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Synopsis of the Biology of the Swordfish, *Xiphias gladius* Linnaeus

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Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service

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*No information available.

Synopsis of the Biology of the Swordfish, *Xiphias gladius* Linnaeus[1]

R. J. PALKO, G. L. BEARDSLEY, AND W. J. RICHARDS[2]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Xiphias gladius Linnaeus, 1758 (Fig. 1).

Originally described by Linnaeus in 1758. The type locality was listed as "European ocean." No type specimen. (Linnaeus 1758. Systema Naturae Vol. 10, p. 248.)

1.12 Objective snyonymy

Xiphias gladius Linnaeus, 1758 (see above).

Xiphias imperator Bloch and Schneider, 1801. Type locality: Mediterranean Sea. Type specimen: none.
Xiphias rondeletii Leach, 1818. Type locality: Queensferry, Scotland. Type specimen: a stuffed specimen at the College at Edinburgh (present status unknown).
Phaetonichthys tuberculatus Nichols, 1923. Type locality: Rapa Island, Austral Group, South Pacific. Type specimen: American Museum of Natural History 8257, mutilated specimen, tail only.
Xiphias thermaicus Serbetis, 1951. Type locality: Gulf of Thermaicus, Mediterranean Sea. Type specimen: none.

Of these names in the objective synonymy, some comment is deserved. *Xiphias imperator* Bloch and Schneider is illustrated as having pelvic fins which *X. gladius* lacks.

Ziphias gladius Hector, 1875 has been listed in other synonymies (Nakamura et al. 1968), but our reading of that citation failed to reveal the use of that name. We expect it may be in some other publication, but simply represents a misspelling of *Xiphias*. *Phaetonichthys tuberculatus* Nichols was described from only the tail of a specimen found in the gullet of a tropic bird. It bears the features of a juvenile swordfish. The description of *X. thermaicus* also appears to be a young speciment 0.30 m in length.

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Scombroidei
Family Xiphiidae

The above classification follows Greenwood et al. (1966), but Gosline (1968), in his review of perciform suborders, presented evidence that the relation of billfishes to scombrids and their allies may be one of convergence. He placed the monotypic family Xiphiidae along with the family Istiophoridae and, provisionally, the Luvaridae, in a separate suborder Xiphioidei.

Generic

Monotypic genus, see specific diagnosis.

Xiphias Linnaeus, 1758 (ref.). Type species: *Xiphias gladius* Linnaeus, 1758 by monotypy.

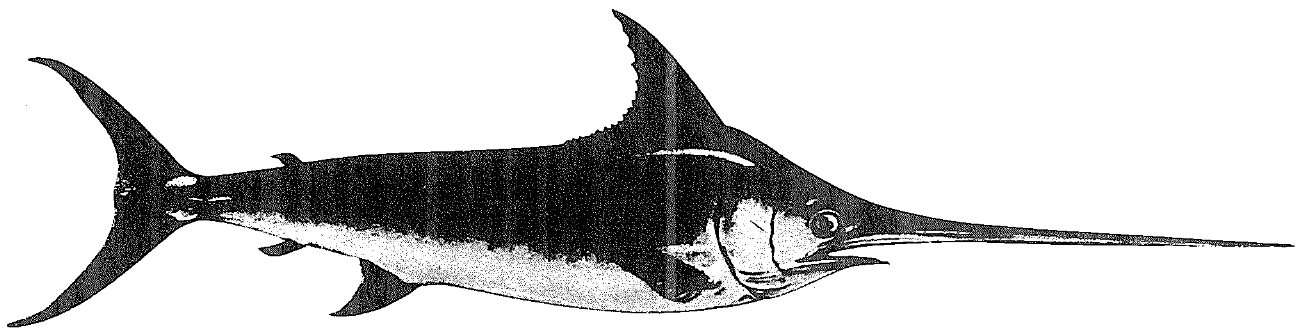

Figure 1.—Swordfish, *Xiphias gladius* Linnaeus, 1758.

[1]Southeast Fisheries Center Contribution No. 81-15m.
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Specific

Diagnosis: pelvic fins absent, scales absent in adult, one pair of caudal keels, snout long and sword shaped, somewhat flattened in cross section, base of first dorsal fin short and broadly separated from the second dorsal fin.

1.22 Taxonomic status

The most recent review is by Nakamura et al. (1968) and they consider the swordfish to be a cosmopolitan species of the monotypic family Xiphiidae.

1.23 Subspecies

None recognized.

1.24 Standard common names and vernacular names

The names capitalized are official or in more common use. Compiled from Rosa (1950) and Nakamura et al. (1968).

Algeria - pesce espada, pez espada
Argentina - PEZ ESPADA
Belgium - ESPADON
Brazil - PEIXE ESPADA, agulhão, espadarte
Ceylon - kadu koppara
Chile - PEZ ESPADA, Albacora
China - chien yu
Cuba - PEZ-ESPADA, emperador
Denmark - SVAERDFISK
France - ESPADON, emperadour, pei empereur
French West Africa - bongjhojh
Germany - SCHWERTFISCH
Greece - XIPHIAS
Ireland - luinniasc
Italy - PESCE SPADA
Japan - MEKAJIKI
Madeira Is. - PEIXE AGULHA
Malta - PISCISPAT, pixxi spad
Mexico - PEZ ESPADA
Netherlands - ZWAARDVISCH
New Zealand - BROADBILL
Norway - SVAERDFISK
Philippines - SWORDFISH; dugso, malasagi (Bikol dialect); malasugi, manumbuk - (marinao, samal and tao sug); dogso, lumod, malasugi, m̃ayaspas - (visayan)
Portugal - AGULHÃO, agulha, espadarte, peixe agulha
Rumania - PESTE CU SPADA
Spain - PEZ ESPADA, espada, chichi spada, emperador, peix espasa, jifia, espasa, espardarte, aja pala
Sweden - SWARDFISK
Taiwan - ting mien chiu chi yu, pai jou ting pan
Tunisia - pesce espada, boussif
USSR - mesh-riba, meshvenosouiye
Union of South Africa - SWORDFISH, broadbill
United States - swordfish, broadbill, common swordfish, spearfish
Venezuela - PEZ ESPADA, emperador, espadon
Vietnam - ho ca mui kiem
Yugoslavia - SABLJAN, sabljack, iglun, jaglun, macokljun, pese spada.

1.3 Morphology

[Condensed from Nakamura et al. (1968) and Richards (1974).]

1.31 External morphology

Adult fish have no scales or teeth, but the young stages have pronounced atypical scales. There is no pelvic fin. The base of the first dorsal is short in the adults but very long in the young and confluent with the second dorsal; in the adult the two fins are widely separated. The snout is long in all sizes, broadly flattened in the adults. The body is rather heavy and round in the adults, but in the young it is long, thin, and snakelike. The cranium is hard and wide; temporal crest and pterotic crest in the posterior end of the cranium are fairly well developed. The posterior projection of the pterotic and the epiotic are weakly developed. The supraoccipital projection is fairly well developed. The neural and haemal spines of the vertebrae are flattened. There are 26, rarely 27 vertebrae, 15–16 trunk plus 10–11 caudal. [Richards (1974) reversed the vertebral counts.] The lateral apophysis is not well developed.

There are two dorsal fins with 38–49 rays in the first and 4–5 rays in the second. There are two anal fins: 12–16 rays in the first, 3–4 rays in the second. There are 17–19 pectoral rays and no pelvic fin.

A striking change in shape takes place during growth. The body not only changes from long and thin, but the fins, coloration, squamation, and bill shape also change radically. There are many recent accounts of swordfish ontogeny as well as accounts early in this century. Richards (1974) gave details of the history of swordfish development and cited the various accounts.

1.32 Cytomorphology

Nothing found in the literature.

1.33 Protein specificity

Nothing found in the literature.

2 DISTRIBUTION

2.1 Total area

Swordfish are the most widely distributed billfish and occur worldwide from about lat. 45°N to 45°S in all tropical, subtropical, and temperate seas (Fig. 2).

In the western Atlantic, swordfish occur from the coast of Newfoundland (Tibbo et al. 1961) to Argentina (de Sylva 1962; Wise and Davis 1973).

In the eastern Atlantic, swordfish have been recorded off Scandinavia (Duncker 1936), Great Britain (Rich 1947), France, Spain, in the Mediterranean Sea (Sanzo 1922), and the Sea of Marmara (Artüz 1963). Swordfish have been reported in the Black Sea off the coast of Bulgaria and Rumania, and there are indications that swordfish migrate from the Black Sea to the Sea of Azov in the summer (Ovchinnikov 1970). In the Baltic Sea, swordfish have been collected off Tallinn and Haapsalu (Ovchinnikov 1970) and Wolin Island (Jakuczun 1971). In the eastern South Atlantic, swordfish occur along the west coast of Africa down to the Cape of Good Hope (Penrith and Cram 1974).

In the eastern Pacific, swordfish range from Oregon (Fitch 1960) to Talcahuano, Chile (Lobell 1947). Swordfish are caught

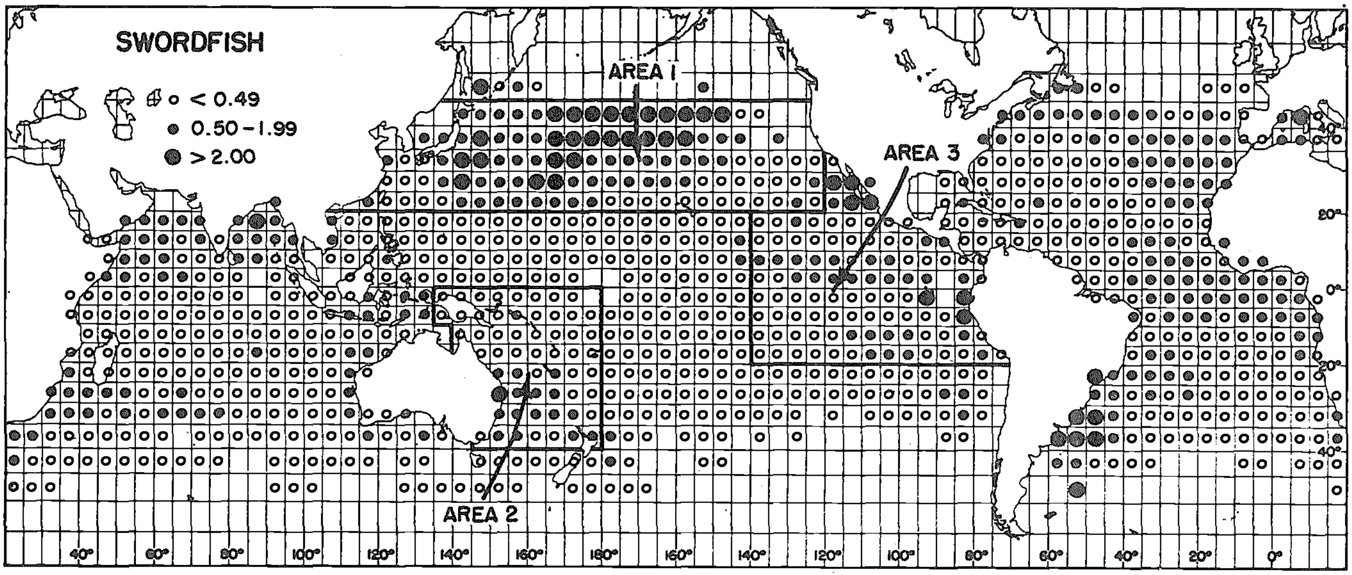


Figure 2.—Distribution of swordfish in the Pacific, Indian, and Atlantic Oceans based on catch rates from the Japanese tuna longline fishery. The circles indicate mean catch rates (number of fish per 1,000 hooks). Also shown (areas 1, 2, and 3) are centers of concentration of hypothesized swordfish stocks in the Pacific (from Sakagawa and Bell see text footnote 10, fig. 1.)

off the Hawaiian (Strasburg 1970) and Galapagos Islands. In the western Pacific, based on Japanese longline data, swordfish are widely distributed from temperate waters off the coast of Japan (Yabe et al. 1959) to the waters of Australia and New Zealand (Webb 1972).

Swordfish occur in the Indian Ocean with areas of concentration off the coasts of India (Chacko et al. 1964), Ceylon (Deraniyagala 1951), Saudi Arabia (Rass 1965), the east coast of Africa, and around the Cape of Good Hope. Nishikawa and Ueyanagi (1974) have also shown areas of concentration between lat. 20° and 40°S, long. 60° and 100°E. Adult swordfish also occur in good concentrations off the southwest coast of Australia.

2.2 Differential distribution

2.21 Spawn, larvae, and juveniles

Swordfish larvae occur in all the tropical seas, and their distribution is closely associated with surface temperatures between 24° and 29°C (Tåning 1955). Gorbunova (1969) found concentrations of swordfish larvae in the southwestern area of the Atlantic, in the eastern part of the Indian Ocean, and in the central waters of the Pacific Ocean south of the equator.

In the western Atlantic, Markle (1974) stated, based on her own sampling plus similar data from other sources, that the greatest densities of swordfish larvae occur from the Straits of Florida to Cape Hatteras and in the Virgin Islands—Leeward Islands area (Fig. 3). Arata (1954) and Arnold (1955) suggested that the Gulf of Mexico serves as a nursery ground for swordfish.

In the eastern Atlantic, Gorbunova (1969) found swordfish larvae off the northwestern shores of Africa in the areas of subtropical divergence. Swordfish larvae also occur in the Mediterranean Sea (Sella 1911; Sanzo 1922) and in the Straits of Messina from June to September. Artüz (1963) presented evidence that swordfish in the Sea of Marmara spawn in coastal waters because eggs and juveniles are found there in April, May, and June. He believed this was a separate stock from those found in the Mediterranean.

Swordfish larvae are widely distributed in the tropical central and western Pacific (Fig. 4), and this distribution pattern appears to be governed by the position of the 24°C surface isotherm (Nishikawa and Ueyanagi 1974).

In the Indian Ocean, swordfish larvae are distributed throughout the area southwest of Sumatra (Bogorov and Rass 1961) and are abundant between lat. 12° and 17°S, approximately in the area of the South Equatorial Current and in the eastern section along long. 85° and 87°E between lat. 5°N and 17°S.

See also section 3.16.

2.22 Adults

In the Atlantic Ocean, relatively little information is available on the seasonal distribution of swordfish. The United States and Canadian longline and harpoon fisheries operate in the western North Atlantic in summer and early fall. In winter, most longline activity moves to more southern waters. Guitart-Manday (1975) noted that swordfish were caught throughout the year off Cuba, but best catches were in the winter and early spring and consisted of mostly large females while catches in summer were few and consisted mostly of males. Recently, however, substantial concentrations of swordfish have been discovered in the Gulf of Mexico and off the east coast of Florida in the summer months. Tagging data shed little light on seasonal distribution. Results of Canadian tagging experiments have shown that all recaptures of tagged swordfish have been made within the same general area of release and at the same season of the year (Beckett 1974). One swordfish tagged in the Gulf of Mexico in March 1974, however, was recaptured off Georges Bank in August 1977, indicating that at least some swordfish make substantial seasonal migrations (Casey 1977[3]).

Joseph et al. (1974) reported areas of good fishing for sword-

[3]Casey, J. 1977. The shark tagger, winter 1977. Newsletter of the Cooperative Shark Tagging Program, 8 p. U.S. Dep. Comm., NOAA, NMFS, Northeast Fisheries Center, RR7A, Box 522A, Narragansett, RI 02882.

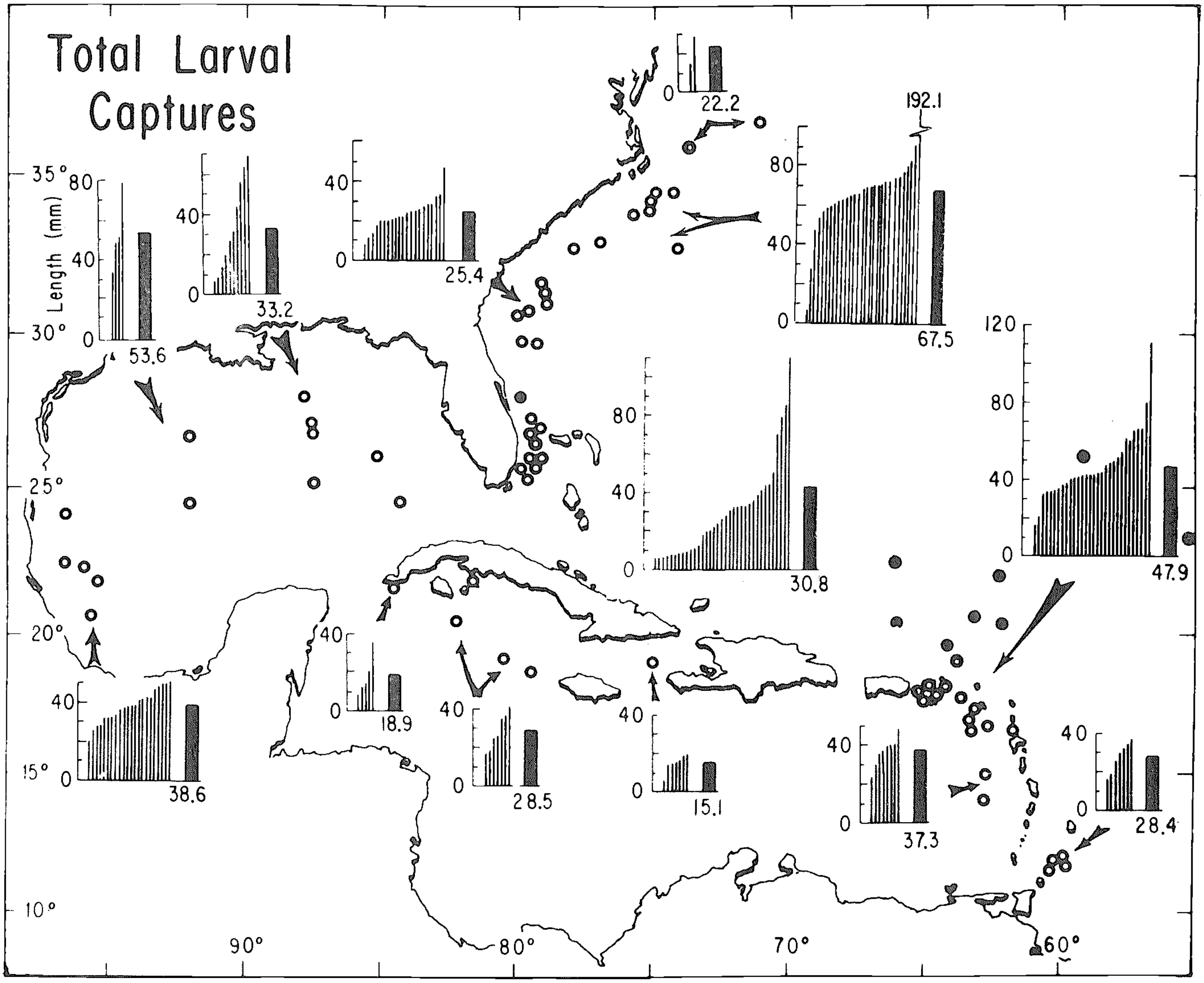


Figure 3.—Numbers, size ranges, and mean lengths of swordfish larvae—collections from various sources including Fisheries Research Board of Canada (from Markle 1974, fig. 3 and caption).

fish between lat. 35°N and 40°S, with best catches in the coastal areas between lat. 20° and 30°N and the areas adjacent to Baja California. For the southeast Pacific, the principal swordfish grounds are centered in coastal waters from the equator to about lat. 15°S and around the Galápagos islands. Concentrations of swordfish extend westward from this area in a longitudinal band along the equator during all seasons. During the first and fourth quarters (southern spring and summer), a secondary longitudinal band extends westward between lat. 10° and 20°S. Royce (1957) believed that the distribution of swordfish in the western Pacific indicates that the adults prefer cooler waters than other billfishes.

In the Indian Ocean, concentrations of swordfish occur off Saudi Arabia at lat. 15°N, and long. 40°-70°E and in the Bay of Bengal between long. 90° and 95°E (Rass 1965; Nakamura 1974).

2.3 Determinants of distribution changes

Their geographical distribution in the northwestern Atlantic apparently varies considerably due to marked seasonal variation in environmental conditions (Beckett 1974). In the winter, swordfish are confined to waters associated with the Gulf Stream, but in the summer they are found over a much wider area. Feeding habits and temperature variations apparently influence a differential distribution by size with larger fish being found in cooler water and few fish under 90 kg seen in waters of <18°C. Sex ratios also differ with temperature, as few males are found in the colder (below 18°C) water.

There is undoubtedly a relationship between the occurrence of swordfish larvae and the distribution, interaction, and modification of water masses according to Tibbo and Lauzier (1969). All larvae they examined were captured within relatively narrow ranges of surface temperature (23.4°-25.6°C) and salinity (35.81-36.36‰).

In the Pacific, distribution of larval swordfish is associated with the North Equatorial Current or the Kuroshio Current during April and May (Nakamura et al. 1951). Nishikawa and Ueyanagi (1974) noted a marked difference between surface and subsurface catches during the day but not as much during the night and felt this difference represented diurnal vertical movements of larval swordfish. In the Pacific, swordfish larvae and juveniles are restricted to areas of upwelling where high productivity provides favorable conditions (Gorbunova 1969). Yabe et al. (1959) stated that young swordfish are distributed in the tropical and subtropical zones and migrate to

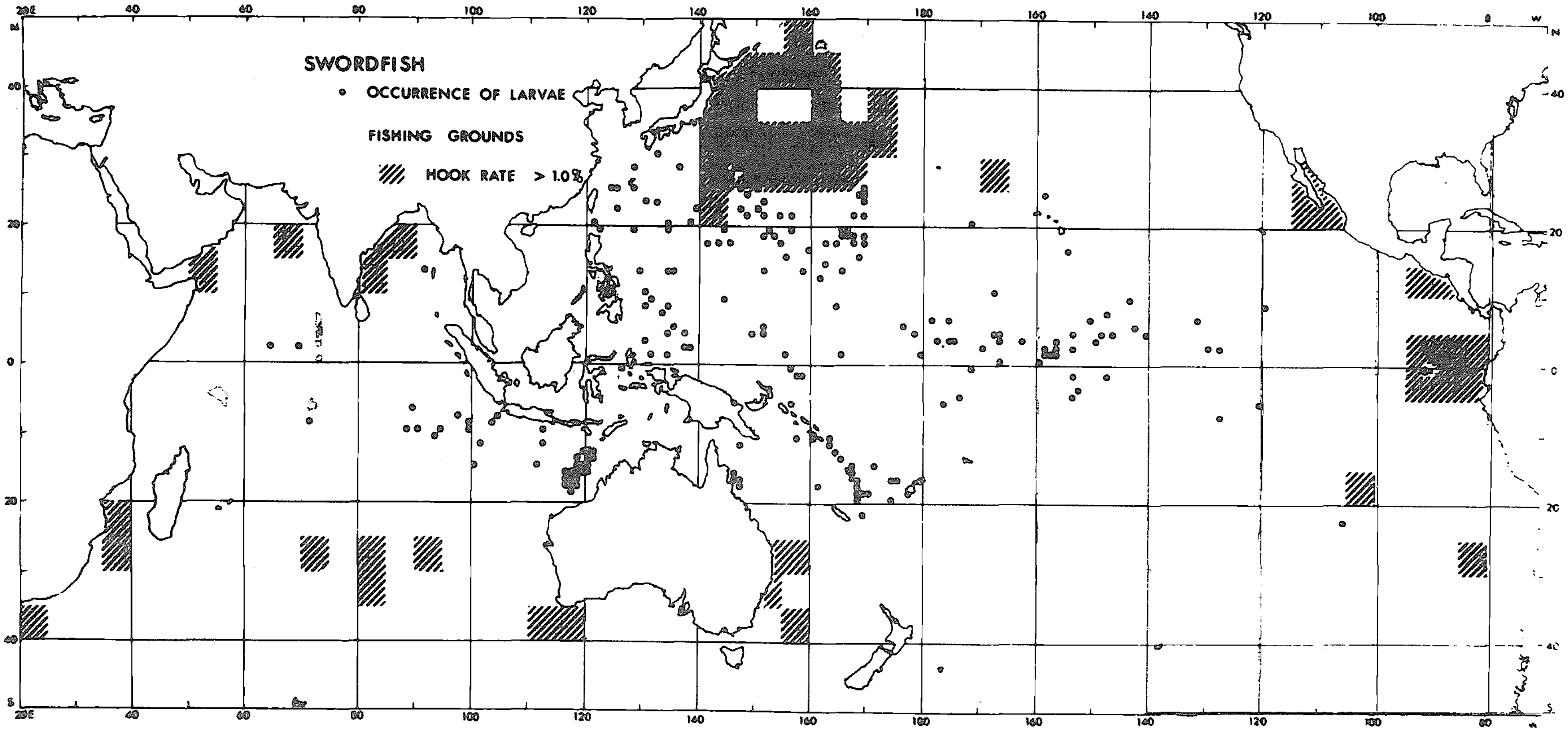


Figure 4.—Distribution of swordfish larvae (dots) and adults (hatched) in the Pacific and Indian Oceans. The adult distribution is represented by areas in which longline catches averaged greater than 1.0 fish per 1,000 hooks during 1970, and where fishing effort exceeded 20,000 hooks fished (from Nishikawa and Ueyanagi 1974, fig. 3 and caption.)

higher latitudes as their size increases, and Gorbunova (1969) indicated that juvenile swordfish do not migrate far during their first year of growth.

Kondritskaya (1970) noted that the distribution of swordfish larvae in the Indian Ocean is bounded by the 24°C mean annual isotherm. In the northwestern Indian Ocean, Osipov (1968) believed that catches of swordfish change from area to area and show a seasonal variation between summer and winter, which is related to environmental conditions or eddy patterns within major current systems such as the Monsoon Current and the Equatorial Countercurrent.

2.4 Hybridization

Nothing found in the literature.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Swordfish are heterosexual. No known external characters distinguish males from females, although large swordfish are usually female.

3.12 Maturity

There is little information on size and age at first maturity and some of it is contradictory. Yabe et al. (1959) stated that swordfish first spawned at 5-6 yr and 150-170 cm eye-fork length. Ovchinnikov (1970) said males reached sexual maturity at a length of around 100 cm and females at a length of 70 cm (author's note: measurement parameters not given in translation); however, recent research conducted on swordfish off the southeast coast of the United States indicates that males mature at a smaller size than females (about 21 kg for males and 74 kg for females) (E. Houde[4]). Kume and Joseph (1969) treated swordfish of <130 cm in eye-fork length as immature.

3.13 Mating

Swordfish are apparently solitary animals and rarely gather in schools. However, several occurrences of pairing thought to be associated with spawning have been noted in the Atlantic (Guitart-Manday 1964) and in the Mediterranean (LaMonte and Marcy 1941), although pairing is considered a rarity.

See section 3.16.

3.14 Fertilization

Fertilization is external.

3.15 Gonads

The testes are paired, elongate organs, thin and ribbonlike in immature fish and flattened, pinkish white, and not round in cross section in adults. The ovaries are paired, elongate, and always round in cross section even in immature fish. The ovaries are always much shorter and thicker than the testes (Artüz 1963). Sella (1911) reported that the swordfish ovary contracts after spawning and remains compact and firm.

3.16 Spawning

Spawning generally takes place in tropical waters where surface temperatures are $>20°$-22°C. In the Atlantic, spawning apparently occurs througout the year in the Caribbean, Gulf of Mexico, and in the waters off Florida with the peak of the spawning season from April through September (Arata 1954). Swordfish with ripe ovaries have been reported off Cuba during the winter months (LaMonte 1944; Guitart-Manday 1975). In the same months, in the waters near Cuba, the Gulf of Mexico, the Caribbean Sea, and around the Cayman Islands, Guitart-Manday (1975) found many swordfish larvae and juveniles.

Tibbo and Lauzier (1969) concluded from their samples and the direction and speed of surface currents that larvae caught in the Florida Straits and off Cape Hatteras were hatched in the southern Gulf of Mexico and probably in the Yucatan Channel. They also believed that larvae taken near the Virgin Islands most probably originated in the southernmost part of the Sargasso Sea and possibly at the northern edge of the Equatorial Current. The sizes also indicated spawning from mid-December to mid-February.

Additional spawning areas have been reported—one in the Mediterranean Sea off Sicily and the Straits of Messina from June through August with peak spawning in the early July (Sella 1911; Sanzo 1922; Cavaliere 1963) and the other in the Sea of Marmara where there is some evidence that swordfish spawn in coastal waters in April, May, and June (Artüz 1963).

In the eastern Pacific, fish about to spawn are found in every month of the year but appear to be most abundant from March through July in northern latitudes and around January in southern latitudes (Kume and Joseph 1969). Although Yabe et al. (1959) assumed that all ripe ova were spawned at one time, Uchiyama and Shomura (1974) indicated that partial spawning could not be discounted since they found one ripe ovary which contained residual ova from an earlier spawning.

Matsumoto and Kazama (1974) believed that there was evidence of a difference in spawning time in various parts of the Pacific, which was reflected by the seasonality of occurrence of larvae and juveniles. Spawning occurs in spring and summer (March–July) in the central Pacific and in spring (September–December) in the western South Pacific. They noted that spawning takes place all year in equatorial waters and begins and ends 1 or 2 months earlier in the western Pacific in the Philippine-Formosa areas compared with the Hawaiian Islands area. Tsi-Gen (1960) stated that spawning individuals could be found at any time of the year in the western Pacific. Yabe et al. (1959) found a spawning area south of the subtropical convergence which they believed formed the recruitment for the fishing grounds of the North Pacific. They also collected mature ovaries in the northern part of the Coral Sea in October and in the Fiji Islands in June.

In the Indian Ocean, Yabe et al. (1959) found ripe ovaries in April and young swordfish in the lower latitude areas near the equator in August, November, and December. Based on swordfish larvae found in stomach contents of tunas and marlins, they concluded that the spawning season started after April and continued until December. In the Mozambique Channel, a swordfish larva was collected in late January (Kondritskaya 1970) and larvae have been reported east of Madagascar Island (Lütken 1880; Gorbunova 1969), although no dates are available.

[4]Dr. Ed Houde, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, FL 33149, pers. commun. June 1979.

3.17 Spawn

Uchiyama and Shomura (1974) classified the ova into several developmental states that are not dependent on ova diameters:

1. Primordial ova—Ova transparent, ovoid, and diameters range from 0.01 to 0.05 mm. Primordial ova are present in all ovaries.
2. Early developing ova—Ova still transparent and ovoid; diameters range from approximately 0.06 to 0.24 mm. A chorion membrane has developed around the ovum and opaque yolklike material has begun to be deposited within the ovum.
3. Developing ova—Ova completely opaque, more wedge-shaped than ovoid, and diameters range between 0.16 and 0.96 mm. The chorion is stretched and not visible in this stage.
4. Advanced developing ova—Ova ovoid and diameters range from 0.47 to 1.20 mm. Ova have a translucent margin, a fertilization membrane, and a round yolk.
5. Early ripe ova—Ova diameters range from 0.60 to 1.20 mm. The yolk material is translucent and oil globules have begun to form.
6. Ripe ova—Ova transparent and with oil globules. Diameters range from 0.80 to 1.66 mm.
7. Residual ova—Ova in this stage show signs of degeneration and ova are thin-walled, translucent, and measure approximately 0.80 mm in diameter.

According to Sella (1911) and Sanzo (1922), "the eggs are buoyant and transparent with a large oil droplet. The yolk sac is very small; yolk vesicular; capsule with a quite evident amorphous network. The egg diameter is about 1.6–1.8 mm; the oil droplet, 0.4 mm."

Fish (1926) noted that a swordfish weighing 68 kg contained maturing ovaries weighing 1.5 kg and estimated the number of ova at 16,130,400, measuring ova only from 0.1 mm to 0.55 mm in diameter.

3.2 Preadult phase

3.21 Embryonic phase

Embryonic development is rapid (2½ days of incubation or a little more). At an early stage, melanophores are over all the surface of the yolk and trunk. After 1 day of incubation, they are already well dispersed, and at this stage there begins to appear on the trunk a diffused straw-yellow color. The development of the chromatophores on the yolk and their branching render the egg less transparent and a dirty-white color. At the beginning of the third day, the melanophores are again augmented, and those on the trunk, corresponding to the segments, have stronger ramification. The diffused straw color is intensified. There are 24 segments (Padoa 1956).

3.22 Larval phase

See section 3.23

3.23 Adolescent phase

Like other billfishes, swordfish gradually metamorphose from a larva to an adult (Fig. 5); therefore, all descriptive phases will be discussed as one continuous transformation.

Sanzo (1909, 1910, 1922, 1930) described eggs, described eggs and larvae at hatching, reared larvae from eggs through the yolk sac stage, and described a 13 mm and a 6 mm specimen. Sella (1911) confirmed Sanzo's (1910) work. Yasuda et al. (1978) described in detail embryonic and larval development of swordfish from the Mediterranean. Their results differed slightly from Sanzo (1910) and Sella (1911), particularly in the numbers of myomeres and in total length in the most advanced larval stages.

Cuvier (*in* Cuvier and Valenciennes 1831) was the first to describe a young swordfish and include a figure of a juvenile. In 1880 both Günther and Lütken (separate papers) described young specimens. Goode (1883) reviewed all previous work and added another descriptive note by Steindachner (1868) who described two young subadults. Regan (1909) pointed out the resemblance of a young *Xiphias* (200 mm in length) to the fossil species *Blochius longirostris*. Regan (1924) described and figured this 200 mm juvenile and noted that *Phaethonichthys tuberculatus* Nichols (1923) is actually a young swordfish and placed in the synonymy of *X. gladius*. Fowler (1928) also figured a young swordfish (ca. 225 mm) and like Regan (1924) noted that *P. tuberculatus* Nichols was a synonym of *X. gladius*. Therefore, by early in the century the young stages of swordfish were well described. Later accounts, which include descriptions of young swordfish, are Nakamura et al. (1951), Yabe (1951), Arata (1954), Tåning (1955), Jones (1958), Yabe et al. (1959), Gorbunova (1969), and Tibbo and Lauzier (1969[5]).

According to Richards (1974) there is no problem in separating young swordfish from istiophorids since swordfish lack the strong pterotic and preopercular spines which are so prominant in the early stages of other billfishes. In sizes over 20 mm, young swordfish are very dissimilar to other billfishes in appearance.

Swordfish larvae are easily recognized by their long snouts, heavily pigmented elongate bodies, and prominent supraorbital crest. Above 8.0 mm they have one or more rows of spinous scales on each side of the dorsal and anal fins, with those along the latter continuing forward to the level of the pectoral fin (Matsumoto and Kazama 1974).

Arata's (1954) observations on color of a live 68.8 mm swordfish are as follows: "The over-all color of the dorsal surface ... was royal blue marked alternately with seven vertical bands of light blue from the head to the caudal fin .... The bands were not uniform in width and did not become silver until the ventral-most one-fifth of the lateral aspect was reached. The first band was located behind the head and the last band reached from midway on the caudal peduncle onto the caudal fin. The lower edge of the anal was hyaline, as was the posterior edge of the dorsal. Both tips of the caudal were also hyaline and the pectoral showed no color. The distal one-fourth of the premaxillary was white, and the extreme tip of the mandible lacked color. In profile only the extreme edge of the ventral aspect was silver, continuing from the tip of the mandible all the way to the caudal base. The dorsal fin was dark blue (almost black) with light blue areas corresponding to the light bars on the body. The anal fin lacked any carryover of pigment. There was a dark blue bar running obliquely from the gape (ahead of the angle of the mouth)

[5]Tibbo, S. N., and L. M. Lauzier. 1969. On the origin and distribution of larval swordfish *Xiphias gladius* L. in the Western Atlantic. Fish. Res. Board Can. Tech. Rep. 136, 20 p. Department of Environment, Fisheries and Marine Service, Office of the Editor, 116 Lisgar St., Ottawa, Canada K1A OH3.

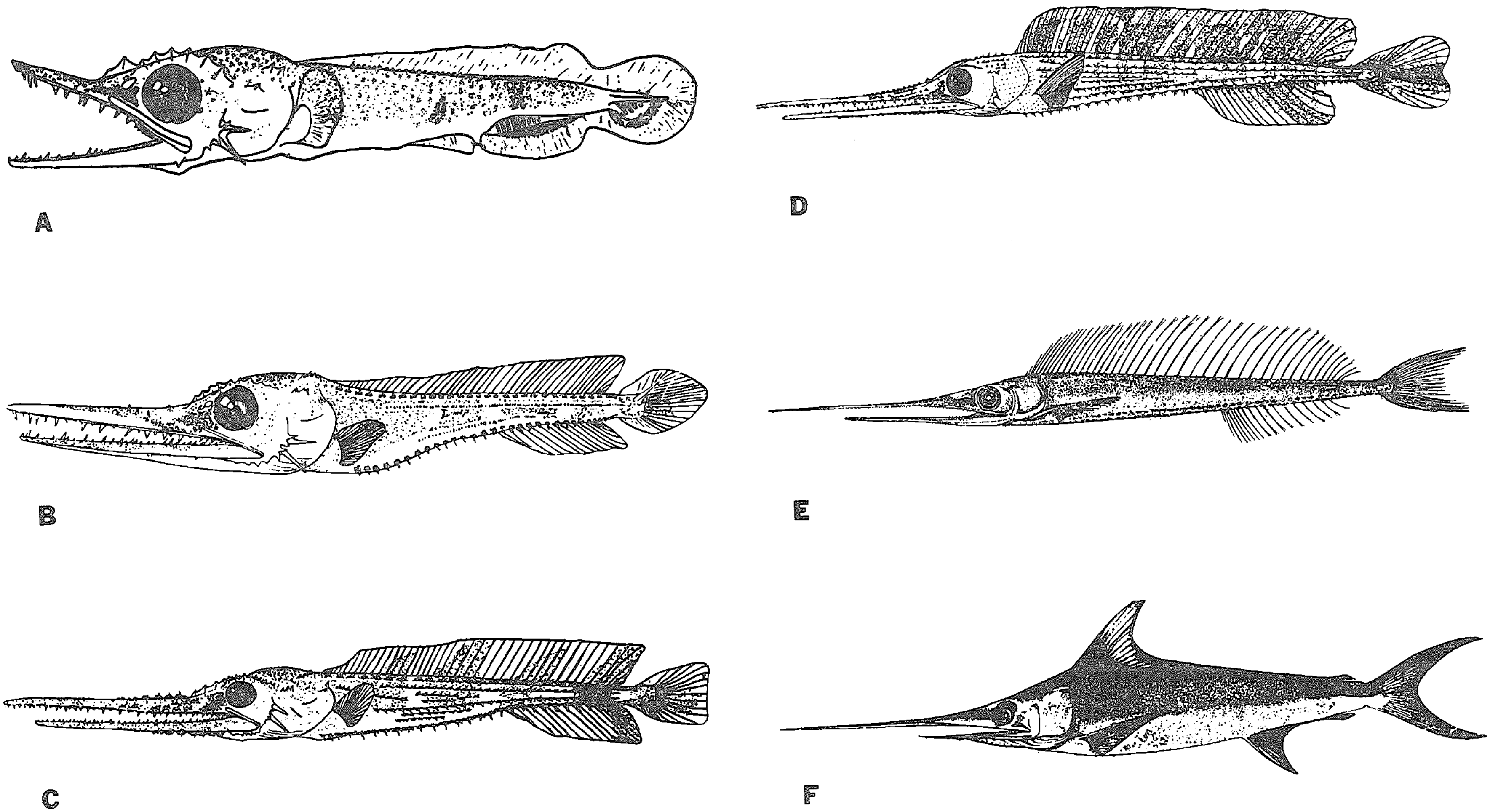


Figure 5.—Larvae and young of the swordfish: (A) 7.8 mm SL; (B) 14.5 mm SL; (C) 27.2 mm SL; (D) 68.8 mm SL; (E) 252 mm BL (length from posterior edge of orbit to base of caudal fin); (F) 580 mm BL. Specimens A, B, C, and D from Arata (1954); E and F from Nakamura et al. (1951).

through the middle of the eye and was lost about three-fourths of the way across the opercle."

3.3 Adult phase

3.31 Longevity

Based on tagging data from 1961 to 1976, the maximum age is at least 9 yr, assuming it takes a minimum of 2 yr for a swordfish to grow large enough to tag (Beardsley 1978[6]).

There are insufficient data to determine whether the greater size attained by females relative to males is due to a more rapid growth rate or to a considerably longer life span (Beckett 1974). No information is available for the Pacific and Indian Oceans, although Beardsley (see footnote 6) noted that age-weight data suggest Pacific stocks may have a slower growth rate and grow to a smaller asymptotic size than Atlantic swordfish.

3.32 Hardiness

Adult swordfish must be adaptable to relatively large changes in their environment. They make feeding excursions into waters of 5°–10°C and depths of at least 650 m (Church 1968). They are able to make horizontal migrations from tropical and subtropical zones to the temperate waters in all oceans of the world. They have been sighted at the head of submarine canyons in the Gulf of Mexico in depths in excess of 455 m (Church 1968). In addition, swordfish are adaptable in their ability to utilize a variety of food sources, feeding on both surface and near surface animals as well as benthic species and those species which occur in between.

3.33 Competitors

Swordfish presumably compete with other billfishes as well as other large pelagic predators for the same organisms in the food chain. There is no information, however, on the effect this competition has on their survival. That effect is probably minimal since swordfish are capable of feeding on a variety of foods from the surface to the floor of the oceans, can travel from tropical to temperate waters, and are opportunistic predators.

3.34 Predators

The larvae of swordfish are a common food source of other fishes, including larger swordfish. The juveniles and young swordfish presumably are also preyed upon by any sufficiently larger predacious fish. Yabe et al. (1959) found young swordfish in the stomachs of the following 10 predators: blue marlin, *Makaira nigricans*; black marlin, *M. indica*; sailfish, *Istiophorus platypterus*; yellowfin tuna, *Thunnus albacares*; albacore, *T. alalunga*; bigeye tuna, *T. obesus*; dolphin, *Coryphaena hippurus*; striped marlin, *Tetrapturus audax*; shortbill spearfish, *T. angustirostris*; and blue shark, *Prionace glauca*.

Adult swordfish have few known natural enemies. Sperm whales, *Physeter catodon*; killer whales, *Orcinus orca*; and large sharks are perhaps the only species capable of preying on adult swordfish (Tibbo et al. 1961). Sharks are the only creatures ever seen in actual combat with swordfish (Stark 1960; Maksimov 1968; Bozhkov 1975). Bigelow and Schroeder (1953) reported finding a good sized swordfish in the stomach of a mako shark, *Isurus oxyrinchus*. Sharks are regularly known to attack swordfish that have been harpooned, hooked on longlines, or caught by sport fishermen.

3.35 Parasites, diseases, injuries, and abnormalities

Silas (1967) and Silas and Ummerkutty (1967) summarized records of parasites in swordfish (Table 1). Iles (1971) noted that the presence of distinct species of *Tristoma* on swordfish from Hawaii and the possible difference in numerical incidence of *T. coccineum* and *T. integrum* on swordfish from the Mediterranean suggest that these monogenetic trematodes may be useful as biological tags to distinguish populations of swordfish.

Swordfish in the northwest Atlantic are usually heavily parasitized with many species, including sea lampreys (Tibbo et al. 1961). Guitart-Manday (1964) found the following parasites in swordfish off Cuba: *Ascaris incurva* in almost all stomachs; unidentified cestoda attached to outer walls of the stomach; unidentified *Hirudinea* also found in the stomach; and an ectoparasite of the genus *Pennella* deeply inserted in the subcutaneous muscular tissue. Swordfish in the Sea of Marmara frequently have a parasitic copepod (family Pennellidae) attached. Numerous nematodes are found in their stomachs and two kinds of cestodes are found in the intestines (Artüz 1963).

In the eastern Pacific off Hawaii, Yamaguti (1968a) reported two monogenetic trematodes, *Tristoma adintegrum* and *T. adcoccineum*, as occurring in the gills of swordfish. Two digenetic trematodes, *Maccallumtrema xiphiados* and *Reniforma mutilobularis*, occur in the abdominal muscle and gill filaments (Yamaguti 1970). In addition, he noted two cestodes, *Pseudeubothrium xiphiados* and *Bothriocephalus manubriformis*, as occurring in the intestines (Yamaguti 1968b). Ho (1963) reported a parasitic copepod, *Gloiopotes longicaudatus*, occurring on the general body surface and ventral surface of the "sword" in the waters off Formosa. Many swordfish have marks of sea lampreys on them but few have open wounds (Tibbo et al. 1961). The marks consist mostly of longitudinal scratches along the side of the body and indicate that the swordfish is fairly successful in ridding itself of these pests. Guitart-Manday (1964) found one or more very shallow oval wounds which apparently did not affect the subadjacent muscular layers. He assumed that these wounds were caused by a species of Ciclostomata (sic Cyclostomata). More recent information (Jones 1971) has shown that these wounds are probably caused by a small species of squaloid shark, *Isistius brasiliensis*.

There is no information on disease associated with swordfish.

3.4 Nutrition and growth

3.41 Feeding

Gorbunova (1969) had one of the best descriptions of feeding behavior in larval swordfish. These larvae apparently take food items lying either slightly above or on the same level as themselves, but mainly the larvae of planktophages which also feed during daylight hours. The intensity of capture of food is increased in the morning and evening and reduced at midday and at night. According to Leshcheva (1967) (cited in Gor-

[6]Beardsley, G. L. (editor). 1978. Report of the Swordfish Workshop held at the Miami Laboratory, Southeast Fisheries Center, Miami, Fla. June 7-9, 1977. Coll. Vol. Sci. Pap., VII(SCRS-1977):149-158. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid 1, Spain.

Table 1.—List of parasites found on swordfish (adapted from Silas 1964 and Silas and Ummerkutty 1964).

Locality	Parasite	Location on host
Monogenetic trematodes (Silas 1967)		
Atlantic	*Capsala laevis*	
Adriatic, Mediterranean, N.W. Atlantic, Pacific	*Tristoma integrum*	
Atlantic	*Tristoma coccineum*	gills
Digenetic trematodes (Silas 1967)		
Atlantic—Woods Hole	*Didymocystis xiphoides*	muscle and gill cavity
Pacific, Atlantic	*Hirudinella clavata*	stomach
Atlantic	*Hirudinella ventricosa*	
Cestodes (Silas 1967)		
N.W. Atlantic, Europe	*Fistulicola plicatus*	walls of intestine and rectum
N.W. Atlantic	*Grillotia erinaceus*	stomach and intestine walls
N.E. Atlantic and Mediterranean	*Gymnorhynchus (Gymnorhynchus) gigas*	muscles
Atlantic (Woods Hole)	*Gymnorhynchus (Molicola) uncinatus*	muscles
N.W. Atlantic	*Nybelinia (Nybelinia) bisulcata*	viscera
N.W. Atlantic	*Nybelinia (Nybelinia) lamontae*	
Atlantic	*Nybelinia (Nybelinia) lingualis*	
Atlantic (Woods Hole)	*Otobothrium (Otobothrium) crenacolle*	flesh and viscera
Atlantic	*Otobothrium (Pseudotobothrium) dispacum*	
N.W. Atlantic	*Phyllobothrium loliginis*	stomachs
N.W. Atlantic	*Scolex pleuronectis*	intestine
N.W. Atlantic	*Tentacularia bicolor*	stomach
Atlantic	*Tentacularia coryphaena*	
Copepods (Silas and Ummerkutty 1967)		
N.W. Atlantic	*Brachiella ramosa*	gills
	Brachiella thynni	gills
N.W. Atlantic	*Caligus chelifer*	body surface
Atlantic, Mediterranean	*Caligus elongatus (C. rapax)*[1]	body surface
Atlantic ?	*Chondracanthus xiphiae*	gills
N.W. Atlantic	*Gloiopotes ornatus*	body surface

[1]Bassett-Smith, P. W. 1899. A systematic description of parasitic Copepoda found on fishes, with an enumeration of the known species. Proc. Zool. Soc. Lond. 1899:438-507. Incorrectly reported in Silas and Ummerkutty (1967) and reported as synonym of *rapax* in 1899 by Bassett-Smith.

bunova 1969; manuscript not seen by authors), the periods of intensive feeding coincide in time with the periods of greatest frequency of larvae caught in sampling nets. Juvenile swordfish 8 mm long will swallow fish that are as long as themselves (Tånning 1955).

Adult swordfish are opportunistic feeders, known to forage for their food from the bottom to the surface over great depths and distances. Their diet varies with location and species. According to Beardsley (see footnote 6), "Swordfish are diurnal feeders, rising to the surface and near surface waters at night. Over deep water they feed primarily on pelagic fishes and squids, while in shallower water large adults make feeding excursions to the bottom where the temperatures may be 5-10 °C and feed on demersal species."

In temperate waters of the Atlantic and Pacific, swordfish frequently bask on the surface. This behavior is rarely observed in tropical waters and is thought to facilitate digestion in temperate waters (surface waters being relatively warmer). Stomachs sampled from swordfish caught at the surface were either full or completely empty (Tibbo et al. 1961). They noted that swordfish would on occasion regurgitate everything from their stomachs before capture and sometimes would even evert the stomach.

There is some question as to the use of the sword in obtaining food. Goode (1883) reported that swordfish rise beneath a school of fish, striking to the right and left with their swords until they have killed a number of fish, which they then proceed to devour. Recent researchers (Tibbo et al. 1961) have found evidence from stomach contents that the swordfish uses its sword to kill some of its food. Scott and Tibbo (1968) stated the swordfish differs from the spearfishes (marlins and sailfish) in that the sword is long and dorsoventrally compressed. Thus, the swordfish appears to be more highly specialized for lateral slashing. They believed such a specialization would be pointless unless directed towards a vertically oriented prey or unless the swordfish slashes mainly while vertically oriented, as when ascending or descending.

3.42 Food

Arata (1954) examined stomach contents from larvae from the western Atlantic ranging in size from 7.8 to 192.1 mm. Only the two smallest specimens (7.8 and 9.0 mm) contained zooplankton, while for all of the other specimens, fish larvae were the main food source.

In the Pacific, swordfish at 9.0-14.0 mm feed on organisms such as Mysida, Phyllopoda, and Amphipoda and do not begin to feed on other fish until about 21 mm long (Yabe et al. 1959).

As juveniles, swordfish feed on squids, fishes, and some pelagic crustaceans. It is widely accepted that, in general, large predatory fishes eat whatever is available in the greatest abundance in their immediate environment (Scott and Tibbo 1968), and swordfish appear to be no exception. The major portion of their diet consists of squids, fishes, and occasional crustaceans and varies with location and species available (Table 2). There is no information available on either sexual differences in food habits or feeding habits in relation to size and sex.

3.43 Growth rate

Information on swordfish growth is limited and somewhat contradictory. Swordfish hatch at a length of 4.0-4.2 mm and larvae 5.5 mm are about 5 days old (Sanzo 1922). Arata (1954) stated that swordfish larvae have a high growth rate, about 0.6 mm/day, while Tibbo and Lauzier (1969) indicated that the growth rate was around 2 mm/day. In the Pacific, swordfish grow to 500-600 mm in the first year (Yabe et al. 1959).

In the northwest Atlantic, adults enter temperate waters in June, are usually thin, but will add 22-34 kg as the season advances (Tibbo et al. 1961). Beckett (1974) suggested that the growth of female swordfish may be rapid with a general age weight relationship of:

Age 1 - 4 kg
Age 2 - 15 kg
Age 3 - 40 kg
Age 4 - 70 kg
Age 5 - 110 kg

based on a rough analysis of size frequencies from commercial catches and the analysis of tagging results. However, Guitart-Manday (1964) believed that a swordfish of 160 cm and 59 kg in the southwest Atlantic (off Cuba) was 2 yr old.

In the Pacific, Yabe et al. (1959) indicated that swordfish 50-60 cm long were 1 yr old, that the fish caught commercially were predominately 4–5 yr old, and that swordfish spawned for the first time at 5–6 yr. Swordfish in the western Pacific grow about 25 cm/yr (Yabe et al. 1959), while eastern Pacific swordfish between 62 and 165 cm grow about 38 cm/yr (Kume and Joseph 1969).

There is good evidence for differential growth between males and females with females attaining the larger size (Cavaliere 1963; Guitart-Manday 1964; Kume and Joseph 1969). Females grow more rapidly than males and not only grow to a greater length than males, but are proportionally heavier at the same length (Skillman and Yong 1974). Beckett (1974) suggested that few males exceed 200 cm FL (fork length) (approximately 120 kg).

3.5 Behavior

3.51 Migrations and local movements

There are few data on migrations of swordfish. Tag return data from the northwest Atlantic indicate that swordfish either make very limited local movements during the year or return each year to the same feeding grounds (Beckett 1971[7]).

Table 2.—Food organisms found in stomachs of adult swordfish by location (and reference).

Location (reference)	Food organisms
N.W. Atlantic (Scott and Tibbo 1968)	Mackerel
	Barracudinas
	Silver hake
	Redfish
	Herring
	Saury
	Hake
	Snake mackerels
	Filefish - triggerfish
	Lanternfish
	Lancetfish
	Bigeye scad
	Sand lances
	Viperfish
	Marlin-spike
	Eels
Cuba (Guitart-Manday 1964)	*Brama brama*
	Squids
	Unidentified fishes
	Shrimp
	Epinephelus guttatus
	Unidentified crustacea
	Octopus sp.
	Thysanoteuthis rhombus
Brazil (Ovchinnikov 1970)	Teuthoidae
	Vomer sp.
	Octopoda (Cephalopoda)
	Exocoetidae
E. Atlantic (Ovchinnikov 1970)	Cephalopods
	Peristedion
	Brama
	Lepidopus
	Thunnus
	Trachipterus
	Palinurichthys
	Coryphaena
	Alepisaurus
	Tetraodon
	Gempylus
	Trichiurus
	Carcharhinus
Mediterranean (Cavaliere 1963, Part II)	*Illex coindetii*
	Loligo todarus
	Todarodes sagittatus
	Engraulis encrasicholus
	Sardinella aurita
	Sardina pilchardus
	Scomberesox saurus
	Anguilla anguilla
	Boops boops
	Lepidopus caudatus
Sea of Marmara (Artüz 1963)	*Smaris alcedo*
	Scomber scombrus
	Scomber colias
	Engraulis
	Merluccius sp.
	Belone belone
	Unidentified fish
	Ommastrephes (squids most important)
	Shrimps
N.W. Pacific (Yabe et al. 1959)	Lepidotidae
	Cephalopoda
	Squid
	Unidentified fish
	Acinaceidae
	Octopus
	Cololabis saira
	Amphipoda
	Shellfish
	Chiasmodontidae
Pacific (Nakamura 1949)	Cod
	Sebastodes
	Myctophids

Although only 20 recoveries were recorded from 231 fish released between 1961 and 1976, all were recaptured within a few hundred kilometers of the release point. Only one long distance recovery has been recorded. Casey (see footnote 3) reported the recapture of a tagged swordfish on Georges Bank in August 1977 that had been released in the northern Gulf of Mexico in March 1974.

Tibbo et al. (1961) proposed two hypotheses on the migration of swordfish in the northwest Atlantic: 1) swordfish migrate to the north and east along the edge of the continental shelf during summer and return to the south and west in autumn, or 2) there are different groups of swordfish migrating from deep waters towards the continental shelf in summer and then move off to deep water again in autumn.

Carey and Roberson (1977[8]) conducted sonic tagging experiments in the eastern Pacific and western Atlantic which showed that most tagged swordfish generally stay inshore near the bottom during the day. At dusk they head seaward, swimming up and down through a considerable range of depths. After sunset they feed near the surface (2-13 m), and at sunrise they return to the 90-125 m inshore depth. Large individuals did

[7]Beckett, J. S. 1971. Canadian swordfish longline fishery. Working paper (SCRS/71/36) submitted to the Standing Committee on Research and Statistics, November 1971. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid 1, Spain.

[8]Carey, F. G., and B. Roberson. 1977. Tracking swordfish in the Sea of Cortez. Hubbs-Sea World Res. Inst., Currents No. 1, p. 1-7. Hubbs-Sea World Research Institute, 1700 S. Shores Road, San Diego, CA 92109.

not come inshore but set up a meandering course seaward. These experiments involved two tagged fish in the Atlantic and five tagged fish in the Pacific.

In the eastern Pacific, catch records indicate a movement of fish from off the tip of Baja California during the spring and towards the north during the summer and fall (Kume and Joseph 1969). Kume and Joseph also suggested that swordfish along the coastal regions of South America move northward from Chile to Peru from June to September, and they further postulated that swordfish move seaward to spawn from November through February.

3.52 Schooling

Nothing found in the literature.

3.53 Pugnacity

Swordfish have a reputation for being a pugnacious fish. There are records of attacks on boats (Gray 1871; Smith 1956), whales (Brown 1960; Machida 1970; Peers and Karlsson 1976), and even submersibles (Zarudski 1967).

4 POPULATION

4.1 Structure

4.11 Sex ratio

In the northwestern Atlantic harpoon fishery, only large (120 kg) females are caught; however, in the longline fishery both sexes appear in the catch (Lee 1942; Tibbo et al. 1961). Guitart-Manday (1964) found both sexes in the catch in the southwestern Atlantic with males in greater numbers than females (72-28%); however, most of the large (75-137 kg) fish were females. Beckett (1974) found that sex ratios differ with temperature, as few males are found in the colder (under 18°C) water. In the Caribbean and adjacent regions, for example, Beckett found that males comprise from 67 to 100% of the catch.

In the eastern Pacific, the proportion of females to males in a sample of 1,449 swordfish was roughly equal over the size range 130-170 cm, but above this range the proportion of females became progressively higher (Kume and Joseph 1969).

4.12 Age composition

Using Beckett's (1974) age estimates and length-frequency data from Beardsley et al. (1979[9]), the age composition of swordfish in the western North Atlantic sport fishery is primarily ages three to five with some 1 and 2 yr olds and some 6 yr and older also being caught. In the Sea of Marmara (using Beckett's age estimates), commercially caught swordfish are primarily 3 and 4 yr olds with very few 2 yr olds and some 5 and 6 yr olds in the catch (Artüz 1963).

Yabe et al. (1959) concluded from an 8 yr study of the Pacific swordfish fishery that swordfish taken commercially in the North Pacific fishing grounds are approximately 2 yr old and older, and the predominant age group consists of 4-5 yr olds, although there are some 1 yr olds caught.

4.13 Size composition

Swordfish grow to a very large size, occasionally attaining weights of over 500 kg. The world record swordfish taken by sportfishing gear was captured off Chile in 1953 and weighed 536 kg (International Game Fish Association 1979). Beckett (1974) reported a swordfish landed at Cape Breton, Nova Scotia, that weighed approximately 550 kg.

Size data from the Japanese longline fishery in the Atlantic show a broad range from 80 to 300 cm in length (rear of the orbit to the caudal fork) with the majority between 130 and 230 cm (Fig. 6). Beckett (see footnote 7) showed a rapid decline in the average size of swordfish caught in the Canadian longline fishery, from 120 kg round weight in 1963 to 60 kg in 1969. Part of this decline Beckett attributed to a gradual expansion of the fishery into warmer waters where smaller males are more common in the catches.

In the eastern Pacific, Kume and Joseph (1969) presented size data for swordfish taken by longline vessels (Fig. 7). The range was from 50 to 275 cm eye-fork length with the mode located at about 170 cm. In the western pacific, Yabe et al. (1959) presented length data for swordfish captured by the longline fishery from 1948 to 1956. Average size decreased steadily from about 170 cm to about 130 cm body length during that period (Fig. 8).

Length-weight relationships of swordfish are summarized in Table 3.

4.2 Abundance and density (of population)

4.21 Average abundance

No estimates of population size are available.

4.22 Changes in abundance

See section 4.24.

4.23 Average density

Nothing found in the literature.

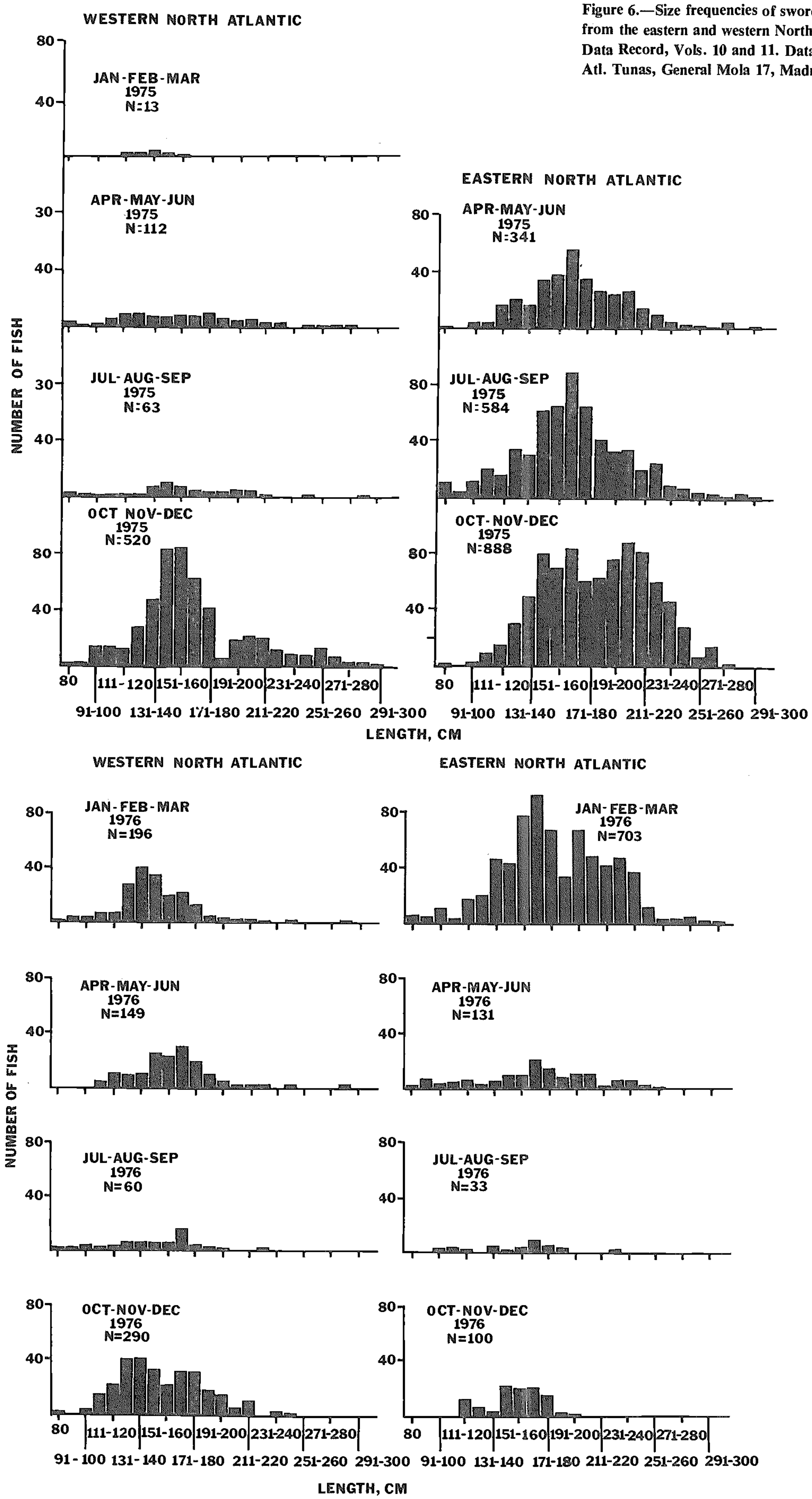
4.24 Changes in density

In the western North Atlantic, catch per unit effort (CPUE) in the Canadian longline fishery declined from 2.88 fish/100 hooks in 1963 to 0.92 fish/100 hooks in 1965. This decline in CPUE was accompanied by a decrease in average size from 120 kg round weight to <60 kg (Beardsley see footnote 6). Part of this decline in average size may have been due to an expansion of the fishery to more southern grounds. In 1975, however, following a 4 yr period when there was no fishing due to restrictions on the sale of swordfish due to mercury contamination, CPUE had risen to 2.31 fish/100 hooks (Caddy 1976). Guitart-Manday (1975) showed a general increasing trend in the catch per days fishing for swordfish off Cuba by the Cuban longline fleet. CPUE in the Japanese longline fishery for the total Atlantic increased steadily from 1956 to 1968 then stabilized through 1975. (Fig. 9).

In the eastern Pacific, catch rates for swordfish by the

[9]Beardsley, G. L., R. J. Conser, A. M. Lopez, M. Brassfield, and D. McClellan. 1979. Length and weight data for western Atlantic swordfish, *Xiphias gladius*. Coll. Vol. Sci. Pap., VIII(SCRS-1978):490-495. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid 1, Spain.

Figure 6.—Size frequencies of swordfish captured in the Japanese longline fishery from the eastern and western North Atlantic in 1975 and 1976 (data from ICCAT Data Record, Vols. 10 and 11. Data records available from Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid 1, Spain).



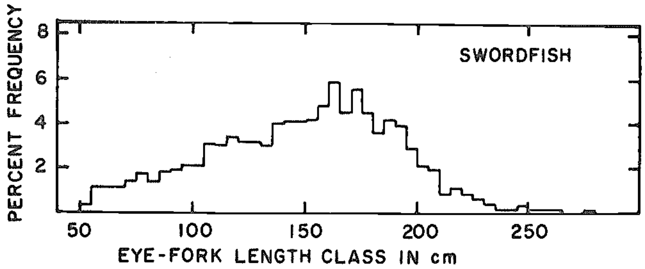


Figure 7.—Size-frequency curve, in percentage, for 1,449 swordfish caught by longline vessels in the eastern Pacific (from Kume and Joseph 1969, fig. 14 and caption).

Japanese longline fishery show generally an increasing trend in the two main fishing areas through 1969 (Fig. 10) (Joseph et al. 1974). The authors pointed out, however, that the increase may be due to an increase in the number of night sets and concentration on the more productive swordfish areas. Sakagawa and Bell (1978[10]) showed the same general increase in CPUE through 1969 but then a sharp decline through 1975 (Fig. 11, Area 3). CPUE over the entire Pacific, however, shows a gradual decline from 1958 through 1967 then stabilizing through 1975 (Fig. 12).

4.3 Natality and recruitment

4.31 Reproduction rates

See section 3.1.

4.32 Factors affecting reproduction

Nothing found in the literature.

4.33 Recruitment

A rough estimate of size at first capture using a comparison of commercial size frequencies by longline and harpoon in the mid-1960's indicates that size at first capture by harpoon is in the vicinity of 36 kg (155 cm FL) and probably slightly lower than this in the Pacific (Beardsley see footnote 6). The size at first capture by longline in the Atlantic is in the vicinity of 4.5 kg (80 cm FL)

4.4 Mortality and morbidity

4.41 Mortality rates

For western North Atlantic stocks, estimates of total mortality (Z) have been made for the harpoon fishery ($Z=0.12-0.65$) and for the longline fishery ($Z=0.16-0.59$). The natural mortality of swordfish may be relatively low when compared to other billfishes because of their longevity, and preliminary estimates derived from the relationship between M and K,

$$M=-0.0195+1.9388\ (K),$$

[10]Sakagawa, G. T., and R. R. Bell. 1978. Swordfish, *Xiphias gladius*. *In* R. S. Shomura (editor), Summary report of the Billfish Stock Assessment Workshop, Pacific Resources, Honolulu, Hawaii, 5-14 December 1977. Mimeo. Rep., p. 43-55. Honolulu Laboratory, Southwest Fisheries Center, NMFS, NOAA, P.O. Box 3830, Honolulu, HI 96812.

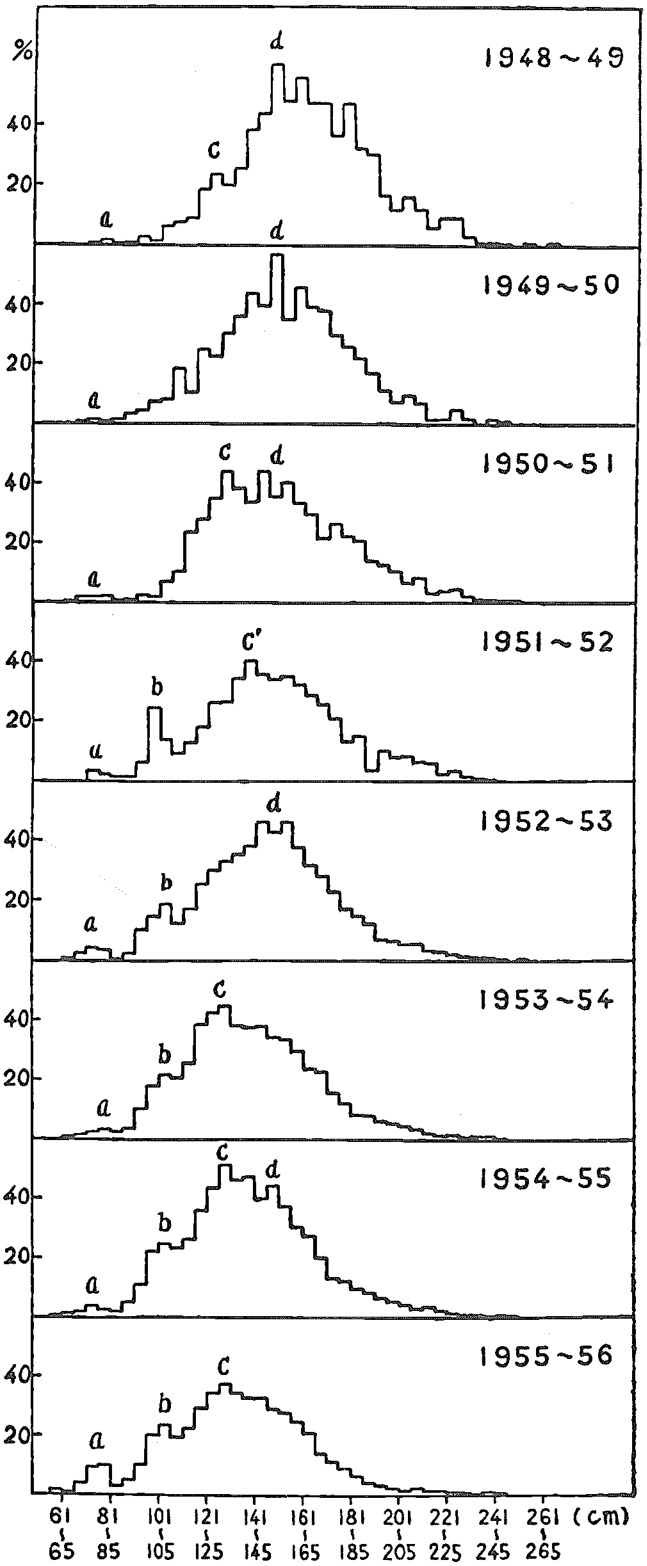


Figure 8.—Body length (distance from the posterior end of the upper jaw to the terminal of the hypural bone) compositions of swordfish from the North Pacific fishing grounds (140°-160°E) for an eight-year period from 1948-56 (from Yabe et al. 1959, fig. 25 and caption; authors note: the abscissa is body length in cm; although the ordinate is labeled percent, we do not believe the numbers as shown on the figure represent percent. The letters a, b, c, and d represent modes).

Table 3.—Length-weight relationships of swordfish, *Xiphias gladius*, sexes combined. The form of the equation is $y = ax^b$. Beardsley et al. (1979) used the geometric mean form; all others are predictive.

Author (area)	Measurement	Length range	N	a	b
Guitart-Manday (1964) (western Atlantic)	lower jaw fork length (cm) round weight (kg)	84.5-254.5	242	4.8643×10^{-7}	3.64237
Skillman and Yong (1974) (Pacific)	tip of upper bill to fork (cm) round weight (kg)	ca. 150-325	7	2.3296×10^{-7}	3.5305
Caddy (1976) (western Atlantic)	lower jaw fork length (cm) dressed weight (kg) ca 77% of round weight	ca. 50-260	—	1.30978×10^{-5}	3.0992
Beardsley et al. (1979)[1] (western Atlantic)	lower jaw fork length (cm) round weight (kg)	81-281	166	3.689×10^{-5}	3.2994
Rey and Gonzales-Garcés (1979)[2] (eastern Atlantic)	lower jaw fork length (cm) eviscerated weight (kg) (eviscerated weight = 0.75 × round weight$^{1.04}$)	90-234	486	5.17×10^{-6}	3.16
(Mediterranean)	lower jaw fork length (cm) eviscerated weight (kg)	94-180	105	9.7×10^{-7}	3.49
Amorim and Arfelli (1977) (western Atlantic)	eye-fork length (cm) gilled and gutted weight (kg) (gilled and gutted weight = 0.8009 × live weight$^{1.015}$)	—	1173	1.24×10^{-5}	3.04
Amorim (1977)[3] (western Atlantic)	eye-fork length (cm) gilled and gutted weight (kg)	73-240	865	5.36×10^{-6}	3.2

[1]See text footnote 9.
[2]See text footnote 11.
[3]Amorim, A. F. de. 1977. Informe preliminar sobre las investigaciones del pez espada *Xiphias gladius* en el sudeste sur del Brazil, en el periodo de 1971-76. Coll. Vol. Sci. Pap., VI(SCRS-1976):402-407. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid 1, Spain.

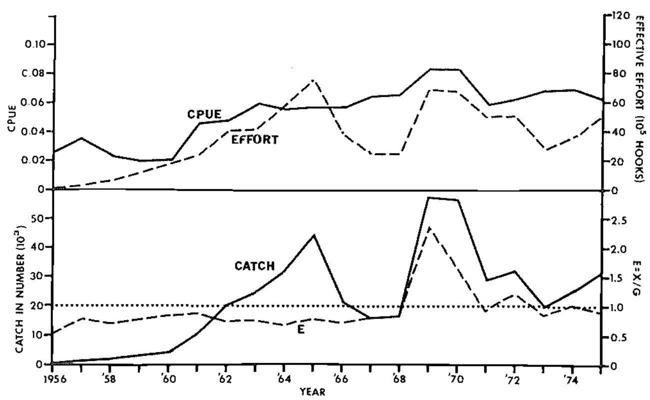


Figure 9.—Catch-per-unit-of-effort, effective number of hooks, catch in number, and index of effectiveness for Atlantic swordfish by the Japanese longline fishery, 1956-1975. X = effective number of hooks, G = nominal hooks (from Beardsley see text footnote 6, fig. 5 and caption).

indicate that M ranges from 0.21 to 0.43 (Beardsley see footnote 6).

4.42 Factors causing or affecting mortality

See section 3.34.

4.43 Factors affecting morbidity

See section 3.35.

4.44 Relations of morbidity to mortality rates

Nothing found in the literature.

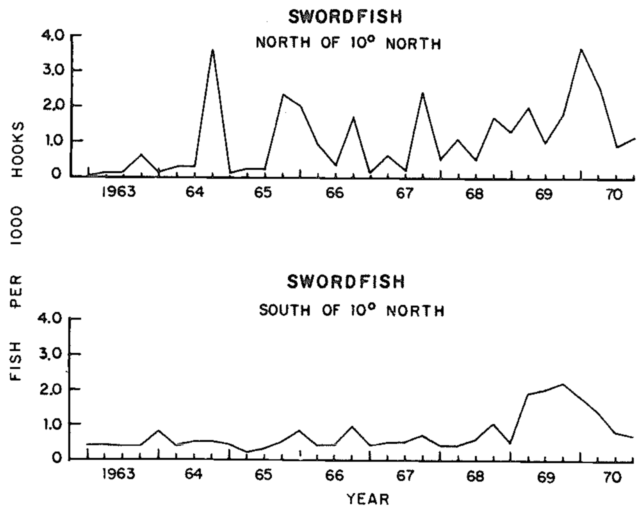


Figure 10.—Quarterly hook rate of swordfish expressed as catch in numbers per 1,000 hooks, for areas north and south of lat. 10°N in the eastern Pacific (from Joseph et al. 1974, fig. 19 and caption).

4.5 Dynamics of population (as a whole)

Nothing found in the literature.

4.6 The population in the community and the ecosystem

Studies on the distribution of swordfish worldwide and its relationship to the total ecosystem have not been done. However, the geographical distribution of swordfish in the northwestern Atlantic varies considerably due to marked

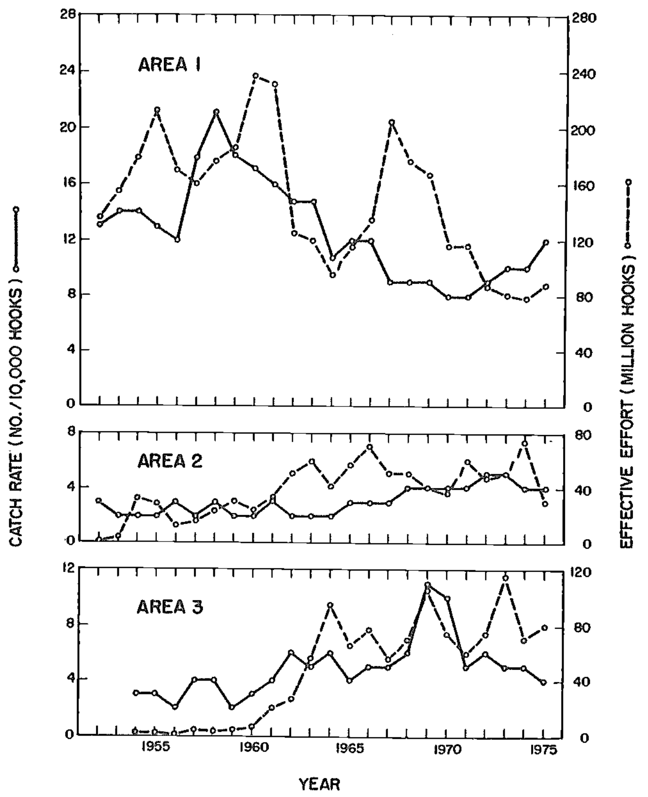


Figure 11.—Catch rates and effective fishing effort for swordfish in the Pacific (from Sakagawa and Bell see text footnote 10, fig. 6 and caption. Note: areas pertain to same areas portrayed in Fig. 2).

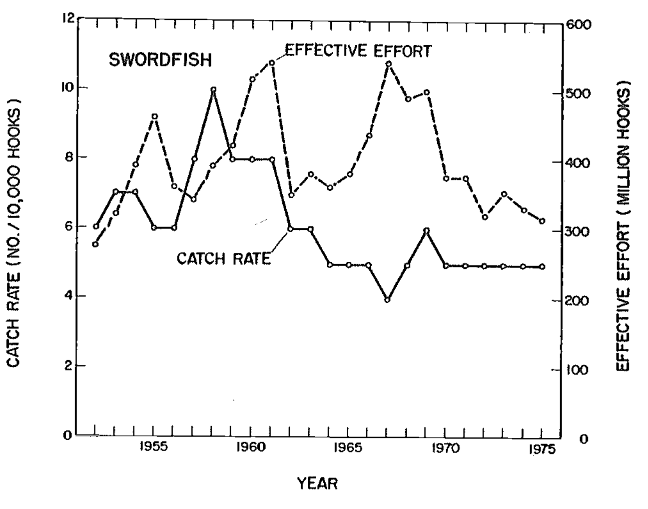


Figure 12.—Pacific-wide catch rate and effective fishing effort for swordfish (from Sakagawa and Bell, see text footnote 10, fig. 3 and caption).

seasonal variations in environmental conditions (Beckett 1974). In the eastern Pacific, swordfish populations are most abundant throughout the year in the inshore areas, probably in association with cool upwelled waters in that region (Kume and Joseph 1969).

Temperature apparently is important to the distribution of swordfish in all oceans (Yabe et al. 1959; Kume and Joseph 1969; Ovchinnikov 1970; Beckett 1974), and optimal surface temperatures appear to be 25°-29°C (Tåning 1955). Current systems such as the Gulf Stream in the Atlantic, the Kuroshio and Humboldt in the Pacific, as well as the Equatorials and Equatorial Countercurrents, play a major role in the distribution of swordfish because frontal zones with sharp gradients of temperature, salinity, and amounts of biogenous matter are created, and these are surrounded by areas of high productivity where swordfish and other predators concentrate (Ovchinnikov 1970).

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gear

Swordfish are taken by longlines and harpoons in the commercial fishery. The harpoon for many years was the primary commercial gear in most areas of the Atlantic and Pacific. In the early 1960's, however, following the disclosure of substantial catches of swordfish by the Japanese tuna longline fishery and the Norwegian shark fishery in the Atlantic and high catch rates by exploratory fishing vessels in the northwest Atlantic using longline gear at night, most of the Canadian and United States vessels converted to longlines. In the eastern Atlantic and Mediterranean, longlines are used by the French and Spanish fleets, while harpoons are still the traditional gear of the Sicilian swordfish fleet.

In the Pacific, longlines and harpoons are used. In the eastern Pacific, however, the U.S. commercial fishery is restricted to the use of harpoons only.

Trolling and drift fishing using rod and reel gear are the primary fishing methods in the sport fishery. Until 1976, only trolling was used and involved initial visual observation of a swordfish basking at the surface before the lines were placed into the water. In 1976, however, sport fishermen off the east coast of Florida discovered that swordfish could be caught by drifting baited lines at night. Fishing success is substantially higher using this method than by the trolling method, and night sport fishing for swordfish now takes place all along the Atlantic and Gulf of Mexico coasts of the United States.

5.12 Boats

Commercial fishing vessels for swordfish range in size from the large, high-seas tuna longliners to small harpoon and longline boats < 10 m in length. Good descriptions of various types of fishing vessels used for longlining and harpooning for swordfish are described in Tibbo et al. (1961) and Guitart-Manday (1964). Vessels used in the sport fishery vary considerably in size and style. Rybovich (1965) presented a good description of a typical sport fishing vessel.

5.2 Fishing areas

5.21 General geographic distribution

Catch records from the high-seas tuna longline fishery indicate that swordfish are taken almost throughout the range of the fishery. For the most part, however, swordfish are incidental catches in the tuna longline fishery. Important directed commercial fisheries for swordfish are located in the western North Atlantic from the Grand and Georges Banks to the Gulf of Mexico, in the eastern Atlantic and Mediterranean Sea, and in the South Atlantic off the coast of Brazil and Uruguay. In the western Pacific, the major fishing grounds extend from Japan eastward to long. 165°W.

Major sport fishing areas are located off the east coast of the United States from New York to Texas and off the coast of southern California. Some sport fishing for swordfish also takes place in the South Pacific, notably off Chile and Ecuador.

5.22 Depth ranges

Swordfish are caught by both commercial and sport fisheries over a wide range of depths. Generally, major fishing areas are located near continents in the Atlantic in depths of <1,000 m. In the Pacific, major fisheries take place at considerably greater depths.

5.3 Fishing seasons

5.31 General patterns of seasons

Swordfish are caught throughout the year.

5.32 Dates of beginning, peak, and end of seasons

In the western Atlantic, the longline fishery for swordfish operates year round; however, there is a substantial geographic shift in the fishery with the seasons. In the summer and early fall, most fishing takes place off Grand and Georges Banks. In winter, many of the larger boats move into more southern waters, operating from Cape Hatteras southward around Florida and throughout the Gulf of Mexico. In the eastern Atlantic and Mediterranean, Artüz (1963) stated that landings from the Sea of Marmara peaked in May, while Rey and Gonzales-Garcés (1979[11]) presented data that showed the peak of the Spanish fishery during July to December.

In the eastern Pacific, longline catches are made all year long, but the peak season is from January through March (Kume and Joseph 1969). The California harpoon fishery operates mainly in summer and fall.

5.4 Fishing operations and results

5.41 Effort and intensity

In the Atlantic, effective fishing effort for swordfish by the Japanese longline fleet increased rapidly from 1956 to a peak in 1965 then fluctuated widely through 1975 (Fig. 9). The United States and Canadian fisheries expanded rapidly following the conversion to longline gear in 1962. In 1971, however, both fisheries were essentially terminated following restrictions on the sale of swordfish with high levels of mercury contamination in the flesh. In recent years, this fishery has undergone a resurgence and although no hard data are available, effort is probably as great if not greater than during the pre-1971 years.

The recreational fishery has historically been rather insignificant, both in terms of effort expended and in catch. In recent years, however, the development of a nighttime fishery for swordfish has dramatically increased catches and this type of fishing has expanded all along the Gulf and Atlantic coasts of the United States.

In the Pacific, fishing effort by the Japanese longline fleet attained two major peaks, one in 1961 and the other in 1967, but since 1967 it has declined steadily through 1975 (Fig. 12). In the eastern Pacific, effort increased sharply from 1954 to 1964 then leveled off through 1975.

[11]Rey, J. C., and A. Gonzales-Garcés. 1979. Nuevos datos sobre la pesqueria Española de pez espada, *Xiphias gladius*, biologia y morphometria. Coll. Vol. Sci. Pap., VIII(SCRS-1978): 504-509. Int. Comm. Conserv. Atl. Tunas, General Mola 17, Madrid 1, Spain.

5.42 Selectivity

Nothing found in the literature.

5.43 Catches

Landings of swordfish from the Atlantic are shown in Table 4 and from the Pacific, Table 5.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (legislative measures)

6.11 Limitation or reduction of total catch

Restrictions on the sale of swordfish containing levels of mercury in the flesh >0.5 ppm were imposed in Canada and the United States in the early 1970's. These restrictions caused the complete collapse of the Canadian fishery and severely reduced landings in the United States. Gradually, however, the U.S. fishery began to resume normal operations, but essentially in a clandestine fashion. In 1979, the mercury guidelines were raised to 1.0 ppm as a result of legal action initiated by the American Swordfish Association. By 1980, catch and fishing effort were probably at an all time high in the Atlantic and the fishery extended from Canada to Mexico.

6.12 Protection of portions of population

In Turkey, no swordfish <10 kg can be caught, offered, stored, or exposed for sale (Artüz 1963).

6.2 Control or alteration of physical features of the environment

Nothing found in the literature.

6.3 Control or alteration of chemical features of the environment

Nothing found in the literature.

6.4 Control or alteration of the biological features of the environment.

Nothing found in the literature.

6.5 Artificial stocking

Nothing found in the literature.

7 POND FISH CULTURE

Not applicable.

Table 4.—Landings in metric tons of swordfish, *Xiphias gladius*, from the Atlantic Ocean, 1967-1977. (ICCAT Statistical Bulletin, Vol. 8-1977, p. 25.)

Country	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Algeria	0	0	0	xx	xx	2	100	196	500	368	370
Argentina	100	300	500	400	100	100	48	0	10	111	132
Brazil	120	120	240	120	0	120	137	348	318	330	275
Bulgaria	0	0	0	0	0	0	0	0	0	0	3
Canada	4,800	4,400	4,300	4,800	0	0	0	0	21	15	113
Taiwan	0	0	0	0	0	750	1,092	821	928	935	922
Cuba	200	0	0	0	0	0	0	0	0	600	700
Cyprus	0	0	0	0	0	0	0	0	5	72	118
Ghana	0	0	0	0	0	0	0	0	0	0	642
Italy	1,900	1,400	2,000	1,800	2,900	3,700	2,700	1,500	1,500	2,140	1,935
Japan	754	1,121	2,273	3,175	1,576	1,805	998	1,369	1,500	809	792
Korea	0	0	0	0	0	0	0	0	451	1,147	1,240
Libya	300	500	xx	xx	100	xx	xx	xx	0	0	0
Malta	xx	xx	xx	100	200	200	200	171	191	156	199
Mexico	0	0	0	0	0	2	4	3	0	0	0
Morocco	204	240	270	231	360	273	201	211	133	198	151
Norway	300	200	600	400	200	xx	xx	xx	0	0	0
Panama	0	0	0	0	0	167	445	0	0	0	0
Poland	0	0	0	0	xx	0	100	0	0	0	0
Spain	3,390	4,550	4,600	4,060	4,484	4,510	4,938	3,593	3,836	2,905	3,976
Tunisia	0	0	0	xx	xx	xx	xx	5	0	0	0
Turkey	98	0	119	88	76	76	xx	6	0	0	0
USA	474	274	171	287	35	246	406	1,125	1,700	1,429	0
USSR	xx	xx	100	200	200	200	200	1,400	263	562	121
Venezuela	360	0	120	0	0	0	0	0	0	0	0
TOTAL:	13,000	13,105	15,293	15,661	10,231	12,151	11,569	10,748	11,356	11,777	11,689

Table 5.—Swordfish catches (metric tons) by countries for the Pacific Ocean (Sakagawa and Bell, see text footnote 10).

Year	Japan	Taiwan	Korea	United States	Chile	Peru	Others	Total
1952	11,182			157				11,339
1953	11,604			85				11,689
1954	13,301	77		14				13,392
1955	16,220	185		80				16,485
1956	12,167	254		163				12,584
1957	15,771	250		222				16,243
1958	20,815	247		279				21,341
1959	19,136	262		265				19,663
1960	22,944	273		192				23,409
1961	23,636	432		218				24,286
1962	14,037	544		23				14,604
1963	13,775	300		58				14,133
1964	9,703	300		109				10,112
1965	11,955	300		194	200	300		12,949
1966	13,283	600	41	277	200	200		14,601
1967	13,083	838	47	181	200	1,300		15,649
1968	12,983	974	55	118	200	800	100	15,230
1969	15,612	1,023	89	610	300	1,200	100	18,934
1970	11,301	1,053	115	558	200	2,400	100	15,727
1971	9,182	1,149	115	91	200	200	100	11,037
1972	8,846	1,111	115	157	100	600	100	11,029
1973	9,644	1,269	115	363	400	1,900	100	13,791
1974	9,517	1,157	115	384	218	270	3	11,664
1975	11,274	1,099	115	512	218	158		13,376

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