack spinous rays in the fins. The eyes are on the right side except in rare sinistral individuals of some species and in *Platichthys stellatus* which is sinistral in populations off Japan and about equally divided between sinistral and dextral off California (Sakamoto 1984a). The eyed side is pigmented and the blind side normally has light coloration or is white. The eyes may protrude above the body surface to allow vision while buried in the substrate. The form and pattern of branching of the lateral line may aid in identification. Both pleuronectine tribes (Nelson 1994), Hippoglossini and Pleuronectini, are represented in the CalCOFI region. Hippoglossins have large symmetrical mouths with the maxillae extending to, or past the pupils, and the teeth are well developed on both sides of the jaws. This group includes large species of great importance to commercial and recreational fisheries. Pleuronectins have small asymmetrical mouths with maxillae not extending to the pupils, and their teeth are mainly on the blind side of the jaws. Although smaller than the hippoglossins, many species have high commercial and recreational value (Nelson 1994).

Pleuronectines are oviparous and spawn planktonic or demersal eggs, 0.66–4.5 mm in diameter (Table Pleuronectidae 2). The yolk is homogeneous, pigmented or not, and usually lacks oil globules. Demersal eggs may be off-round, and may have a sticky, chorion that permits them to adhere to each other or to a substrate. Pleuronectid chorions generally have sculpturing or surface features ranging from faint striations to a striking hexagonal pattern. Pleuronectine larvae hatch at 1.7–16.0 mm (Table Pleuronectidae 3); species that hatch from a smaller egg lack eye pigment, a functional mouth, and pectoral fins, while those that hatch from a larger egg usually have pigmented eyes, a functional mouth, and pectoral fins. Yolk-sac and preflexion stage larvae are slender, with many species becoming very deep-bodied during the postflexion stage. The gut is straight initially, becoming coiled as the yolk is absorbed. Preanal length shortens as the gut coils and may be as long as ca. 50% BL but usually is shorter (ca. 35–45% BL). Head spines develop on a few species during the preflexion stage (Table Pleuronectidae 3). Larval pigmentation, including the finfold, varies considerably (Table Pleuronectidae 3) and, during the yolk-sac stage, migration of pigment is common. Migration of the left eye to the right side occurs at transformation. In *Microstomus pacificus* the left eye migrates to the dorsal midline early (at 15–20 mm) in the larval period where it remains until transformation.

Matarese et al. (1989) provided early life history descriptions of 23 pleuronectid species, including 12 of the species in this guide; the information presented here complements their descriptions. Our descriptions of 15 pleuronectid species are based on detailed examination of 210 specimens (Table Pleuronectidae 4) and on the literature (Smith 1936; Budd 1940; Orcutt 1950; Orton 1953a; Orton and Limbaugh 1953; Yusa 1957; Hickman 1959; Pertseva-Ostroumova 1961; Orsi 1968; Alderdice and Forrester 1971; Ahlstrom and Moser 1975; Eldridge 1975; White 1977; Sumida et al. 1979; Ahlstrom and Moser 1980; Richardson et al. 1980; Richardson 1981b; Ahlstrom et al. 1984a; Matarese et al. 1989; Markle et al. 1992). For consistency in calculating morphometric relationships, some specimens of *Pleuronichthys* and *Hypsopsetta* from Sumida et al. (1979) were reexamined and assigned different stages from those originally designated. Adult ecological, meristic, and morphometric data were taken from Norman (1934), Miller and Lea (1972), Hart (1973), Eschmeyer et al. (1983), Sakamoto (1984a), Matarese et al. (1989), Nelson (1994), and Sommer (1995).

Table Pleuronectidae 1. Meristic characters for 19 pleuronectid species in the California Current vicinity.

	Vertebrae			Fin rays				
Species	PrCV	CV	Total	D	A	P_1	P_2	Total C
Atheresthes stomias	12	35–38	47–50	92–115	72–99	14–15	6	17
Embassichthys bathybius	13–14	44–51	57–65	109–117	94–102	11	5–6	19–21
Eopsetta jordani	11	30–34	41–45	82–103	67–80	13	6	19
Glyptocephalus zachirus	12–14	50–52	62–66	87–110	78–93	11–13	6	21–24
Hippoglossoides elassodon	12–13	32–35	42–47	72–90	55–71	10–12	6	18
Hippoglossus stenolepis	16	35	49–51	89–109	64–81	19	6	19
Hypsopsetta guttulata	11–12	22–24	34–36	65–75	47–55	11–13	6	19–20
Isopsetta isolepis	9–11	31–32	39–42	78–92	58–69	11–13	6	17–18
Lepidopsetta bilineata	10–12	28–31	38–42	65–84	50–65	8–13	6	18–19
Lyopsetta exilis	11–13	31–35	42–47	72–88	57–66	9–10	6	19
Microstomus pacificus	11–13	37–41	50–55	86–116	75–96	8–12	5–6	19–23
Parophrys vetulus	10–12	31–34	41–47	72–93	52–70	10–12	6	18
Platichthys stellatus	10–12	24–26	35–38	52–66	38–47	9–10	5–6	17–19
Pleuronichthys coenosus	12–13	24–26	36–39	65–78	44–56	9–12	6	18–20
P. decurrens	13–15	24–27	38–41	67–81	45–55	9–14	4–7	18–20
P. ritteri	12–13	22–24	34–36	62–72	43–52	9–11	6	18–20
P. verticalis	13	22–25	36–38	66–79	44–51	10–12	6	19–20
Psettichthys melanostictus	11–12	28–30	37–41	72–90	53–66	10–12	6	18
Reinhardtius hippoglossoides	17–19	43–46	61–64	83–105	63–79	11–15	5–7	19

Table Pleuronectidae 2. Summary of egg characters of pleuronectid species described in this guide. All have planktonic eggs except *Lepidopsetta bilineata*. Oil globules are absent in eggs of all except *Hypsopsetta guttulata* and *Pleuronichthys ritteri*, which have single oil globules. Based on literature and original observations (see Table Pleuronectidae 4 and species descriptions).

Species	Diameter (mm)	Chorion characteristics	Yolk pigmentation	Pigmentation on embryo
Embassichthys bathybius	2.7–3.1	Dimpled and wave-like ridges	Light around hindgut of embryo	3 postanal bars; eye pigmented in late-stage embryo
Eopsetta jordani	1.2–1.3	Unknown	Absent	None prior to hatching
Glyptocephalus zachirus	1.8–2.3	Weak to strong dimpling or interconnected ridges and depressions	Moderate	4 postanal bars and on gut; eye pigmented in late-stage embryo
Hypsopsetta guttulata	0.78–0.89	Smooth	Moderate	Heavy on anterior 60% of embryo; on terminal section of gut
Isopsetta isolepis	0.84–1.1	Striations	Absent	Scattered on head; series on dorsum and ventral margin of tail of late-stage embryo
Lepidopsetta bilineata	0.87–1.0	Reticulated and corrugated	Moderate	On dorsum and ventral midline of tail, cleithrum, and anus of late-stage embryo
Lyopsetta exilis	1.5–1.7	Fine, elongate ridges	Moderate	Scattered over entire late-stage embryo, heavy in caudal region, dorsal and ventral series may start to form just before hatching
Microstomus pacificus	2.1–2.7	Smooth, or with faint, interconnected, wave-like ridges and depressions	Light	Discontinuous on dorsum; series ventrally and laterally; several indistinct bars may form just before hatching; caudal finfold; eye becomes pigmented in late-stage embryo
Parophrys vetulus	0.80–1.1	Smooth or with fine striations	Absent	Dorsally and ventrally on late-stage embryo
Platichthys stellatus	0.88–1.3	Irregular reticulations	Moderate	Sparsely scattered on head and dorsum, some on gut, few on dorsal and ventral finfolds of late-stage embryo
Pleuronichthys coenosus	1.2–1.6	Hexagonal sculpturing	Light	Heavy on late-stage embryo, except at caudal region, dorsally and ventrally on notochord tip and on finfold at ca. 75% BL
P. decurrens	1.8–2.1	Hexagonal sculpturing	Heavy	Heavy on late-stage embryo and finfold, except for tip of tail and adjacent finfold
P. ritteri	0.94–1.1	Hexagonal sculpturing	Moderate	Heavy on late-stage embryo, except posterior half of tail, few on finfold, blotch ventrally at notochord tip
P. verticalis	1.0–1.2	Hexagonal sculpturing	Heavy	Heavy on late-stage embryo, except for caudal region, patches on D and A finfold and notochord tip
Psettichthys melanostictus	0.83–1.0	Striated	Moderate	Few on head, body, and finfold of late-stage embryo

Table Pleuronectidae 3. Summary of some larval features of pleuronectid species included in this guide. Based on literature and original observations (see Table Pleuronectidae 4 and species descriptions).

Species	Size at hatching (mm)	Size at flexion (mm)	Size at transformation (mm)	Head spines	Diagnostic early pigmentation (yolk-sac and early preflexion)
Embassichthys bathybius	ca. 9	15.4–16.2	>60	Absent	3 postanal bars, including 1 on tip of tail; patches associated with bars on dorsal, ventral, and caudal finfolds
Eopsetta jordani	ca. 2.8	ca. 10.9	16.2–17.6	Preopercular	2 postanal bars, including 1 on tip of tail; absent, then developing scattered patches on finfold
Glyptocephalus zachirus	ca. 5	14.6–26.0	47.4–52.8 through 49.7–70.1	Preopercular	4 postanal bars, including 1 on tip of tail; blotches on ventral margin alternate with bars; on caudal finfold
Hypsopsetta guttulata	ca. 2.2	4.6–5.2	6.6–8.8	Otic	Solid sheath except for posteriormost 9 or 10 myomeres; none on finfold
Isopsetta isolepis	ca. 2.7	9.0–10.9 through 13.3–14.0	15.0–16.0 through ≥21	Absent	3 postanal bars, including 1 just anterior to tip of tail; few developing on ventral finfold
Lepidopsetta bilineata	3.1–4.0	7.2–8.0 through 8.1– >9.7	10.0 – >17.7	Absent	Alternating postanal dorsal and ventral midline patches; bar in caudal region; double row of melanophores on ventral margin of tail; patches on dorsal and ventral finfold margins
Lyopsetta exilis	5.2–5.6	9.0–10.8 through 13.3–13.5	15.7–16.7 through 20.6–24.7	Absent	Series on dorsal and ventral midlines continuous around notochord tip; scattered on caudal finfold, spreading to ventral finfold and posterior region of dorsal finfold
Microstomus pacificus	4.4–6.9	7.8–11.4 through 9.8–15.0	43.1–47.3 through 47.0–79	Otic	Several indistinct postanal bars; continuous series above and below notochord tip; in dorsal and ventral finfolds (associated with bars) and in caudal finfold
Parophrys vetulus	2.3–2.9	7.6–7.9 through 9.8–11.5	16.7–17.6	Absent	Heavy series on dorsal and ventral margins, on nape, dorsal series discontinuous; on ventral finfold, initially in patches that become scattered
Platichthys stellatus	1.9–2.1	5.5 through 5.7–7.4	8.3–8.5 through 10.5	Absent	Scattered on postanal hypaxial myomeres, heaviest posteriorly and forming a broad indistinct bar; large triangular patches in dorsal and ventral finfolds become dispersed
Pleuronichthys coenosus	ca. 3.7	6.1–8.5	8.2–11.4	Absent	Complete body sheath except for tip of tail; small melanophores above and below notochord tip; apposing mound-like patches in dorsal and ventral finfolds at midtail
P. decurrens	4.9–5.5	7.8–11.0	10.0– >21	Otic	Complete body and finfold sheath except for tip of tail
P. ritteri	ca. 2.1	4.5–5.6	6.4–10.0	Absent	Complete body sheath except for last 8–9 myomeres; blotch becoming a series below tip of tail; form weak patches in dorsal and ventral finfolds; some on margin of dorsal finfold
P. verticalis	<2.4	5.0–7.2	7.9–11.0	Absent	Complete body sheath except for last 3–5 myomeres; triangular patch on dorsal and ventral finfolds, the dorsal patch anterior to ventral patch
Psettichthys melanostictus	ca. 2.1	7.5–10.3	13.9–14.2 through 20.9 – >22.6	Absent	Alternating patches on dorsal and ventral margins; series of small patches on margins of dorsal and ventral finfolds

Table Pleuronectidae 4. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the pleuronectid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Transformation	Juvenile
Embassichthys bathybius	L[a,b]	0	L[a,b,c]	L[a,b,c]	0	1 58.6	0
Eopsetta jordani	L[a,d]	L[a,c,d]	L[a,c,d], 2 4.6–4.9	1 10.9	1 12.4	L[a,c], 4 16.2–17.6	0
Glyptocephalus zachirus	L[a,e]	0	L[a,c,f], 7 5.3–13.3	L[a,c,f], 4 14.6–26.0	L[a,c,f], 6 27.5–52.8	L[a,c,f], 4 47.4–70.1	L[c], 3 49.7–63.4
Hypsopsetta guttulata	L[g,h,i]	L[c,g,j]	L[c,g,j]	L[g,j]	L[g,j]	L[g,j]	L[g]
Isopsetta isolepis	L[a,k]	L[a,k]	L[a,c,k], 7 2.8–10.9	L[a,k], 4 11.7–13.9	L[k], 6 13.3–16.0	L[k], 4 16.4–19.6	L[k]
Lepidopsetta bilineata	L[l,m]	L[l], 1 3.1	L[a,c,l], 6 3.4–8.0	L[a,l], 3 7.2–9.3	L[l], 3 8.1–9.6	L[a,l], 5 10.0–12.3	3 19.1–30.9
Lyopsetta exilis	L[a]	L[c], 4 5.2–5.8	L[a,c,f], 7 6.3–10.8	L[a,f], 4 11.5–13.5	L[f], 6 13.3–16.7	L[f], 4 15.7–24.2	3 20.6–25.0
Microstomus pacificus	L[a,b,f]	L[f,n], 4 4.4–6.9	L[a,b,c,f,n], 5 7.4–11.4	L[a,b,f,n], 4 7.8–12.3	L[a,b,f,n], 10 9.8–47.3	L[b,f,n], 6 43.1–55.3	L[n], 2 47.0–53.3
Parophrys vetulus	L[a,o,p], 1 0.96	L[c,o,p], 3 2.7–3.2	L[a,c,f,p], 5 3.4–7.9	L[a,f], 4 7.6–11.5	L[a,c,f], 6 9.8–14.9	L[a,c,f], 3 16.7–17.4	3 19.6–31.0
Platichthys stellatus	L[a,q,r]	L[a,q,r], 3 2.1–3.3	L[a,c], 7 2.6–4.5	L[a,c], 4 5.5–7.4	L[a], 7 5.7–8.5	L[a], 3 8.3–8.5	3 11.5–23.4
Pleuronichthys coenosus	L[a,f,g,p]	L[a,f,g,p]	L[a,c,g]	L[a,g]	L[a,g]	L[a,g]	L[g]
P. decurrens	L[a,f,g,p]	L[a,c,f,g]	L[a,c,g]	L[a,g]	L[a,g]	L[a,g]	L[g]
P. ritteri	L[g,h,s]	L[g]	L[g]	L[g]	L[g]	L[g]	L[g]
P. verticalis	L[f,g,p]	L[f,g,p]	L[f,g]	L[f,g]	L[g]	L[f,g]	L[g]
Psettichthys melanostictus	L[a,t]	L[a,c,t], 2 2.1–4.2	L[a,c,t], 7 4.5–6.7	L[t], 4 7.5–10.3	L[t], 6 10.3–14.2	L[a,t], 3 14.5–20.3	L[t], 3 20.9–32.0

[a] Matarese et al. 1989
[b] Richardson 1981b
[c] Ahlstrom et al. 1984a
[d] Alderdice & Forrester 1971
[e] Ahlstrom & Moser 1980
[f] Ahlstrom & Moser 1975
[g] Sumida et al. 1979
[h] Orton & Limbaugh 1953
[i] Orton 1953a
[j] Eldridge 1975
[k] Richardson et al. 1980
[l] Pertseva-Ostroumova 1961
[m] Smith 1936
[n] Markle et al. 1992
[o] Orsi 1968
[p] Budd 1940
[q] Orcutt 1950
[r] Yusa 1957
[s] White 1977
[t] Hickman 1959

MERISTICS

	Range	Mode
Vertebrae:		
Total	57–65	62
Precaudal	13–14	14
Caudal	44–51	48
Fins:		
Dorsal spines	0	0
Dorsal rays	109–117	
Anal spines	0	0
Anal rays	94–102	
Pelvic	5–6	
Pectoral	11	11
Caudal:		
Total	19–21	
Principal	10–11+9–10	11+9
Gill rakers:		
Upper	6–9	
Lower	14–16	
Branchiostegals	7–8	

LIFE HISTORY

Range: Bering Sea (54°–66°N) to southern California (32°–34°N)

Habitat: Demersal on continental slope at 320–1,433 m depth

Spawning season: Winter–spring

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Matarese et al. 1989
Richardson 1981b

ORIGINAL ILLUSTRATIONS (Illustrator)

Postflexion larva, 20.9 mm (B. Sumida MacCall)

* Values from Richardson 1981b.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.7–3.1 mm **Yolk:** Homogeneous; 2.1–2.6 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Dimpled & wave-like ridges
Pigment: On hindgut, extending out onto yolk; 3 postanal bars; eye pigmented in late-stage embryo
Diagnostic features: Size & pigmentation pattern

LARVAE

Hatching length: ca. 9 mm
Flexion length: 15.4–16.2 mm
Transformation length: >60 mm; eye moves to midline at ca. 20 mm
Fin development sequence: C & D & A, P_2, P_1
Pigmentation: *Preflexion*—Initially 3 postanal blotches including 1 at tip of tail, on finfold dorsal & ventral to blotches. *Flexion*—ca. 7 blotches dorsally & 5 ventrally distally on finfold; blotches condense on dorsal & ventral margins; dorsally on gut; late in stage, ventrally on gut. *Transformation*—Finely scattered from gular region to P_2, 1 blotch dorsally on gut; 7 patches on D base & rays; short series 5 dorsally & 4 ventrally on myosepta; few on caudal peduncle, 5 blotches on A base & rays.
Diagnostic features: Total vertebrae 57–65; distinct pigmentation pattern; pronounced gut loop; preflexion larvae slender, becoming deep-bodied in postflexion stage; attains large size before transformation >60 mm.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF*	F*	PoF	Tr	Juv
Sn-A/BL		31–33 32	34–40 37		25	
BD/BL		8–13 10	11–31 21		58	
HL/BL		12–19 15	13–23 18		19	
HW/HL					29	
SnL/HL					27	
ED/HL		26–33 30	19–25 22		12	
P_1L/BL					4	
BDA/BL		7–10 8	13–35 24		58	

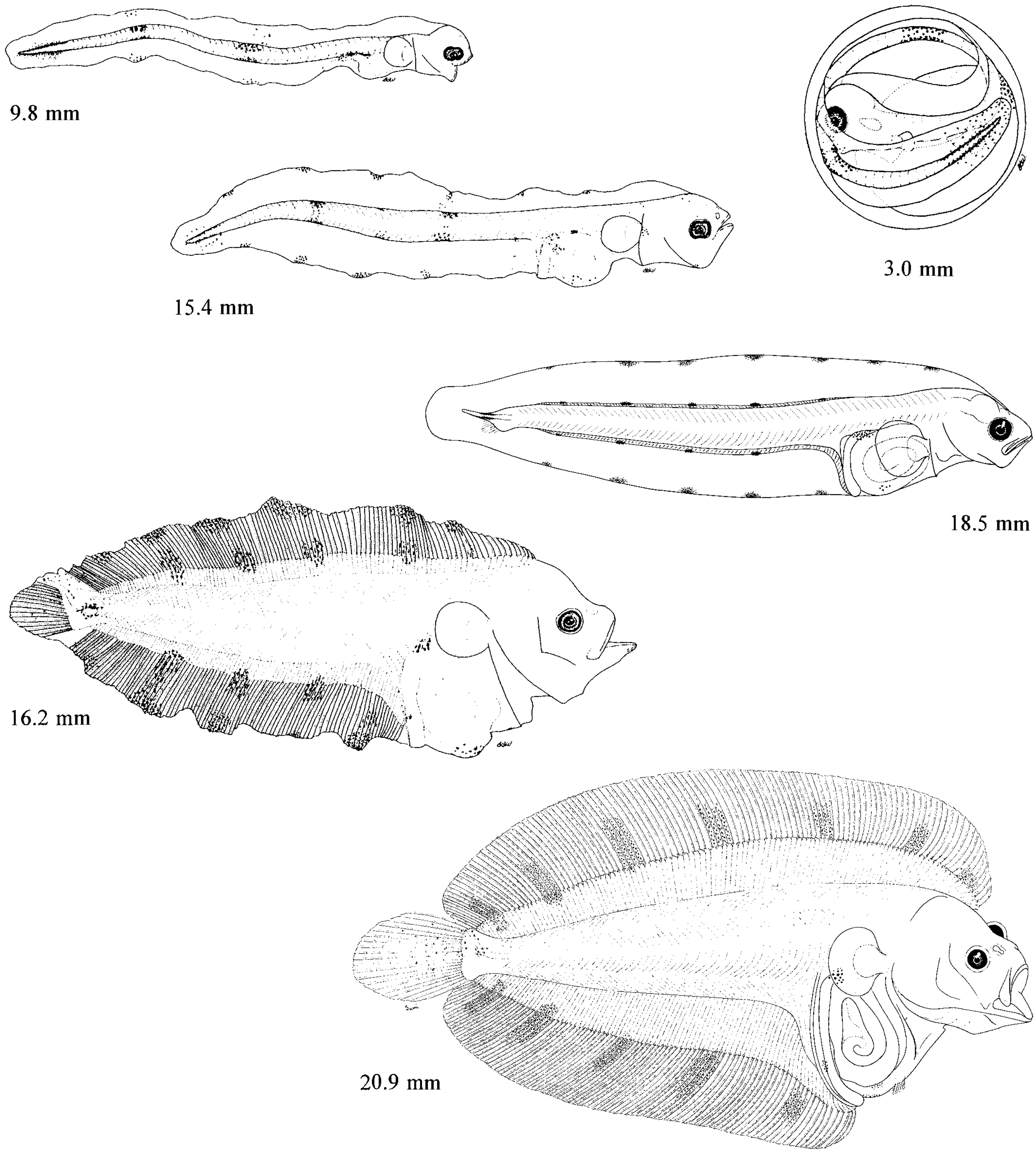


Figure Pleuronectidae 1. Egg, 3.0 mm; preflexion larvae, 9.8 mm, 15.4 mm (Richardson 1981b); flexion larvae, 18.5 mm (Ahlstrom et al. 1984a), 16.2 mm (Richardson 1981b); postflexion larva, 20.9 mm (CFRD Ref. Coll., OSU 6606NH-65, station MT-A66-17).

MERISTICS

	Range	Mode
Vertebrae:		
Total	41–45	43
Precaudal	11	11
Caudal	30–34	32
Fins:		
Dorsal spines	0	0
Dorsal rays	82–103	97
Anal spines	0	0
Anal rays	67–80	73
Pelvic	6	6
Pectoral	13	13
Caudal:		
Total	19	19
Principal	8–9+8	8+8
Gill rakers:		
Upper		
Lower	15–17	
Branchiostegals	7–8	7

LIFE HISTORY

Range: Gulf of Alaska to Islas Los Coronados, Baja California

Habitat: Demersal on shelf & slope to 550 m depth

Spawning season: December–April; in CalCOFI area, larvae collected in April & June

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Alderdice & Forrester 1971
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Flexion larva, 10.9 mm (R. C. Walker)

* Eye slightly oval in transforming specimens; horizontal axis is given first, vertical second.
† Pectoral blade damaged in all but one preflexion specimen.
‡ Pelvic rays broken in postflexion specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.2–1.3 mm
Yolk: Homogeneous
No. of OG: 0
Diam. of OG:
Shell surface:
Pigment: None
Diagnostic features:

LARVAE

Hatching length: ca. 2.8 mm
Flexion length: ca. 10.9 mm
Transformation length: 16.2–17.6 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Unpigmented at hatching. *Preflexion*—Posteriorly on head; above gut; few laterally on myomeres above hindgut; wide bar at midtail; bar on tip of tail, extending onto finfold. *Flexion*—Increasing on epaxial & hypaxial myosepta, on developing D & A fins, & on finfolds; on preopercle, opercle, upper & lower jaws, & top of head; on ventral midline of gut & isthmus. *Postflexion–transformation*—Myosepta become completely outlined; ca. 5 patches on D pterygiophores, 4 on A pterygiophores; D & A covered, except posteriorly; heavy on head & branchiostegal membrane; heavy from gular region to anus; increasing on gut.
Diagnostic features: Total vertebae 41–45; 2 postanal bars during preflexion stage; body becomes relatively deep with elongate D & A pterygiophores; extensive pigment on myosepta & on D & A fins; prominent preopercular spines; lacks dashes along lateral midline.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		34–36			36–40	
		35	37	43	38	
BD/BL		5–6			42–48	
		6	27	31	44	
HL/BL		11–12			31–34	
		12	26	27	32	
HW/HL		37–57			17–32	
		47	35	30	26	
SnL/HL		19–29			20–28	
		24	29	28	23	
ED/HL*		44–54			17–21× 16–19	
		49	19	18	18×18	
P_1L/BL†					3–7	
		3	4	4	5	
P_2L/BL		0–0		‡	5–8	
		0	0		6	
BDA/BL		9–10			46–52	
		9	26	33	49	

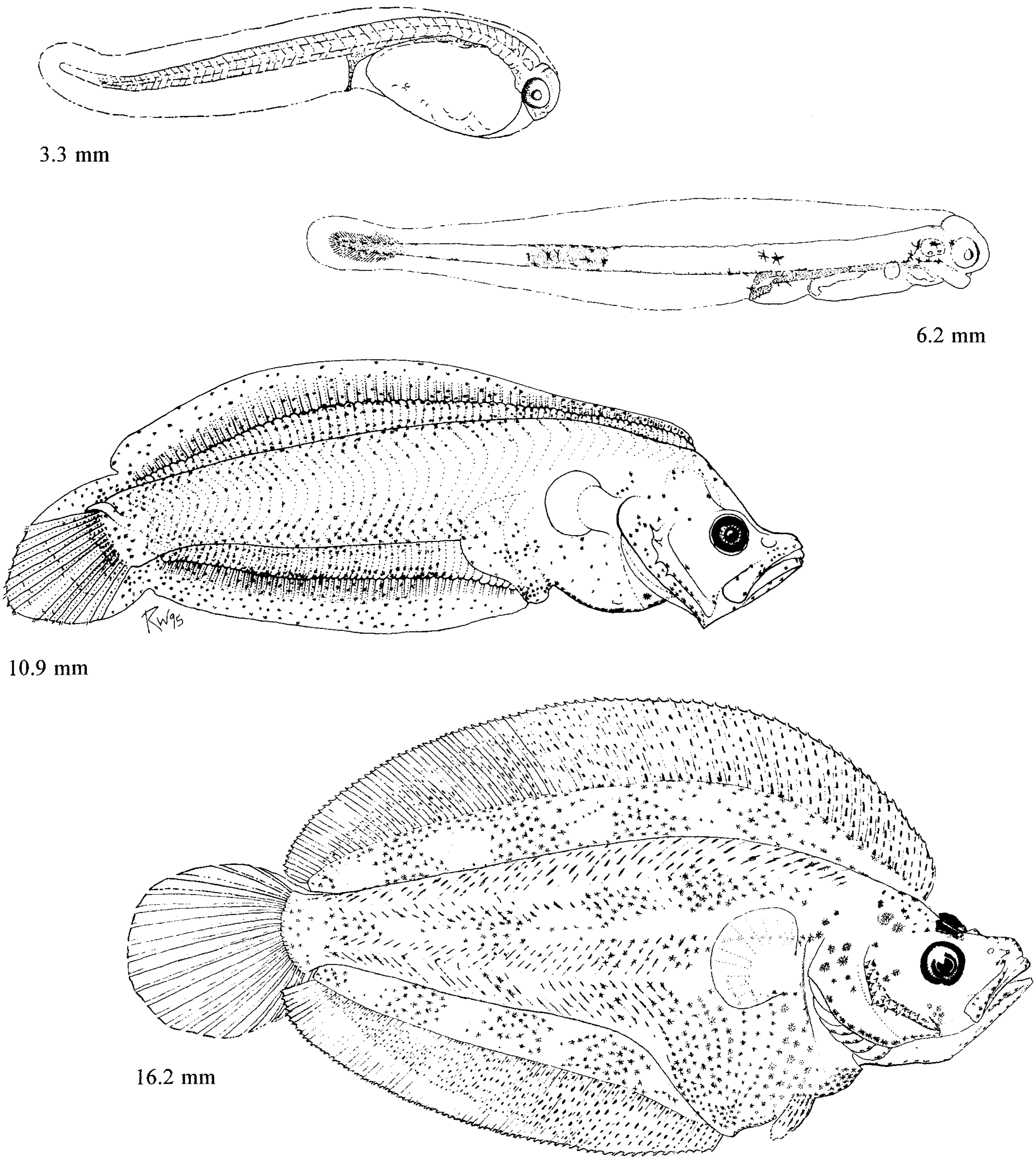


Figure Pleuronectidae 2. Yolk-sac larva, 3.3 mm; preflexion larva, 6.2 mm (Alderdice & Forrester 1971); flexion larva, 10.9 mm (CFRD Ref. Coll., OSU VMN, station 649); transformation specimen, 16.2 mm (Ahlstrom et al. 1984a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	62–66	64
Precaudal	12–14	13
Caudal	50–52	51
Fins:		
Dorsal spines	0	0
Dorsal rays	87–110	102
Anal spines	0	0
Anal rays	78–93	85
Pelvic	6	6
Pectoral	11–13	
Caudal:		
Total	21–24	22–23
Principal	10–11+10–12	10–11+11
Gill rakers:		
Upper	0–4	4
Lower	5–8	
Branchiostegals	7	7

LIFE HISTORY

Range: Bering Sea to Isla Cedros, Baja California

Habitat: Demersal on shelf & slope to 850 m depth

Spawning season: January–June; in CalCOFI area, larvae collected January–October, with peak abundance in June

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Matarese et al. 1989

* Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.8–2.3 mm **Yolk:** Homogeneous; 1.5–1.9 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Variably dimpled or with ridges & depressions, less obvious in late-stage eggs
Pigment: On yolk; in late-stage embryo, postanal bars, on gut, & solid on eyes
Diagnostic features: Size; wide perivitelline space in early-stage eggs; development through most of yolk-sac stage before hatching, larva coiling within shell; pigment pattern

LARVAE

Hatching length: ca. 5 mm
Flexion length: 14.6–26.0 mm
Transformation length: 47.4–52.8 mm through 49.7–70.1 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Preflexion*—Laterally on head; on lower jaw; above gut & posteriorly on lateral region of gut; 4 postanal bars; caudal bar extends onto finfold; small ventral blotches between bars. *Flexion*—Above eye; postanal bars recede from dorsum; ventral blotches enlarge; caudal bar more concentrated. *Postflexion–transformation*—9 lateral blotches from cleithrum to base of C; few dorsally & ventrally on myosepta; series on D & A bases; on isthmus; blotch on lower cleithral region; on P_2. *Pelagic juvenile*—Large blotches remain visible.
Diagnostic features: Elongate, growing to large size; high total vertebral count (62–66); preopercular spines; postanal pigment bars, increasing with development; lack of pigment on D & A until postflexion stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		23–35	24–31	25–30	26–28	23–25
		30	28	28	27	24
BD/BL		11–15	13–18	16–22	21–25	24–27
		13	14	19	22	25
HL/BL		14–21	16–20	17–19	15–17	20–22
		17	18	18	16	21
HW/HL		29–46	23–29	23–31	26–33	26–34
		34	27	26	30	29
SnL/HL		11–19	16–20	19–22	18–23	14–21
		15	18	21	20	18
ED/HL*		23–41× 23–32	18–25× 16–23	14–18× 15–19	16–20× 17–20	22–35× 17–24
		29×26	20×18	16×16	17×18	29×21
P_1L/BL		2–5	3–4	3–5	3–4	4–23
		4	4	4	4	12
P_2L/BL		0–0	0–0	0–2	3–3	5–6
		0	0	1	3	5
BDA/BL		9–15	10–21	17–27	28–29	25–28
		12	15	23	29	26

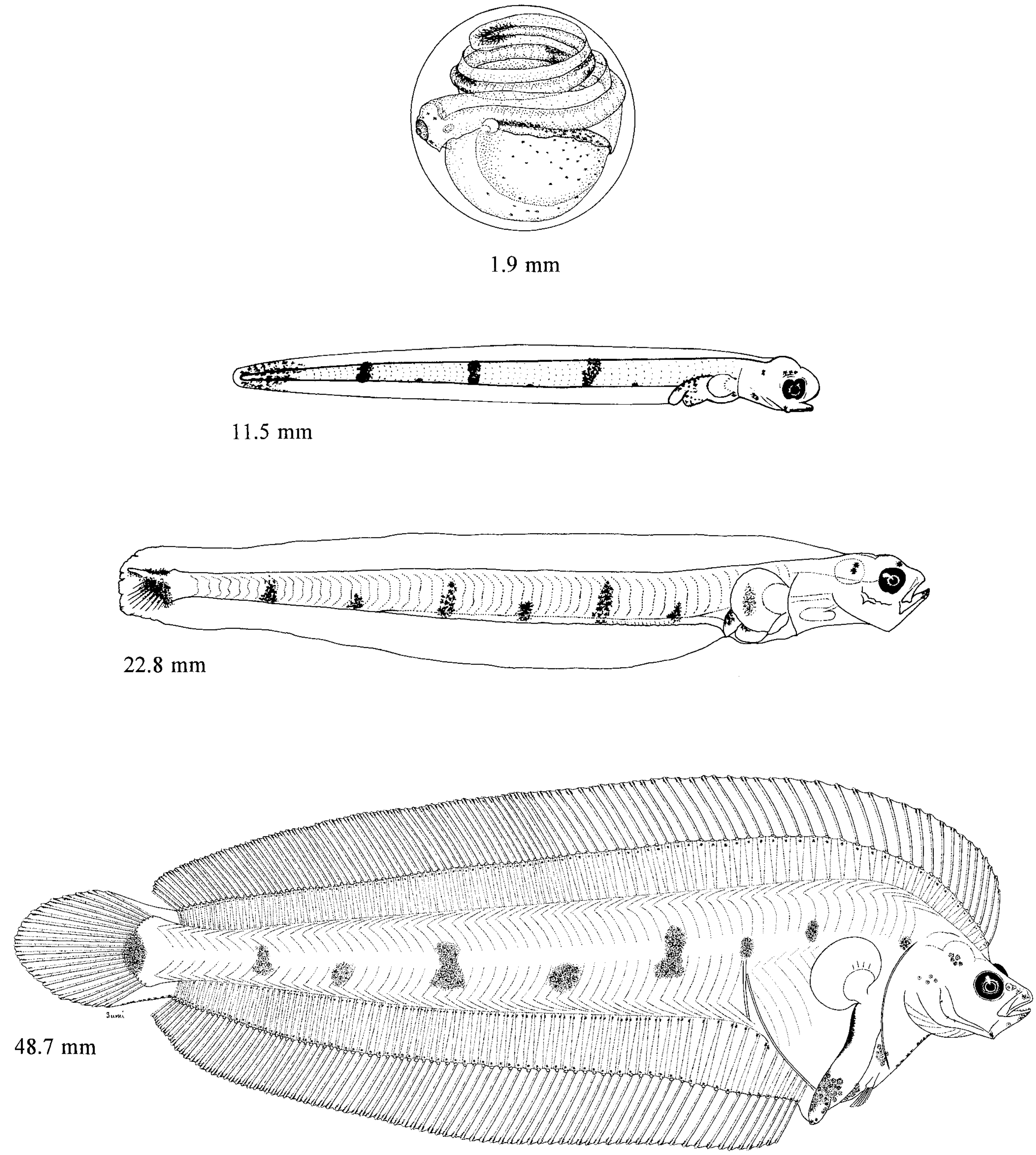


Figure Pleuronectidae 3. Egg, 1.9 mm (Ahlstrom and Moser 1980); preflexion larva, 11.5 mm (Matarese et al. 1989); flexion larva, 22.8 mm; postflexion larva, 48.7 mm (Ahlstrom et al. 1984a).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	35
Precaudal	11–12	12
Caudal	22–24	23
Fins:		
Dorsal spines	0	0
Dorsal rays	65–75	69
Anal spines	0	0
Anal rays	47–55	51–52
Pelvic	6	6
Pectoral	11–13	11–12
Caudal:		
Total	19–20	19
Principal	8+8	8+8
Gill rakers:		
Upper	1–2	
Lower	5–6	
Branchiostegals	7	7

LIFE HISTORY

Range: Cape Mendocino, California to Bahía Magdalena, Baja California Sur; isolated population in the Gulf of California

Habitat: Mud or sand bottom, often in bays & sloughs; 1.5–46 m depth

Spawning season: In CalCOFI area, larvae collected from July–April, with maximum abundance in December–January

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Eldridge 1975
Matarese et al. 1989
Orton 1953a
Orton & Limbaugh 1953
Sumida et al. 1979

* Values calculated from Sumida et al. (1979).
† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.78–0.89 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.12–0.14 mm
Shell surface: Smooth
Pigment: Moderate on yolk & OG; in late-stage embryo, heavy on anterior 60% of embryo; around anus; lacking on finfold
Diagnostic features: Small size; smooth chorion; pigment on OG

LARVAE

Hatching length: ca. 2.2 mm
Flexion length: 4.6–5.2 mm
Transformation length: 6.6–8.8 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Heavy on anterior 60% of larva, lacking on posteriormost 9 or 10 myomeres; on terminal gut section, yolk sac, & OG. *Preflexion*—Few on P_1 base; head covered except below eye; series on isthmus. *Flexion*—Posterior to anus, body sheath expands onto developing D & A pterygiophores to form apposing mound-like extensions of the body sheath; sheath expands posteriad to ca. 75% of body, lacking on last 5–6 myomeres. *Postflexion–transformation*—Increasing on head & P_1 base; body covered except caudal region. *Juvenile*—Small dark spots & mottling over entire body & pterygiophores.
Diagnostic features: Low total vertebral count (34–36); development at smaller size than *Pleuronichthys* species, except for *P. ritteri*; early preflexion larvae lack ventral notochord pigment (see *P. ritteri* for pigment differences); presence of pterotic spine (the only *Pleuronichthys* with pterotic spine is *P. decurrens*); pigment pattern & lack of finfold pigment in early flexion stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	48–50 49	50–52 50	46–50 49	43–53 48	37–48 41	35–38 36
BD/BL	8–8 8	22–25 23	22–24 23	33–41 35	35–47 43	51–54 53
HL/BL	17–20 19	20–25 23	24–27 26	31–36 33	32–34 34	32–34 33
HW/HL						
SnL/HL	21–26 24	18–24 21	17–20 19	18–20 19	16–19 17	12–17 15
ED/HL†	43–45× 34–37 44×36	37–41× 29–36 39×33	31–33× 27–30 32×29	28–32× 22–27 30×25	30–36× 25–28 33×26	28–38 21–30 31×25
P_1L/BL						
BDA/BL	13–15 14	18–22 20	22–23 22	35–43 38	36–48 45	54–57 55

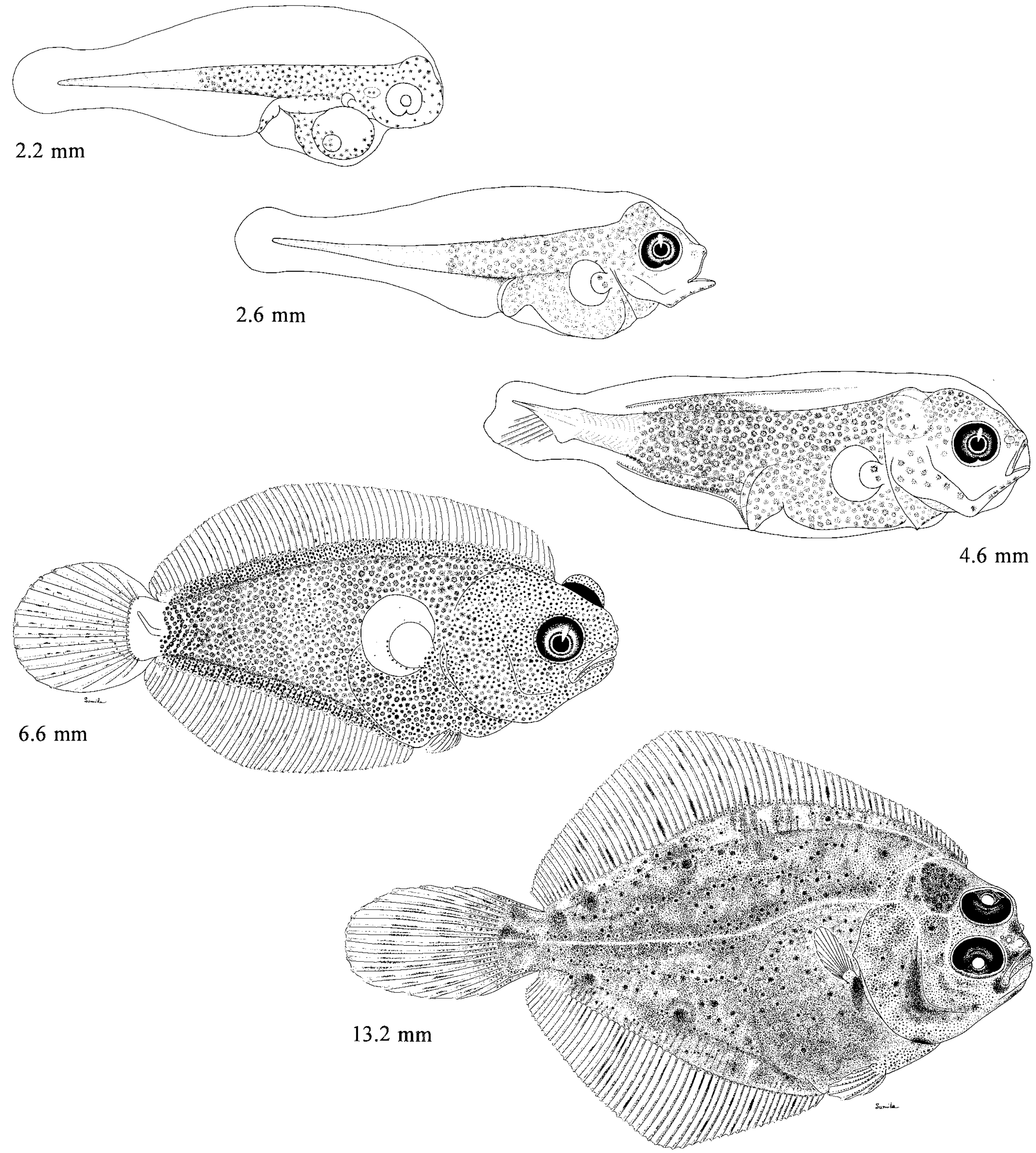


Figure Pleuronectidae 4. Yolk-sac larva, 2.2 mm; preflexion larva, 2.6 mm; flexion larva, 4.6 mm; transformation specimen, 6.6 mm; juvenile, 13.2 mm (Sumida et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	39–42	42
Precaudal	9–11	10
Caudal	31–32	32
Fins:		
Dorsal spines	0	0
Dorsal rays	78–92	86
Anal spines	0	0
Anal rays	58–69	66
Pelvic	6	6
Pectoral	11–13	
Caudal:		
Total	17–18	
Principal	8+9	8+9
Gill rakers:		
Upper		
Lower	7–8	
Branchiostegals	7–8	7

LIFE HISTORY

Range: Bering Sea to Ventura, California

Habitat: Demersal on shelf & upper slope, 20–425 m depth

Spawning season: February–April; in CalCOFI area, larvae collected April, May & July, with peak abundance in May

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Matarese et al. 1989
Richardson et al. 1980

ORIGINAL ILLUSTRATIONS (Illustrator)

Transformation specimen, 19.2 mm (B. Sumida MacCall)

* Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.84–1.1 mm **Yolk:** Homogeneous; 0.60–0.95 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Striated
Pigment: In late-stage embryo, scattered on head, dorsum & ventral margin of tail
Diagnostic features: Late embryo with head & anterior trunk pigment; sparse ventrally on tail (difficult to separate from *Parophrys vetulus, Platichthys stellatus*, & *Psettichthys melanostictus*)

LARVAE

Hatching length: ca. 2.7 mm
Flexion length: 9.0–10.9 mm through 13.3–14.0 mm
Transformation length: 15.0–16.0 mm through ≥21 mm
Fin development sequence: C & D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Irregular series on dorsal & ventral margins; few laterally; above & below tip of tail. *Preflexion*—On lower jaw; on isthmus to gut region (not continuous); posterolaterally on gut; 3 postanal bars; sparse on ventral finfold. *Flexion*—Increasing on lateral midline; heavy posteriorly on gut; postanal bars becoming embedded in myosepta & some in myosepta between bars; series on D & A bases. *Early postflexion*—On lips, angular, & preopercle; on C base; on D & A pterygiophores. *Late postflexion–transformation*—Patches & poorly defined bars extending onto D & A pterygiophores & rays; distinct posterior bar; heavy posteriorly on gut.
Diagnostic features: Total vertebrae 39–42; 3 postanal bars, including one in caudal region; myoseptal pigment in bars & some between bars; finfold pigment.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		26–40 33	33–37 35	33–40 36	30–38 33	
BD/BL		12–20 16	16–22 20	23–28 25	29–36 33	
HL/BL		14–20 17	18–20 20	21–23 22	23–27 25	
HW/HL		30–50 41	33–34 33	28–36 32	27–31 29	
SnL/HL		17–27 21	14–20 18	14–17 15	16–21 18	
ED/HL*		21–35× 22–29 28×26	20–25× 21–22 23×22	21–23× 20–23 22×22	22–24× 19–24 22×21	
P_1L/BL		2–8 4	3–6 5	4–10 6	5–7 6	
P_2L/BL		0–0 0	0–0 0	0–0 0	2–6 4	
BDA/BL		13–22 16	17–25 22	26–36 28	33–40 37	

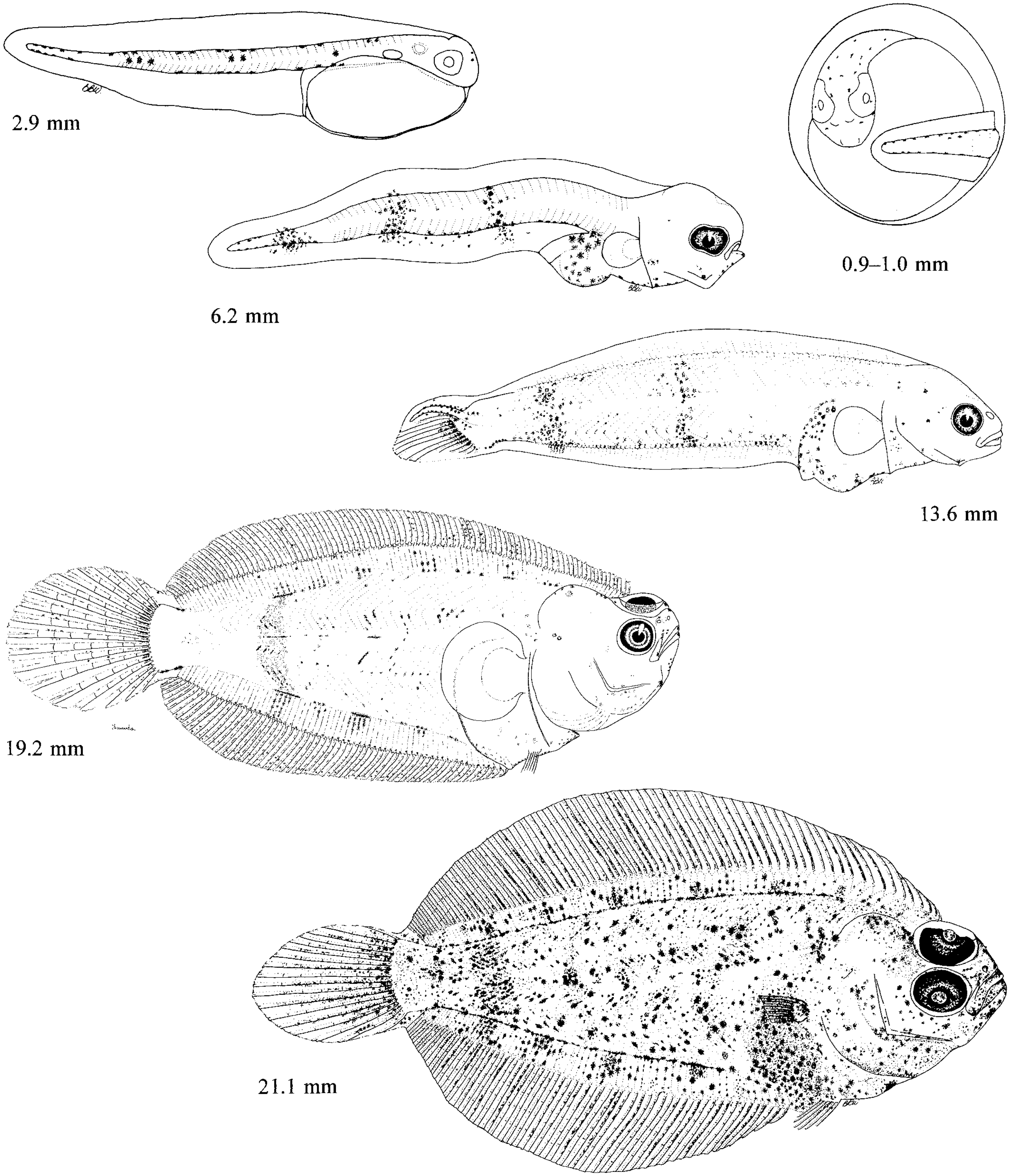


Figure Pleuronectidae 5. Egg, 0.9–1.0 mm; yolk-sac larva, 2.9 mm; preflexion larva, 6.2 mm; flexion larva, 13.6 mm (Richardson et al. 1980); transformation specimen, 19.2 mm (CFRD Ref. Coll., OSU, station 589E, June 1971); juvenile, 21.1 mm (Richardson et al. 1980).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–42	40
Precaudal	10–12	11
Caudal	28–31	30
Fins:		
Dorsal spines	0	0
Dorsal rays	65–84	76
Anal spines	0	0
Anal rays	50–65	58
Pelvic	6	6
Pectoral	8–13	11
Caudal:		
Total	18–19	18
Principal:	7–8+8–9	7–8+8
Gill rakers:		
Upper	3	3
Lower	5–8	
Branchiostegals	7	7

LIFE HISTORY

Range: Bering Sea to southern California (Tanner Bank)

Habitat: Demersal on soft to hard substrate of shelf & slope to ca. 500 m depth; shallower in summer, deeper in winter

Spawning season: February–April; in CalCOFI area, larvae collected February–July, with peak abundance in May

ELH pattern: Oviparous; demersal, adhesive eggs; pelagic larvae

LITERATURE

Ahlstrom et al. 1984a
Matarese et al. 1989*
Pertseva-Ostroumova 1961
Smith 1936

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 3.1 mm (R. C. Walker)

* Two larval forms are recognized for *Lepidopsetta bilineata* (Pertseva-Ostroumova 1961; Matarese et al. 1989). All larvae from CalCOFI collections match the form designated as "*Lepidopsetta* 2" by Matarese et al. (1989). The two forms are now recognized as distinct species (A. C. Matarese, pers. comm.).

† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.87–1.0 mm **Yolk:** Homogeneous; 0.48–0.65 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Reticulated & corrugated
Pigment: On yolk; on late-stage embryo, dorsally on head & body, cleithrum, anus, & tail, scattered on ventral midline.
Diagnostic features: Demersal egg; pigmentation

LARVAE

Hatching length: 3.1–4.0 mm
Flexion length: 7.2–8.0 mm through 8.1 – >9.7 mm
Transformation length: 10.0–>17.7 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—4 postanal patches on dorsum & 4 less well-defined patches on ventral margin of tail, with intervening double row along ventral margin; on top of head; laterally in cleithral region; on yolk sac & gut; above & below tip of tail; 2 patches on ventral finfold. *Preflexion*—Double row on ventral margin ends ca. 3 myomeres anterior to bar on tail; on gular & isthmus region; several along cleithrum; heavy ventrally on gut; 3–5 patches distally on dorsal finfold; by 7.2 mm, dorsal & ventral patches expanding to epaxial & hypaxial myosepta; internally above spinal column. *Flexion–postflexion*—Double series along ventral margin decreasing; 1 to several on hypural region; on angular. *Transformation*—3rd dorsal patch & apposing ventral patch expand to form an indistinct bar; other patches form in myosepta & continue onto D & A pterygiophores & rays; posteriorly on brain.
Diagnostic features: Total vertebrae 38–42; distal dorsal & ventral finfold pigment; pigment patches on dorsum & on ventral margin of tail; also, a double row of melanophores on ventral margin of tail; bar posteriorly on tail; relatively large eyes; compared with *Psettichthys melanostictus*, *L. bilineata* larvae are more slender, have a relatively larger eye, shorter preanal length, & different pigment pattern.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		33–41	37–39	38–44	37–41	32–38
	37	36	38	42	39	35
BD/BL		13–25	20–24	27–29	34–41	38–84
	9	18	22	28	38	56
HL/BL		16–23	20–23	26–27	28–32	31–32
	17	18	21	27	30	32
HW/HL		32–46	39–40	31–37	33–41	28–30
	65	42	39	35	36	29
SnL/HL		19–23	18–21	18–20	17–21	17–20
	23	20	20	19	20	19
ED/HL†		26–37× 24–35	26–27× 25–27	24–26× 24–25	22–27× 23–26	18–29× 14–21
	42×38	31×28	27×26	26×25	25×25	24×16
P_1L/BL		5–6	5–6	4–7	5–7	6–10
	1	5	5	5	6	8
P_2L/BL		0–0	0–0	0–0	4–7	9–10
	0	0	0	0	6	10
BDA/BL		13–24	21–27	31–34	41–47	43–84
	8	18	23	32	43	58

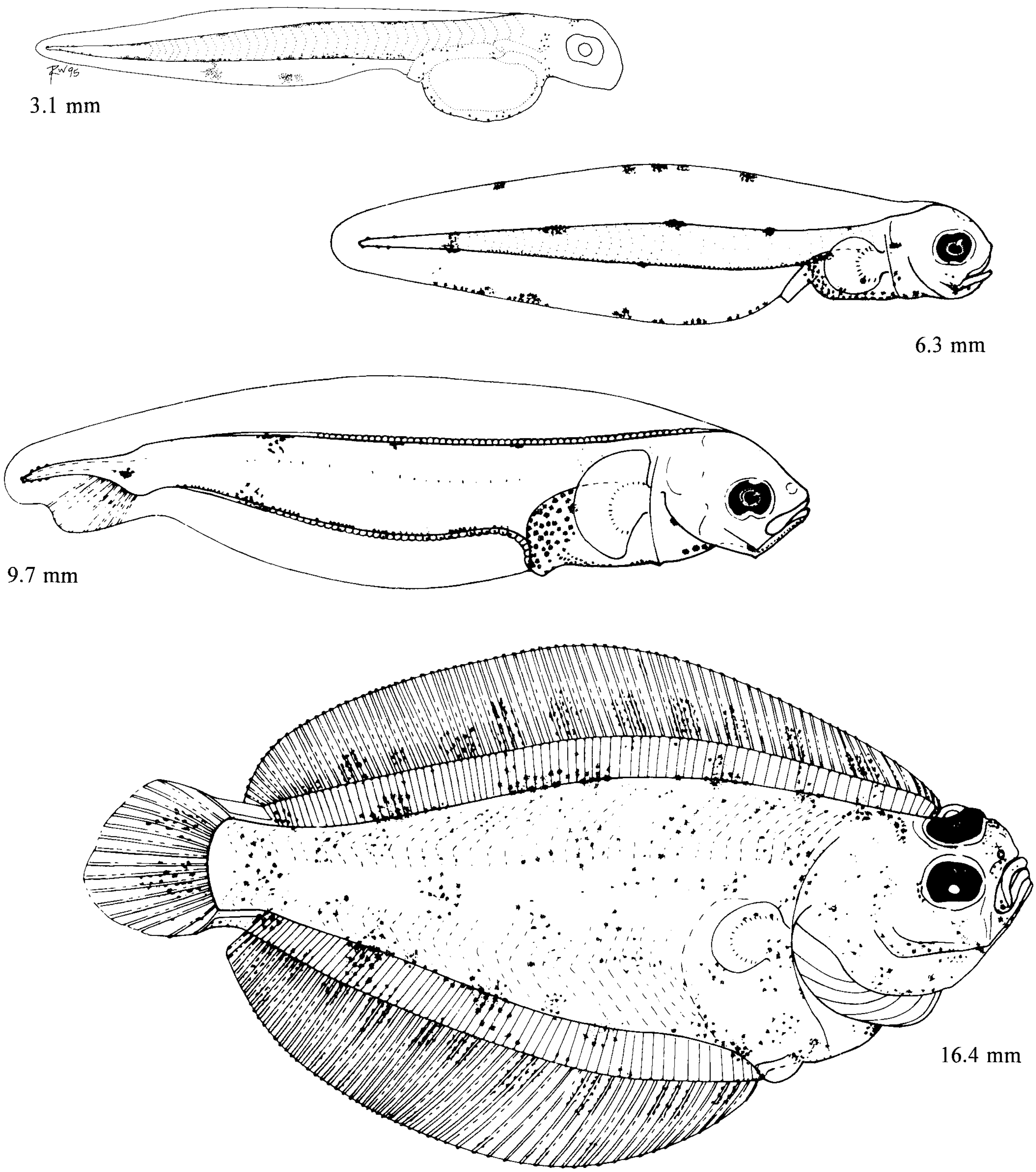


Figure Pleuronectidae 6. Yolk-sac larva, 3.1 mm (CalCOFI 6204, station 87.50); preflexion larva, 6.3 mm; flexion larva, 9.7 mm; transformation specimen, 16.4 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	42–47	45
Precaudal	11–13	12
Caudal	31–35	33
Fins:		
Dorsal spines	0	0
Dorsal rays	72–88	77
Anal spines	0	0
Anal rays	57–66	60
Pelvic	6	6
Pectoral	9–10	10
Caudal:		
Total	19	19
Principal	8–10+7–9	9+9
Gill rakers:		
Upper	2–3	
Lower	9–11	
Branchiostegals	6–7	7

LIFE HISTORY

Range: Gulf of Alaska (54°–60° N) to central Baja California

Habitat: Demersal on shelf to mid-slope, 25–800 m depth

Spawning season: February, April; in CalCOFI area, larvae collected throughout the year, with peak abundance in April

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Matarese et al. 1989

* Eye somewhat oval, becoming round or nearly so in flexion, returning to oval in late transformation; horizontal axis is given first, vertical axis second.

† Pelvic blade damaged in all but one flexion specimen.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.5–1.7 mm **Yolk:** Homogeneous; 1.2–1.5 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Fine, elongate ridges
Pigment: On yolk; distributed over entire late-stage embryo, heavy in caudal region, dorsal & ventral series may start to form just before hatching
Diagnostic features: Size; surface features on chorion; pigment on embryo, especially in caudal region

LARVAE

Hatching length: 5.2–5.6 mm
Flexion length: 9.0–10.8 mm through 13.3–13.5 mm
Transformation length: 15.7–16.7 mm through 20.6–24.7 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Preflexion-flexion*—Series on dorsal & ventral midline; above & below tip of tail & on caudal finfold; with development, dorsal & ventral series expand laterally onto myosepta; expands on finfold to cover ventral finfold & posterior half of dorsal finfold; series of heavy dashes on isthmus & ventral margin below gut; heavy above gut; increased laterally on gut with development; few above brain; on P_1 blade; by late flexion stage, several short series on ventral margin of tail & continuous series on ventral margin from gular region to anus. *Postflexion*—Above brain; in otic & preopercular regions; at angular; in & on myosepta laterally on trunk & tail; linear patches along D & A fin bases; 3 streaks along lateral midline by late stage; heavy on notochord tip. *Transformation-juvenile*—6 vague bars on myosepta of trunk & tail extending onto D & A pterygiophore zones; on upper & lower jaws.
Diagnostic features: Total vertebrae 42–47; prominent series of melanophores along dorsal & ventral body margins expand onto myosepta; extensive dorsal & ventral finfold pigment; no postanal pigment bars in preflexion larvae.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	34–43 37	39–43 41	40–47 42	43–50 46	35–45 40	34–36 35
BD/BL	10–13 11	10–19 16	19–31 25	23–32 29	34–38 36	31–34 33
HL/BL	12–14 13	13–23 20	21–30 25	24–33 29	30–34 32	32–34 33
HW/HL	43–67 59	40–50 47	42–46 44	35–45 39	36–40 38	31–34 33
SnL/HL	17–24 21	15–29 23	24–28 25	22–29 25	23–27 25	20–23 21
ED/HL*	35–50× 30–43 42×37	20–39× 22–34 27×26	21–25× 22–23 23×23	19–25× 20–25 22×22	21–23× 20–25 22×22	25–31× 15–19 28×17
P_1L/BL	1–2 2	2–6 5	4–7 6	6–8 7	4–8 6	8–11 10
P_2L/BL†	0–0 0	0–0 0	1	1–5 3	6–9 8	9–11 10
BDA/BL	9–13 11	10–22 16	20–32 25	23–33 29	37–39 38	31–36 33

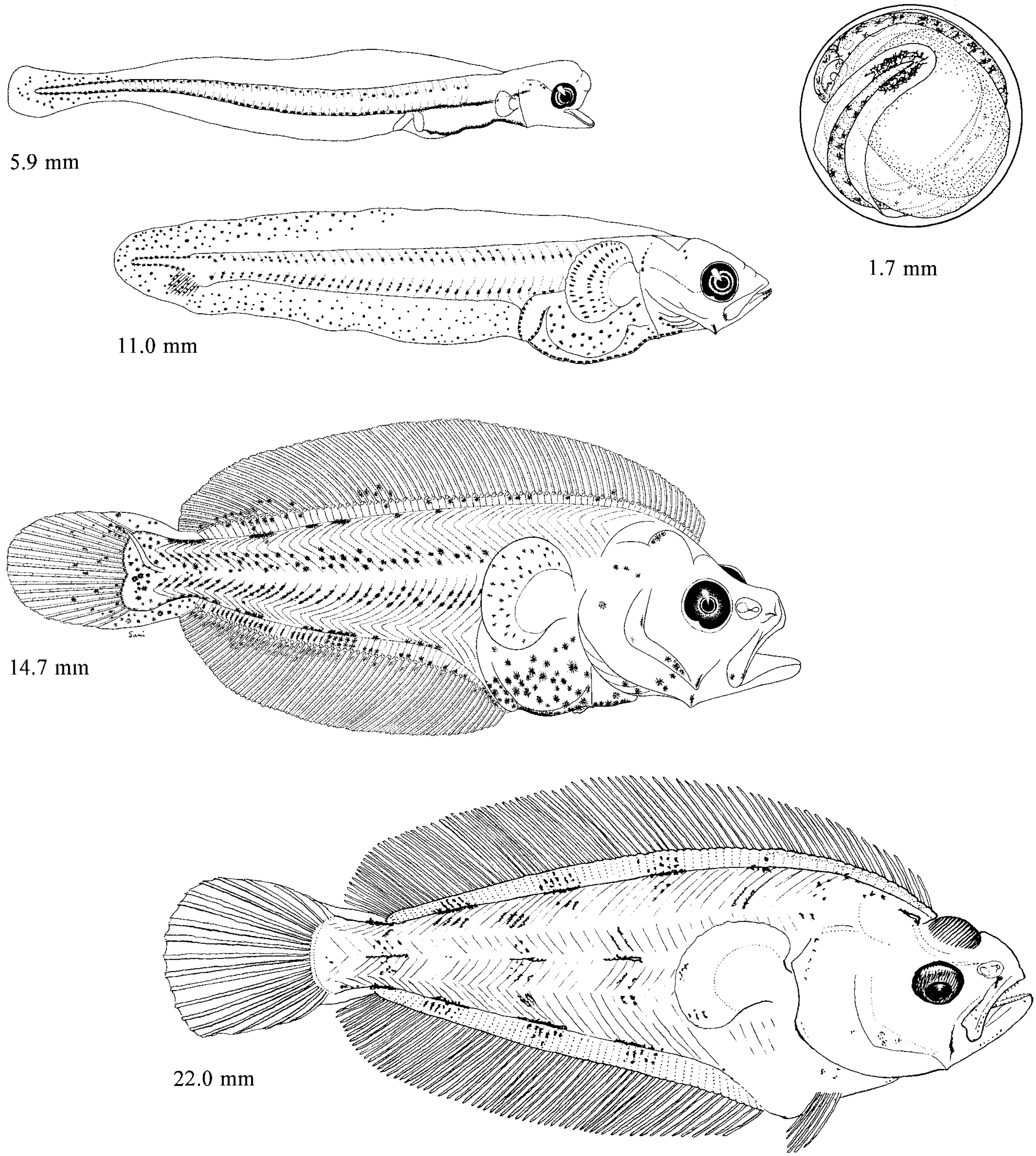


Figure Pleuronectidae 7. Egg, 1.7 mm (Matarese et al. 1989); preflexion larvae, 5.9 mm, 11.0 mm (Ahlstrom and Moser 1975); postflexion larva, 14.7 mm (Ahlstrom et al. 1984a); transformation specimen, 22.0 mm (Ahlstrom and Moser 1975).

MERISTICS

	Range	Mode
Vertebrae:		
Total	50–55	52
Precaudal	11–13	12
Caudal	37–41	38–39
Fins:		
Dorsal spines	0	0
Dorsal rays	86–116	105
Anal spines	0	0
Anal rays	75–96	87
Pelvic	5–6	6
Pectoral	8–12	11
Caudal:		
Total	19–23	21
Principal	7–10+9–10	10+9
Gill rakers:		
Upper	5–8	
Lower	8–11	
Branchiostegals	7	7

LIFE HISTORY

Range: Bering Sea to Bahía Asuncion, Baja California Sur (SIO 65–212)

Habitat: Demersal on shelf to deep slope at 9–1,189 m depth; shallower in summer, deeper in winter

Spawning season: In CalCOFI, larvae collected throughout the year, with maximum abundance in May & June

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Markle et al. 1992
Matarese et al. 1989
Richardson 1981b

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 6.9 mm (R. C. Walker)

* Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 2.1–2.7 mm **Yolk:** Homogeneous; 1.5–2.2 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth or some with wave-like ridges or dimples
Pigment: On yolk; in late-stage embryos, series on dorsum (discontinuous), ventrally on tail, some laterally, & distinct in caudal region; several indistinct bars may form just before hatching
Diagnostic features: Size; very wide perivitelline space; caudal pigment not as heavy as in *Lyopsetta exilis*; dorsal & ventral pigment series

LARVAE

Hatching length: ca. 4.4–6.9 mm
Flexion length: 7.8–11.4 mm through 9.8–15.0 mm
Transformation length: 43.1–47.3 mm through 47.0–79 mm; eye migrates to midline at ca. 15–20 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—On yolk sac; incomplete dorsal series; continuous ventral series; above midgut; above & below terminus of gut; above & below notochord tip & on caudal finfold; few posterior to eye; on lower jaw. *Preflexion*—Postanal series coalescing into 2 small dorsal & 3 small ventral patches that extend onto finfolds; series from isthmus to anus; on notochord tip & caudal finfold. *Flexion*—Heavy series from gular region to anus; small patches on epaxial myomeres; above & below notochord; series of patches on pterygiophores & distally on dorsal & ventral finfolds. *Postflexion–transformation*—Series of linear patches along proximal & distal margins of D & A pterygiophores & series of 5 rounded patches in middle regions of D & A pterygiophores. *Juvenile*—Entire body covered; denser along lateral line where 5–6 patches form; heavy dashes along body edge.
Diagnostic features: Total vertebrae 50–55; otic spines by 8.6 mm; preflexion larvae slender, becoming very deep-bodied in postflexion stage; in preflexion larvae, 3–4 pigment bars on tail extend onto finfold; series of pigment patches on body & fins in later larval stages; larvae reach >50 mm length.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	39–47 41	39–42 41	41–46 44	19–40 27	13–23 19	26–28 27
BD/BL	11–23 18	17–27 22	40–49 43	54–80 62	16–57 35	30–31 31
HL/BL	13–23 17	19–23 21	26–32 30	19–32 25	20–27 24	26–28 27
HW/HL	39–45 42	25–41 31	27–34 30	29–39 32	27–37 32	29–29 29
SnL/HL	15–24 20	14–20 18	22–29 25	11–33 21	11–14 13	9–10 9
ED/HL*	28–35× 26–29 30×27	16–25× 18–22 20×20	15–19× 15–19 17×17	15–21× 12–17 17×15	19–34× 14–22 29×20	32–32× 20–23 32×21
P_1L/BL	1–6 4	5–6 5	4–7 5	1–7 4	4–13 10	10–10 10
P_2L/BL	0–0 0	0–0 0	0–0 0	0–4 2	3–6 5	2–3 2
BDA/BL	16–22 18	21–31 26	37–46 41	51–84 61	18–53 34	30–31 31

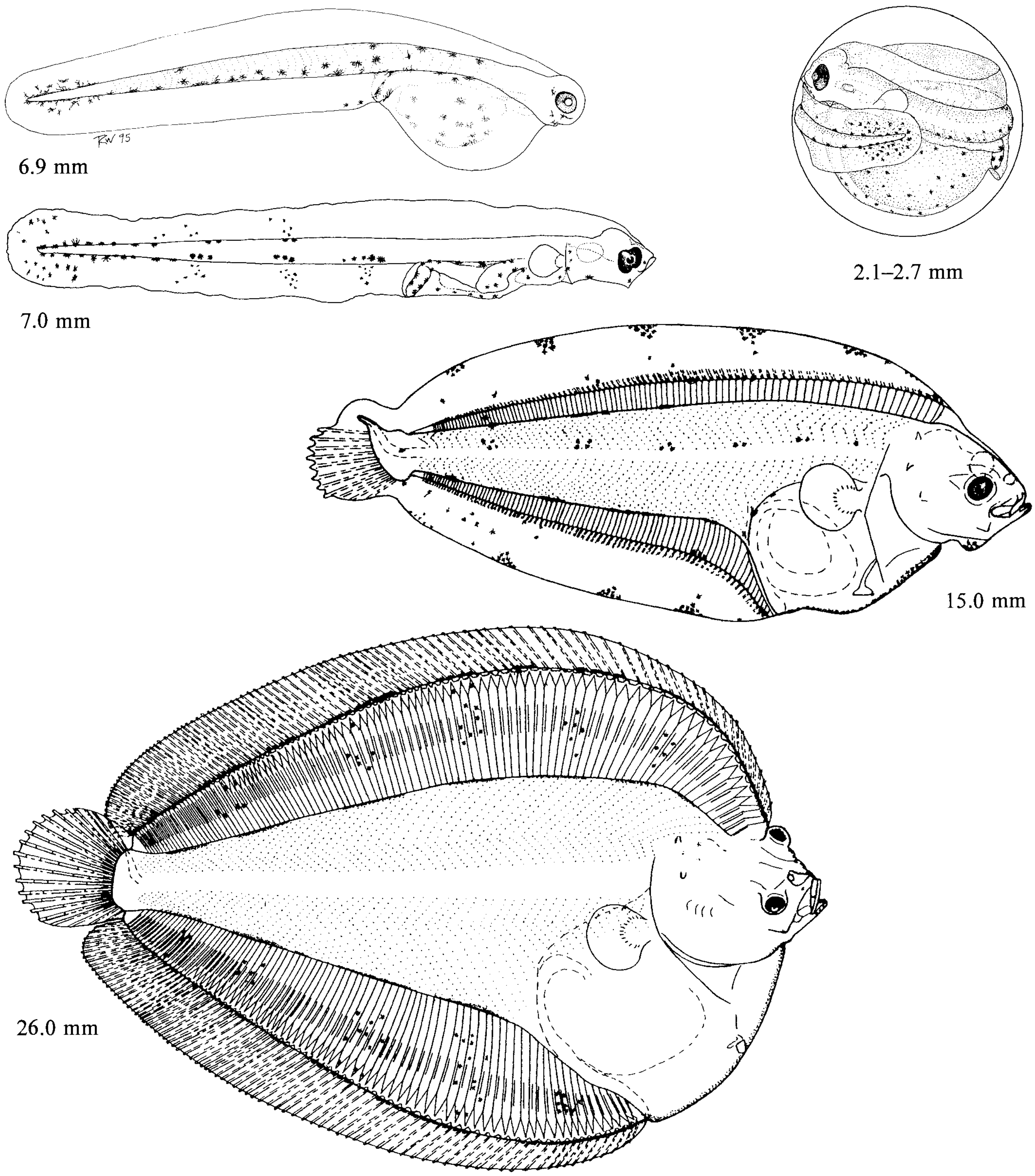


Figure Pleuronectidae 8. Egg, 2.1–2.7 mm (Matarese et al. 1989); yolk-sac larva, 6.9 mm (CFRD Ref. Coll., reared at SWFSC, 911020 Vial # 83, 15 days old); preflexion larva, 7.0 mm (Ahlstrom et al. 1984a); flexion larva, 15.0 mm; postflexion larva, 26.0 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	41–47	44
Precaudal	10–12	11
Caudal	31–34	33
Fins:		
Dorsal spines	0	0
Dorsal rays	72–93	80
Anal spines	0	0
Anal rays	52–70	60
Pelvic	6	6
Pectoral	10–12	
Caudal:		
Total	18	18
Principal	8+9	8+9
Gill rakers:		
Upper	4–6	
Lower	10–13	
Branchiostegals	7–8	7

LIFE HISTORY

Range: Bering Sea to Bahía San Cristobal, Baja California Sur

Habitat: Demersal on shelf & upper slope from intertidal to 550 m depth

Spawning season: October–May; in CalCOFI area, larvae collected throughout the year, with peak abundance in April

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Budd 1940
Jow 1969
Matarese et al. 1989
Orsi 1968

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.96 mm diameter (R. C. Walker)

* Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.80–1.1 mm, **Yolk:** Homogeneous; 0.83 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Smooth or with fine striations
Pigment: Dorsal & ventral series on late-stage embryo
Diagnostic features: Size; difficult to separate from *Isopsetta isolepis*, *Platichthys stellatus* & *Psettichthys melanostictus*.

LARVAE

Hatching length: 2.3–2.9 mm
Flexion length: 7.6–7.9 mm through 9.8–11.5 mm
Transformation length: 16.7–17.6 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Preflexion*—Above angular; ventral series from cleithrum to anus; ventrolaterally on gut coil; on nape; discontinuous dorsal series; continuous ventral series; on ventral finfold. *Flexion*—On tip of lower jaw; laterally anterior to cleithrum; on isthmus; dorsal series reduced to 2 areas on tail; embedded series above spinal column; around notochord tip; on bases of C rays; usually 2 patches on hypaxial myomeres. *Postflexion*—Increasing on lower jaw; heavy dorsally on gut; on C base; increasing on hypaxial myosepta; heavy series on A pterygiophores extending to ventral margin of caudal peduncle. *Transformation*—On D & A pterygiophores, on hypaxial myosepta, & on A rays.
Diagnostic features: Total vertebrae 41–47; no pigment bars; dorsal & ventral pigment series in early larvae; hypaxial & epaxial myoseptal pigment; pigment on ventral finfold & A rays.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	34–38 36	32–39 35	33–38 36	37–42 40	36–40 38	30–34 32
BD/BL	15–16 16	13–18 16	17–20 19	22–25 24	24–30 28	36–42 40
HL/BL	14–17 16	14–17 16	17–22 19	21–26 22	22–25 24	28–31 30
HW/HL	43–59 53	42–54 47	36–40 38	33–41 37	34–36 35	29–39 33
SnL/HL	11–24 19	4–21 15	20–24 22	12–20 17	18–20 19	15–20 17
ED/HL*	39–44× 35–41	30–46× 27–38	25–28× 25–27	23–27× 22–26	22–24× 21–23	26–29× 17–22
	41×38	36×31	26×27	25×25	23×22	27×20
P_1L/BL	3–8 5	3–7 5	5–8 6	4–6 5	6–7 6	5–10 8
P_2L/BL	0–0 0	0–0 0	0–0 0	0–0 0	1–5 3	9–10 10
BDA/BL	14–16 15	14–18 16	16–20 19	24–28 25	29–36 33	39–43 41

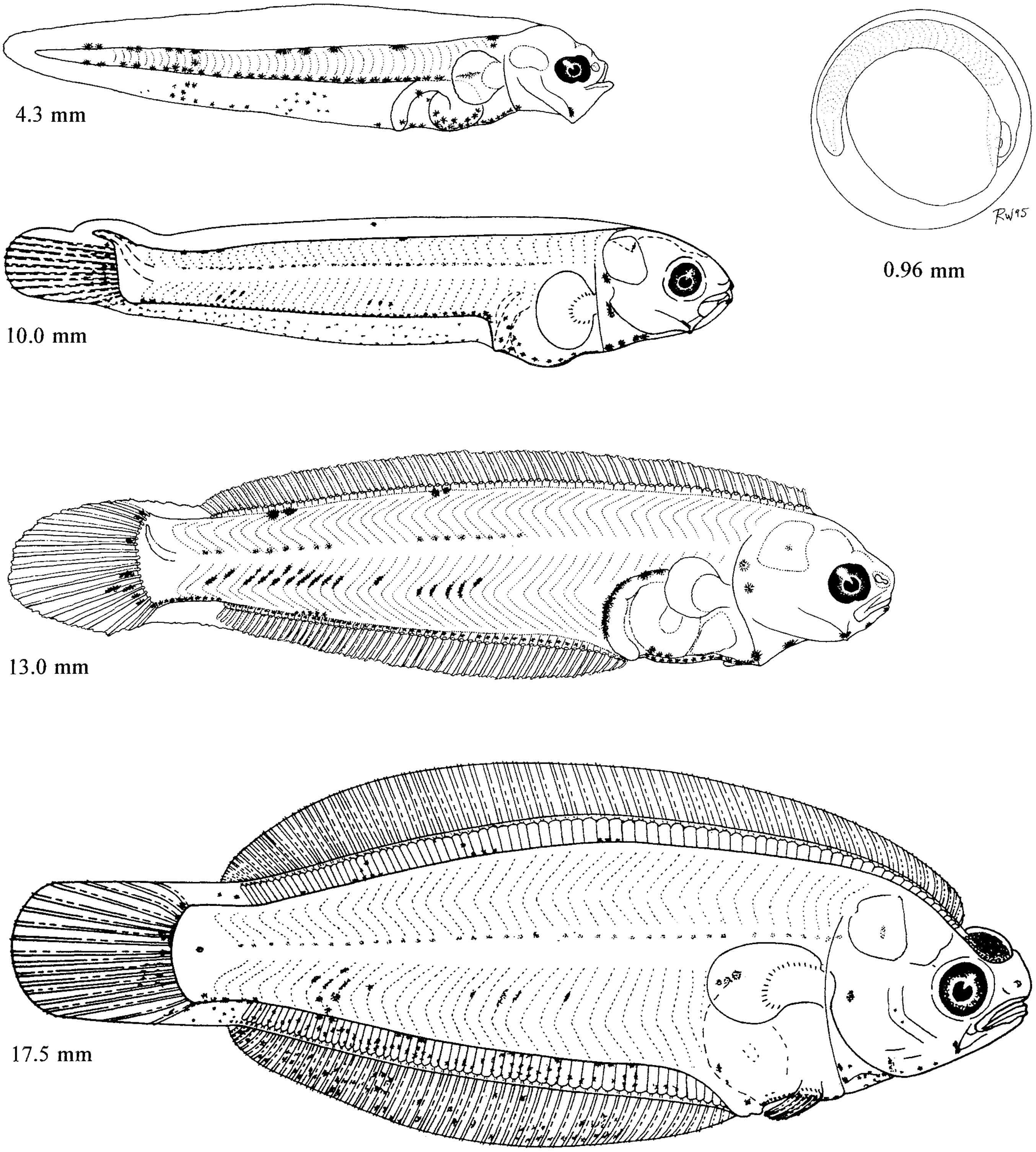


Figure Pleuronectidae 9. Egg, 0.96 mm (CFRD Ref. Coll., reared by Preston Porter, 48 hrs.); preflexion larva, 4.3 mm (Ahlstrom and Moser 1975); flexion larva, 10.0 mm (Matarese et al. 1989); postflexion larva, 13.0 mm (Ahlstrom and Moser 1975); transformation specimen, 17.5 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	35–38	36
Precaudal	10–12	11
Caudal	24–26	25
Fins:		
Dorsal spines	0	0
Dorsal rays	52–66	59
Anal spines	0	0
Anal rays	38–47	42
Pelvic	5–6	6
Pectoral	9–10	10
Caudal:		
Total	17–19	18
Principal	7+8–9	7+8
Gill rakers:		
Upper	3–4	3
Lower	6–9	8
Branchiostegals	7	7

LIFE HISTORY

Range: Sea of Japan & Arctic Alaska to Santa Barbara, California

Habitat: Demersal on shelf & upper slope to 375 m depth; often in estuaries

Spawning season: November–February; in CalCOFI area, larvae collected January to May, with peak abundance in March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Matarese et al. 1989
Orcutt 1950
Yusa 1957

* Eye somewhat oval, horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.88–1.3 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Irregular reticulations
Pigment: Sparsely scattered on yolk; on late-stage embryo, sparsely scattered around eyes & nares, on dorsum, some posteriorly on gut, & few on dorsal & ventral finfolds
Diagnostic features: Very difficult to distinguish from *Isopsetta isolepis*, *Parophrys vetulus*, & *Psettichthys melanostictus*

LARVAE

Hatching length: 1.9–2.1 mm
Flexion length: 5.5 mm through 5.7–7.4 mm
Transformation length: 8.3–8.5 mm through 10.5 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Series on entire dorsum; irregular series on ventral margin of tail; above & below gut; sparse on yolk sac; triangular patches on dorsal & ventral finfolds with some on finfold margin anterior & posterior to each patch. *Preflexion*—Sparse on top of head; on lower jaw & angular; on gill cover; posterolaterally on gut; ventral series from isthmus to anus; on most of ventral finfold & on adjoining musculature of tail, heaviest posteriorly, becoming less concentrated with development; some posteriorly on dorsal finfold; above & below notochord tip; few on P_1 & anterior to cleithrum; embedded above spinal column. *Flexion–postflexion*—On upper & lower jaws; basally on C rays. *Transformation*—Coalescing into sparse patches over head & body; a series of patches on D & A pterygiophores & on caudal peduncle; some scattered on rays of all fins.
Diagnostic features: Total vertebrae 35–38; finfold patches in yolk-sac larvae; pigment pattern on tail; lack of pigment bars & lateral midline pigment; small size at transformation.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	44–54 50	38–50 42	26–40 36	38–47 41	37–44 41	36–38 37
BD/BL	19–35 29	14–24 19	20–25 22	24–28 26	28–44 34	42–45 44
HL/BL	16–17 17	16–23 19	20–23 21	22–27 24	26–31 28	33–34 34
HW/HL	46–59 54	41–59 49	34–48 42	31–41 37	37–40 38	28–36 33
SnL/HL	13–21 17	11–23 18	18–29 21	14–19 17	13–17 16	17–20 19
ED/HL*	39–47× 32–42 42×38	34–50× 29–36 37×33	24–30× 23–29 28×25	22–26× 19–26 24×23	26–29× 21–26 27×24	22–24× 13–15 23×14
P_1L/BL	0–4 1	3–7 5	5–11 7	6–9 8	2–9 6	3–11 8
P_2L/BL	0–0 0	0–0 0	0–0 0	0–0 0	1–6 3	10–10 10
BDA/BL	21–25 22	13–28 19	21–25 22	26–31 29	36–47 40	46–48 47

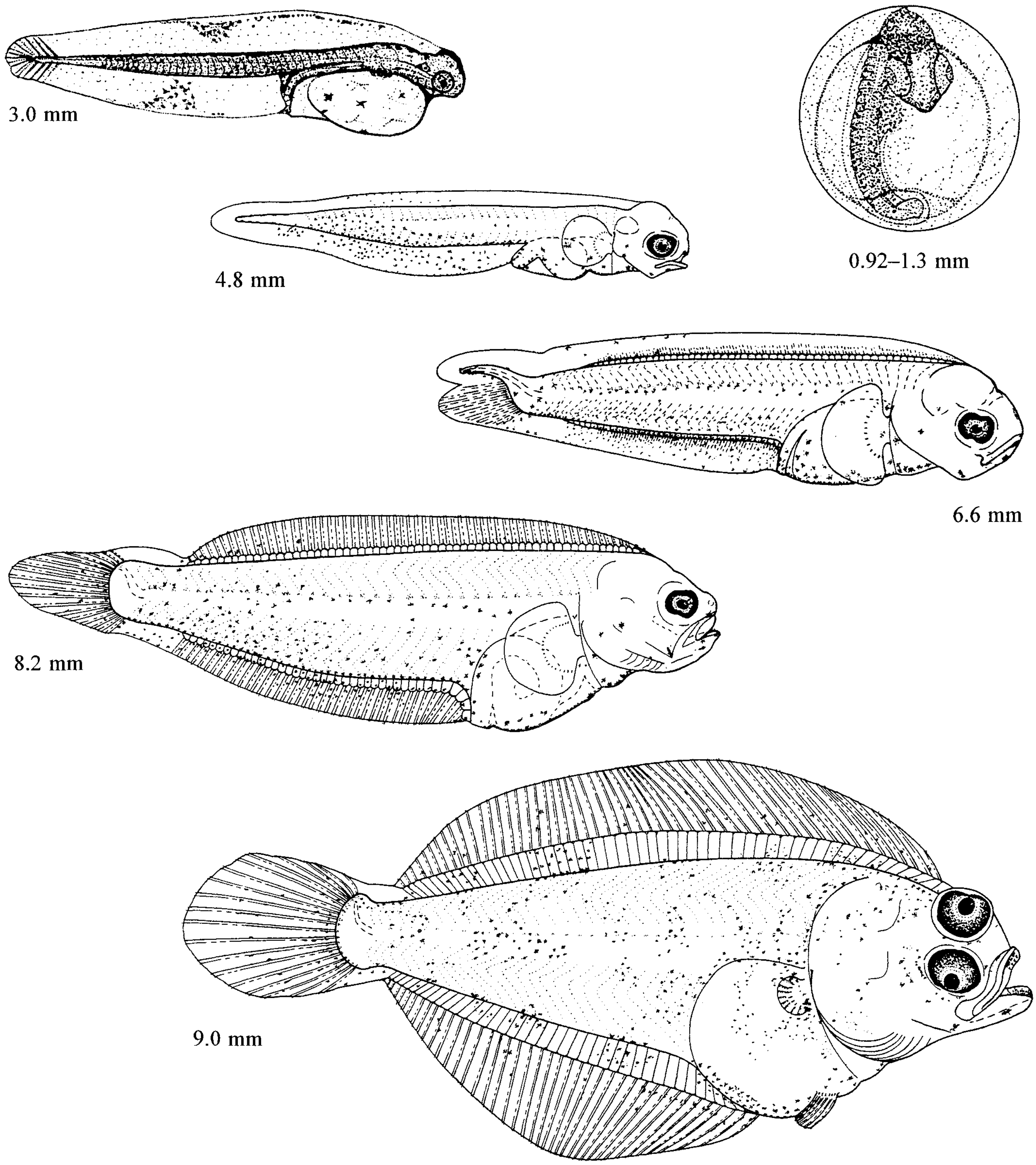


Figure Pleuronectidae 10. Egg, 0.92–1.3 mm; yolk-sac larva, 3.0 mm (Orcutt 1950); preflexion larva, 4.8 mm; flexion larva, 6.6 mm; postflexion larva, 8.2 mm; juvenile, 9.0 mm (Matarese et al. 1989).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–39	37
Precaudal	12–13	13
Caudal	24–26	24
Fins:		
Dorsal spines	0	0
Dorsal rays	65–78	
Anal spines	0	0
Anal rays	44–56	49
Pelvic	6	6
Pectoral	9–12	
Caudal:		
Total	18–20	19
Principal	7–8+8–9	8+8
Gill rakers:		
Upper	3–4	
Lower	8–11	
Branchiostegals	7	7

LIFE HISTORY

Range: Southeast Alaska to Punta Abreojos, Baja California Sur

Habitat: Demersal on shelf & upper slope to 350 m depth; soft or rocky bottom

Spawning season: In CalCOFI area, larvae collected February–October, with maximum abundance in April–July

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Budd 1940
Matarese et al. 1989
Sumida et al. 1979

* Values calculated from Sumida et al. (1979).
† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.2–1.6 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Hexagonal sculpturing
Pigment: Lightly scattered on yolk; heavy on head & body of late-stage embryo, lacking posteriorly on tail, except at notochord tip
Diagnostic features: Size; hexagonal sculpturing

LARVAE

Hatching length: ca. 3.7 mm
Flexion length: 6.1–8.5 mm
Transformation length: 8.2–11.4 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Preflexion*—Head & body covered heavily except for snout & cheek area & caudal region; above & below notochord tip; apposing rounded patches on dorsal & ventral finfolds in midtail region; lacking on P_1 & caudal finfold. *Flexion*—Increasing on ventral surface of head & anteriorly on finfold. *Postflexion–transformation*—Increasing on P_1 base, D & A pterygiophores & C region.
Diagnostic features: Total vertebrae 36–39, precaudal vertebrae 13 (rarely 12); size at transformation; no pterotic spines; pigment pattern.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		39–50	42–51	41–46	37–49	
	46	46	45	44	41	31
BD/BL		16–22	22–33	31–38	44–45	
	8	19	27	34	44	46
HL/BL		18–23	22–31	28–31	30–33	
	15	21	25	30	32	28
HW/HL						
SnL/HL		16–24	14–21	16–19	15–20	
	27	19	18	18	18	12
ED/HL†		31–40× 29–35	28–35× 24–34	30–31× 27–28	26–31× 25–27	
	43×33	36×32	32×29	30×28	29×26	30
P_1L/BL						
BDA/BL		13–25	24–35	32–41	47–50	
	12	17	28	37	49	49

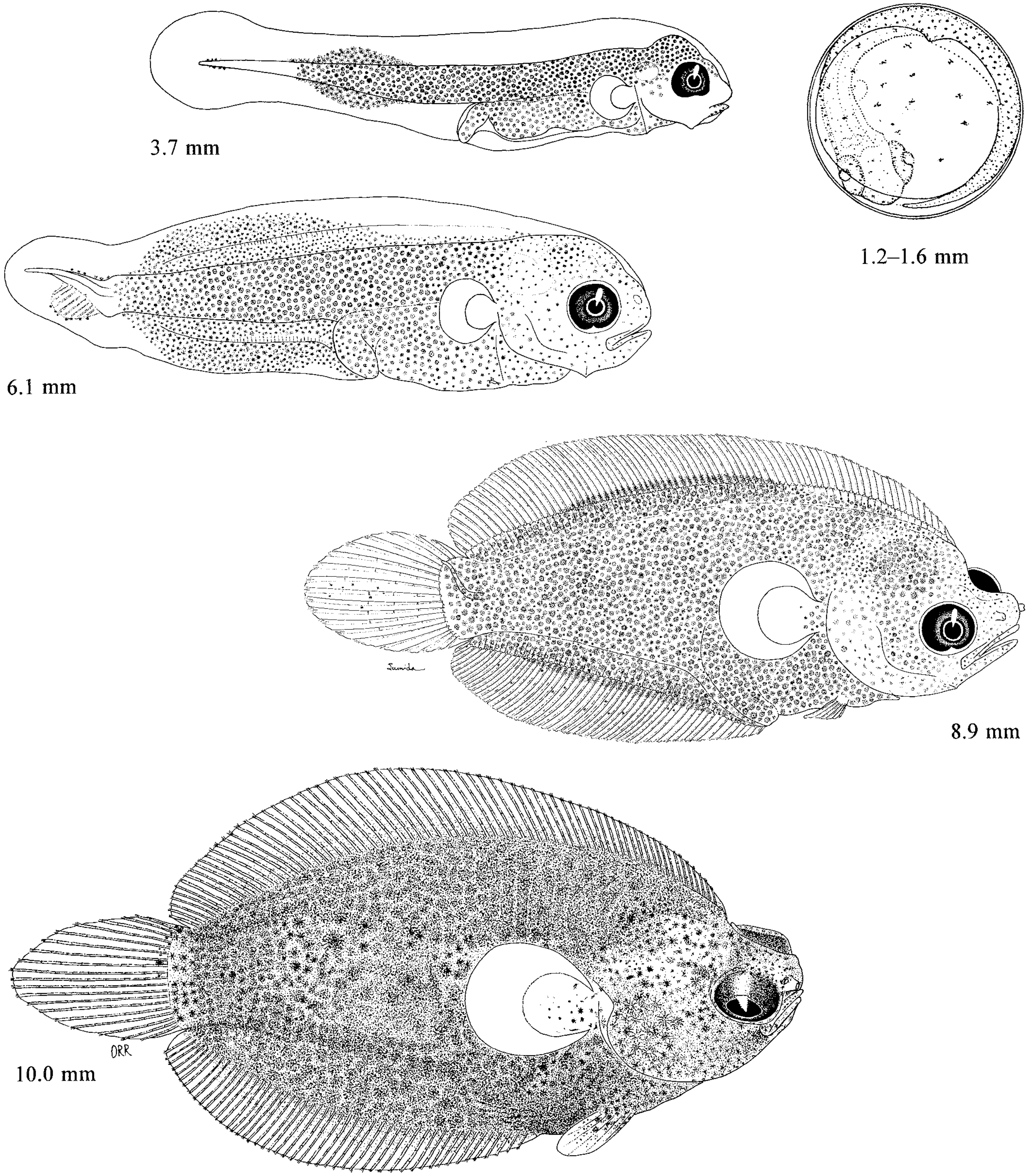


Figure Pleuronectidae 11. Egg, 1.2–1.6 mm (Budd 1940, as *P. decurrens*; sculpting on shell not shown in illustration); preflexion larva, 3.7 mm; flexion larva, 6.1 mm; transformation specimens, 8.9 mm, 10.0 mm (Sumida et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	38–41	39
Precaudal	13–15	14
Caudal	24–27	25
Fins:		
Dorsal spines	0	0
Dorsal rays	67–81	75
Anal spines	0	0
Anal rays	45–55	50
Pelvic	4–7	6
Pectoral	9–14	12
Caudal:		
Total	18–20	19
Principal	8–9+8–9	8+8
Gill rakers:		
Upper	2–4	3
Lower	5–9	7
Branchiostegals	7–8	7

LIFE HISTORY

Range: Bering Sea to Isla Cedros, Baja California

Habitat: Demersal on shelf & upper slope at 8–532 m depth

Spawning season: In CalCOFI area, larvae collected in all months except September, with peak abundance in March

ELH pattern: Oviparous; planktonic pelagic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Ahlstrom et al. 1984a
Budd 1940
Matarese et al. 1989
Sumida et al. 1979

* Values calculated from Sumida et al. (1979).
† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.8–2.1 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Hexagonal sculpturing
Pigment: Heavy on yolk; on late-stage embryo, heavy on body & finfold, except lacking at tip of tail region & adjacent finfold
Diagnostic features: Large size; hexagonal sculpturing

LARVAE

Hatching length: ca. 4.9–5.5 mm
Flexion length: 7.8–11.0 mm
Transformation length: 10.0 – >21 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac–early flexion*—Heavy on entire body & finfolds, except sparse on snout & cheek & none on P_1, notochord tip, or caudal finfold. *Flexion*—Few on P_1 base. *Late flexion–transformation*—Heavy pigment on finfolds increases to form 3–4 dorsal & 3 ventral bars extending from the body distally to the D & A pterygiophores.
Diagnostic features: Total vertebrae (38–41), higher than other species in genus; largest size-at-stage of all *Pleuronichthys* species; pterotic spine; pigment pattern.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		44–54	44–53		40–52	
	49	49	50	52	46	33
BD/BL		14–20	26–36		46–58	
	11	17	30	44	53	47
HL/BL		18–22	23–29		32–38	
	16	20	26	33	35	31
HW/HL						
SnL/HL		16–19	15–19		10–18	
	18	18	17	17	13	7
ED/HL†		31–36× 29–33	31–34× 28–34		25–33× 18–31	
	38×30	34×31	32×31	28×28	30×26	37×28
P_1L/BL						
BDA/BL		12–22	27–42		51–67	
	13	18	32	45	59	49

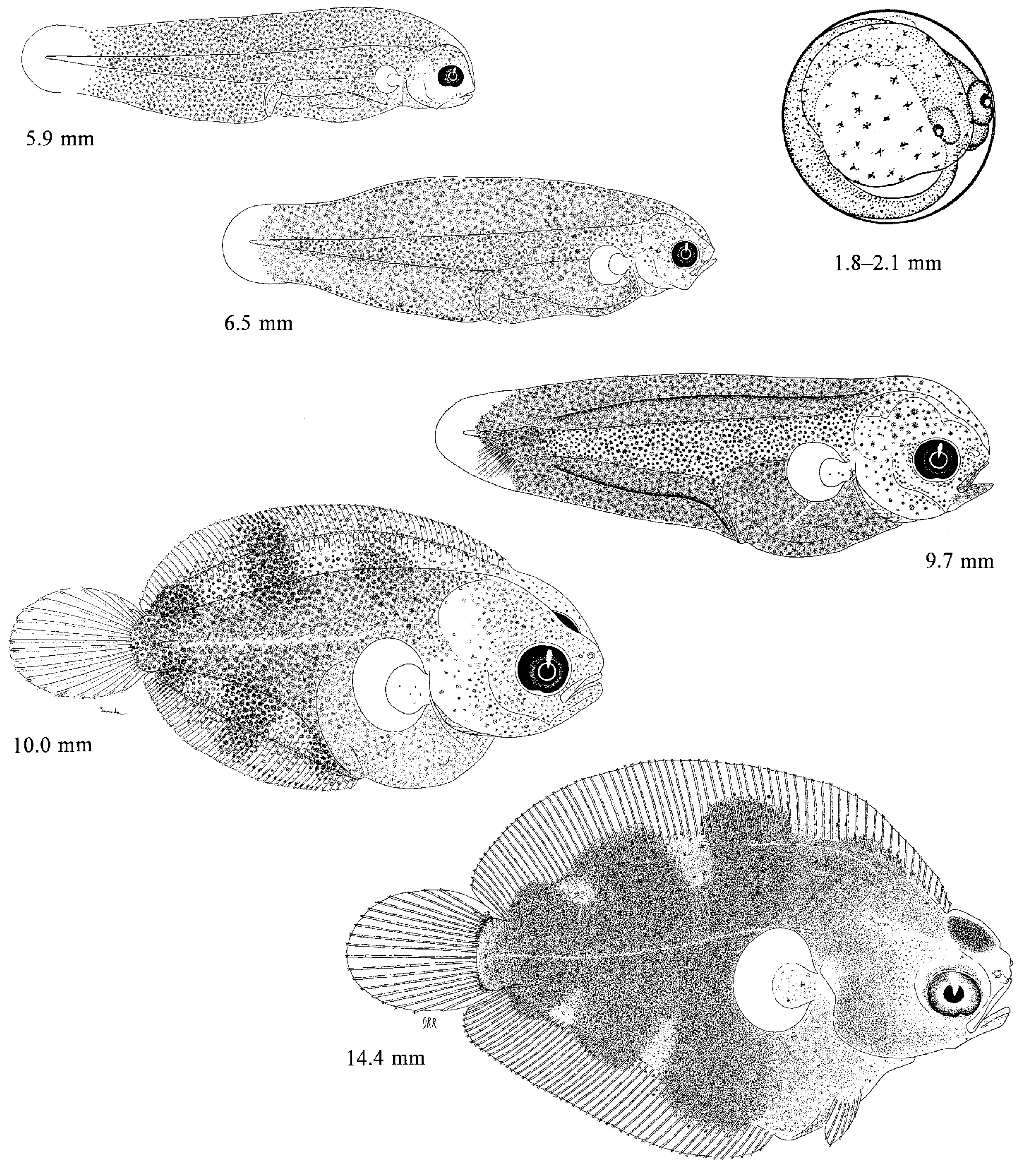


Figure Pleuronectidae 12. Egg, 1.8–2.1 mm (Budd 1940, as *P. coenosus*; sculpting on shell not shown in illustration); preflexion larvae, 5.9 mm, 6.5 mm; flexion larva, 9.7 mm; postflexion larva, 10.0 mm; transformation specimen, 14.4 mm (Sumida et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	34–36	35
Precaudal	12–13	12
Caudal	22–24	23
Fins:		
Dorsal spines	0	0
Dorsal rays	62–72	68–69
Anal spines	0	0
Anal rays	43–52	47
Pelvic	6	6
Pectoral	9–11	10
Caudal:		
Total	18–20	19
Principal	7–8+8–9	8+8
Gill rakers:		
Total	12–17	
Upper	3–5	4
Lower	8–11	9
Branchiostegals	7	7

LIFE HISTORY

Range: Morro Bay, California, to Bahía Magdalena, Baja California Sur

Habitat: Inshore on soft bottom at 1–46 m depth

Spawning season: In CalCOFI area, larvae collected throughout the year, with maximum abundance in July, August & September

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Orton & Limbaugh 1953
Sumida et al. 1979
White 1977

* Values calculated from Sumida et al. (1979).
† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.9–1.1 mm **Yolk:** Homogeneous
No. of OG: 1 **Diam. of OG:** 0.08–0.14 mm
Shell surface: Hexagonal sculpturing
Pigment: Moderate on yolk; on late-stage embryo, heavy on head & body, few on finfold edge, lacking posteriorly on tail, blotch on ventral notochord tip
Diagnostic features: Hexagonal sculpturing; presence of an OG (smaller than in *Hypsopsetta guttulata*); small size

LARVAE

Hatching length: ca. 2.1 mm
Flexion length: 4.5–5.6 mm
Transformation length: 6.4–10.0 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Heavy on head & body except for last 8–9 myomeres; a blotch ventrally near notochord tip; above & below gut; scattered on yolk sac; few distally on dorsal & ventral finfolds. *Early preflexion*—Increasing proximally on finfolds; few on edge of P_1 blade; decreasing on cheek & laterally on snout; gut covered; series ventrally on notochord tip; heavy on gular & isthmus regions. *Late preflexion–flexion*—Lacking on dorsum from the nape to anterior margin of midbrain, & ventrally on gut; the few on P_1 blade migrate to base of fin. *Postflexion*—Head, body, & pterygiophores become covered except for last 3–5 myomeres; dusky bar developing posteriorly on tail; some on D, A, & C. *Transformation*—Oval blotch on middle of body; solid bar just anterior to clear hypural zone; series of patches at bases of D & A rays; heavy basally on P_1.
Diagnostic features: Total vertebrae 34–36; pigment pattern, notochord tip pigment in yolk-sac & early preflexion stages, heavy except for last 8–9 myomeres in preflexion stage; few melanophores on dorsal & ventral finfolds; small size at each developmental stage.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	47–57 52	44–52 48	48–51 49	 51	31–48 39	30–33 31
BD/BL	10–14 12	23–35 26	31–36 34	 42	39–42 40	37–42 40
HL/BL	20–24 22	24–27 25	22–31 27	 32	31–35 33	28–30 29
HW/HL						
SnL/HL	20–20 20	17–22 18	17–28 22	 18	15–18 16	9–12 11
ED/HL†	43–48× 37–40 46×38	31–40× 29–33 34×31	29–43× 27–40 34×31	 31×31	29–32× 25–27 31×26	32–38× 26–30 36×28
P_1L/BL						
BDA/BL‡	14–18 16	18–33 24	27–36 33	 42	40–45 42	38–43 41

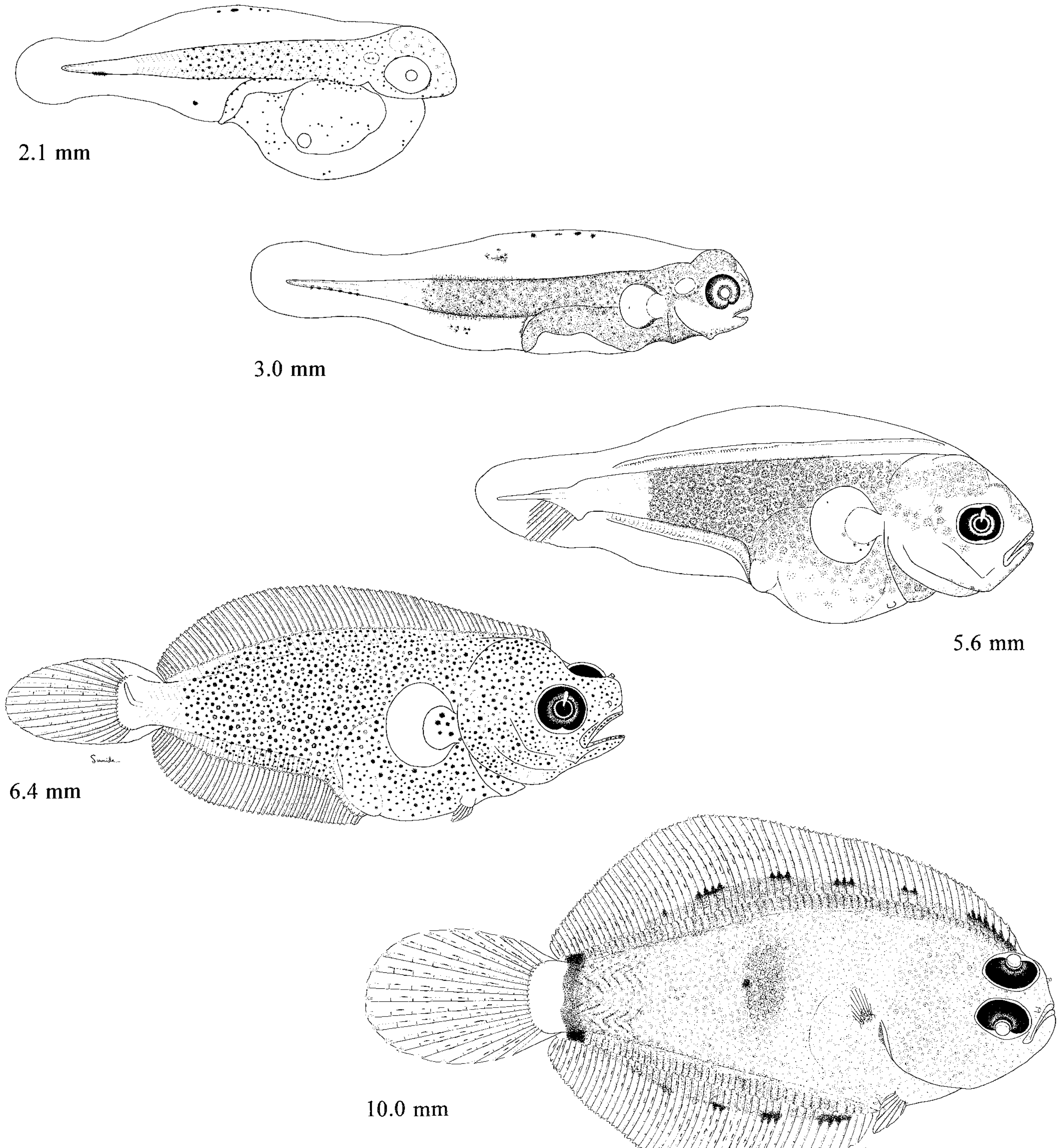


Figure Pleuronectidae 13. Yolk-sac larva, 2.1 mm; preflexion larva, 3.0 mm; flexion larva, 5.6 mm; transformation specimens, 6.4 mm, 10.0 mm (Sumida et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	36–38	36
Precaudal	13	13
Caudal	22–25	23
Fins:		
Dorsal spines	0	0
Dorsal rays	66–79	72
Anal spines	0	0
Anal rays	44–51	47
Pelvic	6	6
Pectoral	10–12	11
Caudal:		
Total	19–20	19
Principal	7–8+8–9	8+8
Gill rakers:		
Upper	2–4	3
Lower	6–9	7
Branchiostegals	7	7

LIFE HISTORY

Range: Point Reyes, California to Bahía Magdalena, Baja California Sur; isolated population in Gulf of California

Habitat: Soft bottom at ca. 10–200 m depth

Spawning season: In CalCOFI area, larvae collected throughout the year, with maximum abundance in March & August

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom & Moser 1975
Budd 1940
Sumida et al. 1979

* Values calculated from Sumida et al. (1979).
† Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 1.0–1.2 mm **Yolk:** Homogeneous
No. of OG: 0 **Diam. of OG:**
Shell surface: Hexagonal sculpturing
Pigment: Heavy on yolk; heavy on late-stage embryo (except for caudal region); on finfolds; some at notochord tip
Diagnostic features: Hexagonal sculpturing; size; lack of OG

LARVAE

Hatching length: <2.4 mm
Flexion length: 5.0–7.2 mm
Transformation length: 7.9–11.0 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Heavy on head & body except for last 3–5 myomeres; few above & below notochord tip; above & below gut; sparse blotches on dorsal & ventral finfolds. *Preflexion*—Triangular patches form in dorsal & ventral finfolds posterior to anus, the dorsal patch slightly anterior to the ventral one; some small specimens may have a few proximally on P_1 blade; lacking on top of head to behind nape, laterally on snout, on cheek below eye, & on P_1 base. *Flexion*—Triangular patches diminish; lacking on notochord; on body except for last 2–3 myomeres. *Postflexion*—Body sheath spreads posteriad to caudal peduncle, absent only on hypural region; sparse on outlying regions of head, body, & pterygiophores. *Transformation*—Heavy patches on body giving a mottled appearance; series of blotches basally on D & A rays; heavy basally on P_1.
Diagnostic features: Total vertebrae 36–38; preflexion larvae have triangular pigment patches on dorsal & ventral finfolds; pigment sparse on head & dorsal & ventral pterygiophores in flexion & postflexion stages; size-at-stage (relatively larger than *Hypsopsetta guttulata* & *P. ritteri* but smaller than *P. coenosus* & *P. decurrens*); transformation specimens are mottled compared with those of *P. ritteri* which are evenly pigmented except for central blotch & caudal peduncle band.

MORPHOMETRICS (range & mean in %)*

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	50–52 51	50–53 51	44–56 50	45–49 47	42–42 42	31–36 33
BD/BL	9–14 12	16–20 18	25–33 30	31–42 37	39–46 42	39–41 40
HL/BL	20–23 22	21–25 22	25–30 28	31–36 33	32–37 34	26–31 28
HW/HL						
SnL/HL	18–22 20	20–26 23	15–23 19	15–18 17	12–18 15	2–11 7
ED/HL†	39–44× 36–41 42×38	31–36× 26–34 34×31	31–34× 28–33 32×30	29–32× 26–30 31×28	29–33× 23–29 31×26	34–42× 23–33 39×29
P_1L/BL						
BDA/BL	14–15 14	13–15 14	21–32 28	31–45 38	42–46 44	40–43 42

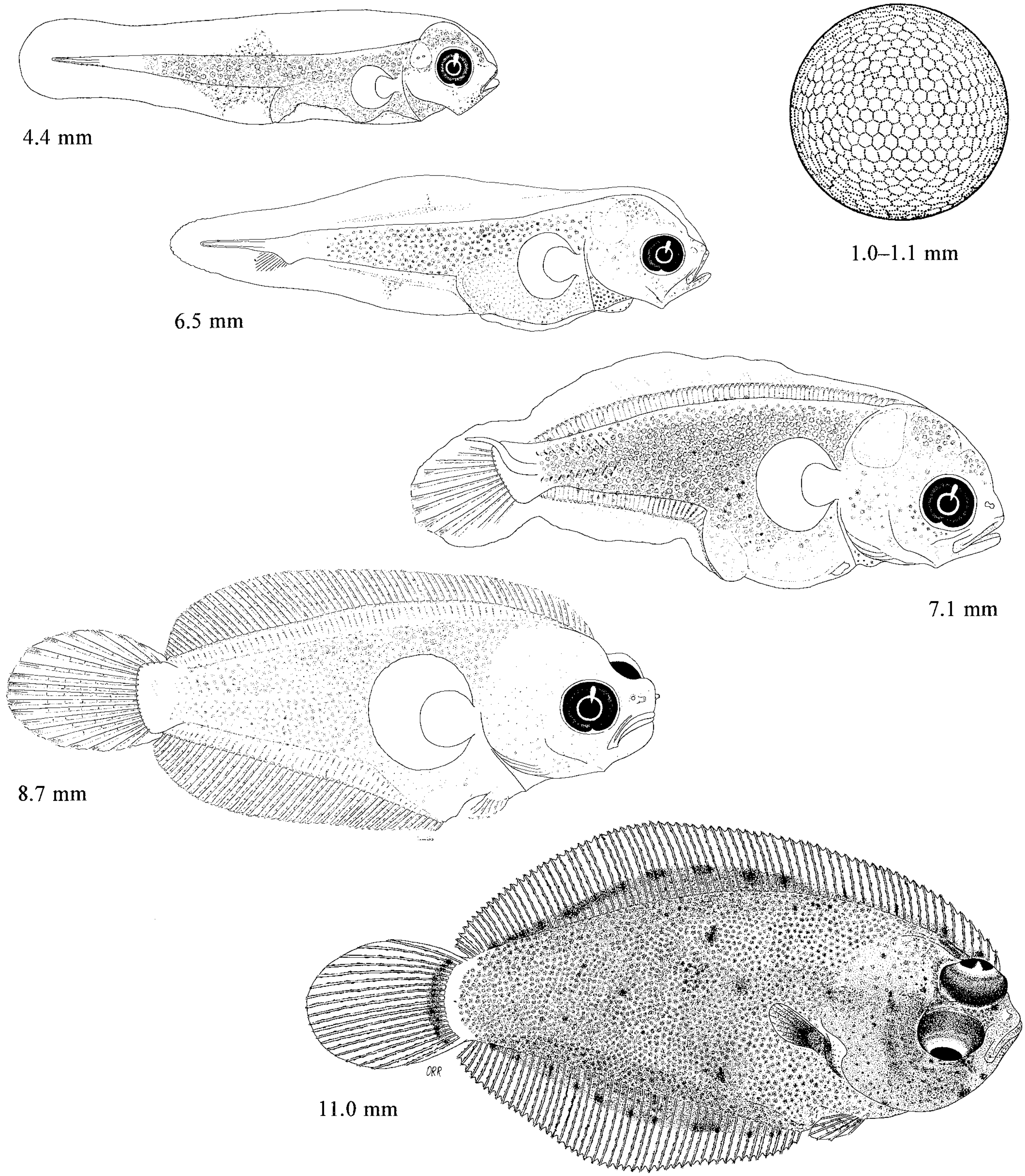


Figure Pleuronectidae 14. Egg, 1.0–1.1 mm (Budd 1940; embryo not shown in illustration); preflexion larvae, 4.4 mm, 6.5 mm; flexion larva, 7.1 mm; early transformation specimen, 8.7 mm; early juvenile 11.0 mm (Sumida et al. 1979).

MERISTICS

	Range	Mode
Vertebrae:		
Total	37–41	39
Precaudal	11–12	11
Caudal	28–30	28
Fins:		
Dorsal spines	0	0
Dorsal rays	72–90	85
Anal spines	0	0
Anal rays	53–66	58
Pelvic	6	6
Pectoral	10–12	
Caudal:		
Total	18	18
Principal	8+9	8+9
Gill rakers:		
Upper	5–7	
Lower	14–18	
Branchiostegals	7	7

LIFE HISTORY

Range: Bering Sea to Redondo Beach, California

Habitat: Demersal on shelf to upper slope at 1–325 m depth

Spawning season: In CalCOFI area, larvae collected in January–March, July, August, & October, with peak abundance in March

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Hickman 1959
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Egg, 0.96 mm (R. C. Walker)
Flexion larva, 10.1 mm (R. C. Walker)

* Eye somewhat oval; horizontal axis is given first, vertical axis second.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.83–1.0 mm **Yolk:** Homogeneous; 0.76 mm diam.
No. of OG: 0 **Diam. of OG:**
Shell surface: Striated
Pigment: Moderate on yolk; few on head, body, & finfolds
Diagnostic features: Size; pigment; difficult to separate from *Isopsetta isolepis, Parophrys stellatus & Platichthys melanostictus*

LARVAE

Hatching length: ca. 2.1 mm
Flexion length: 7.5–10.3 mm
Transformation length: 13.9–14.2 mm through 20.9– >22.6 mm
Fin development sequence: C, D & A, P_2, P_1
Pigmentation: *Yolk-sac*—Few on yolk sac; above & below gut; on top of head; series in dorsal & ventral finfolds; series on dorsum & postanal ventral margin continuing to notochord tip. *Preflexion*—On top of head, upper & lower jaw tips, & isthmus; patch in upper cleithral region; continuous from cleithral symphysis to anus; large patch posterolaterally on gut; 3 patches on dorsum in alternating arrangement with 3 patches on ventral margin of tail; few around notochord tip; series of small patches on margins of dorsal & ventral finfolds. *Flexion–postflexion*—Anterior to angular; continuous on ventral margin from gular region to anus; dorsal & ventral margin patches extending onto developing D & A pterygiophores; posteriormost patch on dorsum & one on ventral margin expand onto epaxial & hypaxial myosepta to form bar; becoming continuous on margins of dorsal & ventral finfolds; on C rays & hypural region. *Transformation*—Patches spreading onto body from D & A pterygiophores; coalescing into linear patches on fin margins, heaviest at anterior edge of D.
Diagnostic features: Total vertebrae 37–41; 3 patches on dorsum & 3 on ventral margin of tail, in alternating arrangement; wide finfold with unique sequential pigment pattern; heavy pigment on ventral margin of head & gut & patch posteriorly on gut; bar posteriorly on tail; relatively small eye.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	37–54 44	36–46 40	39–47 43	45–49 47	36–42 40	30–35 32
BD/BL	16–35 26	19–34 25	25–38 33	37–51 42	48–60 55	42–54 46
HL/BL	12–16 15	15–22 19	18–26 22	23–30 26	26–29 28	25–31 29
HW/HL	53–71 59	37–44 41	29–45 36	29–37 32	27–30 29	26–39 32
SnL/HL	18–29 24	14–25 21	17–22 19	18–24 21	17–22 20	18–25 22
ED/HL*	30–53× 27–41	24–33× 26–35	20–26× 21–24	18–22× 18–23	17–20× 18–20	17–21× 16–18
	45×37	29×29	22×22	21×21	19×19	19×17
P_1L/BL	0–4 1	4–9 6	6–7 6	5–8 6	7–8 7	7–20 13
P_2L/BL	0–0 0	0–0 0	0–0 0	0–2 1	5–8 6	6–9 8
BDA/BL	19–25 22	21–34 27	30–45 36	44–62 52	59–66 62	42–57 48

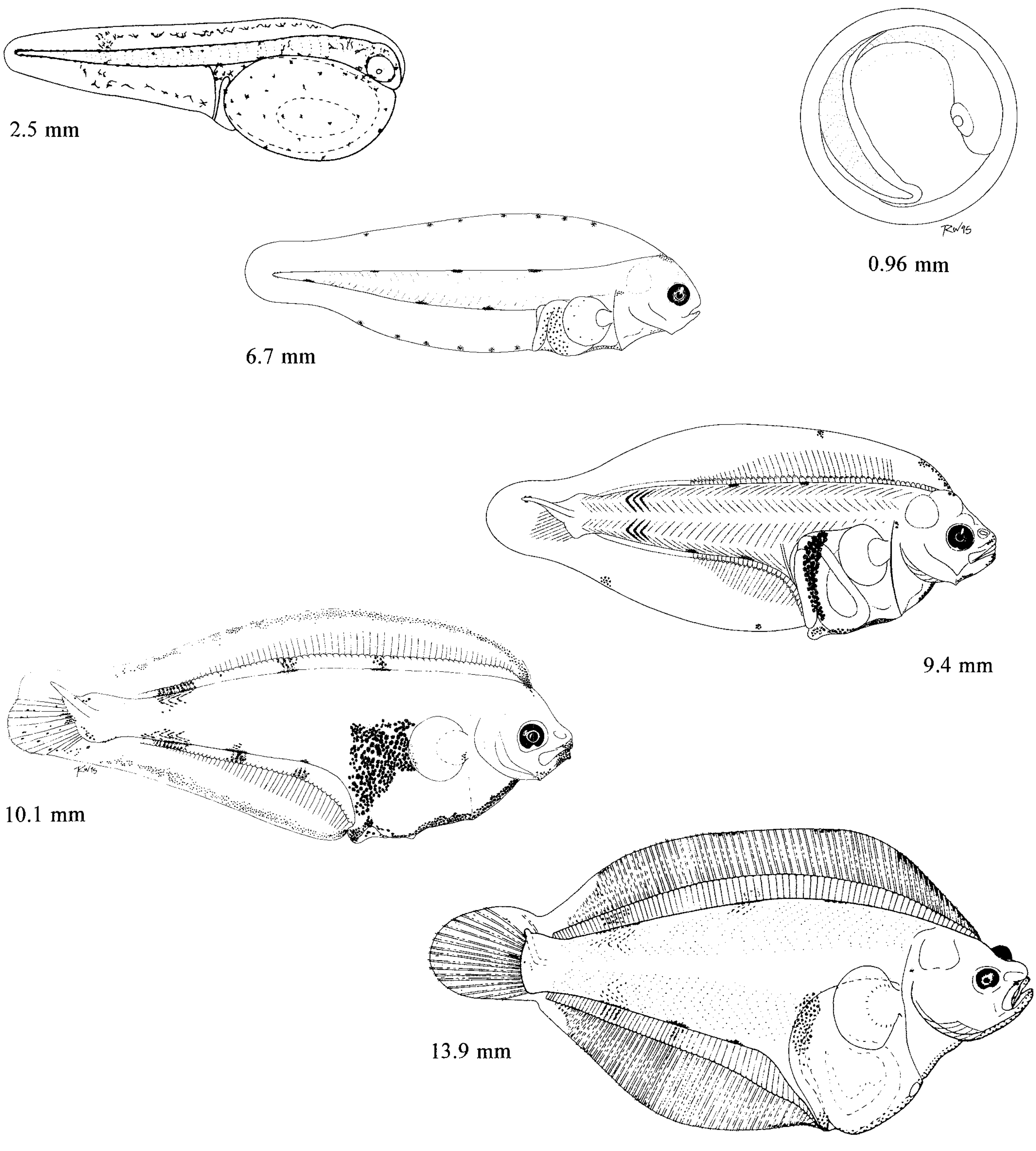


Figure Pleuronectidae 15. Egg, 0.96 mm (CFRD Ref. Coll., reared by Preston Porter, 68 hrs.); yolk-sac larva, 2.5 mm (Matarese et al. 1989); preflexion larva, 6.7 mm; flexion larvae, 9.4 mm (Ahlstrom et al. 1984a), 10.1 mm (CFRD Ref. Coll., reared by Preston Porter, 29 days old); transformation specimen, 13.9 mm (Matarese et al. 1989).

ACHIRIDAE: American soles

H. G. Moser

Achiridae includes 9 genera and about 28 species of tropical to temperate New World flatfishes; most species occur in shallow marine or estuarine waters and some species enter freshwater (Nelson 1994). Traditionally, these fishes have been classified as a subfamily (Achirinae) within the family Soleidae (Hensley and Ahlstrom 1984). Recent studies on the relationships of soles (Chapleau 1988, 1993; Chapleau and Keast 1988) have altered traditional concepts and classifications. Chapleau and Keast (1988) established achirine monophyly on the basis of five synapomorphies involving characters of the suspensorium, upper jaw, branchial apparatus, and ethmoid bones. Also, they presented six synapomorphies supporting soleine monophyly and another seven demonstrating that soleines and cynoglossids are sister groups. Accordingly, they elevated the achirines to family status. *Achirus mazatlanus* is the only achirid species found on the Pacific coast of Baja California (Krupp 1995a); *A. scutum* and *Trinectes fonsecensis* are found throughout the Gulf of California and off the southernmost region of Baja California (Table Achiridae 1). Larvae of *A. mazatlanus* are extremely rare in CalCOFI plankton collections because they are restricted to shallow coastal water or bays and transform and settle at a very small size (< 5.0 mm).

Achirids are small to medium-sized (most species <30 cm) flatfishes with the eyes on the right side of the head, the margin of the preopercle visible as a superficial groove, the dorsal and anal fins free from the caudal fin, and the right pelvic fin joined to the anal fin. In soleids the eyes are on the right side, the preopercular margin is obscured, the dorsal and anal fins are united with the caudal fin (some species), and the pelvic fins are free from the anal fin. In cynoglossids, the eyes are on the left side, the opercular margin is obscured, the median fins are continuous, and pectoral fins are lacking (present in soleids and some achirids). Most cynoglossids have a single pelvic fin (blind side fin) located on the ventral margin and connected by a membrane to the anal fin; however, the pelvic fin is not united with the anal fin in some species and some Indo-Pacific cynoglossids have both ocular and blind side fins. Achirids are oval to almost round. The dorsal fin originates far forward on the head and the caudal fin is rounded. Pectoral fins are reduced or absent on the ocular side and absent on the blind side. The small mouth is curved and slightly asymmetrical, with minute teeth. A lateral line is present on both sides and straight. Scales are strongly ctenoid. Color patterns vary among species from uniformly tan or brown with dark vertical lines, to light or dark with wavy bars of contrasting color, to spotted. Achirids are not commercially important.

Spawning takes place from spring to fall in warm temperate regions and may be year-round in the tropics (Futch 1970; Houde et al. 1970; Martin and Drewry 1978; Ortiz-Galindo et al. 1990). Apparently, some species move shoreward or enter estuaries to spawn. Hildebrand and Schroeder (1928) reported 145,000 eggs in a 165 mm *Trinectes maculatus* female. The planktonic eggs are round, have a smooth shell, and numerous oil globules. Egg diameter ranges from 0.67 mm to 0.80 mm. Ortiz-Galindo et al. (1990) reported a range of 0.68–0.80 mm for *Achirus mazatlanus*. In *A. mazatlanus*, newly hatched yolk-sac larvae are 1.34–1.65 mm and the yolk is absorbed at ca. 1.7–1.8 mm (Ortiz-Galindo et al. 1990; Figure Achiridae 1). Larval development is completed within a small size interval in *A. mazatlanus* (e.g., notochord flexion occurs at ca. 2.5 mm and metamorphosis at ca. 2.8–4.7 mm). Late yolk-sac larvae of *A. mazatlanus* have melanistic pigmentation in the dorsal and ventral finfolds and anterior to the gut (Figure Achiridae 1). In early preflexion larvae, the pigment in the dorsal finfold becomes concentrated distally and pigment appears on the brain, internally from the snout to the otic region, laterally on the gut, and in apposing dorsal and ventral blotches posterior to the midpoint of the tail. Flexion stage larvae develop gas bladder and lower jaw pigment and three embedded lines of melanophores (above the spinal column and in the epaxial and hypaxial musculature). Postflexion larvae have additional lines on the dorsal and ventral margins of the tail, heaviest at the caudal peduncle. Blotches develop posteriorly, anteriorly, and in the middle of the dorsal fin. One large blotch and a more anterior small blotch form on the anal fin and the pelvic fins become pigmented (Ortiz-Galindo et al. 1990).

Morphological development of *A. mazatlanus* is complex and involves several highly specialized structures (Figure Achiridae 1). The elongate fourth dorsal ray begins to develop in first-feeding larvae and is >50 % body length by the end of the flexion stage. Lateral rows of spinous scales begin to form in flexion larvae; initially, single rows develop in the epaxial and hypaxial regions and ultimately three epaxial and two hypaxial rows are present, along with a patch of spines on the gut. Thin bony ridges begin to form on the head in late preflexion larvae. When fully developed, the following ridges are present: an arch-like ridge above the eye, two in the otic region, one along the preopercular margin, two on the lower jaw, and a short one on the opercle. Transformation begins soon after notochord flexion; the left eye begins to migrate upward and through a dorsal notch forming behind the snout, the elongate dorsal ray becomes equal in length to adjacent rays, and the posterior dorsal and anal fin rays lengthen. Eye migration is completed by ca. 4.7 mm, followed by settlement.

A second type of achirid larva with a different pigment pattern and a relatively longer anterior dorsal ray was found in samples from Panama (Figure Achiridae 2). A 2.3 mm preflexion larva has a relatively large eye (EL 40% HL), elongate dorsal ray anlagen, and pigment in the following areas: above the brain, on the lower jaw, surrounding the gut, in apposing clusters on the dorsal and ventral finfolds, scattered laterally on the tail, and in a diffuse bar posteriorly on the tail. In the largest specimen, a 3.2 mm flexion larva, the elongate dorsal ray is as long as the body and has a series of pigment blotches and a fleshy terminus. Pigment is present on the lower region of the head, above the gas bladder, and covers most of the gut. Melanistic lines are present above the spinal column, on the lateral midline, and on the dorsal and ventral margins. A series of melanophores is present on the anal fin base and a blotch is forming on the dorsal fin. Thin bony ridges similar to those on *A. mazatlanus* are present above the eye, on the otic region, and on the preopercle, opercle, and lower jaw. Identification of this incomplete achirid larval series is uncertain since the fins are not complete. The myomere count for the 3.2 mm larva is 31. Among eastern Pacific achirids, only *A. klunzingeri* with 30–32 vertebrae has a vertebral count higher than 30 (data of C. L. Hubbs, made available by H. J. Walker, SIO) and this is the most likely species identification for the larval series. Although this species has not been reported north of Costa Rica (H. J. Walker, pers. comm.), a partial description and illustrations of preflexion stages are presented here to aid in the identification of other achirid larvae as they become available. Progress in achirid larval identification will require more intensive sampling of bay and estuarine waters and rearing of field-collected eggs as in the studies of Houde et al. (1970) and Ortiz-Galindo et al. (1990).

Table Achiridae 1. Meristic characters (range above, mode below) for the achirid species in the California Current vicinity. Counts for pectoral and pelvic fins are from the ocular side.

	Vertebrae			Fin rays					
Species	PrCV	CV	Total	D	A	P_1	P_2	Total C	Gill rakers
Achirus mazatlanus	8–10	19–21	28–30	53–60	41–46	1–5	4–5	16	0–5+7–11
	9	20	29	57	43	5	5	16	5+7–8
A. scutum	8–9	17–20	26–29	53–59	42–46	3–4	4–5	16–17	4–5+6–8
	9	19	28	53	44	3	4	16	4+7
Trinectes fonsecensis	8–10	18–21	27–30	57–63	41–47	1–3	4–5	15–16	4–5+7–8
	9	20	29	59	44	2	5	16	4+7–8

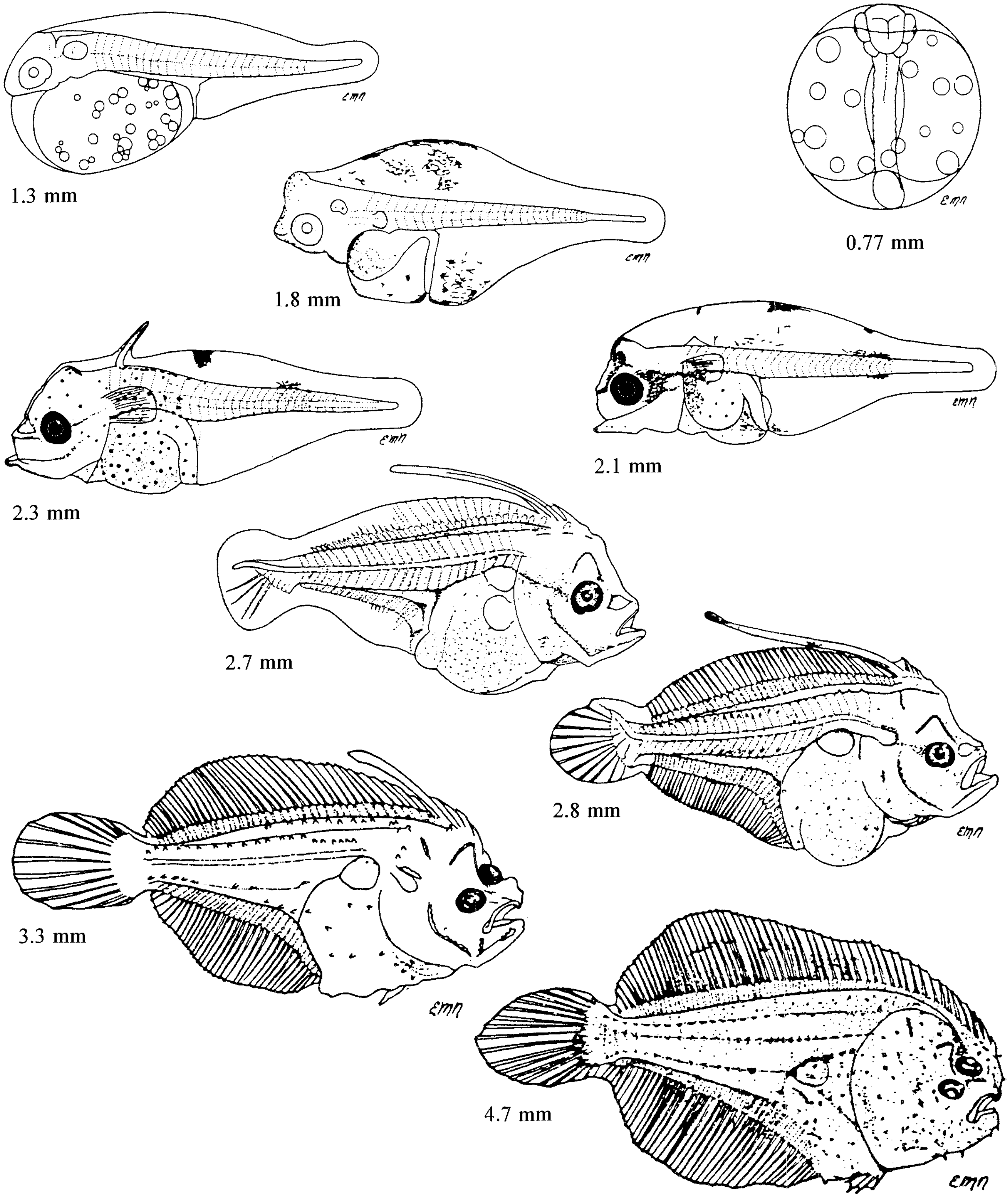
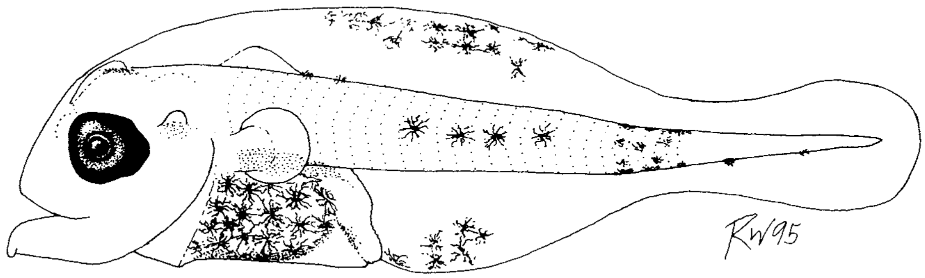
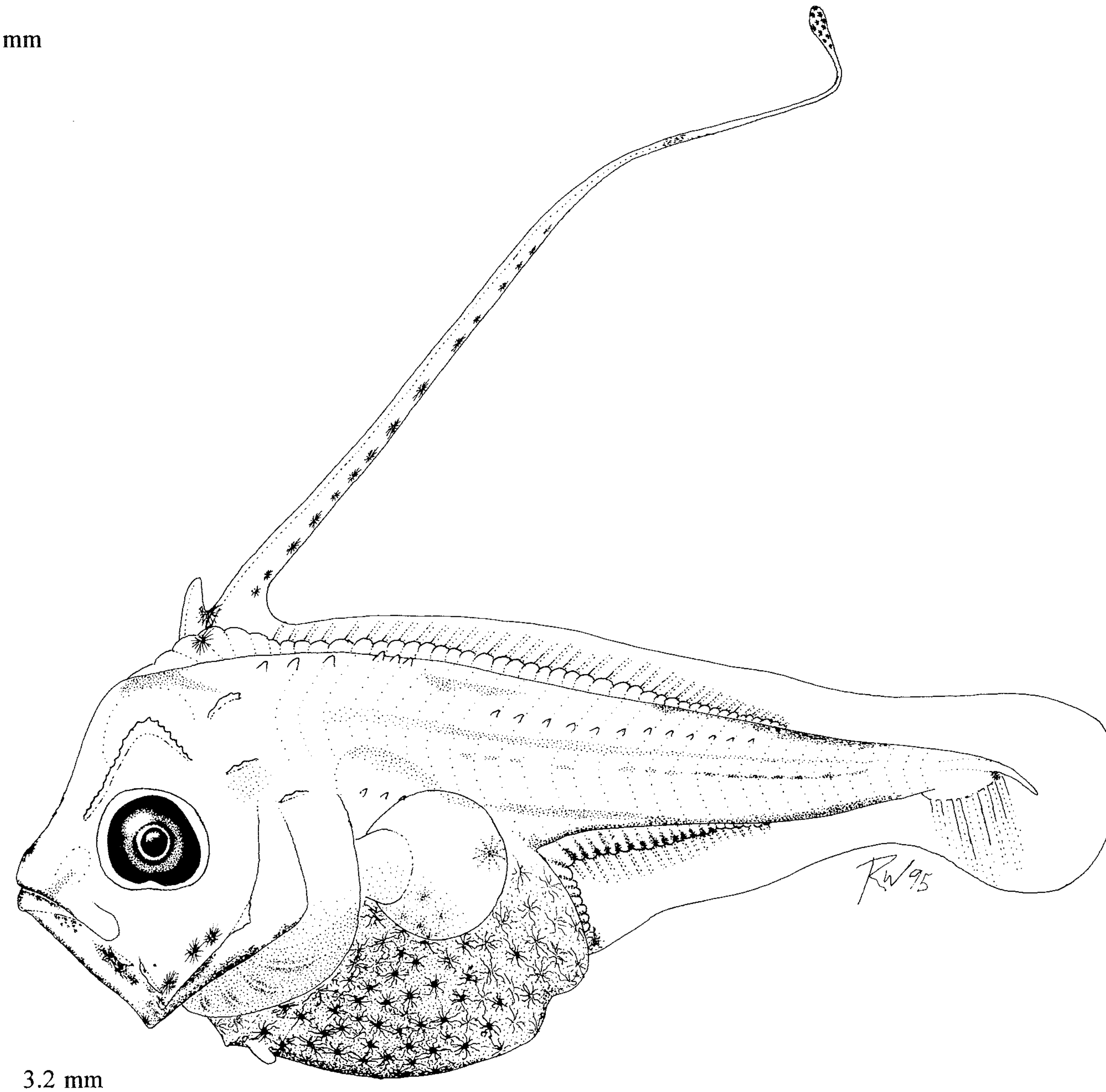


Figure Achiridae 1. Developmental stages of *Achirus mazatlanus*: egg, 0.77 mm; yolk-sac larvae, 1.3 mm, 1.8 mm; preflexion larvae, 2.1 mm, 2.3 mm; flexion larva, 2.7 mm; postflexion larva, 2.8 mm; transformation specimen, 3.3 mm; juvenile, 4.7 mm (Ortiz-Galindo et al. 1990).



2.3 mm



3.2 mm

Figure Achiridae 2. Larvae of an achirid, tentatively identified as *Achirus klunzingeri*: preflexion larvae, 2.3 mm (IATTC 90022, station ASB #1 Red), 3.2 mm (IATTC 90032, station AS2 #2 Grn). Original illustrations by R. C. Walker.

CYNOGLOSSIDAE: Tonguefishes

S. R. CHARTER AND H. G. MOSER

The family Cynoglossidae consists of approximately 110 species placed in three genera (Nelson 1994). Most of the species inhabit tropical to warm temperate seas (between ca. 40° N and 40° S) and some occur in freshwater (Chapleau 1988; Nelson 1994). Only the subfamily Symphurinae, composed of the genus *Symphurus,* occurs in the eastern North Pacific (Table Cynoglossidae 1). Eight species are known from the CalCOFI study area, with an additional five species in the Gulf of California. *Symphurus atricaudus,* the only northern species, ranges from Washington to the tip of Baja California Sur and the southern part of the Gulf of California; its eggs and larvae are common in CalCOFI ichthyoplankton samples. *Symphurus elongatus* occurs from the southern part of the Gulf of California to Ecuador; its larvae have been identified in samples from southern stations of CalCOFI cruises in 1972. *Symphurus atramentatus, S. callopterus, S. melanurus, S. oligomerus, S. prolatinaris,* and *S. williamsi* occur along the outer coast of Baja California Sur, in the Gulf of California, and south to Peru; *S. atramentatus* ranges to the Galápagos Islands. *Symphurus fasciolaris* occurs on the outer coast of Baja California Sur, in the Gulf of California, and south to Panama. *Symphurus leei* and *S. gorgonae* range from the Gulf of California to Colombia, while *S. chabanaudi* and *S. melasmatotheca* range from the Gulf of California to Peru (Chabanaud 1948; Mahadeva 1956; Munroe and Mahadeva 1989; Mahadeva and Munroe 1990; Munroe and Nizinski 1990; Munroe et al. 1991). No larvae of these 11 species have been identified in CalCOFI collections.

Adult cynoglossids are small to medium-sized (most species <20 cm, the largest up to 24 cm) flatfishes with confluent dorsal, anal and caudal fins; the caudal fin is pointed. The small eyes are on the left side. The posterior margin of the preoperculum is concealed by skin and scales. Juvenile and adult cynoglossids lack pectoral fins. The blind-side pelvic fin is on the ventral margin; the eyed-side fin is lacking, except in some Indo-Pacific species. Symphurines lack lateral lines on both sides of the body, and their mouths are small, terminal, and asymmetrical. Symphurinae is speciose and meristic characters of many of the species overlap. The relationship of proximal dorsal fin-ray pterygiophores to the anteriormost interneural spaces, expressed as the interdigitation formula (ID pattern), is a diagnostic character (Munroe 1992). Cynoglossids bury in sand or mud bottoms (maximum depth ca. 325 m, usually <100 m depth in the CalCOFI study area) during the day and emerge at night to feed on benthic invertebrates.

Cynoglossids are oviparous with planktonic eggs. Eggs of *S. atricaudus* are 0.7–0.8 mm in diameter with homogeneous yolk and multiple (10–23) oil globules; eggs may appear amber to pinkish. Cynoglossid larvae hatch at <2 mm, are symmetrical, with unpigmented eyes, a straight gut, and distinct pigmentation. The gut begins to coil late in the yolk-sac stage. In *S. atricaudus* and *S. elongatus* larvae of ca. 6.5 mm length, the gut mass protrudes beyond the ventral profile; in some species it trails posteriad. During transformation, which occurs quickly, the migrating eye passes through the soft tissues of the head, in front of the brain and under the frontal element and rostral hook, emerging on the left side. Additionally, pectoral fins and the gas bladder are lost, the gut protrusion is brought into the body cavity, larval pigmentation is replaced by juvenile pigmentation, and scales form. *Symphurus atricaudus* larvae have characteristic pigment on the dorsal and ventral margins and finfolds, on the head and gas bladder, and laterally on the gut. Larval *S. atricaudus* and *S. elongatus* may be separated by myomere and anal fin-ray counts (Table Cynoglossidae 1) and each has a distinct pigmentation pattern. Yevseyenko (1990) identified an additional species, *S. callopterus*. Two other distinctly pigmented cynoglossid larval types occur in CalCOFI ichthyoplankton samples but they cannot be identified without transformation specimens.

Ecological and meristic information was taken from literature (Chabanaud 1948; Mahadeva 1956; Miller and Lea 1972; Eschmeyer et al. 1983; DeMartini and Allen 1984; Chapleau 1988; Munroe and Mahadeva 1989; Mahadeva and Munroe 1990; Munroe and Nizinski 1990; Kramer 1991; Munroe et al. 1991; Munroe et al. 1995). Larval descriptions are based on detailed examination of 21 *S. atricaudus* and 4 *S. elongatus* (Table Cynoglossidae 2) and literature (Ahlstrom et al. 1984a; Matarese et al. 1989; Kramer 1991).

Table Cynoglossidae 1. Meristic characters for the cynoglossid species in the California Current vicinity. Cynoglossids lack pectoral fins and a pelvic fin on the eyed side. The pelvic fin on the blind side has 4 rays for all species.

	Vertebrae			Fin rays			
Species	PrCV	CV	Total	D	A	Total C	ID pattern
Symphurus atramentatus	9	40–44	49–53	89–96	75–82	12	1–3–3
S. atricaudus	9	40–44	49–53	94–106	77–90	12	1–5–3
S. callopterus	9	48–52	57–61	105–114	91–98	12	1–3–4
S. chabanaudi	9	43–48	52–57	96–109	82–92	12	1–5–3
S. elongatus	9	44–47	53–56	99–107	83–90	12	1–5–3
S. fasciolaris	9	39–43	48–52	90–97	75–80	10	1–4–3
S. gorgonae	9	37–40	46–49	80–89	63–74	12	1–3–2
S. leei	9	42–43	51–52	93–104	78–88	12	1–4–3
S. melanurus	9	41–45	50–54	96–104	79–87	12	1–5–3
S. melasmatotheca	9	40–43	49–52	90–96	74–80	11	1–5–3
S. oligomerus	9	39–43	48–52	87–97	72–83	12	1–3–2
S. prolatinaris	9	45–47	54–56	103–110	86–93	12	1–5–3
S. williamsi	9	38–42	47–51	89–95	73–79	12	1–5–3

Table Cynoglossidae 2. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the cynoglossid species descriptions. An "L" indicates literature used in the description.

Species	Egg	Yolk-sac	Preflexion	Flexion	Postflexion	Juvenile
Symphurus atricaudus	L[a], 10 0.7–0.8	3 1.9–2.0	7 2.5–8.0	3 8.6–10.5	5 13.7–19.7	3 20.8–23.3
S. elongatus	0	0	1 6.8	1 8.8	1 18.9	1 28.3

[a] Matarese and Sandknop 1984

MERISTICS

	Range	Mode
Vertebrae:		
Total	49–53	51
Precaudal	9	9
Caudal	40–44	42
Fins:		
Dorsal spines	0	0
Dorsal rays	94–106	
Anal spines	0	0
Anal rays	77–90	
Pelvic	4	4
Pectoral	0	0
Caudal:		
Total	12	12
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Washington to the southern Gulf of California

Habitat: Demersal on shelf at 3–100 m depth; usually 30–80 m depth

Spawning season: June–September; in CalCOFI area larvae collected July–February, with maximum abundance in September; settlement occurs in late fall & winter

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

Ahlstrom et al. 1984a
Kramer 1991
Matarese et al. 1989

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larva, 1.9 mm (R. C. Walker)
Transformation specimen, 23.0 (G. Mattson/B. Nyugen)
Juvenile, 23.8 mm (G. Mattson/B. Nyugen)

* Flexion & postflexion stage larvae measured at A origin.
† Eye somewhat oval in flexion & juvenile specimens; horizontal axis is given first, vertical axis second.
‡ Sn-GL = measured from tip of snout to tip of gut loop; gut slightly protruding.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: 0.74–0.80 mm **Yolk:** Homogeneous; 0.48–0.57 mm diam.
No. of OG: 10–23 **Diam. of OG:** 0.03–0.08 mm
Shell surface: Smooth; may appear amber or pinkish
Diagnostic features: Small diameter; multiple oil globules

LARVAE

Hatching length: ca. 1.9 mm
Flexion length: 8.6–10.8 mm
Transformation length: 19–24.2 mm
Fin development sequence: D, A & C, P_2 (P_1 resorbed during transformation)
Pigmentation: *Yolk-sac*—Eyes pigmented at ca. 2 mm; 2 small blotches distally on dorsal finfold; around anus; some dorsally on tail at ca. 60–65% BL; dorsally & ventrally on notochord tip. *Preflexion*—2, increasing to 4, blotches distally on dorsal finfold; 1, increasing to 2, blotches distally on ventral finfold; ventrally on gut; at angular; bar posteriorly on tail becomes reduced to dorsal & ventral patches; above gas bladder; series on ventral margin of tail. *Flexion*—Dashes on dorsal & ventral margins. *Postflexion–transformation*—On lower jaw; on anterior D pterygiophores; series on margin of D & A; above gas bladder; dorsally & ventrally on gut; increasing on D & A rays; on P_2; dashes on lateral midline on blind side. *Juvenile*–Scattered on snout & head & on brain; blotch internally over gut; on D & A pterygiophores; dashes on lateral midline at ca. 50% BL continuing posteriad (anteriorly embedded).
Diagnostic features: Total myomeres 9 (11 in yolk-sac)+40–44; D 94–102; A 77–84; compared to *S. elongatus*, head relatively smaller (HL 15–21 vs. 18–22% BL), preanal length shorter, gut loop longer & more acute, body more slender, & different pigment pattern.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL*	40–41 41	35–42 38	32–35 34	23–36 30		27–28 28
BD/BL	18–20 19	18–30 23	27–34 30	30–35 32		21–25 23
HL/BL	20–21 21	15–18 17	18–20 19	18–19 19		17–19 18
HW/HL	45–50 48	39–53 44	35–42 39	31–39 35		20–27 23
SnL/HL	20–21 20	15–29 23	22–25 24	18–23 20		29–31 30
ED/HL†	31–38 34	20–23 23	17–19× 17–21 18×19	13–15 14		12–16× 9–13 14×11
P_1L/BL	0–3 1	3–5 4	4–4 4	3–9 5		0–0 0
P_2L/BL	0–0 0	0–3 0.5	3–6 4	7–10 8		7–10 8
BDA/BL	16–22 20	14–32 23	28–39 32	32–39 36		21–25 24
Sn-GL/BL‡			38–43 41	42–54 47		

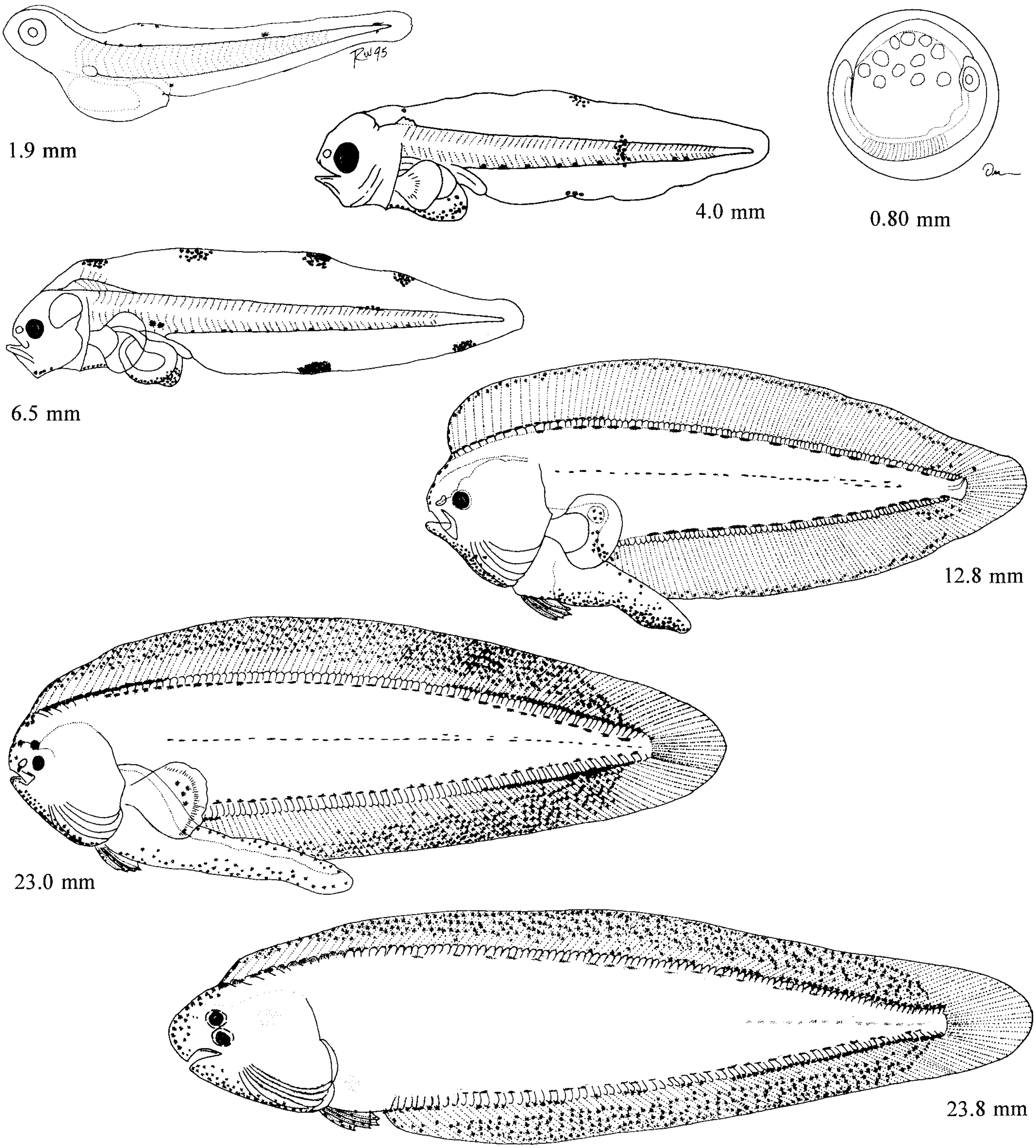


Figure Cynoglossidae 1. Egg, 0.80 mm (Matarese and Sandknop 1984); yolk-sac larva, 1.9 mm (CalCOFI 6407, station 137.21); preflexion larvae, 4.0 mm, 6.5 mm; postflexion larva, 12.8 mm (Ahlstrom et al. 1984a); transformation specimen, 23.0 mm; juvenile, 23.8 mm (CalCOFI).

MERISTICS

	Range	Mode
Vertebrae:		
Total	53–56	54–55
Precaudal	9	9
Caudal	44–47	45–46
Fins:		
Dorsal spines	0	0
Dorsal rays	99–107	102
Anal spines	0	0
Anal rays	83–90	86
Pelvic	4	4
Pectoral	0	0
Caudal:		
Total	12	12
Procurrent:		
Upper		
Lower		
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Southern Gulf of California to Ecuador

Habitat: Demersal on shelf at 1–100 m depth; usually ≤40 m depth; on sand or mud bottoms; in estuaries

Spawning season: In CalCOFI area, larvae collected in February & May

ELH pattern: Oviparous; planktonic eggs & larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larva, 6.8 mm (R. C. Walker)
Early flexion larva, 8.8 mm (R. C. Walker)
Postflexion–early transformation specimen, 18.9 mm (R. C. Walker)
Juvenile, 28.3 mm (R. C. Walker)

* Flexion & postflexion stage larvae measured at A origin.
† Eyes somewhat oval in flexion & juvenile specimens; horizontal axis given first, vertical axis second.
‡ Sn-GL = measured from tip of snout to tip of gut loop; gut slightly protruding.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length:
Flexion length: >6.8 mm, <18.9 mm
Transformation length: >18.9 mm, <28.3 mm
Fin development sequence: D, A, P_2, C (P_1 resorbed during transformation)
Pigmentation: *Late preflexion*—5 blotches on dorsal midline; 1 on branchiostegal membrane; ventrally from gular region to anus; on gas bladder; scattered on ventral midline; on A pterygiophores, heavy near posteriormost ventral midline blotch; 1 blotch distally on A. *Early flexion*—1 dorsally on braincase; on P_2; few distally on A rays; coalescing to 3 blotches on ventral midline. *Postflexion–early transformation*—ca. 12 dashes on the lateral midline at ca. 50% BL; small blotch on C rays. *Juveniles*—Lightly scattered over entire body; internally on braincase; on gut; series on spinal column at ca. 50% BL & series above spinal column in C region.
Diagnostic features: Total myomeres 9+44–45; D 103–106; A 84–86; compared to *S. atricaudus*, head larger (HL 18–22% vs. 15–21% BL), preanal length longer, gut loop shorter & more rounded, body deeper, & pigment pattern different.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL*		44	35	32		26
BD/BL		33	33	32		23
HL/BL		22	20	18		20
HW/HL		41	40	36		18
SnL/HL		19	22	21		21
ED/HL†		18	16×20	13		10×9
P_1L/BL		6	5	3		0
P_2L/BL		5	7	9		6
BDA/BL		34	35	34		24
Sn-GL/BL‡			45	41		

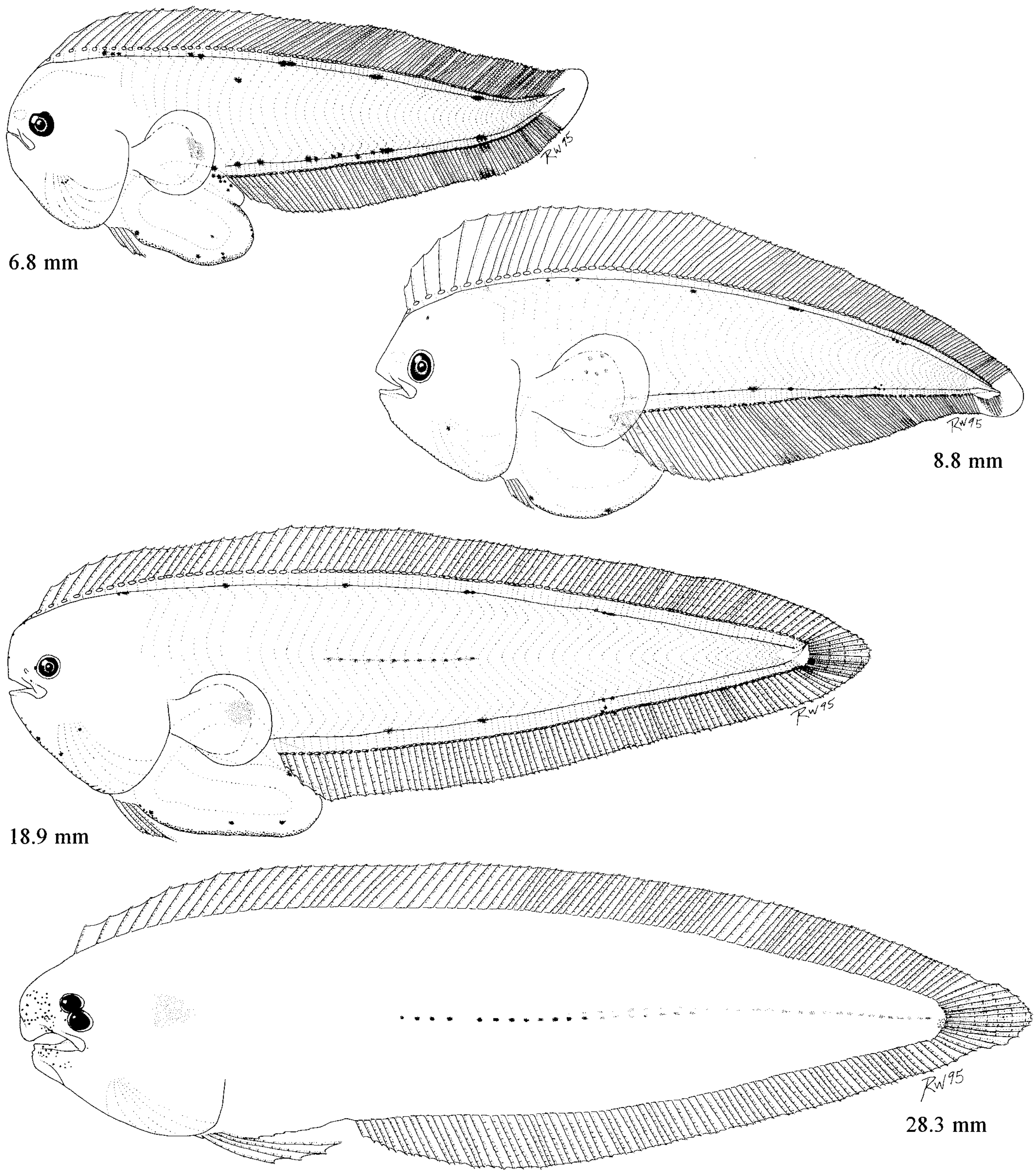


Figure Cynoglossidae 2. Preflexion larva, 6.8 mm (CalCOFI 7205, station 150.25); early flexion larva, 8.8 mm (CalCOFI 7202, station 157.10); postflexion–early transformation specimen, 18.9 mm (CalCOFI 7202, station 157.15); juvenile, 28.3 mm (CFRD Ref. Coll., FB62–114).

TETRAODONTIFORMES

W. WATSON

Although monophyly of the Tetraodontiformes is not seriously questioned, relationships within the order and the systematic position of the order are not settled (e.g., Winterbottom 1974; Tyler 1980; Leis 1984b; Rosen 1984; Nelson 1994). Here we follow Eschmeyer (1990) in retaining the Tetraodontiformes in their traditional postperciform position, although Rosen (1984) and Leis (1984b) provided some evidence that their affinities might instead be with the preperciform order Zeiformes.

Tetraodontiform fishes typically are coastal residents of tropical and warm temperate oceans; there are both epipelagic and freshwater species as well. Adults typically are small to medium-size (<1 m, but the larger molids can exceed 2 m and 1000 kg), deep-bodied and rotund to compressed. Some species can inflate by swallowing water or air. Tetraodontiforms have somewhat simplified skeletons, particularly the skull, with some bones absent and others fused (Tyler 1980). The gill opening is reduced to a slit or pore on each side. The pelvic fins are reduced to a spine or tubercle in balistoids and are absent in all the others except triacanthoids. Most have 12 or fewer principal caudal fin rays; molids lack a true caudal fin.

All tetraodontiform fishes for which information is available are oviparous. Eggs range from ca. 0.6–2.3 mm in diameter, usually are spherical or nearly so, usually contain oil globules, and are either planktonic or demersal and adhesive (Aboussouan and Leis 1984; Leis 1984a). The demersal eggs may or may not receive parental care. Larval development at hatching ranges from relatively undeveloped, with unpigmented eyes, an unformed mouth, and a moderate yolk sac to well developed with pigmented eyes, an open mouth, and little yolk. Larvae initially range from somewhat elongate to rotund, with short to long preanal length. The elongate larvae tend to become deeper-bodied and preanal length increases in those with an initially short preanal length. Most have large eyes and a snout that at least initially is short and rounded. The epidermis is inflated, at least during the preflexion stage, in many. All lack spines on the bones of the head and pectoral girdle. Caudal fin rays are the last to begin forming in all except the monacanthids. Most tetraodontiform larvae develop directly into small (<10–20 mm) pelagic juveniles which may remain pelagic for long periods.

Twenty-three of the approximately 339 tetraodontiform species, representing six of the nine families, occur in the California Current vicinity (Table Tetraodontiformes 1). Small numbers of larval tetraodontiforms have been collected during CalCOFI surveys, primarily off southern Baja California Sur. Nearly all are balistids and tetraodontids.

Families included: Balistidae
Monacanthidae
Ostraciidae
Tetraodontidae
Diodontidae
Molidae

Table Tetraodontiformes 1. Meristic characters for the tetraodontiform species in the California Current vicinity. All lack pelvic fin rays.

	Vertebrae			Fin rays		
Species	PrCV	CV	Total	D	A	P_1
Balistidae						
Balistes polylepis	7–8	10–11	18	III, 26–28	24–26	13–15
Canthidermis maculatus	7	11	18	III, 23–25	20–23	13–15
Melichthys niger	7	11–12	18–19	III, 23–25	23–25	13–15
Pseudobalistes naufragium	7	11	18	III, 30–33	27–30	14–15
Sufflamen verres	7–8	10–11	18	III, 28–32	25–29	12–13
Xanthichthys mento	7–8	10–11	18	III, 31–34	27–30	14–16
Monacanthidae						
Aluterus scriptus	7	14	21	II, 43–49	46–52	13–15
Cantherines dumerilii				II, 34–39	28–35	14–15
Ostraciidae						
Lactoria diaphana	10	5	15	9	9–10	10–11
Ostracion meleagris				9	9	10–11
Tetraodontidae						
Arothron hispidus	9–10	8–9	18	10–11	10–11	17–19
A. meleagris	10	9	19	11–12	11–12	16–18
Canthigaster punctatissima	11	6	17	9–10	9	16–17
Lagocephalus lagocephalus	8–9	10	18–19	11–13	10–12	14–18
Sphoeroides annulatus	8–9	10–11	18–19	7–9	6–9	14–17
S. lobatus	8	9–10	17–18	7–8	6–7	14–16
Sphoeroides sp.	8–9	9–10	17–18	8–9	7	13–15
Diodontidae						
Cheilomycterus reticulatus	12–13	10	22–23	12–14	11–14	19–22
Diodon eydouxii				16–18	16–18	19–22
D. holocanthus	12	9	21	13–15	13–15	20–24
D. hystrix	11–12	8–10	20–21	14–17	14–16	21–25
Molidae						
Mola mola	8–9	8–9	17–18	17–18	14–18	12–13
Ranzania laevis	8	10–11	18–19	17–19	18–19	13

BALISTIDAE: Triggerfishes

W. Watson

Six of the approximately 40 triggerfish species, representing six of the 11 genera, occur in the CalCOFI study area (Table Tetraodontiformes 1; Berry and Baldwin 1966). A few larvae have been collected at CalCOFI stations off southern Baja California Sur; they are more common during summer and autumn in collections from the Gulf of California and the Pacific coasts of Mexico and Central America. *Balistes polylepis* is by far the most common species, particularly in collections from the Gulf of California.

Triggerfishes are small to medium-size (largest species to ca. 75 cm) residents of reefs and adjacent open waters; some may range far to sea as juveniles and *Canthidermis maculatus* is primarily epipelagic. Triggerfishes are deep-bodied and compressed, with preanal length ca. 60% BL. The head is large and the snout long and deep. The long-based anal and soft dorsal fins originate opposite one another just behind midbody and the first two spines of the spinous dorsal fin form a lock and trigger mechanism. There are no pelvic fins but a single pelvic tubercle is present. The body and most of the head are covered with plate-like scales. Pigmentation ranges from uniformly black, to mottled, to brightly colored and strikingly patterned. Some species are of minor importance in artisanal fisheries and some are well known in the aquarium trade.

Triggerfishes are oviparous, spawning small (0.5–0.6 mm) spherical eggs containing a single oil globule and unsegmented yolk (Aboussouan and Leis 1984). The eggs are attached to the nest site prepared and guarded by a parent (Thomson et al. 1979; Aboussouan and Leis 1984). Larvae initially are moderately slender and oval in cross-section but become deep-bodied and compressed. Preanal length initially is ca. 40–55% BL but increases to ca. 65–70% BL by the postflexion stage. The head and eyes are large and the snout initially is short and rounded, lengthening moderately. There are no spines on the head or pectoral girdle, except that a characteristic tuft of spinules forms on the preopercle early in the preflexion stage and persists until late preflexion to mid-flexion stage. The large first dorsal spine forms early in the preflexion stage. Spinules form ventrally on the gut and/or head late in the preflexion stage and spread to cover nearly the entire body by the early postflexion stage. Preflexion stage larvae typically are pigmented primarily on the head and gut, with no more than a few melanophores on the ventral (and occasionally dorsal) margin(s) of the tail. During the flexion or postflexion stages melanophores often spread to cover much of the body; the spinous dorsal fin often becomes heavily pigmented as well.

Larval balistids resemble larval priacanthids, monacanthids, tetraodontids, and some ceratioids during the preflexion stage. However, the preopercular spinule tuft distinguishes larval balistids from all others except the monacanthids. Larval monacanthids commonly are more elongate and become more compressed than the balistid larvae, and typically have the first dorsal-fin spine more anteriorly located than it is in balistids. Meristic characters also separate balistids and monacanthids (Table Tetraodontiformes 1). Among the balistid species in the CalCOFI area, larvae presently are known only for *Balistes polylepis*, *Canthidermis maculatus* (late postflexion stage only) and *Sufflamen verres*. *B. polylepis* and *S. verres* are separated by pigment characters (cf. Figures Balistidae 1 and Balistidae 2), and postflexion stage larvae of all three are separable by meristic characters (Table Tetraodontiformes 1).

The following description of *B. polylepis* is based on 10 preflexion (1.6–3.8 mm), 6 flexion (3.8–4.4 mm), and 10 postflexion (4.3–10.6 mm) larvae and 4 pelagic juveniles (11.3–26.5 mm). Postflexion specimens were classified as pelagic juveniles when eye diameter exceeded snout length and the mottled or spotted pigment pattern typical of the pelagic juvenile stage (Berry and Baldwin 1966) was discernable. Larval *C. maculatus* and *S. verres* are not described separately because too few specimens were available, but they are shown in Figures Balistidae 1 and Balistidae 2. Meristic data were obtained from Berry and Baldwin (1966) and from counts made during this study. Ecological information is from Berry and Baldwin (1966) and Thomson et al. (1979).

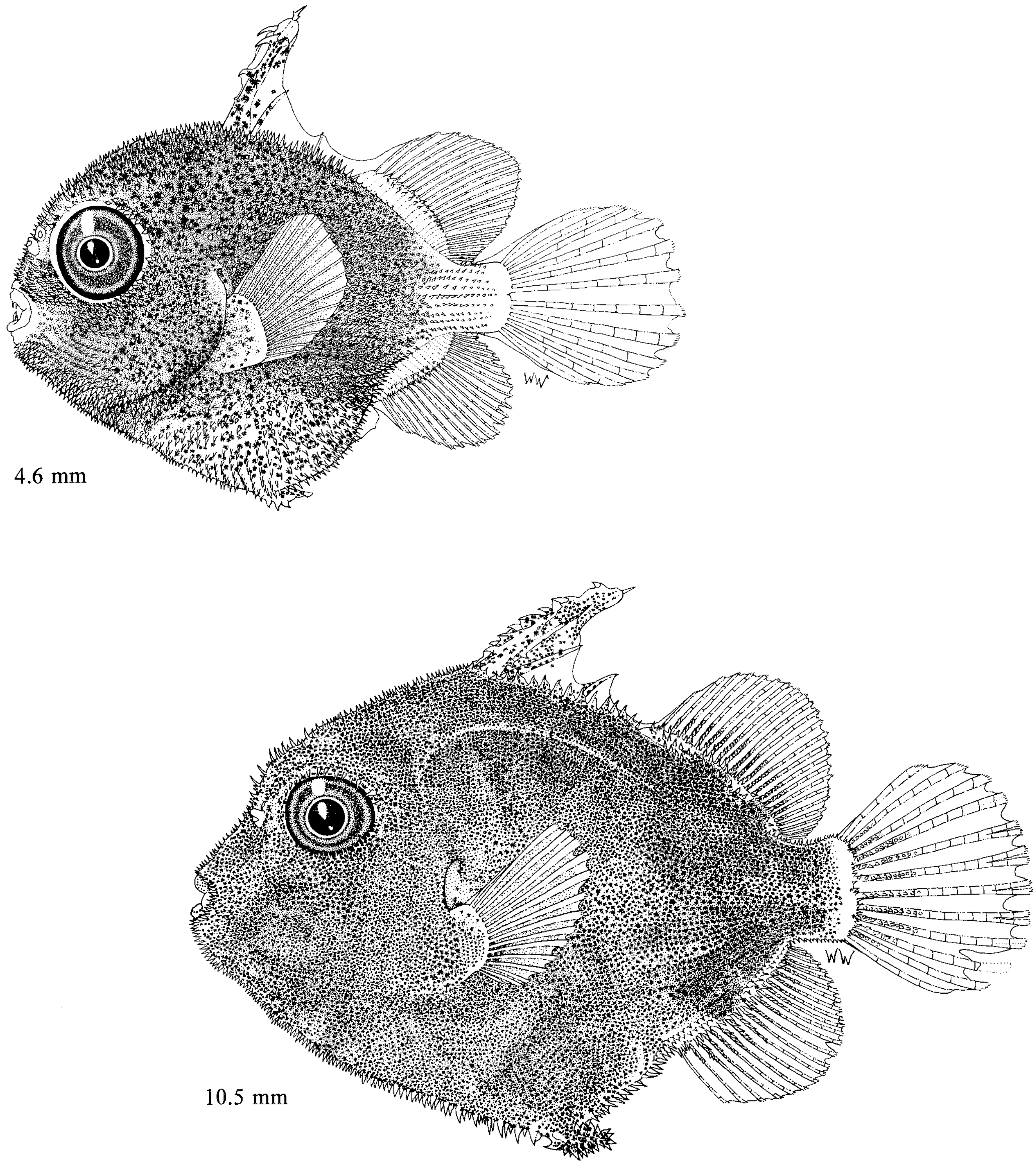


Figure Balistidae 1. *Canthidermis maculatus*, postflexion larva, 4.6 mm (PODS 9210, station 39 Manta); pelagic juvenile, 10.5 mm (CFRD Ref. Coll., 13°29′ N, 91°30′ W, night light collection). Spinules cover the body of the pelagic juvenile, but only those around the margins and on the fins are shown. Illustrations by W. Watson.

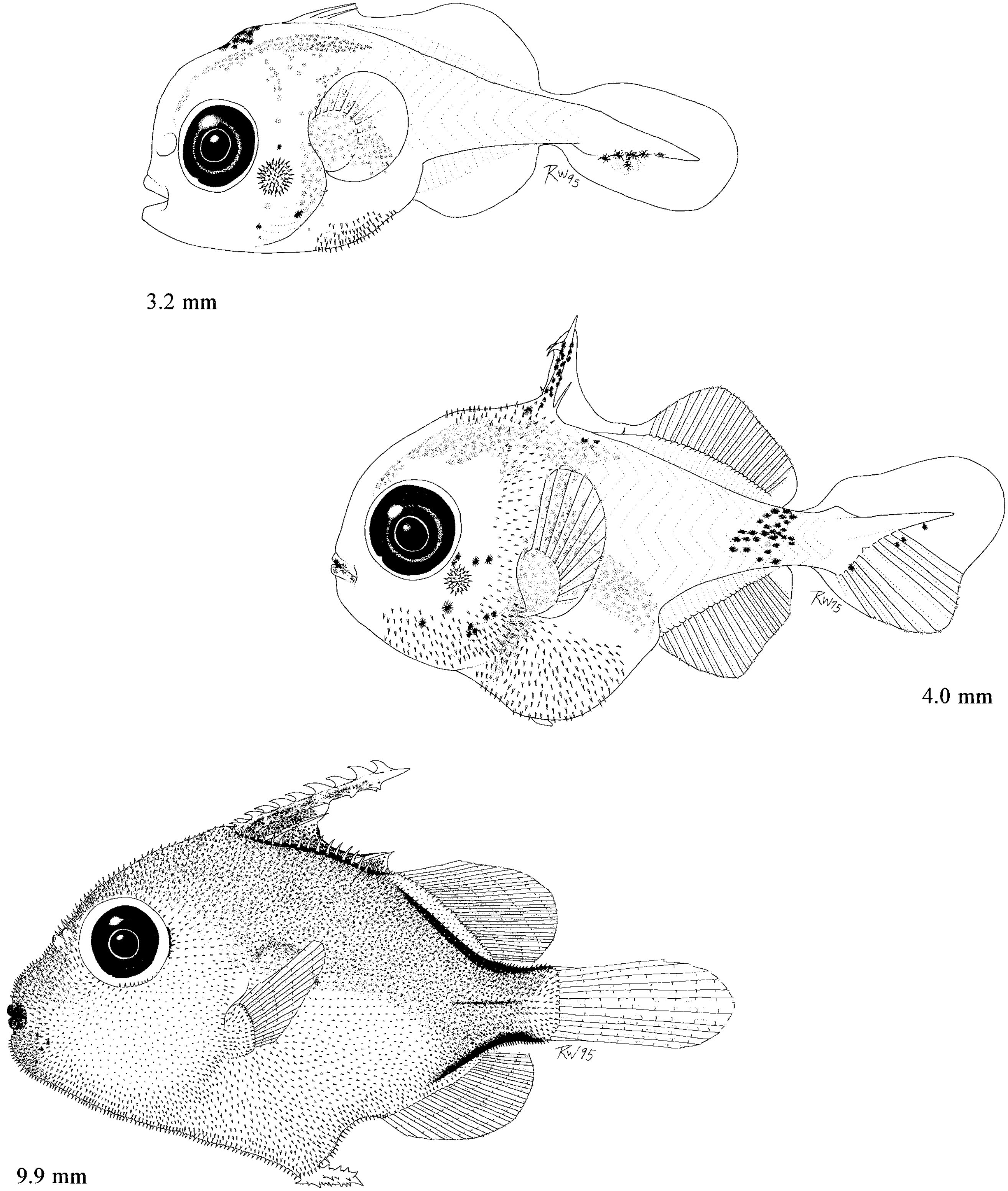


Figure Balistidae 2. *Sufflamen verres*, preflexion larva, 3.2 mm (IATTC 89013, station C2 Grn); flexion larva, 4.0 mm (IATTC 90027, station B9); pelagic juvenile, 9.9 mm (EASTROPAC II, station 47.254). Illustrations by R. C. Walker.

MERISTICS

	Range	Mode
Vertebrae:		
Total	18	18
Precaudal	7–8	7
Caudal	10–11	11
Fins:		
Dorsal spines	III	III
Dorsal rays	26–28	27–28
Anal spines	0	0
Anal rays	24–26	25–26
Pelvic	0	0
Pectoral	13–15	14
Caudal:		
Principal	6+6	6+6
Procurrent:		
Upper	0	0
Lower	0	0
Gill rakers:		
Upper		
Lower	29–37	
Branchiostegals	6	6

LIFE HISTORY

Range: Northern California (41°50'N) to Peru

Habitat: Near bottom, shallow subtidal to ca. 500 m depth; juveniles in upper water column

Spawning season: Larvae collected June–October

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.9 mm, 3.3 mm (R. C. Walker)
Flexion larva, 4.0 mm (R. C. Walker)
Postflexion larva, 5.0 mm (R. C. Walker)

* Development from the larval to pelagic juvenile stage is gradual, without a morphologically distinct transformation stage. "Transformation" here refers to the smallest size at which full fin ray complements are present, the snout length exceeds the eye diameter, & the mottled or spotted pigment pattern typical of the pelagic juvenile stage is discernable.

† Pelvic fins are reduced to a single pelvic tubercle.

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <1.6 mm
Flexion length: 3.8 mm through 4.3–4.5 mm
Transformation length: ca. 11 mm*
Fin development sequence: 1D, P_1, C, 2D & A, P_2†
Pigmentation: *Preflexion*—Initially, under hindbrain, on gas bladder, anteriorly on gut, series along ventral margin of tail, & 3–6 ventrally on caudal finfold; spreading dorsad on hindbrain by 2.3 mm, surrounding it by 2.6–2.9 mm, spreading posteriorly onto midbrain by 2.9 mm & over notochord to myomere 5 by 3.8 mm; over midbrain at 2.4 mm, slowly increasing; over forebrain by 2.6 mm; on branchiostegal membranes by 3.8 mm & increasing on gas bladder & dorsally on gut; spreading down front of gut onto ventrum by 2.4 mm, then posteriorly along ventrum of gut; few dorsally & dorsolaterally on trunk by 3.8 mm; on membranes between DI–II by 3.8 mm; becoming internal along ventral margin of tail, beginning anteriorly by 2.4 mm. *Flexion*—Increasing dorsally on head & trunk, on 1D, & on gut; little on pelvic tubercle; few ventrally & ventrolaterally just behind A insertion & dorsolaterally at D insertion, forming bar by 4.4 mm; little proximally on C. *Postflexion*—Becoming completely pigmented by 5.8 mm except none around mouth or on end of caudal peduncle, P_1, 2D, & A rays; little or none on C rays.
Diagnostic features: Pigment ventrally on gut by 2.4 mm & along ventral margin of tail, becoming internal after 2.4 mm; mouth always unpigmented; D rays 26–28; A rays 24–26 (all present by ca. 5 mm).

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	PJuv
Sn-A/BL		38–54 47	51–63 57	64–69 66	65–68 66
BD/BL		30–46 38	48–57 51	56–65 60	56–61 58
HL/BL		25–35 30	33–41 38	39–46 42	36–42 39
HW/HL		60–103 82	66–118 88	63–98 74	50–64 56
SnL/HL		10–25 19	21–25 22	19–35 28	38–47 43
ED/HL		40–53 45	40–45 44	37–44 40	34–37 35
P_1L/BL		6–13 9	14–19 17	18–21 20	14–19 17
P_2L/BL		0–0.5 0.1	2–6 5	8–13 11	12–15 13

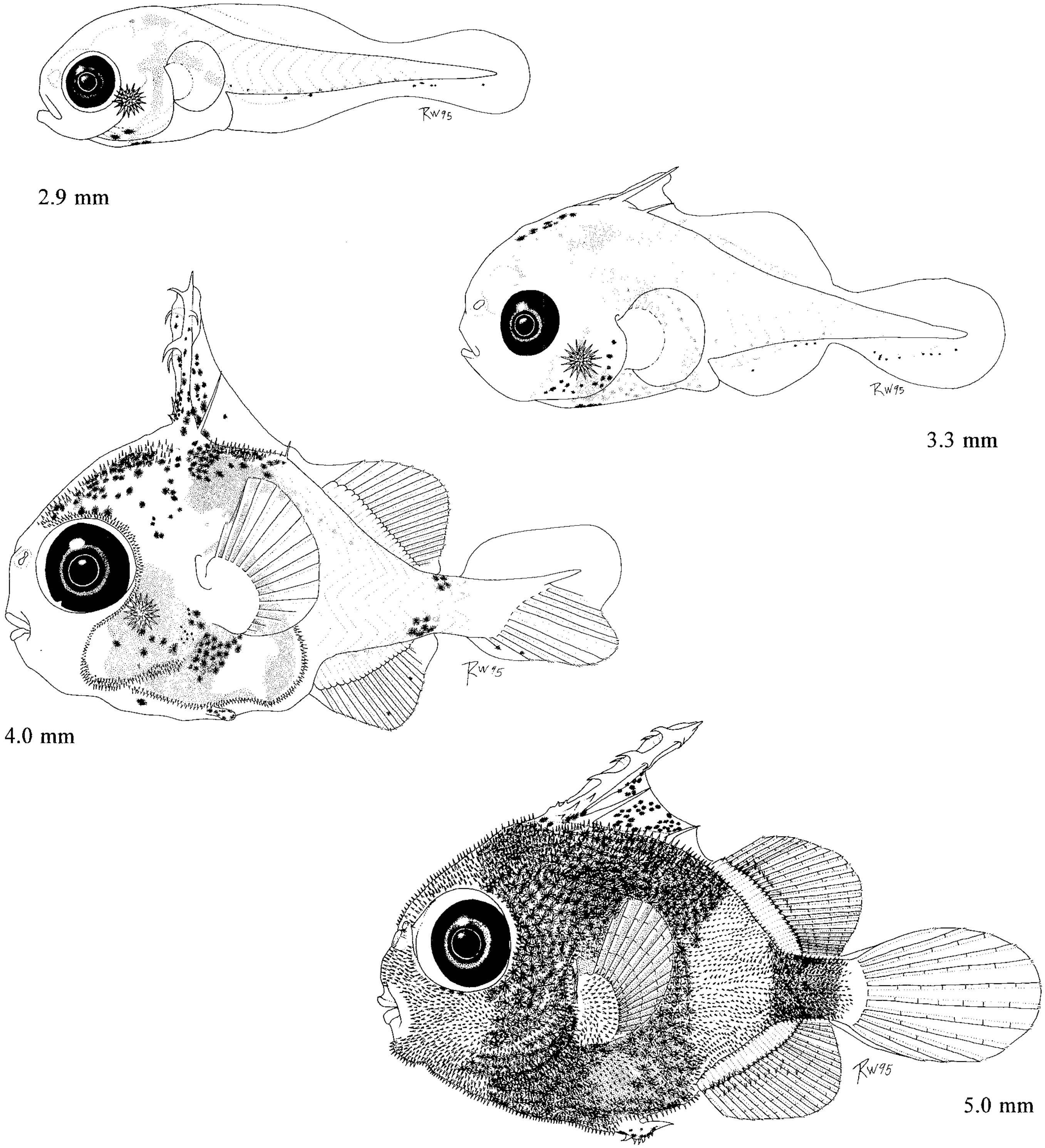


Figure Balistidae 3. Preflexion larvae, 2.9 mm (CalCOFI 5708, station 120G.13), 3.3 mm (CalCOFI 5708, station 105G.70); flexion larva, 4.0 mm (PODS 9310, station 11 Manta); postflexion larva, 5.0 mm (CalCOFI 5708, station 109G.68). The area of the body covered with spinules on the 4.0 mm specimen is outlined, but most spinules within the area are not shown.

MONACANTHIDAE: Filefishes

W. WATSON

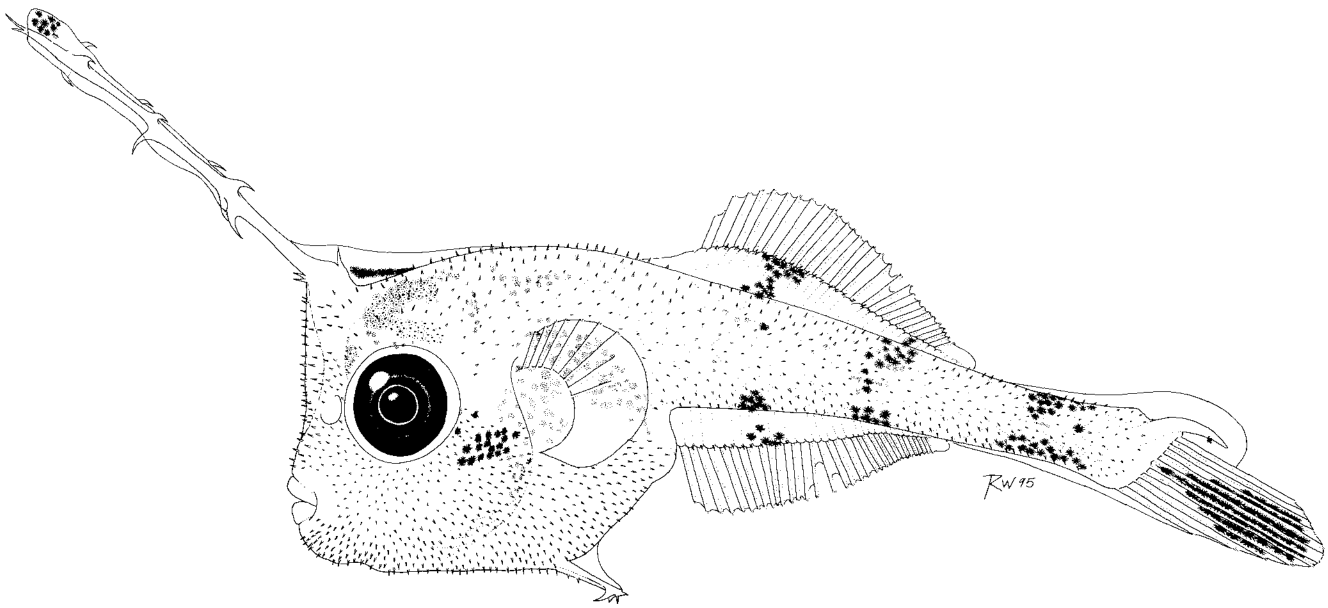
Two of the approximately 95 monacanthid species (Nelson 1994) occur in the California Current vicinity (Table Tetraodontiformes 1). Both are widely ranging tropical fishes that enter the CalCOFI study area at its southern limit off southern Baja California Sur. Larval filefishes have not been collected during CalCOFI ichthyoplankton surveys but larval *Aluterus scriptus* were taken from the Gulf of Panama during other ichthyoplankton studies.

Filefishes are small to medium-size (most ≤30 cm, largest species to ca. 1 m) residents of reefs, macroalgal beds, and floating macroalgal mats in warm seas. They range from deep-bodied to elongate, with preanal length ca. 50–60% BL, and are strongly compressed. The head is large, with a long snout and small eyes. The spinous dorsal fin consists of one or two spines; the larger first spine is located on the head, usually above, or in some species in front of the eyes. The anal and second dorsal fins are long-based, with ca. 20–50 soft rays each. Pelvic fins are lacking. The body is covered with small scales which in many species produce a shagreen-like texture. Filefishes typically are rather drab, with greens, browns and greys predominating; a few species are better described as gaudy.

Filefishes are oviparous, with small (ca. 0.5–0.8 mm), adhesive, demersal eggs containing several small oil globules. There apparently is no parental care of the eggs (Aboussouan and Leis 1984; Akagawa et al. 1995). Larvae near 2 mm long hatch with unpigmented eyes, an unformed to partially formed mouth, and a moderate yolk sac (Aboussouan and Leis 1984; Akagawa et al. 1995). The larvae initially are elongate, oval in cross-section, with preanal length ca. 35–40% BL. Following yolk absorption preanal length increases to ca. 40–60% BL and some species become deep-bodied, while others remain elongate (Leis and Rennis 1983; Aboussouan and Leis 1984). Larvae are somewhat to strongly compressed; the broader species become more compressed with growth. The head and eyes are large, and the snout is short and rounded. A preopercular spinule tuft forms during the preflexion stage in some species, and some acquire elongate, pigmented flaps (Aboussouan and Leis 1984). The elongate first dorsal spine may be the first fin ray to form early in the preflexion stage, or it may form late, after the segmented fin rays have begun developing, depending on species (Leis and Rennis 1983; Aboussouan and Leis 1984). The body becomes covered with spinules just before to just after notochord flexion. Larvae are pigmented dorsally on the head and gut, and may be pigmented on the ventrum and to varying degrees on the tail, depending on species.

Larval monacanthids resemble larval balistids, but are more compressed, have two or three more myomeres, have a more anteriorly placed first dorsal spine, and tend to be less heavily pigmented than the balistids. It is unknown how larval *A. scriptus* and *Cantherines dumerilii* might be distinguished, except that their dorsal and anal fin-ray counts differ (Table Tetraodontiformes 1).

Separate species accounts are not given here since no monacanthid larvae were taken during CalCOFI surveys and only a few larval *A. scriptus* of a very small size range (5.5–5.7 mm: mid-flexion to early postflexion) were available. Instead, a single 5.7 mm mid-flexion specimen of *A. scriptus* is shown in Figure Monacanthidae 1. Refer to Leis and Rennis (1983), Aboussouan and Leis (1984), and Fujita (1988) for additional information.



5.7 mm

Figure Monacanthidae 1. *Aluterus scriptus* flexion larva, 5.7 mm (IATTC 90023, station MSH2 #1 Red). Original illustration by R. C. Walker.

OSTRACIIDAE: Trunkfishes

W. Watson

Two of the approximately 33 ostraciid species occur in the California Current vicinity (Table Tetraodontiformes 1). Both are widely ranging tropical Indo-Pacific species that occur in the CalCOFI study area primarily at the southern tip of Baja California Sur (Thomson et al. 1979), although *Lactoria diaphana* has been recorded as far north as Santa Barbara, California (Miller and Lea 1972). Larval trunkfishes have not been collected at stations within the regular CalCOFI pattern but a few were taken at offshore southern stations on an extended CalCOFI survey (CalCOFI 7205). In addition, larval trunkfishes were collected during the EASTROPAC surveys of the eastern tropical Pacific (Ahlstrom 1971, 1972b) and during other ichthyoplankton studies along the Pacific coasts of Mexico and Central America.

Trunkfishes are small to medium-size (most <20 cm; largest to ca. 60 cm) reef residents. They are moderately deep-bodied, slightly compressed, and enclosed in a bony carapace composed of hexagonal plates. The short-based dorsal and anal fins, both containing only segmented rays, are opposite one another posteriorly. The entire pelvic skeleton is lacking. When stressed, trunkfishes secrete a potent toxin, ostracitoxin (Brock 1956; Thompson 1964). Pigmentation ranges from browns to blues, and includes striking patterns in some species. A few species have some minor commercial value as dried curios.

Ostraciids are oviparous, spawning slightly oval planktonic eggs 1.4–2.0 mm in length that have an ornamented chorion (at one pole only) and contain an unsegmented yolk with one or more oil globules (Aboussouan and Leis 1984; Leis and Moyer 1985). Larvae ca. 1.6–2.5 mm long hatch with unpigmented to fully pigmented eyes, unformed to open mouth, and with fin development ranging from no median fins forming to dorsal and anal fin anlagen present (Leis and Rennis 1983; Aboussouan and Leis 1984). Larvae are deep-bodied and broad, with preanal length initially about half of body length, increasing to ca. 80–90% BL before notochord flexion. The head and eyes are large and the snout is short and rounded. The epidermis of the head and trunk is inflated through much of the preflexion stage. Thickenings form on the epidermis during the preflexion stage, then ossify and expand, forming the bony carapace. Pectoral, dorsal and anal fin rays form during the preflexion stage, and with completion of the caudal fin and notochord flexion the larvae are essentially pelagic juveniles (Leis and Rennis 1983). *Lactoria diaphana* has an extended pelagic phase (Leis and Moyer 1985). Larval pigmentation is moderate and approximately uniform on the head and trunk. The tail and inflated epidermis may be pigmented or not, depending on species (Leis and Rennis 1983; Aboussouan and Leis 1984; Leis and Moyer 1985). Larval pigmentation changes little, except to gradually increase, during development.

Early in the preflexion stage larval ostraciids superficially resemble diodontids, molids, and some ceratioids, but they become easily distinguishable from all others before notochord flexion begins. Key characters are the approximately even pigmentation of the head and trunk (and tail in some species), the deep and only slightly compressed body, and the epidermal thickenings which subsequently become the hexagonal plates of the carapace. The two ostraciid species are distinguished from one another by the presence of melanophores on the epidermis of *Ostracion meleagris* and their absence in *L. diaphana*, and by the generally heavier pigmentation of *O. meleagris*, particularly on the tail. Eggs of the two species are indistinguishable until shortly before hatching (Leis and Moyer 1985).

Separate larval descriptions are not given here for either species, but both are shown in Figures Ostraciidae 1 and Ostraciidae 2. Leis and Moyer (1985) fully describe egg and larval development for both species.

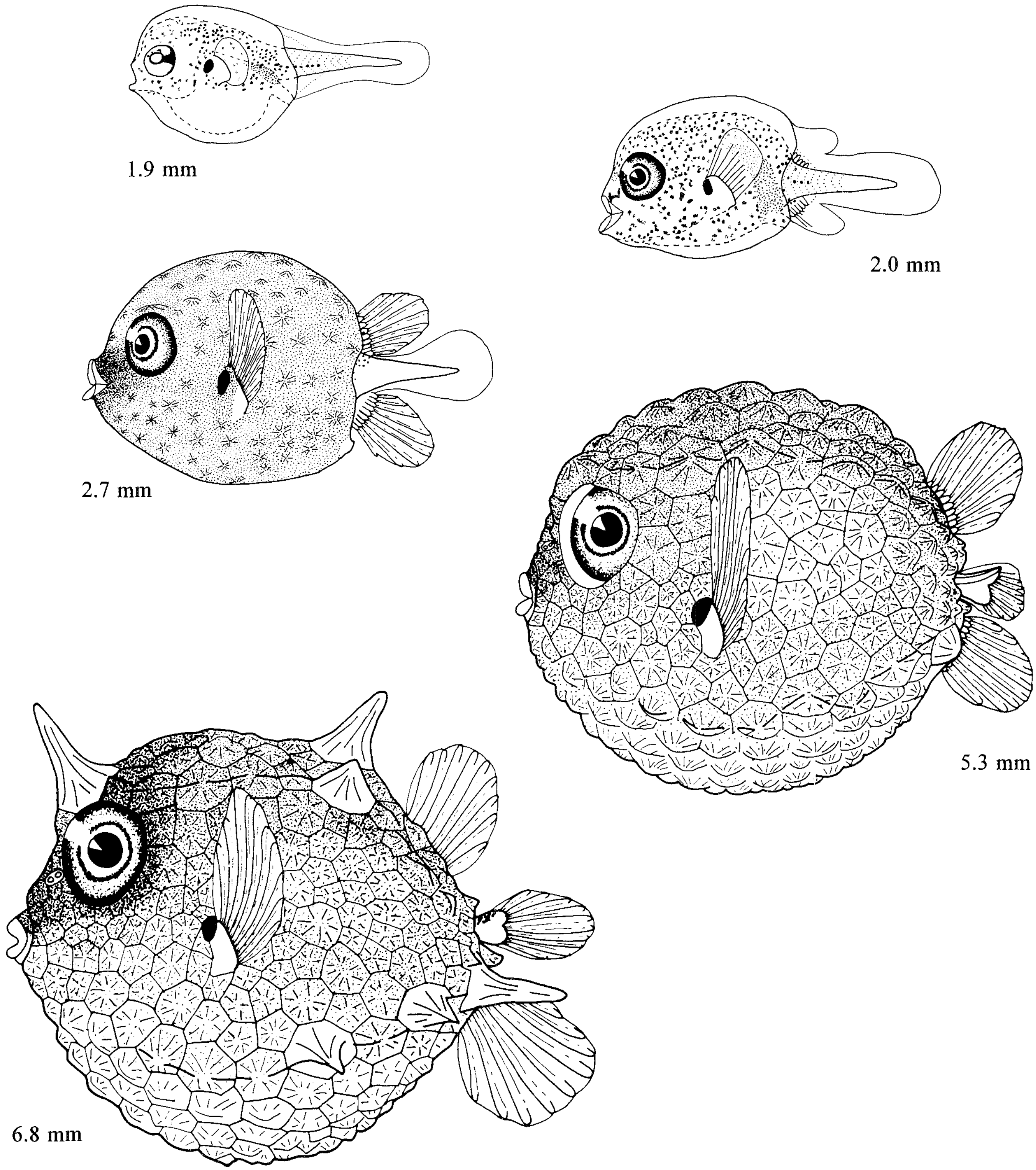


Figure Ostraciidae 1. *Lactoria diaphana*: recently hatched larva, 1.9 mm; preflexion larvae, 2.0 mm, 2.7 mm; flexion larva, 5.3 mm; pelagic juvenile, 6.8 mm (Leis and Moyer 1985).

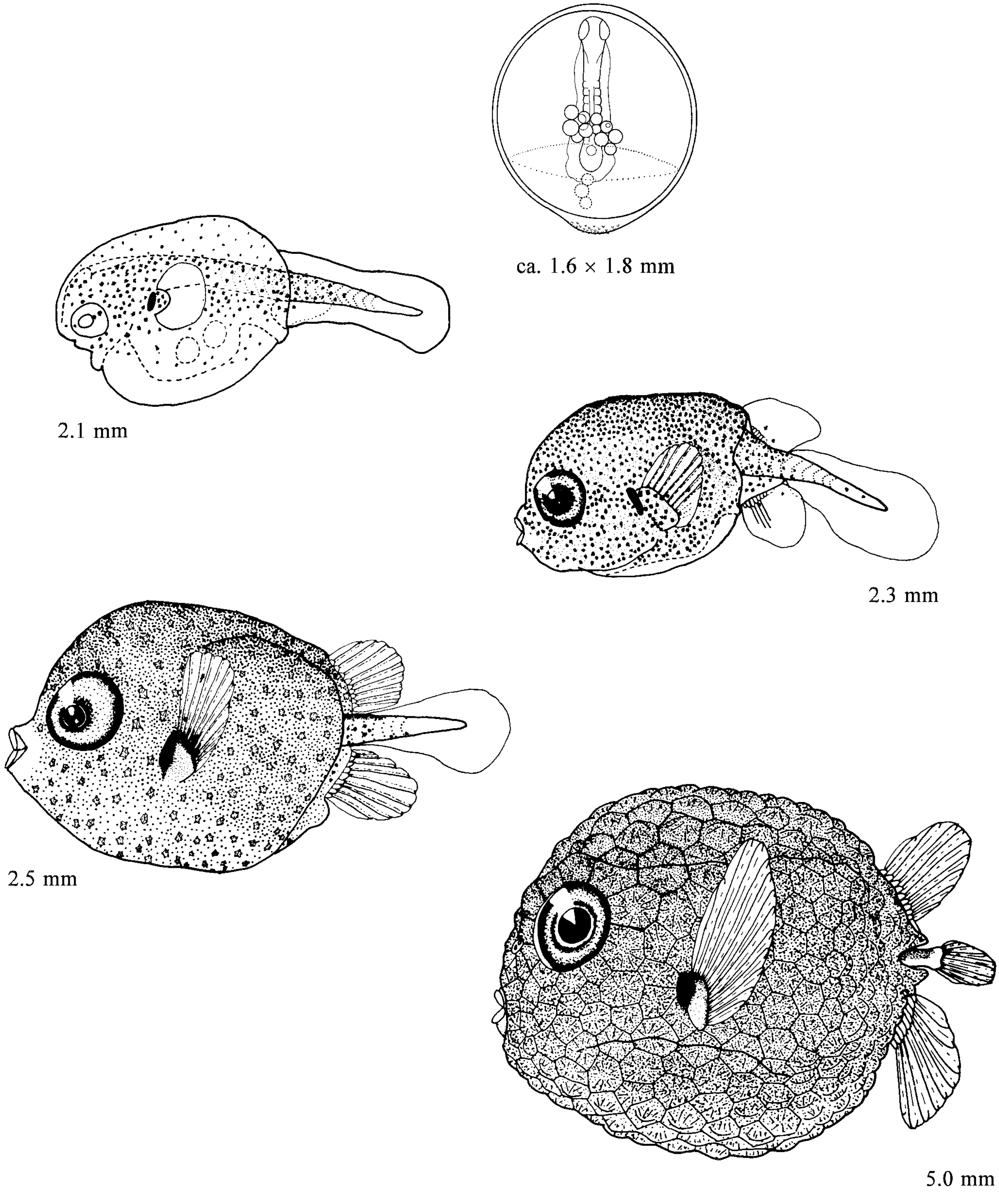


Figure Ostraciidae 2. *Ostracion meleagris*: egg, ca. 1.6 × 1.8 mm; newly hatched larva, 2.1 mm; preflexion larvae, 2.3 mm, 2.5 mm; pelagic juvenile, 5.0 mm (Leis and Moyer 1985).

TETRAODONTIDAE: Puffers

W. WATSON

Tetraodontidae comprises 19 genera and about 121 species (Nelson 1994); eight species in four genera occur within the CalCOFI study area (Table Tetraodontiformes 1). *Sphoeroides annulatus* and *S. lobatus* have been recorded as far north as southern California but both are uncommon north of southern Baja California Sur. The other six species range southward from the Gulf of California and enter the CalCOFI study area in the vicinity of Cabo San Lucas. Few tetraodontid larvae have been collected from within the regular CalCOFI study pattern, although they have been taken in modest numbers from the Gulf of California and along the Pacific coast of mainland Mexico and Central America during other ichthyoplankton surveys.

Puffers are small to medium-size (maximum lengths ca. 9–50 cm) residents of primarily tropical and subtropical, shallow, marine sandy-bottom and reef habitats. Some species enter brackish water and a few occur only in freshwater. A few others, most in the genus *Lagocephalus*, are pelagic. Tetraodontine puffers are broadly oval in cross-section while canthigastrines are more compressed. All can inflate by swallowing water or air. All lack scales but most have small spinules covering at least part of the body. The short dorsal and anal fins, composed only of segmented rays, are opposite one another posteriorly. Pelvic fins are lacking. Each jaw bears two dental plates of fused teeth in a beak-like arrangement. Puffers are well known for their strong alkaloid poison, tetrodotoxin, which is concentrated primarily in the skin and viscera. Despite their toxicity, some species are highly regarded gastronomic delicacies. A few of the more colorful or strikingly marked species are popular in the aquarium trade.

Puffers are oviparous, with weakly to strongly adhesive demersal eggs (e.g., Breder and Rosen 1966; Leis 1984a). The spherical eggs, ranging in diameter from ca. 0.5–2.3 mm, contain an unsegmented yolk with a cluster of oil globules (Leis 1984a; Arai and Fujita 1988). Larvae are ca. 1.5–2.5 mm long at hatching, with unpigmented to fully pigmented eyes, unformed to fully formed mouth, pectoral fin development ranging from none to well-developed bases with finfolds, and moderate yolk sac. Throughout development larvae become increasingly deep-bodied, are broadly oval to round in cross-section and have preanal length ca. half to three-quarters of body length. The eyes are large. The epidermis of the head and trunk is slightly to moderately inflated through at least the preflexion stage. Small spinules may form on the ventral surface of the abdomen during the preflexion stage; these may remain restricted to the belly or spread to cover most of the head and trunk. Larval pigmentation commonly occurs initially mainly on the dorsum of the gut and head and/or trunk, and subsequently spreads to cover much or all of the head, trunk, and gut. Development is direct, with no clearly defined transformation stage.

Larval tetraodontids superficially resemble the larvae of some ceratioids and some other tetraodontiforms. The tetraodontids have a less strongly inflated epidermis than the ceratioids, have 18–19 myomeres vs. 20–21 for most ceratioids, and develop pectoral fin rays before the dorsal and anal fin rays, in contrast to after the dorsal and anal rays in the ceratioids. The other tetraodontiform larvae commonly are deeper-bodied than the tetraodontids during yolk-sac and preflexion stages, and during the preflexion stage they acquire family-specific characteristics that immediately distinguish them from the tetraodontids (e.g., the preopercular spinule tuft of the balistids, the large papillae that cover the body of larval diodontids, and the even larger spines of the molids). The tetraodontids have much lower dorsal and anal fin-ray counts and lack the large, ornamented dorsal fin spine which begins to form during the preflexion stage in the balistids and monacanthids. Larval tetraodontids are much less heavily pigmented than larval ostraciids, and have 1–3 fewer myomeres and lower pectoral fin-ray counts than larval diodontids.

The following descriptions are based on detailed observation of 5 larvae and 9 juveniles of *Sphoeroides annulatus* and 12 larvae and 6 juveniles of *S. lobatus* (Table Tetraodontidae 2). As noted by Leis and Rennis (1983), young puffers are essentially miniature adults following notochord flexion. Accordingly, all specimens that have completed notochord flexion are pooled here and referred to as juveniles. Meristic data were obtained from the literature (Thomson et al. 1979; Allen and Robertson 1994), from H. J. Walker, Jr. (SIO Marine Vertebrates Collection, pers. comm., March 1995), and from counts made during this study. Ecological information was obtained from Thomson et al. (1979), Fitch (1973), and H. J. Walker, Jr. (SIO Marine Vertebrates Collection, pers. comm., February 1995).

Table Tetraodontidae 1. Number of specimens (above) and size ranges (in mm, below) used in the preparation of the tetraodontid species descriptions. All specimens that have completed notochord flexion are pooled in the category "Juvenile."

Species	Yolk-sac	Preflexion	Flexion	Juvenile
Sphoeroides annulatus	0	5 2.2–4.2	0	9 5.3–15.9
S. lobatus	2 1.4–1.7	5 2.2–3.6	5 4.6–5.2	6 4.6–12.1

MERISTICS

	Range	Mode
Vertebrae:		
Total	18–19	18
Precaudal	8–9	8
Caudal	10–11	10
Fins:		
Dorsal spines	0	0
Dorsal rays	7–9	8
Anal spines	0	0
Anal rays	6–9	7
Pelvic	0	0
Pectoral	14–17	16
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	1	1
Lower	1	1
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: San Diego, California, & Gulf of California to Peru & the Galápagos Islands

Habitat: Over sandy bottom & reefs in shallow nearshore waters

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Preflexion larvae, 2.2 mm, 4.2 mm (R. C. Walker)
Juvenile, 5.8 mm, with dorsal view of head (R. C. Walker)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: <2.2 mm
Flexion length: ca. 4.3–5.3 mm
Transformation length: ca. 5.3 mm
Fin development sequence:
Pigmentation: *Preflexion*—Dorsally on head & nape, spreading caudad on trunk; dorsally over gut, spreading ventrally under hindbrain. *Juvenile*—Spreading anteriorly, laterally, & posteriorly to cover nearly entire body except most of snout, D & A bases, & caudal peduncle by 5 mm; covering entire body except nasal capsules, lips, & hypural margin by 11 mm; ventrum of head & gut much lighter.
Diagnostic features: No external melanophores ventrally on gut; nasal capsules not large, separated by at least 25% ED.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL		53–64 59				77–84 79
BD/BL		34–40 38				36–43 39
HL/BL		28–34 31				41–48 44
HW/HL		86–94 88				74–90 82
SnL/HL		13–22 18				22–26 23
ED/HL		38–48 41				29–37 33
P_1L/BL		8–17 11				15–22 19
InW/ED		25–50 33				33–44 38

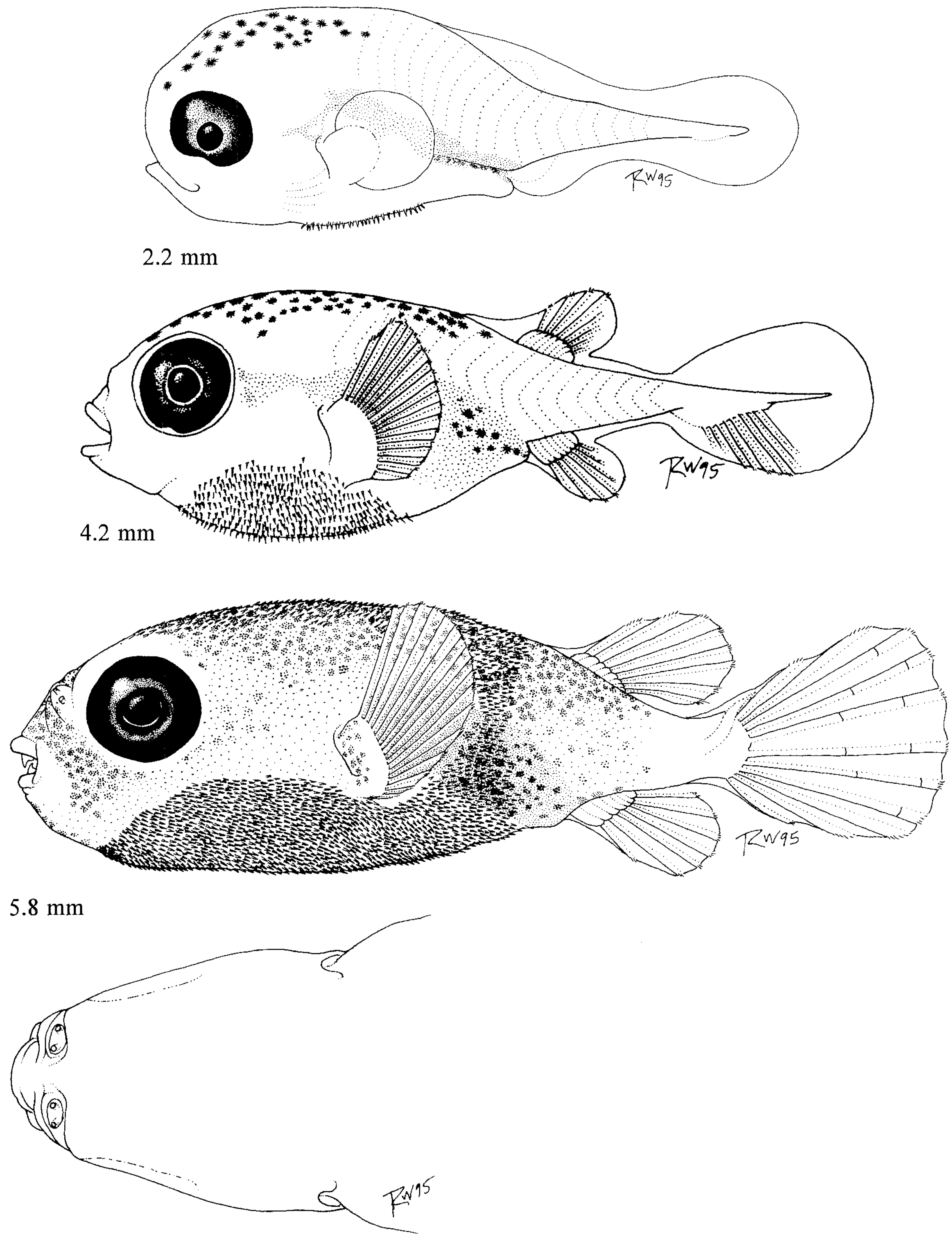


Figure Tetraodontidae 1. Preflexion larvae, 2.2 mm (CalCOFI 5706, station 109G.68), 4.2 mm (IATTC 89021, station ASB #1 Grn); juvenile, 5.8 mm and dorsal view of head (CalCOFI 5706, station 139G.85).

MERISTICS

	Range	Mode
Vertebrae:		
Total	17–18	17
Precaudal	8	8
Caudal	9–10	9
Fins:		
Dorsal spines	0	0
Dorsal rays	7–8	8
Anal spines	0	0
Anal rays	6–7	7
Pelvic	0	0
Pectoral	14–16	15–16
Caudal:		
Principal	4+5	4+5
Procurrent:		
Upper	1	1
Lower	1	1
Gill rakers:		
Upper		
Lower		
Branchiostegals	6	6

LIFE HISTORY

Range: Redondo Beach, California, & Gulf of California to Peru

Habitat: Over sandy bottom & reefs in shallow coastal waters

Spawning season: Larvae collected in summer

ELH pattern: Oviparous; planktonic larvae

LITERATURE

ORIGINAL ILLUSTRATIONS (Illustrator)

Yolk-sac larvae, 1.4 mm, 1.7 mm (N. Arthur)
Preflexion larva, 3.6 mm (N. Arthur)
Flexion larva, 5.2 mm (N. Arthur)
Juvenile, 5.5 mm, with dorsal view of head (N. Arthur)

EARLY LIFE HISTORY DESCRIPTION

EGGS

Shell diam.: **Yolk:**
No. of OG: **Diam. of OG:**
Shell surface:
Pigment:
Diagnostic features:

LARVAE

Hatching length: ca. 1.4 mm
Flexion length: ca. 4 mm through 4.6–5.2 mm
Transformation length: 4.6–5.2 mm
Fin development sequence: P_1, D & A, C_1, C_2
Pigmentation: *Yolk-sac*—Eyes partially pigmented initially, becoming fully pigmented by 1.7 mm; few scattered on dorsum of head & trunk, condensing to 1–few over nape; over gut; on yolk sac. *Preflexion*—Patch at nape spreads forward to above posterior half of eye & posteriorly on trunk; internally under hindbrain; increasing over gas bladder & gut, spreading ventrad; external patch ventrally on gut. *Flexion*—Increasing dorsally on head & trunk, spreading ventrad; patch on snout by 5.2 mm; increasing on gut. *Juvenile*—Becoming fully pigmented except on nostrils, lips, fins, & most of caudal peduncle.
Diagnostic features: External melanophores ventrally on gut, clearly visible on preflexion stage larvae but becoming obscured in older specimens; nasal capsules large, separated by less than 25% ED after the yolk-sac stage.

MORPHOMETRICS (range & mean in %)

	Y-S	PrF	F	PoF	Tr	Juv
Sn-A/BL	57–60 58	59–66 61	62–72 68			73–83 79
BD/BL	11–26 19	30–42 36	35–43 39			36–43 39
HL/BL	24–29 27	27–34 30	35–45 41			41–47 44
HW/HL	76–100 88	84–98 91	71–80 74			70–85 77
SnL/HL	14–19 17	17–21 19	19–25 22			19–26 22
ED/HL	38–43 41	38–44 42	35–42 38			30–41 38
P_1L/BL	0–5 2	8–12 10	17–21 19			18–24 20
InW/ED	 33	14–21 18	5–17 12			8–20 15

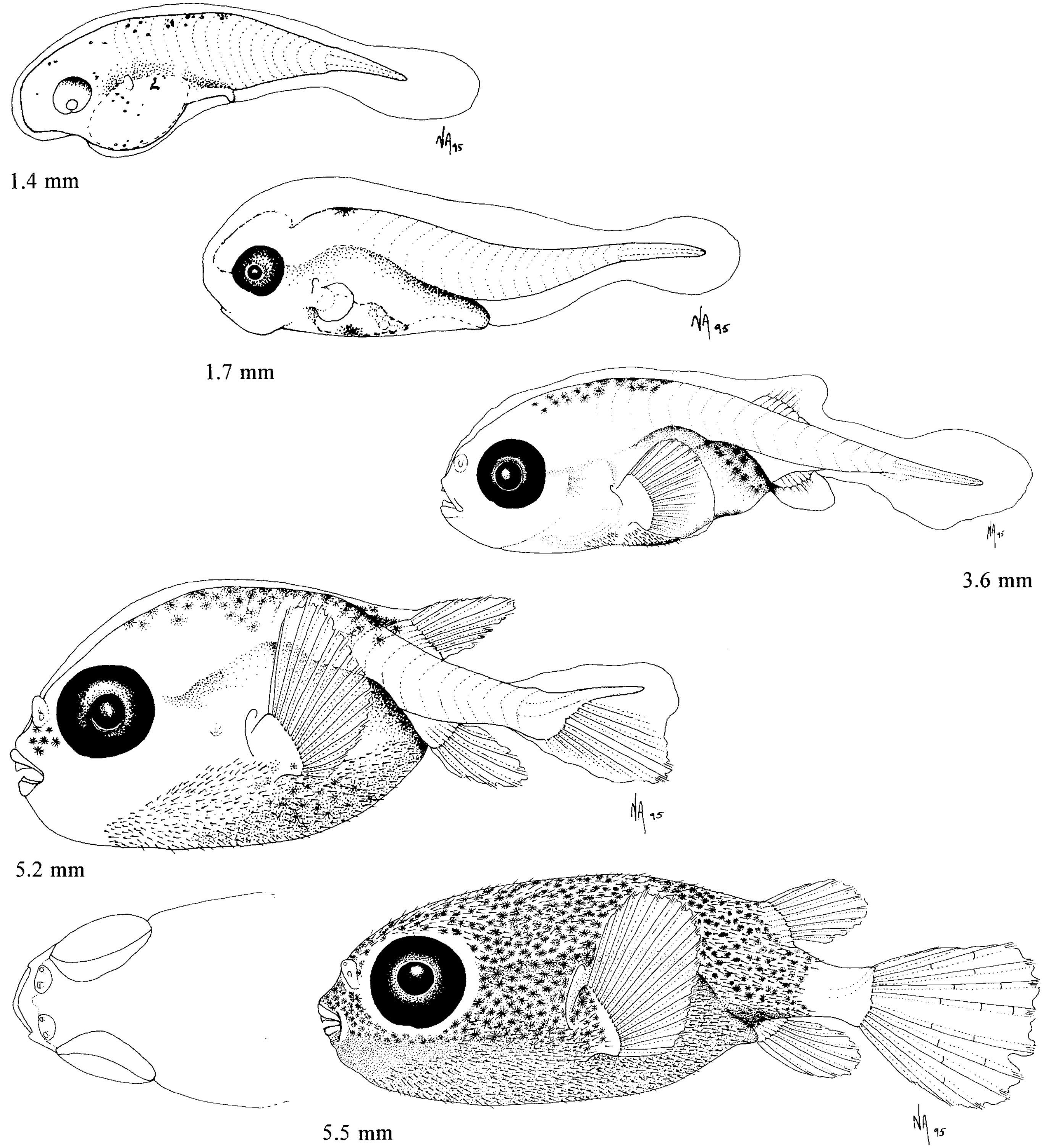


Figure Tetraodontidae 2. Yolk-sac larvae, 1.4 mm (IATTC 89010, station D1 Red), 1.7 mm (IATTC 89008, station B2 Red); preflexion larva, 3.6 mm (IATTC 89024, station ASH2 #1 Red); flexion larva, 5.2 mm (IATTC 90006, station ASH2 #1 Red); juvenile, 5.5 mm and dorsal view of head (IATTC 89008, station A2 Red).

DIODONTIDAE: Porcupinefishes

W. WATSON

Diodontidae contains 19 species in six genera (Nelson 1994); four widely ranging species reach the California Current vicinity (Table Tetraodontiformes 1). Three (*Cheilomycterus reticulatus*, *Diodon holocanthus*, *D. hystrix*) occur in the CalCOFI study area, primarily at its southern end, although *C. reticulatus* and *D. holocanthus* have been recorded from as far north as southern California (Miller and Lea 1972; Leis 1978). Larval porcupinefishes have not been collected during CalCOFI ichthyoplankton surveys but have been taken in other studies from the Gulf of California and along the Pacific coast of mainland Mexico and Central America.

Most porcupinefishes are medium-size (<40 cm; largest species to ca. 1 m) residents of coastal sandy bottom and reefs in warm seas; *Diodon eydouxii* is epipelagic (Leis 1978). Porcupinefishes are covered with large spines and are strongly inflatable. The head and eyes are large, the mouth terminal, and the teeth fused into a parrot-like beak. The posterior, rounded dorsal and anal fins contain only segmented rays. Pelvic fins are lacking. Pigmentation ranges from shades of blue to greens, yellows and browns, usually darker dorsally. Spotted and barred patterns are common. Some porcupinefish species are of minor commercial value as dried curios.

Diodontids are oviparous, with planktonic eggs and larvae (Leis 1984a). The spherical eggs, 1.6–2.2 mm in diameter, contain many small oil globules (Leis 1984a). Larvae ca. 1.9–2.6 mm long hatch with an unformed to open mouth, partially to fully pigmented eyes, inflated epidermis, and a moderate yolk sac (Leis 1984a). Larvae are broad and deep-bodied, with preanal length ca. 70–90% BL. The head and eyes are large and the snout is short and rounded. The epidermis remains inflated through most or all of the preflexion stage. The characteristic body spines form during the preflexion stage, appearing first as epidermal thickenings which subsequently expand into low swellings or project outward into broad papillae inside of which the spines later form (Leis and Rennis 1983; Leis 1984a). Pectoral fin rays are the first to begin forming, and all fins except the caudal are complete before notochord flexion. Following flexion, porcupinefishes are essentially pelagic juveniles (Leis and Rennis 1983). Larvae are moderately to heavily pigmented dorsally on the head, trunk, and gut during the preflexion stage and may become heavily pigmented ventrally during notochord flexion. Pelagic juveniles commonly are spotted.

Small preflexion stage diodontids resemble the early larvae of some ceratioids, molids, ostraciids, and tetraodontids. Ceratioids commonly have a more strongly inflated epidermis that persists longer in larval development than it does in the diodontids. Larval ceratioids often are more compressed, lack the body spines characteristic of diodontids, and females of most species develop an illicium during the preflexion stage (none in diodontids). Larval molids are a little more compressed than larval diodontids, lack pigmentation on the tail, and develop very large, broad-based spines on the head and trunk, in contrast to the more numerous and smaller spines of the diodontids. Larval ostraciids are rounder in cross-section than larval diodontids, are more evenly pigmented, and lack body spines. Larval tetraodontids are more elongate than larval diodontids, and develop much smaller spinules on the body. Meristic characters also separate diodontids from most ceratioids and the other tetraodontiforms (Tables Lophiiformes 1, Tetraodontiformes 1). Larval *D. holocanthus* have a larger eye diameter than *D. hystrix* (Leis 1978), and tail pigment that is only anterior vs. always extending past midtail in *D. hystrix*. It is unknown how larval *C. reticulatus* might be distinguished from the *Diodon* species, except that *Diodon* has one or two fewer myomeres. Pelagic juvenile *C. reticulatus* have much shorter, stouter body spines than the *Diodon* species (Fujita 1988).

Separate descriptions for the diodontid species are not given here since none was collected during CalCOFI surveys, and because development of *Diodon* is well documented in the literature (Leis 1978, 1984a; Leis and Rennis 1983; Fujita 1988). Instead, *Diodon holocanthus* and *D. hystrix* are shown in Figures Diodontidae 1 and Diodontidae 2. Refer to the literature sources above for additional information.

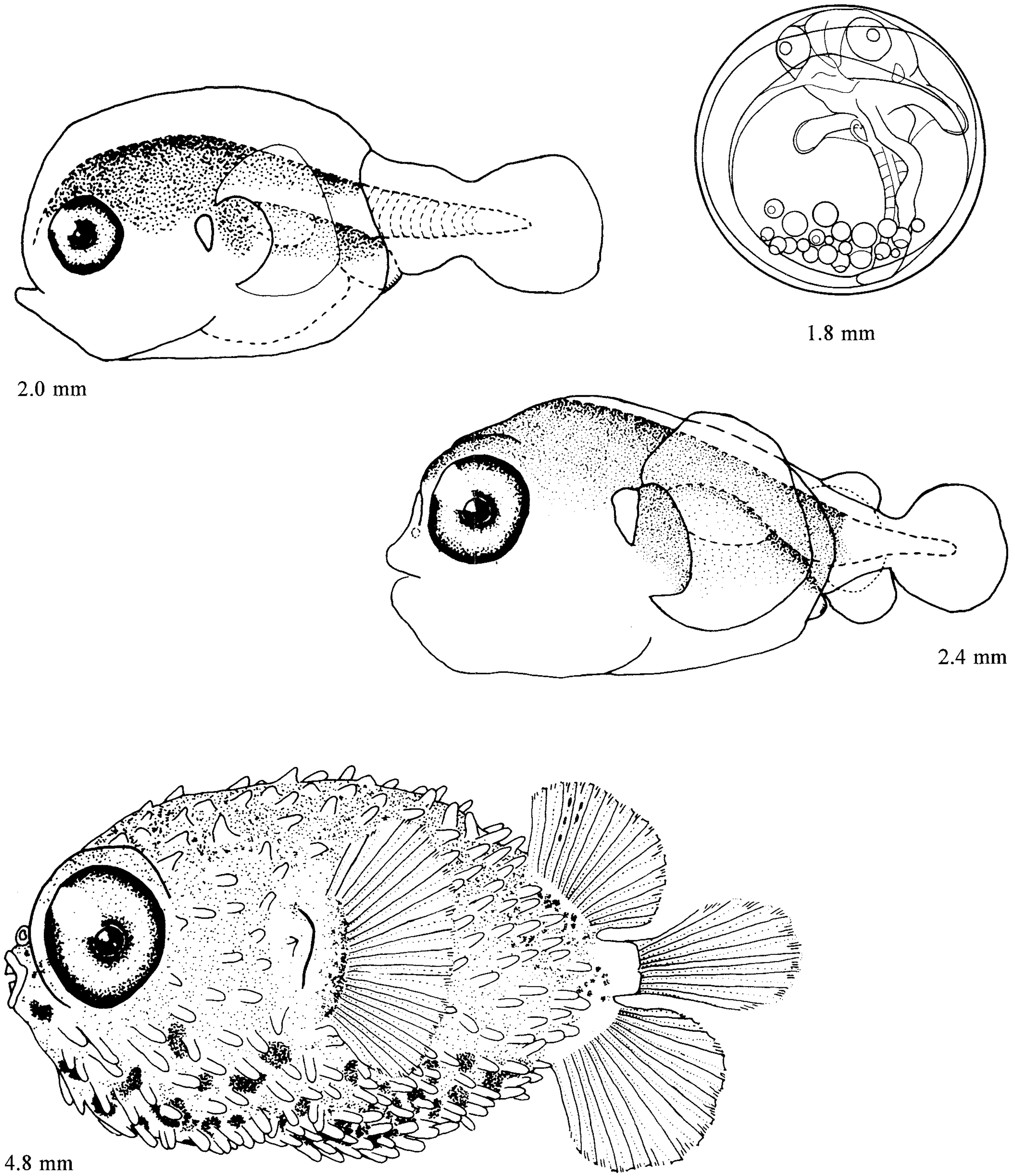


Figure Diodontidae 1. *Diodon holocanthus*: egg, 1.8 mm; newly hatched larva, 2.0 mm; 10-day-old reared larva, 2.4 mm; 25-day-old reared pelagic juvenile, 4.8 mm (Leis 1978).

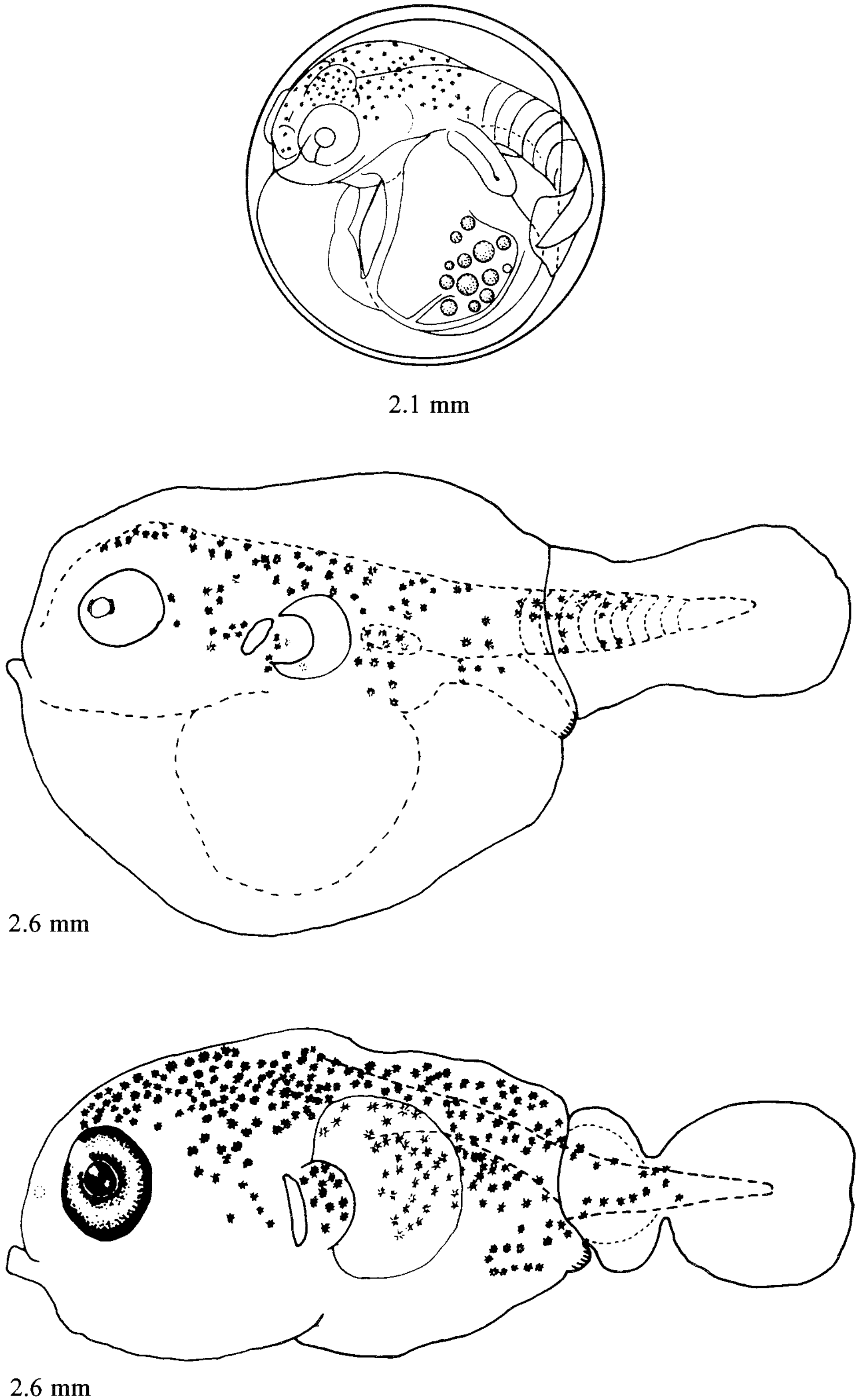


Figure Diodontidae 2. *Diodon hystrix*: egg, 2.1 mm; newly hatched larva, 2.6 mm; 5-day-old reared larva, 2.6 mm (Leis 1978).

MOLIDAE: Molas

W. WATSON

Two of the three molid species, *Mola mola* and *Ranzania laevis*, occur in the California Current vicinity (Table Tetraodontiformes 1). These cosmopolitan tropical to warm temperate species range widely in the CalCOFI study area off southern California and Baja California. No molid larvae have been taken in CalCOFI ichthyoplankton collections, but a few larval *M. mola* were collected during the EASTROPAC surveys of the eastern tropical Pacific (Ahlstrom 1971, 1972b).

Molids are medium-size (*Ranzania*, to ca. 50 cm) to enormous (*Masturus* and *Mola*, both to >2 m and ≥1000 kg) epipelagic predators on jellyfishes and salps in all warm oceans. They are deep-bodied (*Ranzania* is more elongate) and compressed. The head is large, with small eyes and a small mouth. The teeth are fused into a beak. The dorsal and anal fins, composed solely of soft rays, are opposite one another posteriorly. Pelvic and caudal fins are lacking. In place of a true caudal fin, molids have a "clavus" composed of rays which develop primarily or entirely from the dorsal and anal fins (Raven 1939; Fraser-Brunner 1951; Leis 1977). *Mola* and *Masturus* are uniformly or mottled grey to brown; *Ranzania* is more brightly colored.

Molids are oviparous, spawning spherical planktonic eggs 1.4–1.8 mm in diameter that contain an unsegmented yolk and a cluster of oil globules (Schmidt 1921; Leis 1977). Larvae ca. 1.8–2.0 mm long hatch with pigmented eyes, open mouth, little yolk, and with the dorsal fin anlage and upper pectoral fin rays forming (Leis 1977; 1984a). Larvae are deep-bodied and slightly compressed, with preanal length initially ca. 60–70% BL but increasing as the tail atrophies. The epidermis of the head and trunk is inflated. Characteristic pyramidal to lanceolate spines develop on the head and trunk, beginning soon after hatching (Schmidt 1921; Leis 1977). These persist for a relatively short time in *Ranzania* (Leis 1977), but for an extended period in *Masturus* and *Mola* (Leis 1984a). The moderately heavy larval pigmentation occurs primarily on the dorsum and dorsally on the gut.

Once formed, the distinctive spines of molid larvae preclude confusion with the larvae of any other family. During the brief period between hatching and spine formation molids resemble ostraciids and diodontids. The more uniform pigmentation of the ostraciids and broader body of the diodontids should allow identification to family during this interval. Larval molids have species-specific spination and should be readily identifiable on that basis alone, except perhaps during the brief period before spine formation.

Separate species descriptions for *Mola mola* and *Ranzania levis* are not given here because none was collected during CalCOFI surveys and both are described in the literature. Instead, they are shown in Figures Molidae 1 and Molidae 2, and the reader is directed to Schmidt (1921), Leis (1977, 1984a), and Martin and Drewry (1978) for additional information.

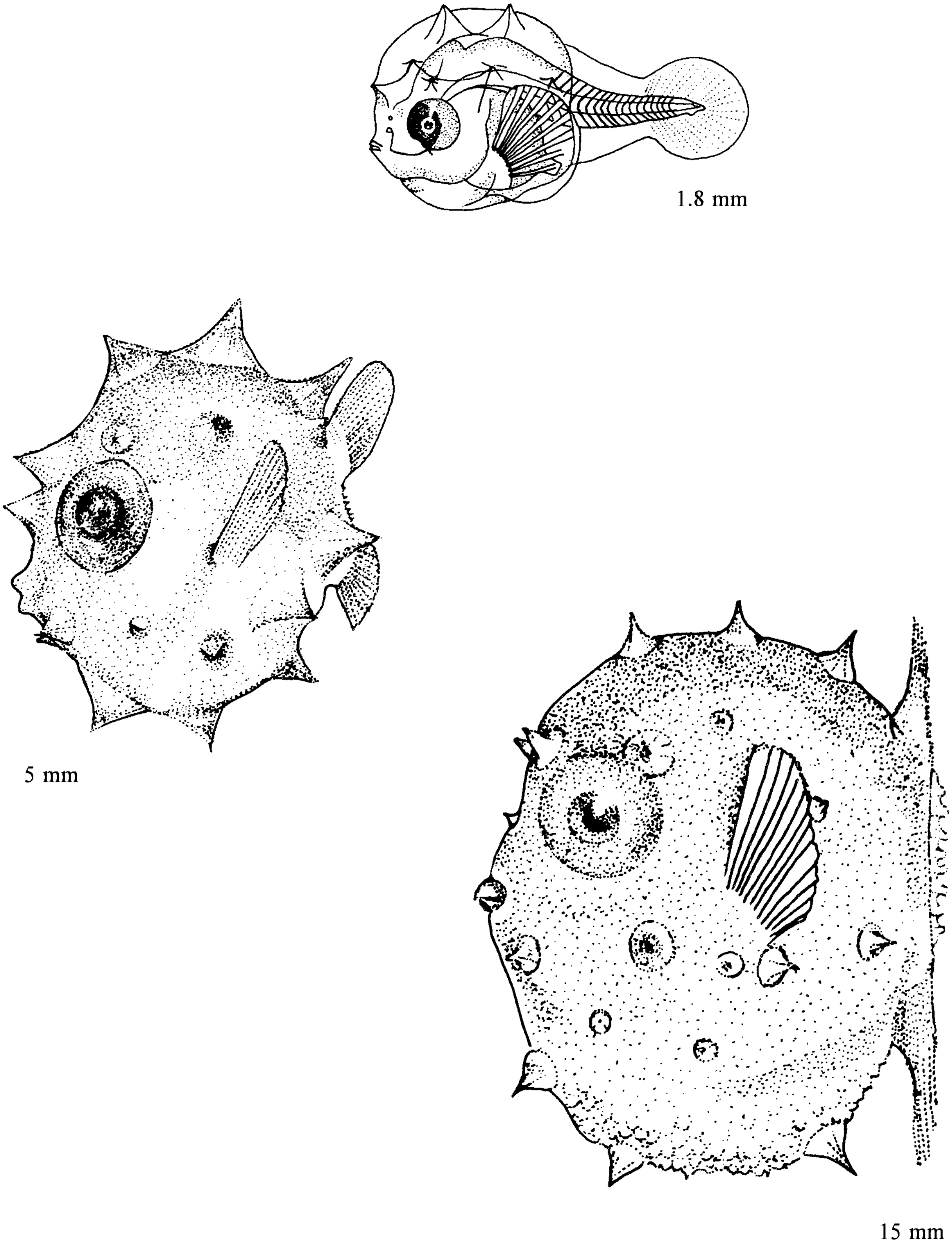


Figure Molidae 1. *Mola mola* larvae: 1.8 mm, 5 mm, 15 mm total lengths (Martin and Drewry 1978).

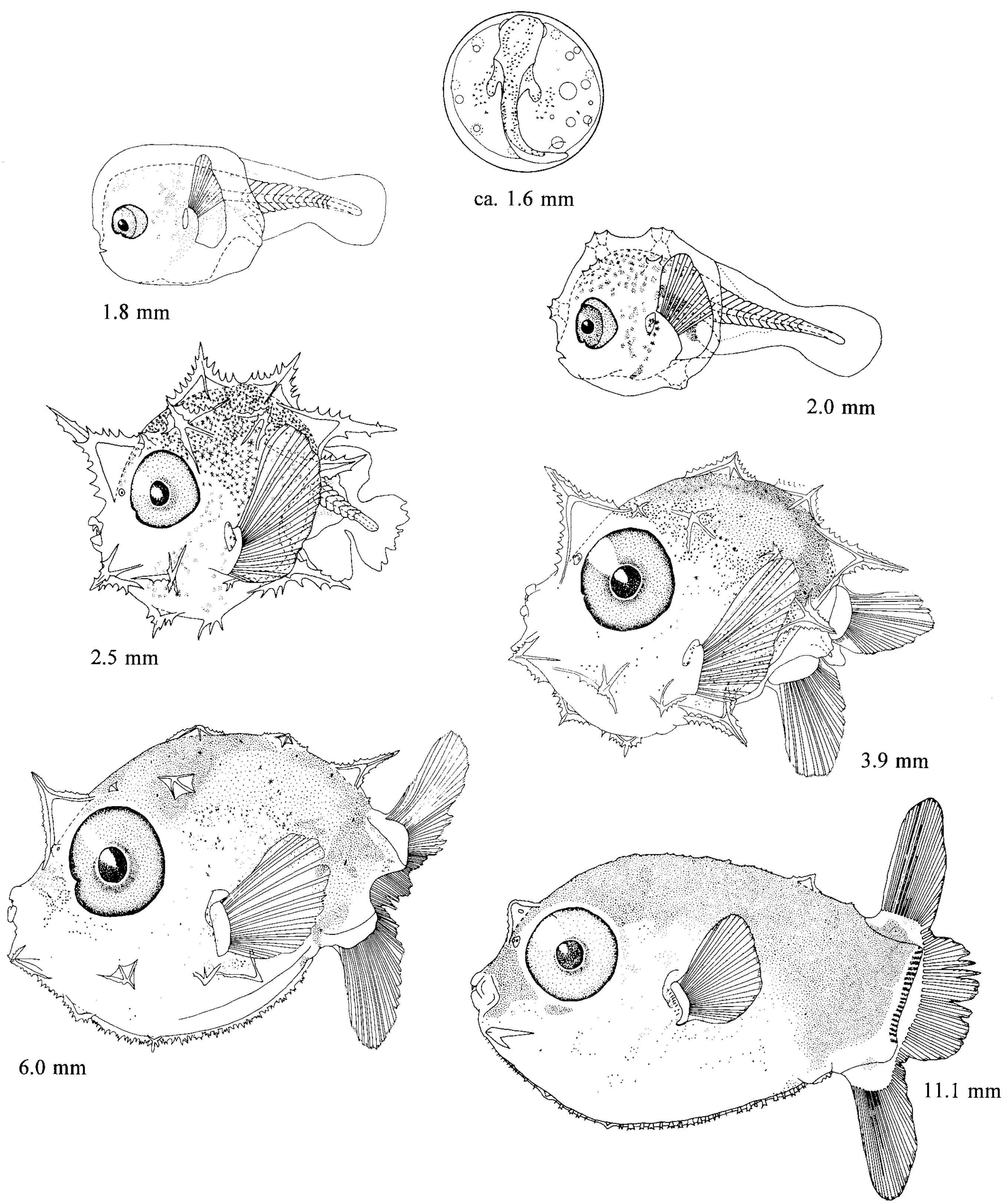


Figure Molidae 2. *Ranzania laevis*: egg, ca. 1.6 mm; newly hatched reared larva, 1.8 mm; 2-day-old reared larva, 2.0 mm; field-collected larvae, 2.5 mm, 3.9 mm, 6.0 mm, 11.1 mm (Leis 1977).

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