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NSF 02-186 **01/10/03**

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DEB - Biotic Surveys & Inventories

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TITLE OF PROPOSED PROJECT **PBI: Pufferfishes and Allies - Tetraodontiformes - as a Model Group for Planetary Biodiversity Inventories**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **4,999,780**	**60** months	**07/01/03**	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

☐ BEGINNING INVESTIGATOR (GPG I.A)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.B, II.C.6)
☐ HISTORIC PLACES (GPG II.C.9)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.C.11)
☒ VERTEBRATE ANIMALS (GPG II.C.11) IACUC App. Date **08/17/00**
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CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 03-2. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Appendix A of the Grant Proposal Guide.

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Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

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Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

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(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

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Intellectual Merit – Tetraodontiform fishes are an ideal model group with which to demonstrate the feasibility and value of Planetary Biodiversity Inventories. The group's size (~450 living and fossil species from ~120 genera in 12 families) is large enough to provide challenges in the development and web-delivery of a comprehensive inventory, but small enough that we can expect to reevaluate the status of every living and fossil species, produce a complete database of all catalogued museum specimens worldwide, collect new specimens from poorly-sampled habitats and to obtain tissues for molecular work, assemble range maps for all species, collect morphological and molecular character data from at least one representative of each genus, and collect additional, specimen-linked data on habitat, life history, development, functional morphology, behavior, conservation status, etc. as opportunities arise. Our goal is to integrate these multiple data streams and to produce a web-revision of the group to provide a comprehensive inventory for systematists, evolutionary biologists, functional morphologists, ecologists, conservation biologists, policy-makers, educators, and recreational SCUBA divers and snorkelers.

Tetraodontiformes is also a good choice as one of the first clades selected for PBI because its members are fairly well-represented in the world's natural history collections and it is a well-studied group, with extensive previous work on osteology, myology, paleontology, early life history and functional morphology, as well as complete genome sequences for two pufferfishes (*Takifugu rubripes* and *Tetraodon nigroviridis*). This history of excellent prior work on the group will give us a head-start and provide context for the results of our inventory.

Tetraodontiform fishes live in vast portions of the Atlantic, Pacific and Indian Oceans as well as in fresh and brackish water environments in South America, Africa and Southeast Asia. Global biodiversity of Tetraodontiformes is concentrated on tropical coral reefs, which are at special risk from anthropogenic factors such as global warming, sea level change, overfishing and pollution. Other species live in tropical freshwater and brackish water habitats, many of which have so far proved challenging to sample in comprehensive ways. Such habitats are at risk from anthropogenic factors such as logging and associated runoff pollution of waterways and degradation of coastal habitats by expanding human populations. Thus, an early focus on global diversity of Tetraodontiformes is appropriate to the stated goals of the PBI Program to inventory biological diversity in critical habitats as rapidly as possible.

We have assembled a truly outstanding team of experts for this project. We propose a "Working Group" approach to the management of this inter-institution and international collaboration. Our five working groups are: Alpha Systematics & Biogeography; Morphology and Development; Genomics & Molecular Phylogenetics; Informatics; and Outreach. Each working group will have two co-leaders and between five and twelve additional members. Some project members will participate in more than one working group, to enhance communication between groups. The PIs and group leaders will participate in a Planning Meeting once per year to review progress and set goals and all participants will be invited to attend Annual Meetings at which participants will present research papers, discuss and evaluate progress and plan for their next period of work as a group.

Broader Impacts – Tetraodontiform fishes are colorful and interesting to observe, making them good public ambassadors for marine biodiversity. We will develop a special exhibit on tetraodontiform biodiversity in a public aquarium and prepare, in conjunction with NOVA, a TV documentary on Tetraodontiformes and how this group is being studied under the auspices of PBI. These public outreach efforts will communicate to the broadest possible audience the importance of globally inventorying entire clades of organisms. Many undergraduate, graduate and post-doctoral students will work on the project (with special attention to recruiting and retaining participants from underrepresented groups), and they will receive integrated training in morphological, molecular and bioinformatics approaches. It is increasingly clear that inter-institutional and international collaboration are necessary to approach major problems in the life sciences, and participating students will gain experience with the process of large-scale collaboration.

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For font size and page formatting specifications, see GPG section II.C.

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Introduction – The 450 living and fossil species of tetraodontiform fishes (sometimes known as Plectognathi) engage life scientists at analytical levels ranging from whole genome sequencing to developmental biology, comparative morphology, paleontology, behavior and ecology. Critical to the future of all of these research areas is better, more accessible, and more integrated knowledge concerning their global biodiversity and evolutionary relationships. With such information, Tetraodontiformes has outstanding potential to become a "model group" for the life sciences (Santini & Stellwag, 2002). Coupled with this potential are conservation concerns, as most living species occur in near-shore, shallow marine environments, including coral reefs (Fig. 1). Because they are colorful and interesting to observe, it is easy to develop outreach programs such as special exhibits in public aquaria and documentary television programs that can communicate to the broadest possible audience the importance of globally inventorying entire clades of organisms. We have assembled an outstanding international team of investigators who bring great strengths to the analyses of global biodiversity of tetraodontiforms. In crafting this proposal, we also have been guided by the outstanding promise that survey and inventory research has to integrate multiple streams of information in web-revisions of individual groups, and to link those streams to specific specimens in world natural history collections.

Figure 1. Queen Triggerfish (*Balistes vetula*), a reef species from the Atlantic. WEB 02-473; 431 mm TL. Salvaged by the PI from a recreational angler. This species is IUCN Listed as Vulnerable (VU A2D).

How the Proposal is Organized – The proposal consists of six sections. **Section 1** provides *Biological Background on Tetraodontiformes*, including a review of families, distribution, evidence for monophyly, hypotheses of higher relationships, and comments on functional morphology, tetrodotoxin, larval biology and genome size. **Section 2** explains *Why Tetraodontiformes is an Ideal Group for PBI*. **Section 3** summarizes *Objectives*. **Section 4** presents *Assembled Expertise and Plans for Its Deployment*, drawing upon information from Sections 1–3 and the *Management Plan* (a Supplementary Document). **Section 5** gives *An Example of a Working Group*. **Section 6** addresses *Broader Impacts*. (Reviewers please note: *Results from Prior Support* is a Supplementary Document.)

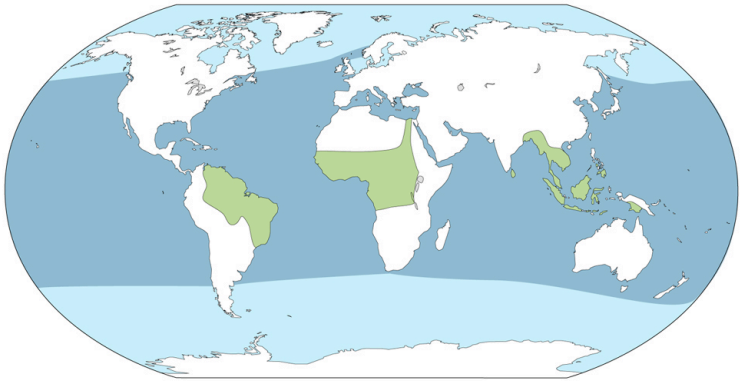

Figure 2. Global distribution of living species of tetraodontiforms. Marine (dark blue); fresh and brackish water (green).

Section 1. Biological Background on Tetraodontiformes – Living tetraodontiforms are known from vast portions of the Atlantic, Pacific and Indian Oceans as well as fresh and brackish water environments in South America, Africa and Southeast Asia (Fig. 2). The group includes ~400 valid living species belonging to 10 families (Table 1). Many are familiar even to non-specialists.

Colorful species of triggerfishes (Balistidae), filefishes (Monacanthidae), cowfishes (Ostraciidae), puffers (Tetraodontidae) and porcupinefishes (Diodontidae) are exhibited in aquaria and illustrated in guides for divers (e.g., Humann, 2002). Species from all five of these families can be observed easily in nature, often simply by snorkeling. Other families are known for other reasons. For example, the ocean sunfish (*Mola mola*, Molidae) is one of the largest extant fishes.

Table 1. Diversity of Living Tetraodontiformes

	Genera	Species
1. Triacanthodidae (Spikefishes)	10	21
2. Triacanthidae (Triplespines)	4	7
3. Balistidae (Triggerfishes)	12	37
4. Monacanthidae (Filefishes)	25	104
5. Aracanidae (Boxfishes)	6	13
6. Ostraciidae (Boxfishes)	6	24
7. Triodontidae (Three-toothed puffer)	1	1
8. Tetraodontidae (Puffers)	26	172
9. Diodontidae (Porcupinefishes)	7	20
10. Molidae (Molas)	3	4
Totals	100	403

Detailed studies of Mesozoic and Cenozoic fossil Tetraodontiformes contribute much to knowledge of phylogenetic relationships (e.g., Tyler & Sorbini, 1996; see Fig. 3) and provide morphological evidence for monophyly. Putative synapomorphies of Tetraodontiformes include: ≤21 vertebrae; absence of anal fin spines; absence of parietal bones; absence of nasal bones; absence of extrascapular bones; absence of pleural ribs; a restricted gill opening; and ≤12 principal caudal rays.

Tetraodontiformes has three major extant clades (Fig. 3). **Triacanthoidea** includes 14 genera and 28 valid species of spikefishes (Triacanthodidae) and triplespines (Triacanthidae) from the Western Atlantic, Indian and Pacific Oceans. **Balistoidea** includes 49 genera and 178 valid species in two subclades: triggerfishes + filefishes (Balistidae + Monacanthidae) and boxfishes (Aracanidae + Ostraciidae). All balistoids are marine; most species occur in relatively shallow waters of the Atlantic, Pacific and Indian Oceans. **Tetraodontoidea** includes 37 genera and 197 valid species. The three-tooth puffer, *Triodon macropterus* (the only extant triodontid) occurs in the Indo-Pacific. It is regarded as sister group to a clade containing pufferfishes (Tetraodontidae), porcupinefishes (Diodontidae) and molas (Molidae). Tetraodontidae is the largest family within Tetraodontiformes; its 26 genera and 172 valid species occur in the Atlantic, Pacific and Indian Oceans as well as brackish and freshwater environments in South America, Africa

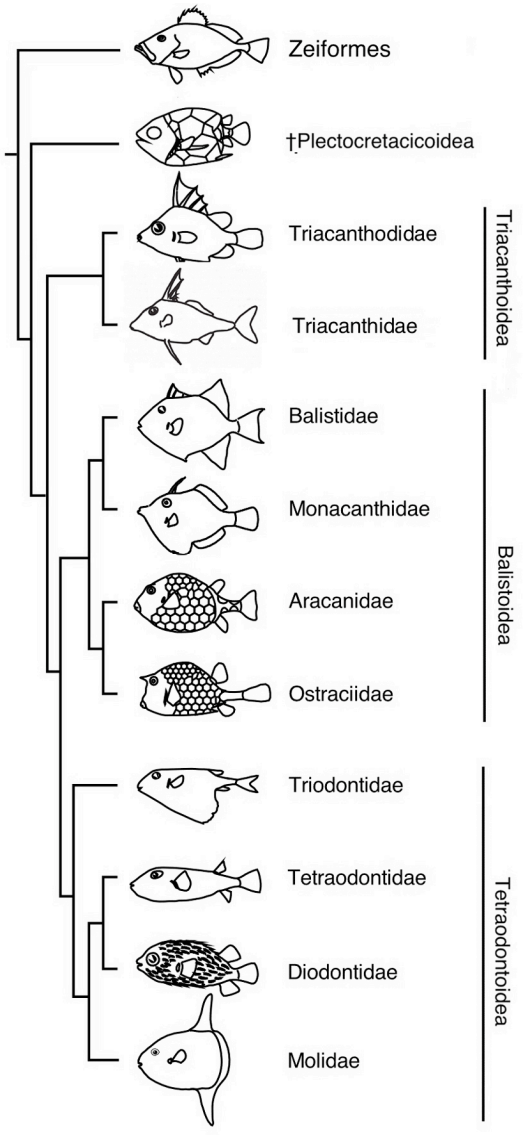

Figure 3. Phylogeny of living Tetraodontiformes, non-caproid Zeiformes as outgroup. Modified from Tyler & Sorbini (1996).

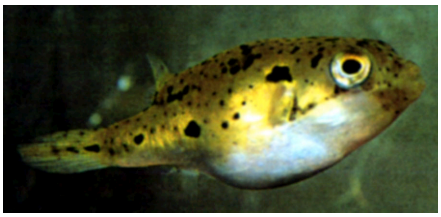

Figure 4. Live female *Carinotetradon imitator* Britz & Kottelat 1999, a recently described brackish water species from India.

and Asia (Fig. 4). The 28 species of sharpnose puffers (*Canthigaster*) usually are given subfamilial rank within Tetraodontidae. *Canthigaster* has a particularly interesting distribution, with one species in the Atlantic and the other 27 in the Indian and Pacific. Diodontids occur in the Atlantic, Indian and Pacific Oceans; like puffers, these fishes can inflate the body with water or air for defense. The four extant species of Molidae are pelagic fishes from the Atlantic, Pacific and Indian Oceans, anatomically noteworthy for their highly modified caudal region.

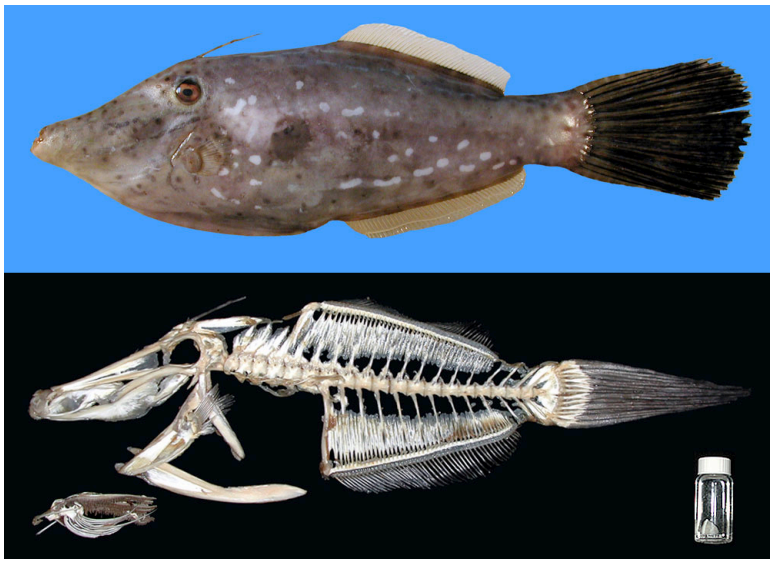

Figure. 5. Scrawled filefish (*Aluterus scriptus*). Above, specimen before dissection. Below, skeleton after preliminary preparation. DNA extracted from a muscle sample preserved in the field in 95% ETOH (vial), is used for sequencing; we work to obtain multiple character sources from each specimen (Bemis et al., submitted) WEB 02-479; 345 mm TL.

Most phylogenetic studies of higher-group relationships of Tetraodontiformes (and teleost fishes generally) are based on studies of the skeletal system (Fig. 5). Based on such characters, Tetraodontiformes long has been considered a highly derived clade of Percomorpha (e.g., Lauder & Liem, 1983; Nelson, 1994). One pre-cladistic view was surgeonfishes (Acanthuroidei) are closely related to Tetraodontiformes (Patterson, 1964; Tyler 1968). In cladistic analyses of the higher relationships of Tetraodontiformes, Rosen (e.g., 1984) found non-caproid Zeiformes (dories and allies) to be their sister group, and this is the view shown in Fig. 3. More recent morphological studies also provide support for this hypothesis (e.g., Tyler & Sorbini, 1996; Tyler et al., in press). A major analysis in 1993 placed non-caproid Zeiformes outside of Percomorpha (Johnson & Patterson, 1993; note that they agreed with Rosen, 1973 and Bannikov, 1991 that caproids are percomorphs). If non-caproid Zeiformes are the sister group of Tetraodontiforms, and if Johnson & Patterson (1993) are correct in their analysis, then Tetraodontiformes lies outside of Percomorpha.

Phylogenetic signals from different morphological and molecular data sets continue to yield conflicting results. For example, a recent analysis of the mitogenomes of 48 teleostean species yielded some unexpected but highly resolved and well-supported relationships (Miya et al., 2003; see Fig. 6). The two tetraodontiforms that they sequenced, a triggerfish and a filefish, grouped together (orange in Fig. 6), and the only caproid sequenced (*Antigonia capros*) fell out as the sister group. Surprisingly, they found Lophiiformes (anglerfishes) to be sister to Tetraodontiformes + Caproidae. Together, Tetrao-

dontiformes + Caproidae + Lophiiformes was found to be sister to two "perciform" families Emmelichthyidae + Lutjanidae (Miya et al., 2003 recovered three separate groups of "Perciformes"). The phylogeny by Miya et al. (2003) may nest tetraodontiforms deeply within Percomorpha – but certainly no one had expected on the basis of morphology that they would group with anglerfishes. The suggestion of a sister group relationship between tetraodontiforms and caproids, based on the presence of a "chain-link pelvic spine articulation," had been made earlier by Mok & Chang (1986). If the hypothesis of relationships proposed by Miya et al. (2003) stands, then many aspects of tetraodontiform evolution will need reevaluation – including morphological synapomorphies regarded as evidence for tetraodontiform monophyly. All in all, these contradictory results are not too surprising under the circumstances; only now are intensive molecular systematic studies of teleosts being undertaken, and the total amount of sequence data available and loci sampled to date is limited. Similarly, despite the considerable enthusiasm of systematic morphologists for studying teleostean interrelationships, there still are too few researchers trained to study anatomical characters – at least, too few relative to the diversity of fishes – to have anything approaching complete comparative data sets for any organ systems in higher teleosts, including the skeletal system.

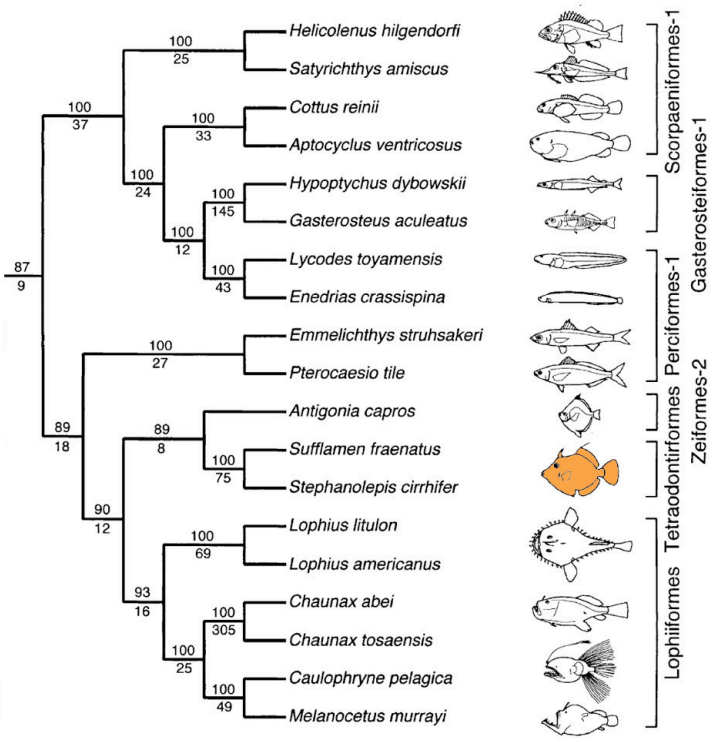

Figure 6. Phylogeny based on mitogenomic DNA sequences from Miya et al., 2003. This analysis recovered a caproid, *Antigonia*, as sister to Tetraodontiformes.

There has been great interest in the functional morphology of Tetraodontiformes, for these fishes exhibit fascinating anatomical specializations. Functional morphologists have studied their feeding, locomotor and defensive inflation behaviors (e.g., Wainwright & Turingan, 1993; Brainerd, 1994; Friel & Wainwright, 1999; Bartol et al., 2003). For example, as noted above, tetraodontiforms have $\leq$21 vertebrae, which is many fewer vertebrae than in most groups of teleosts. Many aspects of their evo-

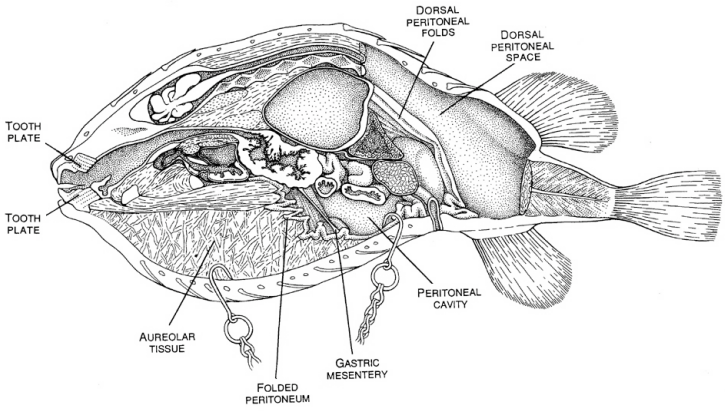

Figure 7. Anatomy of a spiny puffer (*Diodon holacanthus*) showing specializations related to inflation mechanism. From Brainerd (1994).

lution seem to be linked to this character, such as the specializations that allow puffers to inflate with water or air (Fig. 7), for a short and relatively inflexible vertebral column limits the degree to which lateral undulation of the trunk can be used for escape movements (Brainerd & Patek, 1998). Vertebral structure also appears to be linked to the diverse modes of locomotion exhibited by tetraodontiforms. This topic has interested functional morphologists since Breder (1926), for he named a characteristic swimming mode – ostraciform locomotion – based on observations of boxfish swimming. Their trunk region is encased in inflexible armor, so they swim using relatively large and flexible pectoral, dorsal and anal fins as well as the muscular caudal peduncle and fan-shaped tail. Ostraciform locomotion is precise, but slow. In contrast, the balistiform mode of swimming employed by triggerfishes entails powerful side-to-side flapping of elongate dorsal and anal fins, which can produce relatively higher swimming speeds. Detailed studies of tetraodontiform locomotion are receiving renewed interest (e.g., Hove et al., 2001), and especially as new technologies are applied to the study of fish swimming (e.g., digital particle image velocimetry, or DPIV; see Drucker & Lauder 1999 and 2002 for introduction and review), tetraodontiforms will be an especially important group for detailed comparative study.

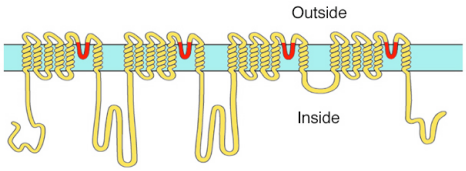

Figure 8. Model of sodium channel protein (yellow) passing through cell membrane (blue). TTX selectively binds to pore loops (red), blocking passage of sodium.

Tetrodotoxin (TTX) is a potent toxin that selectively and with very high affinity binds to sodium channels in cell membranes (Fig. 8). It is named for its presence in tissues of pufferfishes. In some tiger puffers (*Takifugu spp.*), TTX can reach concentrations in the viscera and skin sufficient to poison adult humans. TTX is also known from other tetraodontiforms, certain lissamphibians, as well as blue-ringed octopus and other invertebrates. It has been suggested that TTX has a bacterial origin, and that toxin is acquired by animals either via their diet or via a symbiotic interaction with bacteria (likely *Pseudomonas* or *Vibrio*). Tetraodontiforms exhibit great diversity in TTX-sensitivity. Some species contain TTX and are highly resistant to the toxin, whereas others that lack TTX show more normal sensitivity to TTX. For example, highly toxic members of Tetraodontidae are about 500-fold less sensitive to TTX than are non-toxic species. Some species of non-toxic tetraodontiform families (e.g., Balistidae, Ostraciidae) may still be ten- to twenty-fold less sensitive to TTX than are other teleosts, suggesting limited TTX insensitivity (or pre-adaptations for TTX insensitivity) in these lineages. Even more intriguing is the fact that some families have both TTX-sensitive and TTX-insensitive members: for example, within Tetraodontidae, *Arothron*, *Takifugu*, and *Canthigaster* are highly TTX-resistant whereas *Lagocephalus* is only moderately so. This diversity promises to allow detailed investigation of the evolutionary changes in candidate binding sites at the pore region of the sodium channel (Jost, Hillis & Zakon, NSF IBN-0236147). This and many other aspects of TTX are extremely exciting emerging areas of inquiry, ones that surely will be elucidated by better information about phylogenetic relationships within Tetraodontiformes.

Another especially interesting aspect of tetraodontiform biology is their small genome size (Brainerd et al., 2001). Interspecific variation in vertebrate genome size cannot be explained by changes in the amount of coding DNA from one species to another, nor do there appear to be consistent patterns in the evolution of smaller or larger genomes

within vertebrates (Cavalier-Smith 1985). Genome size in a diverse sample of 275 species of teleosts varies from less than 1 pg to almost 9 pg (Hinegardner & Rosen 1972), and the smallest vertebrate genome measured to date is 0.70 pg (for the smooth pufferfish, *Tetraodon fluviatilis*; Lamatsch et al., 2000). Members of the other subfamily of Tetraodontidae, Canthigasterinae, have comparably small genomes (Fig. 9). The comparative study of genome size in tetraodontiforms by Brainerd et al. (2001) also showed that diodontids have genomes roughly twice the size of tetraodontids, as do molids. Some balistoids, however, also have small genomes. Based the phylogenetic interpretation shown in Fig. 3, this suggests that small genome size evolved independently in at least two groups of tetraodontiforms. Also because of their small genomes, Brenner et al. (1993) identified pufferfishes as a target for whole-genomic sequencing. As a result, two of the five vertebrates for which whole-genome DNA sequencing has been completed are *Takifugu rubripes* and *Tetraodon nigroviridis*, making Tetraodontiformes an outstanding group for broad scale genome-enabled research.

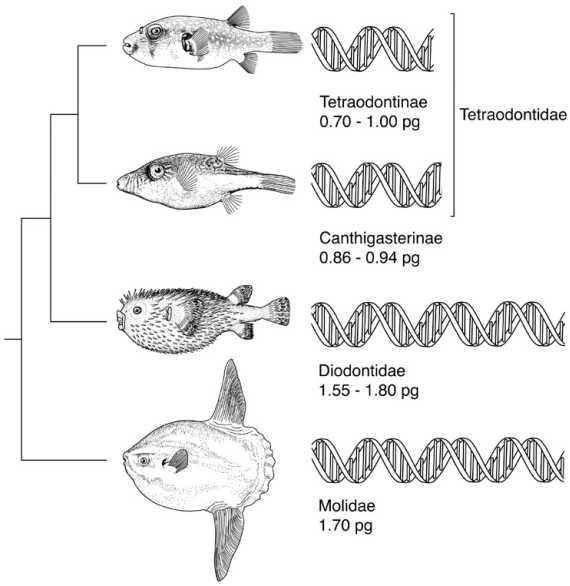

Figure 9. Genome size in puffers and molas (Brainerd et al., 2001). Some Balistoidea also have small genomes, which is hypothesized to represent a convergently evolved decrease in genome size.

Recently, Santini & Stellwag (2002) identified Tetraodontiformes as an ideal group for combined evolutionary/developmental approaches. Few groups of vertebrates can compete with Tetraodontiformes for the peculiar appearance of their larval stages (Fig. 10), but the reasons they are suited for evo-devo research are deeper. Studies of the developmental biology of Tetraodontiformes interface directly with three major areas: phylogenetics, ecology and conservation biology. For example, Leis (1984) examined evolutionary relationships within the group using larval characters. Developmental studies of the skeletal system are also important for interpreting homologies of adult skeletal characters (e.g., work in progress on molids by Britz & Johnson). Some species of tetraodontids can be reared in captivity, making possible detailed developmental descriptions. The pelagic larvae of many marine species spend extended periods – often months – in the plankton, far from the structured reef environments typically inhabited by adults. We know relatively little about the biology of most planktonic larvae, but because these stages can be dispersed by currents they can have important impacts on the distribution of species and their ecology.

Figure 10. Larvae of *Masturus* sp. MCZ 157343. Photo by Karsten Hartel.

Section 2. Why Tetraodontiformes is an Ideal Group for PBI – Species-level taxonomy is experiencing a renaissance driven in part by genomics and in part by informatics in a more general sense (Mallet & Willmott, 2003). In a provocative commentary in *Nature*, Godfray (2002) calls for reinventing taxonomy as a discipline, charging: "*taxonomists lack goals that are both realistic and relevant.*" He goes on to say: "*Taxonomists need to agree on deliverable projects that will receive wide support across the biological and environmental sciences, and attract public interest.*" To Godfray "deliverables" means delivery via the web – not expensive printed monographs. While we are not yet ready to forsake the utility, convenience and "permanence" of printed monographs – and, in fact, we propose to produce such a monograph on Tetraodontiformes as one product of our research – we strongly agree with Godfray about the need for realistic and relevant goals and especially for a ***"group by group"*** approach to help taxonomy and systematics in the larger sense flourish. From our perspective, Tetraodontiformes is an ideal model group to meet Godfray's criterion for eliciting support and interest from many different stakeholder groups in the life sciences while simultaneously demonstrating the importance of the PBI program and the far larger goal of rapidly inventorying the world's species. This is in part because of the fascinating diversity and many intriguing specializations of Tetraodontiformes – specializations that can easily capture the interest of many people – but more importantly because there is an appropriate history of systematic study that can jump-start a truly meaningful PBI-level inquiry and successful web-revision. Here are seven reasons why we think Tetraodontiformes has such potential:

Figure 9. Leafy File Fish, *Chaetodermis penicilligera* in the field. Photo by Paul Humann.

1) The size of the tetraodontiform clade (~450 living and fossil species from ~120 genera in 12 families) is suited to a practical test of the comprehensive, all-species approach. This is because we can realistically expect to examine first hand within a five-year award period specimens of all living and fossil species of Tetraodontiformes. We will be able to evaluate the status of all type materials for all species, and prepare new photographs and x-ray images of all locatable holotypes. This clade's size also lends itself to a new international collecting program, though holdings in world natural history collections will be the focus for much of our work. As a direct result of the all-species approach, we expect to discover new species of Tetraodontiformes, to provide broadly revisionary work across the entire group, and to present new phylogenetic analyses and a new phylogenetic classification for all of its fossil and living species. **We expect that such a "single eye" view of the global diversity of Tetraodontiformes will highlight the promise of the comprehensive all-species approach that is central to the success of PBI, and that this in turn can help lead to comprehensive web-revisions of other groups.** We also know that all future work on higher teleostean fishes will be able to proceed much faster with the groundwork that we can establish in this short, intensive study of all members of one of its most intriguing clades.
2) Our study of Tetraodontiformes will allow us to explore formally the process of working as a team of investigators from different backgrounds (e.g., morphology, paleontology, molecular systematics, genomics, ecology and information technol-

ogy) to study a series of closely related questions. To do this, we will have two formal meetings each year. **Planning Meetings** – small meetings for members of the Management Team and Senior Investigators – will take place in Amherst and by teleconference each August to review progress, finalize the agenda for each year's work and write the annual report (see *Management Plan* for more). We will hold four-day **Annual Meetings** to be attended by all participants and special invitees each January in localities where tetraodontiform diversity is high (e.g., in Year 1, we will meet in Key West Florida). At Annual Meetings, participants will present research papers, discuss and evaluate progress and plan for their next period of work as a group. Such meetings also will provide opportunities for all participants to observe tetraodontiforms in the field as a group (e.g., in Year 1, we will have a special day trip to visit protected reefs at Dry Tortugas National Park), with the goal of helping to knit together this diverse community of scientists. In the final year of the project, we will meet as a group in Arlington Virginia to review all aspects of the project and communicate directly to NSF what we learned about working together as a group. Working in large teams to build consensus is still uncommon in systematics, where limited resources traditionally made single PI's or pairs or relatively small teams the most typical "authorship units" for research investigations and publication. Yet teamwork – and learning to accept inevitable conflicts of interpretation that arise in phylogenetic inquiry – is critical to the success of PBI and other large-scale initiatives in systematic biology. As the science of global biodiversity studies matures, large teams must and will become the norm, not the exception. Thus, we judge it important to explore, document and evaluate processes by which we become a unified team of investigators.

3) The primary habitats where Tetraodontiformes are speciose – such as tropical coral reefs – are at special risk from anthropogenic factors such as global warming, sea level change, overfishing and pollution. Other species live in tropical fresh and brackish water habitats, many of which have so far proved challenging to sample in comprehensive ways (and from which we believe there are still many species of Tetraodontiformes to be discovered). Such habitats are at risk from anthropogenic factors such as logging and associated runoff pollution of waterways to degradation of coastal habitats by expanding human populations. **Thus, a focus on global diversity of Tetraodontiformes is appropriate to the stated goals of the PBI Program to inventory biological diversity in critical habitats as rapidly as possible.**

4) An excellent tradition of morphological systematics provides a tremendous head start on some of the major phylogenetic questions about Tetraodontiformes. Project participants who use morphological characters derived them from studies of the skeleton, soft tissues (e.g., muscles), and larvae. The excellent fossil record of Tetraodontiformes allows us to demonstrate the power and importance of integrated studies of fossil and living taxa using morphological data sets. As explained in Section 1, there are many unresolved questions about the higher relationships of Tetraodontiformes, questions that morphologists on our team can help to answer by an intensive approach to this clade and its putative outgroups. We will benefit from the different perspectives brought by team members, who have experience working on systematics of many different groups of fishes. **Our studies of Tetraodontiformes can provide a model for how to conduct large-scale, comprehensive morphological investigations in systematics.**

5) As noted in Section 1, two of the five vertebrate species with known whole-genomic sequence data are pufferfishes (*Takifugu rubripes* and *Tetraodon nigroviridis*). Molecular and bioinformatics tools already available for these two species qualify Tetraodontiformes as an excellent group for genome-enabled phylogenetic research. Molecular systematic inquiries into evolutionary relationships among Tetraodontiformes are underway in laboratories of several team members using diverse loci. Some (e.g., Miya) focus on mitochondrial genomes, whereas others are concentrating on nuclear genes such as RAG-1 and RAG-2 (Wiley) and sodium channel genes (Jost). Given the momentum of these laboratories, we can realistically expect to sequence at least 15kb per taxon for all of the ~100 extant genera of Tetraodontiformes – a tremendous advance over information presently available for the group. We also hope to be able to use broad patterns of genome organization in Tetraodontiformes – such as major rearrangements of genes – as a source for new phylogenetically informative characters. Such data sets promise not only to yield new phylogenetic insights but also to serve as independent tests for interpretations based on morphology. For example, molecular studies discussed in Section 1 already make it imperative to reexamine the morphology of some outgroups long ignored in studies of higher-group relationships of Tetraodontiformes. If our team of investigators becomes unified in the ways that we hope to achieve during the project, then we have the potential to create dramatic progress in the integration of morphological and molecular data sets. **Even more important, this will allow us to train a generation of students and postdoctoral researchers with strengths in both approaches.**

6) As noted in Section 1, many tetraodontiforms are colorful fishes with intriguing – even bizarre – body shapes. Their fascinating array of functional anatomical specializations for locomotion, feeding, and defense against predators has attracted much attention from leading functional morphologists on our team (e.g., Brainerd, Lauder, Wainwright). Another of our team members, Paul Humann, is world-famous for underwater photography of fishes, so we will be able to illustrate our work with wonderful images of living fishes in nature. These same features make tetraodontiforms excellent subjects for exhibition in public aquaria, where they often are featured in popular reef exhibits. We will work with the New England Aquarium in Boston to develop a special exhibit on global biodiversity of Tetraodontiformes and the PBI initiative. Tetraodontiformes lend themselves to interesting public lectures and to our proposed NOVA Program (the PBS science documentary series). **These tools for informal science education will let us highlight the importance of PBI and the goal of rapidly and comprehensively surveying global biodiversity.**

7) Another strength that flows directly from the size of the group Tetraodontiformes is its suitability for developing and testing **comprehensive** approaches to taxonomic database management and web delivery of taxonomic, biogeographic, stratigraphic, bibliographic, DNA sequence, species identification and other specimen-based information such as morphological character documentation, images, sounds, videos, habitat, population and conservation data. Tetraodontiformes is a large enough group to provide interesting challenges in the development and web-delivery of such information, but small enough that we can expect to produce a comprehensive and useful product at the end of five years. Already, the highly successful, web-delivered "FishBase" gives researchers a practical system for distributing new data by inserting links to each species studied (http://www.fishbase.org). To guarantee immediate dissemination of our research products, we plan to insert and update

FishBase links for tetraodontiforms. However, FishBase does not have the flexibility to integrate all of the data streams that we expect to flow from our tetraodontiform inventory, particularly morphological diagrams with labeling layers. Our goal is to develop the most effective informatics tools for synthesizing data streams from our participants, facilitating communication within our team and producing a comprehensive, integrated and user-friendly database of information on tetraodontiforms. We do not want to duplicate efforts or re-invent wheels, so we shall use existing database and informatics tools, as appropriate, and work with other taxonomic database developers on this aspect of our project. For example, among existing tools, the Manager of Taxonomic Information and Specimens (MANTIS) authored by Piotr Naskreki, MCZ Harvard, shows promise toward comprehensive and flexible database management and web delivery (http://140.247.119.145/Mantis/). MANTIS is internet-ready and comes bundled with a set of customizable HTML pages. To assist with evaluation and development of our informatics tools, a computer scientist with expertise in information retrieval, Bruce Croft, will serve as a Senior Investigator.

Section 3. Objectives – The project has the following specific objectives:

Objective 1. Draw together data from all available cataloged museum specimens worldwide through direct visits by a team member, correspondence with collection personnel, or by searching databases. Convert locality coordinates as needed.

Objective 2. Review and evaluate all type materials, preparing a photograph (and radiograph whenever possible) of each. Construct new diagnoses for all species. As needed, reevaluate alpha-level systematics and describe new species.

Objective 3. Conduct new sampling, targeting poorly-sampled habitats (e.g., freshwaters in south Asia) and taxa for which we still need new tissue samples for molecular phylogenetic work. All newly collected specimens will have complete GPS locality data.

Objective 4. Using data from Objectives 1-3, assemble a range map for each living species, clearly identifying the type locality and linking the map to images of specimens from different localities.

Objective 5. Assemble morphological descriptions. a) **For all species**: photographs (of both living and preserved specimens whenever possible), descriptions, measurements and analyses of external anatomy; b) **For at least one representative of all 100 living genera**: micrographs of scales and teeth; photographs, descriptions and original digital line drawings of complete dry skeletons and/or cleared and double stained skeletons; and photographs, descriptions and original digital line drawings of muscle anatomy; c) wherever possible, photographs and scanning electron micrographs of developmental series; and d) functional anatomical data documented by video clips, special dissections, etc.

Objective 6. Collect and present via GenBank as much new DNA sequence data for the 100 living genera of Tetraodontiformes as possible (e.g., we propose to sequence ~15-20KB of DNA including complete mitogenomes and portions of nuclear genes as RAG1 and RAG2, Cytochrome B, rhodopsin, selected ribosomal genes and developmentally important genes, e.g. *wnt*, *shh* and HOX cluster genes).

Objective 7. Evaluate the hypothesis of tetraodontiform monophyly using molecular and morphological characters. Evaluate competing hypotheses about higher group relationships.

Objective 8. Construct a phylogeny for Tetraodontiformes based on morphological data for all fossil and Recent genera. Construct a new molecular phylogeny of all living genera of Tetraodontiformes. Critically compare congruence of phylogenies based on morphology and molecules; if appropriate, use biogeographic and stratigraphic data to help resolve incongruencies.

Objective 9. Develop our bioinformatics interface to facilitate communication among participants and "go live" as a research product of this project (including links to morphological descriptions in Objective 5).

Objective 10. Develop digital keys to identify all species of fossil and living Tetraodontiformes, linked to photographs, tables of meristic and morphometric data, and auto-updating maps linked to georeferenced specimens in collections.

Objective 11. Develop in conjunction with NOVA a PBS documentary on Tetraodontiformes and how this group is being studied under the auspices of the PBI Program.

Objective 12. Develop and present at the New England Aquarium a public exhibit entitled: "Pufferfishes and Allies – A Planetary Biodiversity Survey."

Section 4. Assembled Expertise and Plans for Its Deployment – This section explains basic aspects of the team we have assembled, management approaches we have developed to meet the 12 Objectives from Section 3, and why we are positioned for success. To do this requires some knowledge of our **Management Plan** and categories of project personnel (details are provided in the five-page supplement). We propose a four-person **Management Team**, composed of PI Bemis, CO-PI Brainerd, a Research Assistant Professor (to be hired for the period of the award; we propose to hire Dr. Ralf Britz) and one Postdoctoral Researcher to serve as Bioinformatics Specialist (person to be determined; to be hired for the period of the award). Bemis will spend 6 months per year on this project, and Brainerd will spend 2 months per year. The Research Assistant Professor and Postdoctoral Researcher will work full time throughout the year on this project. We invited seven other colleagues to serve as **Senior Investigators** for their research expertise, knowledge of tetraodontiforms, and commitment to the project's training objectives. These persons are Bruce Croft, Dave Johnson, Manda Jost, George Lauder, Francesco Santini, Ed Wiley and Rick Winterbottom. Our third category of project personnel is **Project Consultants and Students**, a category that includes a broad array of persons associated with collections and research laboratories in the United States, Canada, England, Australia, and Japan (see Management Plan for complete list of Project Personnel and affiliations). ***All together, our team includes most of the leading authorities in the world on tetraodontiform biology and systematics.*** We also expect to draw other persons into the team during the course of the project period, for this work promises to be an exciting, highly interactive effort that will interest researchers and students.

Our management style is intended to generate conversations and products that will lead to orthogonal, non-traditional solutions. To do this, we seek to allow different ideas to percolate in separate committees, or **Working Groups**, each charged each with specific assignments. Each working group has two co-chairs and a membership of ex-

perts to work together to ensure that the group's charge will be met. Note that some of the 12 Objectives in Section 3 have overlapping importance to different working groups, e.g., Objective 5 (Assemble morphological descriptions) will be of great importance to all Working Groups. Also note that some personnel belong to several Working Groups. The reason for this is to allow cross-fertilization and some degree of competition among groups to generate data and to produce the most elegant solutions to joint problems.

The titles, membership, and tasks charged to the five Working Groups are listed below; note that we expect some membership changes as personnel self-select their own focus within the project and as new persons join us. We also expect the lists of tasks for each working group to be refined and updated annually at the August Planning Meetings. Finally, the fact that a Working Group is tasked with a particular job does not mean that all group members will necessarily engage in all aspects of the day-to-day work to complete that job. Instead, their role is to serve as experts to ensure that the work is completed in the most innovative way possible and to the highest possible standards.

Working Group 1. Alpha Systematics & Biogeography (Bemis & Britz, co-chairs; Cox-Fernandes, Eschmeyer, Forey, Humann, Johnson, Jost, Juanes, Leis, Matsuura, Richmond, Roberts, Thys, Wainwright, Wiley, Winterbottom). Major tasks for this working group are to: 1. Digitize type descriptions for all living and fossil species; 2. Assemble and tabulate global diversity using existing collections; 3. Locate, photograph and x-ray all available holotypes; 4. Verify identifications for specimens held in existing collections; 5. Plot global locality data for each species; 6. Organize new collecting; 6. Construct digital keys to identify all living and fossil species globally (including larval and juvenile stages insofar as possible); 8. Construct and maintain a comprehensive bibliography of scientific literature on Tetraodontiformes; 9. Summarize conservation status for all living species and evaluate reasons for special status (e.g., environmental degradation, restricted habitats, or other threats using new IUCN criteria; see http://www.redlist.org/info/categories_criteria.html); 10. Perform ecological forecasting for selected species or genera using mapping data for taxa and oceanic forecasting models.

Working Group 2. Morphology & Development (Brainerd & Johnson, co-Chairs; Bemis, Britz, Forey, Grande, Hilton, Humann, Matsuura, Johnson, Lauder, Leis, Forey, Hilton, Santini, Wainwright). Major tasks for this working group are to: 1. Provide morphological evidence of monophyly and review all theories of sister group relationships; 2. Review, synthesize and collect new morphological data needed for a generic-level phylogeny including all living and fossil genera; 3. Eplore utility of developmental features as a character source; 4. Establish standards for production of photographs and digital drawings; 5. Integrate studies of functional morphology with phylogenetics. (Note: We recognize that James Tyler (NMNH) is the world's foremost authority on comparative morphology of Tetraodontiformes. We invited him to participate, but he declined, citing many current projects, his impending retirement, and the ability of Francesco Santini to represent their ongoing collaborations on Tetraodontiformes such as Santini & Tyler, submitted).

Working Group 3. Genomics & Molecular Phylogenetics (Wiley & Jost, co-Chairs; Bemis, Benson, Brainerd, Johnson, Karl, Miya, Morse, Normark, Santini, Streelman, Thys). Major tasks for this working group are to: 1. Collect 15–20kb DNA sequence

data from ***at least*** one member of each of the 100 genera and from as many species for which we are able to obtain tissue samples; 2. Examine HOX gene cluster variation among families; 3. Review, synthesize and collect new DNA sequence data needed for a generic-level phylogeny.

Working Group 4. Informatics, (Croft & Britz, co-Chairs; Postdoctoral 1 (to be named), Bemis, Britz, Eschmeyer, Johnson, Jost, Lauder, Morse, Normark, Santini). Major tasks for this working group are: 1. Coordinate plans for linking data to existing search systems (e.g., FishBase, FishNet, GBIF); 2. Design new public interfaces for our web-revision of Tetraodontiformes to allow "virtual monography"; 3. Coordinate ongoing global data collection effort for project with Working Group 1; 4. Partner with Working Group 1 to produce workable digital keys for the web.

Working Group 5. Outreach. (Brainerd & Lauder, co-Chairs; Bemis, Grande, Santini, Thys, Wainwright). Major tasks for this working group are: 1. Negotiate arrangements for and develop special exhibit on tetraodontiforms for New England Aquarium; 2. Coordinate with NOVA on production of public television documentary 3. Coordinate production of the project's monograph "*Tetraodontiform Fishes*,"a 500 page species-by-species summary of the group's global diversity.

Section 5. An Example of a Working Group – To illustrate a working group in action, we will explain how Working Group 1 (Alpha Systematics & Biogeography, Bemis & Britz, co-chairs) will achieve its first three assignments during the first three years of the project. We chose to examine this Working Group and these assignments because they are central to all other aspects of the overall project, especially to our goal of a web-based revision of Tetraodontiformes. Also, a very high percentage of the project's personnel will be members of this working group, which makes it the forum for the practical consensus building needed for overall project success.

The first issue is leadership. Bemis and Britz, based at UMass Amherst for the course of the project, will co-chair Working Group 1. We have dual chairs so that we can share ideas and responsibilities for work and to ensure that a point of contact is present in Amherst at all times in the event of travel or other responsibilities that temporarily affect one of us. Bemis and Britz expect to serve as co-chairs of Working Group 1 through the five years of the project, because stability of group leadership is important.

The second issue is communication among the group's membership. The 16 members of Working Group 1 are at many institutions globally, so we will rely on electronic communication as the most efficient way to exchange information. Our goal is to minimize one-to-one conversations and to maximize participation of all members; such openness of communication is essential to consensus building. This will take place via: http://www.bio.umass.edu/biology/bemis/PBI/Open_communications.htm, which will serve primarily as a link-posting page open to all members. Bemis & Britz will send a monthly newsletter via e-mail to all members of Working Group 1, and archive this record of activities as links on the Open communications page to serve as our "minutes" and to record the history of our progress during the five-years of the project. Others interested in our progress will be welcome to subscribe to the newsletter. In addition to open electronic communication, we will have a face-to-face meeting of the Working

Group each January at our Annual Meeting.

The third issue concerns the credentials, expertise and personalities of the members of the Alpha Systematics & Biogeography Group. For example, Bemis and Britz bring to their co-leadership roles strengths such as expertise with the ICZN, bibliographic skills, ability to work efficiently in a variety of different types of collections, ability to efficiently produce and process digital photographs and x-rays, and skills with an array of digital data (e.g., databases, image files, .pdf files, HTML, etc.). We are fortunate to have as members of Working Group 1 individuals at major institutional collections throughout the world, including Cox-Fernandes (who retains her appointment at Instituto Nacional de Pesquisas da Amazonia in Manaus although she is currently based at UMass Amherst), Eschmeyer (California Academy of Sciences, San Francisco), Forey (Natural History Museum, London), Grande (Field Museum, Chicago), Johnson (United States National Museum, Washington), Lauder (Museum of Comparative Zoology, Cambridge), Leis (The Australian Museum, Sydney), Matsuura (National Science Museum, Tokyo), Wiley (Natural History Museum, University of Kansas, Lawrence) and Winterbottom (Royal Ontario Museum, Toronto). This will facilitate much of the specimen-based study for the project. Also, this is already an excellent network of colleagues in that most members of Working Group 1 have at least one joint publication with another member (and in some cases many members) of the group. There are also several long-term friendships and training relationships among the group's membership. This record bodes well for the growth of a positive "personality" for Working Group 1.

The first assignment for Working Group 1 is to digitize and post on the web the type descriptions for all living and fossil species of Tetraodontiformes. To do this, we will draw upon research libraries at UMass, Harvard, National Museum of Natural History, Field Museum of Natural History and especially the California Academy of Sciences to scan type descriptions for all living and fossil species as Acrobat-compatible .pdf files. The copyright of most scientific publications older than 25 years usually has not been re-issued, so our web re-publication of scans from such works poses few copyright concerns (although we will attempt in all cases to secure explicit written permission to post actual scans of the pages containing original descriptions of taxa). For species descriptions published in the last 25 years, we will work with the copyright holders to establish permission for digital re-publication of needed pages. Success with this requires very high standards, for errors introduced at this level may "ripple" through the project. Thus we will place in charge of this activity a senior participant in the project, Ralf Britz.

The second assignment for Working Group 1 is an effort to which each member of the group will contribute: assemble information on global diversity of Tetraodontiformes using specimens from existing collections. Already, tools availabile for searching networks of collections (e.g., FishNet, http://habanero.nhm.ukans.edu/fishnet/; DEB-9985737, Wiley PI) will facilitate rapid compilation of records for many collection lots. Especially important is our array of participants, who serve as the local authorities on their collection holdings. Whenever possible, Wiley will oversee linking records from additional collections into the FishNet distributed information system. Information summaries for tetraodontiforms will be organized and using the FishNet interface and MANTIS-type tools for managing data records for individual specimens.

For the third assignment, we will locate, photograph (and x-ray, whenever possible) all available holotypes. Such efforts are already underway in some collections (e.g., see http://www.calacademy.org/research/ichthyology/Types/index.html to search for photographs and radiographs of holotypes of fishes at the California Academy of Sciences). This is a comparatively straightforward objective, although it will require travel by Bemis, Britz and others to complete. The fourth assignment, verification of identifications, is one of the most challenging aspects of inventory research. The participation of leading authorities on tetraodontiform subgroups (e.g., Britz, Humann, Leis, Mastsuura, Roberts, Santini, Thys and others) ensures that we will be able to verify identifications of existing specimens as completely as possible. The fifth assignment for Working Group 1 is to plot global locality data for each species. We will do this by linking georeferenced collection records for all verified specimens into the FishNet system. As additional records are linked into FishNet, queries can be conducted using Species Analyst (see http://www.speciesanalyst.net/fishnet/examples.html). Users can then format and visualize the data in GIS programs such as ESRI ArcView or ESRI ArcMap.

Space limitations preclude further discussion of how we will tackle other assignments of Working Group 1, or those of Working Groups 2-5, but we hope that this will be sufficient to give the "flavor" of our approach.

Section 6. Broader Impacts – Our tetraodontiform project will have substantial impacts beyond the scientific value of creating a comprehensive inventory of this fascinating clade of fishes. We expect many undergraduate, graduate and post-doctoral students to work on the project (funds are included in the budget), and they will receive integrated training in morphological, molecular and bioinformatics approaches. It is becoming increasingly clear that inter-institutional and international collaboration are necessary to approach major problems in the life sciences, and participating students as well as our more established researchers will gain experience with the process of large-scale collaboration. We expect to develop web-based tools for facilitating collaboration, and some of these tools may be useful to other collaborative groups. Other web-products delivered by this project, such as range maps and digital keys, will be useful for conservation biologists and policy-makers concerned with maintaining global biodiversity.

The beauty and ease of observing these fishes on shallow coral reefs makes tetraodontiforms ideal for informal science education and also for work toward increasing the participation of students from groups underrepresented in evolutionary biology. To reach the general public, we will develop a public aquarium exhibit and a TV program on Tetraodontiformes. UMass Amherst has excellent programs for recruiting and retaining undergraduates and graduate students from groups underrepresented in the sciences. These include three NSF-funded programs: the Northeast Alliance for Minority Graduate Education and the Professorate, the Lewis Stokes Alliances for Minority Participation and the Undergraduate Mentoring in Environmental Biology (UMEB) Program. A difficulty faced by the UMEB program has been helping students from inner cities relate to issues of conservation and global biodiversity (the Co-PI of this proposal, E.L. Brainerd, Directs the UMEB program). Our UMEB students do, however, express strong interest in marine biology, probably developed from exposure to the beauty of coral reefs and other marine systems through nature programs on TV. Involvement with research on tetraodontiforms would be an excellent way to introduce students from underrepresented groups to careers in ecology, organismal, and evolutionary biology.

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Korsmeyer, K.E., J. F. Steffensen & J. Herskin. 2002. Energetics of median and paired fin swimming, body and caudal fin swimming, and gait transition in parrotfish

(Scarus schlegeli) and triggerfish (Rhinecanthus aculeatus). *Journal of Experimental Biology* 205(9): 1253–1263.
Kottelat, M. & R. Britz, R. 2000. Chaudhuria fusipinnis, n. sp. In: Diagnoses of a new genus and 64 new species of fishes from Laos (Teleostei: Cyprinidae, Balitoridae, Bagridae, Syngnathidae, Chaudhuriidae and Tetraodontidae). M. Kottelat. *Journal of South Asian Natural History* 5: 78–79.
Lamatsch, D. K., C. Steinlein, M. Schmid & M. Schartl. 2000. Noninvasive determination of genome size and ploidy level in fishes by flow cytometry: detection of triploid *Poecilia formosa*. *Cytometry* 39(2): 91–95.
Lauder, G. V. & K. F. Liem. 1983. The evolution and interrelationships of the Actinopterygian fishes. *Bulletin of the Museum of Comparative Zoology* 150(3): 95–197.
Leis, J. M. 1984. Tetraodontiformes: relationships. pp 459–464. In: *Otogeny and Systematics of Fishes*. H. G. Moser, W. J. Richards, D. M. Cohen, M.P. Fahay, A. W. Kendall, Jr. & S. L. Richardson, eds. American Society of Ichthyologistas and Herpetologists, Special Publication 1. Allen Press, Lawrence.
Mallet, J. & K. Willmott. 2003. Taxonomy: Renaissance or Tower of Babel? *Trends in Ecology and Evolution* 18(2): 57–59.
Miya, M ., H. Takeshima, H. Endo, N. B. Ishiguro, J. G. Inoue, T. Mukai, T. P. Satoh, M. Yamaguchi,
A. Kawaguchi, K. Mabuchi, S. M. Shirai & M. Nishida. 2003. Major patterns of higher teleostean phylogenies: a new perspective based on 100 complete mitochondrial DNA sequencers. *Molecular Phylogenetics and Evolution* 26: 110–120.
Mok, H. & H. Chang. 1986. Articulation of the pelvic spine in acanthopterygian fishes, with notes on its phylogenetic implications. *Japanese Journal of Ichthyology* 33: 145–149.
Nelson, J. S. 1994. *Fishes of the World*, 3rd edition. John Wiley & Sons, New York. pp 443–450.
Patterson, C. 1964. A review of Mesozoic acanthopterygian fishes, with special reference to those of the English Chalk. *Philosophical Transactions of The Royal Society London Serial B* 247: 213–482.
Pyle, R. L. 1996. How much coral reef biodiversity are we missing? *Global biodiversity* 6(1): 3–7.
Rosen, D. E. 1973. Interrelationships of higher teleostean fishes. In: *Interrelationships of Fishes*. P. H. Greenwood, R. S. Miles & C. Patterson, eds. Academic Press, London.
Rosen, D. E. 1984. Zeiforms as primitive plectognath fishes. *American Museum Noviates* 2782: 1–45.
Santini, F. & E. J. Stellwag. 2002. Phylogeny, fossils, and model systems in the study of evolutionary developmental biology. *Molecular Phylogenetics and Evolution* 24: 379–383.
Santini, F. & J. C. Tyler. Submitted. A phylogeny of the families of fossil and extant tetraodontiform fishes (Acanthomorpha, Tetraodontiformes), Upper Cretaceous to Recent. *Zoological Journal of the Linnean Society*.
Tyler, J. C. 1968. A monograph on plectognath fishes of the superfamily Triacanthoidea. *Academy of Natural Sciences Philadelphia Monograph* 16. 364 pp.
Tyler, J. C., A. Jerzma´nska, A. F. Bannikov & J. ´Swidnicki. 1993. Two new genera and species of Oligocene spikefishes (Tetraodontiformes: Triacanthodidae), the first

fossils of the Hollardiinae and Triacanthodinae. *Smithsonian Contributions to Paleobiology* 75: vi–27.
Tyler, J. C., B. O'Toole & R. Winterbottom. In press. Phylogeny of the genera and families of zeiform fishes, with comments on their relationships with tetraodontiforms and caproids. *Smithsonian Contributions to Zoology*.
Tyler, J. C. & L. Sorbini. 1996. New superfamily and three new families of tetraodontiform fishes from the upper Cretaceous: the earliest and most morphologically primitive plectognaths. *Smithsonian Contributions to Paleobiology* 83: 1–59.
Wainwright, P. C. & R. G. Turingan. 1993. Coupled versus uncoupled functional systems: motor plasticity in the queen triggerfish, *Balistes vetula*. *Journal of Experimental Biology* 180: 209–227.
Winterbottom, R. 1974. The familial phylogeny of the Tetraodontiformes (Pisces, Acanthopterygii), as evidenced by their comparative myology. *Smithsonian Contributions to Zoology* 155: 201 pp.
Winterbottom, R. & J. C. Tyler. 1983. Phylogenetic relationships of aracanin genera of boxfish (Ostraciidae, Tetraodontiformes). *Copeia* 1983(4): 902–917.

Biographical Sketches of Management Team

William E. Bemis
Elizabeth L. Brainerd
Ralph G. Britz

Biographical Sketch of Dr. William Elliott Bemis

Professional Preparation

Cornell University, Ithaca	Biological Sciences	B.A. 1976
University of Michigan, Ann Arbor	Zoology	M.S. 1978
University of California, Berkeley	Zoology	Ph.D. 1982
University of Chicago, Chicago	NIH Postdoctoral Fellow	1983–1984

Appointments Since 1983

Professor of Biology, University of Massachusetts, Amherst	1998–present
Adjunct Professor of Geosciences, University of Massachusetts, Amherst	2002–present
Founding Director, Massachusetts Museum of Natural History Project	1995–present
Director, Zoological Collections, University of Massachusetts, Amherst	1991–present
Research Associate, Department of Geology, Field Museum of Natural History, Chicago	1988–present
Associate Professor of Zoology, University of Massachusetts, Amherst	1990–1998
Founding Director, Graduate Program in Organismic and Evolutionary Biology, University of Massachusetts, Amherst	1991–1996
Assistant Professor of Zoology, University of Massachusetts, Amherst	1984–1990
Visiting Researcher, Scripps Institute of Oceanography, La Jolla	1990–1991

Five Publications Most Related to this Project

1. Grande, L. & W. E. Bemis. 1998. A Comprehensive Phylogenetic Study of Amiid Fishes (Amiidae) Based on Comparative Skeletal Anatomy. An Empirical Search for Interconnected Patterns of Natural History. Society of Vertebrate Paleontology, Memoir 4. Supplement, Journal of Vertebrate Paleontology 18: i–x, 1–690.
2. Bemis, W. E., E. K. Findeis & L. Grande. 1997. An overview of Acipenseriformes. Environmental Biology of Fishes 48: 25–71.
3. Bemis, W. E. and P. L. Forey. 2000. Occipital structure and the posterior limits of the skull in actinopterygians. pp 41–62. In: Development, Paleontology and Evolution. P. Ahlberg, ed. Taylor and Francis, London.
4. Grande, L. & W. E. Bemis. 1991. Osteology and Phylogenetic Relationships of Fossil and Recent Paddlefishes (Polyodontidae) with Comments on the Interrelationships of Acipenseriformes. Society of Vertebrate Paleontology, Memoir 1. Supplement, Journal of Vertebrate Paleontology 11: i–viii, 1–121.
5. Grande, L., J. Fan, Y. Yabumoto & W. E. Bemis. 2002. †*Protopsephurus liui*, a well-preserved primitive paddlefish (Acipenseriformes: Polyodontidae) from the early Cretaceous of China. Journal of Vertebrate Paleontology 22(2): 209–237.

Five Additional Selected Publications

6. Birstein, V. J., J. R. Waldman & W. E. Bemis, eds. 1997. Sturgeon Biodiversity and Conservation. Kluwer Academic Publishers, Dordrecht. 433 pp + index.
7. Bemis, W. E. & R. G. Northcutt. 1992. Vasculature in the snout of the Australian lungfish and its significance for interpreting the cosmine of Devonian lungfishes. Acta Zoologica 73: 115–139.
8. Liem, K. F., W. E. Bemis, W. F. Walker, Jr. and L. Grande. 2001. Functional Vertebrate Anatomy, 3rd edition. Harcourt College Publishers, Philadelphia. pp 1–703.
9. Bemis, W. E., W. W. Burggren & N. E. Kemp, eds. 1987. The Biology and Evolution of Lungfishes. Alan Liss, NY. pp 1–383. (Simultaneously published as the Centennial Supplement to the Journal of Morphology.)
10. Bemis, W. E. 1984. Paedomorphosis and the evolution of the Dipnoi. Paleobiology 10: 293–307.

Synergistic Activities

1. I have led an annual collecting/training trip to Dauphin Island Sea Lab each July since 1998 to collect and prepare specimens of marine and estuarine fishes from the Northern Gulf of Mexico; we have prepared more than 900 skeletons on these trips for the Ichthyology Collection at the University of Massachusetts, Amherst; these materials are a basis for the research we propose.
2. Since 1995, I have worked to formalize the Massachusetts Museum of Natural History as an umbrella for the seven major systematic collections at the University of Massachusetts. This includes policy formulation, a variety of development and fundraising activities, development of hiring plans and recruitment of new faculty, targeted growth of collections, etc.
3. Since 1984, my major teaching assignments have been: Comparative Anatomy, with lab (7 times, most recently in 2002); Embryology, with lab (8 times, most recently in 1993); and Ichthyology, with lab (13 times, most recently in 2001).
4. I help to write and illustrate textbooks (e.g., Functional Anatomy of Vertebrates, 3rd edition, by Liem, Bemis, Walker & Grande, 2001). I now am preparing a larger text on vertebrate biology that will illustrate anatomical features characteristic of each group.
5. I have many departmental and University-wide service roles, including University Research Council (Chair 2001–2002), Research Library Council (Chair 2002–2003), and Biology Personnel Committee (Chair 2000–present).

Collaborators and Co-Editors

Eugene K. **Balon**, University of Guelph, Ontario; Peter L. **Forey**, NHM, London; Lance **Grande**, FMNH, Chicago; Eric J. **Hilton**, FMNH, Chicago; G. David **Johnson**, NMNH, Washington D.C.; Boyd E. **Kynard**, National Biological Survey, Turners Fall; Karel F. **Liem**, Harvard University, Cambridge; Gareth **Nelson**, AMNH (retired); Bruce **Normark**, University of Massachusetts, Amherst; Andrew **Simons**, University of Minnesota, St. Paul; Warren **Walker**, Jr., Oberlin College (retired)

Graduate and Postdoctoral Advisors

Carl **Gans** (M.S. advisor), University of Michigan (retired); J. T. **Gregory** (Ph.D. reader), University California Berkeley; George V. **Lauder** (Postdoctoral advisor), Harvard University; R. Glenn Northcutt (M.S. guidance), University of California, San Diego; David B. **Wake** (Ph.D. reader), University of California, Berkeley; Marvalee H. **Wake** (Ph.D. advisor), University of California, Berkeley

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 18

Former doctoral students: Dominique **Didier**, Associate Curator of Ichthyology, Academy of Natural Sciences, Philadelphia; Eric K**. Findeis**, no longer working in immediate field; Terry **Grande**, Associate Professor of Biology, Loyola University, Chicago; Eric J. **Hilton**, Postdoctoral Fellow, FMNH, Chicago; Nathan **Kley**, Postdoctoral Fellow, FMNH, Chicago; Bryn **Mader**, Director/Curator, Long Island NHM, Patchogue; Alan **Richmond**, Lecturer in Biology, University of Massachusetts, Amherst; James **Ryan**, Colgate College, Hamilton; Andrew **Simons**, Bell MNH, University of Minnesota, St. Paul; Judith **Shardo**, Assistant Professor of Biology, Middle Tennessee State University, Mufreesboro; Adam **Summers**, Assistant Professor, University of California, Irvine; Howard P. **Whidden**, Assistant Professor, Augustana College, Rock Island, and Research Associate, AMNH, New York

Former master students: James **DuPrie**, no longer working in immediate field; Anne **Everly**, New England Aquarium, Boston; David **Fahey**, no longer working in immediate field; Catherine **Tannert**, no longer working in immediate field

Current graduate students: Kerin **Claeson**, Colin **Little**

Total number of postgraduate scholars: 3

Former postgraduate scholars: Dominique **Didier** (see graduate students)**,** Judith **Shardo** (see graduate students), Andrew **Simons** (see graduate students)

Biographical Sketch of Dr. Elizabeth L. Brainerd

Professional Preparation

Harvard College	Biology	A.B. 1985
Harvard University	Organismic and Evolutionary Biology	Ph.D. 1991
Harvard University	Biomechanics, Postdoctoral Fellowship	1991–1994

Appointments

Director, Interdepartmental Program in Organismic and Evolutionary Biology, University of Massachusetts, Amherst	2002–present
Associate Professor, Department of Biology, University of Massachusetts, Amherst	2000–present
Assistant Professor, Department of Biology, University of Massachusetts, Amherst	1994–2000

Five Publications Most Related to this Project

1. Brainerd, E. L., S. S. Slutz, E. K. Hall & R. Phillis. 2001. Patterns of genome size evolution in tetraodontiform fishes. Evolution 55: 2363–2368.
2. Brainerd, E. L. & S. N. Patek. 1998. Vertebral column morphology, C-start curvature, and the evolution of mechanical defenses in tetraodontiform fishes. Copeia 4: 971–984.
3. Wainwright, P. C., R. G. Turingan & E. L. Brainerd. 1995. Functional morphology of pufferfish inflation: mechanism of the buccal pump. Copeia 3: 614–625.
4. Brainerd, E. L. 1994. Pufferfish inflation: functional morphology of postcranial structures in *Diodon holocanthus* (Tetraodontiformes). Journal of Morphology 220: 243–261.
5. Brainerd, E. L., K. F. Liem & C. T. Samper. 1989. Air ventilation by recoil aspiration in polypterid fishes. Science 246: 1593–1594.

Five Additional Selected Publications

6. Federle, W., E. L. Brainerd, T. A. McMahon & B. Hölldobler. 2001. Biomechanics of the movable pretarsal adhesive organ in ants and bees. Proceedings of the National Academy of Sciences, 98: 6215–6220.
7. Kley, N. J. & E. L. Brainerd. 1999. Mandibular raking: a novel feeding mechanism in snakes. Nature 402: 369–370.
8. Owerkowicz, T., C. Farmer, J. W. Hicks & E. L. Brainerd. 1999. Contribution of gular pumping to lung ventilation in monitor lizards. Science 284: 1661–1663.
9. Brainerd, E. L. 1998. Mechanics of lung ventilation in a larval salamander, *Ambystoma tigrinum.* Journal of Experimental Biology 201: 2891–2901.
10. Summers, A. P., T. J. Koob & E. L. Brainerd. 1998. Stingray jaws strut their stuff. Nature 395: 450–451.

Synergistic Activities

1. NSF CAREER award recipient (1999–2004).
2. Director, NSF Undergraduate Mentoring in Environmental Biology Program at the University of Massachusetts, Amherst (1999–2003). UMEB Mentor for three African-American UMEB Scholars (two in 2001–2002 and one in 2002–2003).
3. Scientific Program Committee Chair, International Congress of Vertebrate Morphology (2004).
4. Chair, Membership Diversity Committee, Society for Integrative and Comparative Biology (2001–present).
5. Chair Elect, Division of Vertebrate Morphology, Society for Integrative and Comparative Biology

Collaborators and Co-Editors

Emanuel **Azizi**, University of Massachusetts, Amherst; Wallace **Bennett**, none; David **Carrier**, University of Utah, Salt Lake City; Kelly **Druzisky**, University of Massachusetts, Amherst; Colleen **Farmer**, University of Utah, Salt Lake City; Walter **Federle**, University of California, Berkeley; Gary **Gillis**, Mt. Holyoke College, South Hadley; Edward **Hall**, University of Minnesota, St. Paul; James **Hicks**, University of California, Irvine; Bert **Hölldobler**, University of Würzburg, Peppering Castle; Nathan J. **Kley**, FMNH, Chicago; Thomas **Koob**, Shriners' Hospital, Tampa; James **O'Reilly**, Miami University; Tomasz **Owerkowicz**, Harvard University, Cambridge; Sheila **Patek**, University of California, Berkeley; Randall **Phillis**, University of Massachusetts, Amherst; Rachel **Simons**, University of South Maine, Portland; Sandra **Slutz**, Stanford University, Stanford; Adam **Summers**, University of California, Irvine

Graduate and Postdoctoral Advisors

Alfred W. **Crompton** (Ph.D. reader), Harvard University; Farish A. **Jenkins** (Ph.D. reader), Harvard University; Karel F. **Liem** (Ph.D. advisor), Harvard University; Thomas A. **McMahon** (Postdoctoral advisor), Harvard University (deceased)

Thesis Advisor and Postdoctoral-Scholars Sponsored

Total number of graduate students: 8

Former doctoral students: Nathan J. **Kley**, Postdoctoral Fellow, FMNH, Chicago; Adam P. **Summers**, Assistant Professor, University of California, Irvine

Former master students: Wallace O. **Bennet**, no longer working in immediate field; Kelly A. **Druzisky**, no longer working in immediate field

Current graduate students: Emanuel **Azizi**, Tobias **Landberg**, Robert **Levine**, Andrea **Ward**

Total number of postgraduate scholars: 3

Former postgraduate scholars: Nathan J. **Kley**, Postdoctoral Fellow, FMNH, Chicago; James C. **O'Reilly**, Assistant Professor, Miami University, Tampa; Rachel S. **Simons**, University of Southern Maine, Portland

Biographical Sketch of Dr. Ralf G. Britz

Professional Preparation

Tübingen University, Germany	Biology	1992
Tübingen University, Germany	Biologiediplom	M.S. 1992
Tübingen University, Germany	Doktorarbeit	Ph.D. 1995
American Museum of Natural History, New York	Postdoctoral Fellow, Ichthyological	1995–1996

Appointments

Visiting Researcher, Division of Fishes, National Museum of Natural History, Smithsonian Institution, Washington D.C.	since April 2002
Research Associate, Ichthyological Department, American Museum of Natural History, New York	1998–present
Assistant Professor, Lehrstuhl für Spezielle Zoologie, Universität Tübingen, Germany, Head of the Department's research aquarium section	1996–present

Five Publications Most Related to this Project

1. Britz, R. & M. Kottelat, M. 1999. *Carinotetraodon imitator*, a new freshwater pufferfish from India (Teleostei: Tetraodontiformes). Journal of South Asian Natural History 4(1): 39–47.
2. Kottelat, M. & R. Britz, R. 2000. *Chaudhuria fusipinnis*, n. sp. In: Diagnoses of a new genus and 64 new species of fishes from Laos (Teleostei: Cyprinidae, Balitoridae, Bagridae, Syngnathidae, Chaudhuriidae and Tetraodontidae). M. Kottelat. Journal of South Asian Natural History 5: 78–79.
3. Britz, R. & G. D. Johnson. 2002. "Paradox Lost": Skeletal ontogeny of *Indostomus paradoxus* and its significance for the phylogenetic relationships of Indostomidae (Teleostei, Gasterosteiformes). American Museum Novitates, 85 ms pages.
4. Britz, R. & S. O. Kullander. In press. Polycentridae—Leaffishes for Cloffsca (Checklist of freshwater fishes of South and Central America. R. Reis, C. Ferraris & S. Kullander, eds. 2 pp.
5. Britz, R. & P. Bartsch. 1998. On the reproduction and early development of *Erpetoichthys calabaricus*, *Polypterus senegalus*, and *P. ornatipinnis* (Actinopterygii: Polypteridae). Ichthyological Explorations of Freshwaters 9(4): 325–334.

Five Additional Selected Publications

6. Britz, R. 2000. Aspects of the reproduction and development of *Indostomus paradoxus* Prashad & Mukerji 1929 (Teleostei, Gasterosteiformes). Ichthyological Explorations of Freshwaters 11: 305–314.
7. Britz, R. & J. Cambray. 2001. Structure of egg surfaces and attachment organs in anabantoids. Ichthyological Explorations of Freshwaters 12: 267–288.
8. Britz, R. 2001. The genus *Betta* - monophyly and intrarelationships, with remarks on the subfamilies Macropodinae and Luciocephalinae. Ichthyological Explorations of Freshwaters 12: 305–318.
9. Britz, R. & G. D. Johnson. In press. On the homology of the posteriormost gill arch in polypterids (Cladistia, Actinopterygii). Zoological Journal of the Linnean Society. 30 ms pp.
10. Britz, R. & M. Kottelat. Submitted. Descriptive osteology of the family Chaudhuriidae (Teleostei, Synbranchiformes, Mastacembeloidei). 100 ms pp, with 100 drawings.

Synergistic Activities

1. Since 1995, I have conducted field work to collect and prepare specimens for museums, zoological reference, or own teaching collection at Dauphin Island, Alabama (1996 & 2000), Myanmar and Malyasia (1996 & 1998).

2. I serve as a referee for international journals (i.e., African Journal of Zoology, Neotropica, , Ichthyological Explorations of Freshwaters, Raffles Bulletin of Zoology, Environmental Biology of Fishes, Zoomorphology, Journal of South Asian Natural History, Aca Zoologica, Annales de Musée Royale, de l'Afrique Centrale, Sciences Zoologiques).
3. I am a referee for the National Research Foundation, Republic of South Africa.
4. Since 1996, I have lectured, taught lab classes, and led excursions in vertebrate anatomy, and the anatomy of basal vertebrates and telosts. In 1998, I gave a seminar for future school teachers to learn how to organize and conduct zoological excursions for elementary and high school students.
5. Since 1991, I have routinely participated in international congresses, workshops, and symposiums.

Collaborators and Co-Editors

G. David **Johnson**, NMNH, Washington D.C.

Graduate and Postdoctoral Advisors

Thesis Advisor and Postdoctoral-Scholars Sponsored

Total number of graduate students: 7

Former doctoral students: T. **Breining**
Former master students: T. **Breining**, M. **Hoffman**, R. **Kerle**, R. **Roesler**, I. **Schunger**
Current graduate students: M. **Hoffman**

Total number of postgraduate scholars: 0

Biographical Sketches of Senior Investigators

W. Bruce Croft
G. David Johnson
Manda Clair Jost
George V. Lauder
Francesco Santini
Edward O. Wiley
Richard Winterbottom

Biographical Sketch of Dr. W. Bruce Croft

Professional Preparation

Monash University, Melbourne, Australia		B.Sc. 1974
Monash University, Melbourne, Australia	Computer Science	M.Sc. 1975
University of Cambridge, Cambridge, England	Computer Science	Ph.D. 1979

Appointments

Chair, Department of Computer Science, University of Massachusetts, Amherst	2001–present
Distinguished Professor, University of Massachusetts, Amherst	2000–present
Professor of Biology, University of Massachusetts, Amherst	1998–present
Director, NSF State/Industry/University Center for Intelligent Information Retrieval (CIIR), University of Massachusetts, Amherst	1992-present
Professor, Computer Science Department, University of Massachusetts, Amherst	1991–2000
Associate Professor, Computer and Information Science Department, University of Massachusetts, Amherst	1985–1991
Digital Artificial Intelligence Chair of Computer Science, University College, Dublin, Ireland (sabbatical leave)	1985–1986
Assistant Professor, Computer and Information Science Department, University of Massachusetts, Amherst	1979–1985

Five Publications Most Related to this Project

1. Ponte, J. & W. B. Croft, 1998. A language modeling approach to information retrieval. Proceedings of ACM Special Interest Group on Information Retrieval 99: 275–281.
2. Lavrenko. V. & W. B. Croft, 2001. Relevance-based language models. Proceedings of Special Interest Group on Information Retrieval 2001, 120–127.
3. Song, F. & W. B. Croft. 1999. A general language model for information retrieval.", Proceedings of the Conference on Information and Knowledge Management (CIKM), pp 316–321.
4. Xu, J. & W. B. Croft. 1999. Cluster-based language models for distributed retrieval. Proceedings of ACM Special Interest Group on Information Retrieval 1999, pp 254–261.
5. Cronen-Townsend, S., Y. Zhou & W. B. Croft. In press. Predicting query performance. Proceedings of ACM Special Interest Group on Information Retrieval 2002.

Five Additional Selected Publications

6. Croft, W. B., ed. 2000. Advances in Information Retrieval: Recent Research from the CIIR. Kluwer Academic Publishers, Boston.
7. Greiff, W., W.B. Croft & H. Turtle. 1999. PIC matrices: a computationally tractable class of probabilistic query operators. ACM Transactions on Information Systems, 17(4): 367–405.
8. Feng, F. F. & W. B. Croft. 2001. Probabilistic techniques for phrase extraction. Information Processing and Management, 37: 199–220.
9. Xu, J. & W. B. Croft. 1998. Corpus-based stemming using co-occurrence of word variants. ACM Transactions on Information Systems, 16(1): 61–81.
10. Croft, W. B., S. Cronen-Townsend & V. Lavrenko. 2001. "Relevance Feedback and Personalization: A Language Modeling Perspective", Joint DELOS-NSF Workshop on Personalization and Recommender Systems in Digital Libraries, Dublin, Ireland.

Synergistic Activities

1. Member, National Research Council Computer Science and Telecommunications Board.
2. Chair, ACM Special Interest Group on Information Retrieval (SIGIR), 1987–1991.
3. Consulting Editor, Kluwer Series on Information Retrieval, 1996–present.
4. Editor-in-Chief, ACM Transactions on Information Systems, 1995–present.

Collaborators and Co-Editors

Nicholas J. **Belkin**, Rutgers University

Graduate and Postdoctoral Advisors

Keith **van Rijsbergen** (Ph.D. advisor), Glasgow University

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 13

Former graduate students: Lisa **Ballesteros**, Assistant Professor, Mt. Holyoke College; E. **Brown**; H. **Fujii**; Warren **Greiff**; David **Haines**, Professor, Bates College; Robert **Krovetz**, Research Experience Scientist, NEC Research Institute; J. **Ponte**; H. **Turtle**; J. **Xu**

Total number of postdoctoral scholars: 7

Former postdoctoral scholars: J. **Allan**, J. **Callan**, J. **Xu**, R. **Manmatha**, M. **Sanderson**

Biographical Sketch of Dr. G. David Johnson

Professional Preparation

University of Texas at Austin		B.A. 1967
Scripps Institution of Oceanography		Ph.D. 1977
National Museum of Natural History	Postdoctoral Fellow	

Appointments

Curator/Research Scientist, Division of Fishes, National Museum of Natural History, Smithsonian Institution,	1984–present
Chairman, Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution	1992–1999
Asst. Marine Scientist, South Carolina Marine Resources Research Institute	1978–1983

Five Publications Most Related to this Project

1. Johnson, G. D. 1993. Percomorph phylogeny: progress and problems. Bulletin of Marine Science 52(1): 3–28.
2. Johnson, G. D. & C. Patterson. 1993. Percomorph phylogeny: a survey of acanthomorphs and a new proposal. Bulletin of Marine Science 52 (1): 554–626.
3. Wiley, E. O., G. D. Johnson & W. Dimmick. 1998. The phylogenetic relationships of lampridiform fishes (Teleostei: Acanthomorpha), based on a total evidence analysis of morphological and molecular data. Molecular Phylogenetics and Evolution 10(3): 417–425.
4. Tang, K. L., P. B. Berendzen, E. O. Wiley, J. F. Morrissey, R. Winterbottom & G. D. Johnson. 1999. The phylogenetic relationships of the Suborder Acanthuroidei (Teleostei: Perciformes) based on morphological and molecular evidence. Molecular Phylogenetics and Evolution 11(3): 415–425.
5. Wiley, E. O., G. D. Johnson & W. W. Dimmick. 2000. The interrelationships of acanthomorph fishes: A total evidence approach using molecular and morphological data. Biochemical Systematics and Ecology 28: 319–350.

Five Additional Selected Publications

6. Johnson, G. D. 1984. Percoidei: development and relationships. pp 464–498. In: Ontogeny and Systematics of Fishes. H. G. Moser et al., eds. Special Publication no. 1, American Society of Ichthyologists and Herpetologists, Allen Press, Lawrence.
7. Johnson, G. D. 1986. Scombroid phylogeny: an alternative hypothesis. Bulletin of Marine Science 39(1): 1–41.
8. Tyler, J. C., G. D. Johnson, I. Nakamura & B. B. Collette. 1989. Morphology of *Luvarus imperialis* (Luvaridae), with a phylogenetic analysis of the Acanthuroidei (Pisces). Smithsonian Contributions to Zoology 485: 1–78.
9. Patterson, C. & G. D. Johnson. 1995. The intermuscular bones and ligaments of teleostean fishes. Smithsonian Contributions to Zoology 559: 1–83.
10. Mooi, R. D. & G. D. Johnson. 1997. Dismantling the Trachinoidei: evidence of a scorpaenoid relationship for the Champsodontidae. Ichthyological Research 44: 143–176.

Synergistic Activities

1. As Chairman of Vertebrate Zoology, I interacted extensively with our Public Programs and Exhibits Department for various exhibits, and was involved in the inception of our Biology Vision 2000 concept for total renovation of biology exhibits at NMNH.
2. I organized and convened Symposium on Phylogeny of Percomorpha (American Society of Ichthyologists and Herpetologists (1990). The proceedings were published in the Bulletin of Marine Science (William D. Anderson co-editor).
3. I was co-convener of the Symposium on Interrelationships of Fishes (American Society of Ichthyologists and Herpetologists (1994). Proceedings were published as *Interrelationships of Fishes* (M. Stiassny & L. Parenti, co-editors).

Collaborators and Co-Editors

P. B. **Berendzen**, University of Minnesota; Ralf **Britz**, University of Tuebingen; Kent E. **Carpenter**, Old Dominion University; Walter **Dimmick,** University of Kansas; Anthony C. **Gill**, The Natural History Museum, London; Jeffrey M. **Leis**, The Australian Museum, Sydney; Randall D. **Mooi**, Milwaukee Public Museum; J. F. **Morrissey**, Hofstra University; Thomas M. **Orrell**, National Museum of Natural History; Lynne R. **Parenti**, National Museum of Natural History; Colin **Patterson** The Natural History Museum, London (deceased); John **Paxton**, The Australian Museum, Sydney; Richard H. **Rosenblatt**, Scripps Institution of Oceanography; Johnson **Seeto**, University of the South Pacific, Fiji; Victor G. Springer, National Museum of Natural History; Melanie L. J. **Stiassny**, American Museum of Natural History; Kevin L. **Tang**, The University of Kansas; Tom **Trnski**, The Australian Museum, Sydney; Betsy B. **Washington**, National Museum of Natural History; Edward O. **Wiley**, The University of Kansas; Richard **Winterbottom**, Royal Ontario Museum

Graduate and Postdoctoral Advisors

Richard H. **Rosenblatt** (graduate advisor), Scripps Institution of Oceanography;
Victor G. **Springer** (postdoctoral sponsor), National Museum of Natural History

Thesis Advisor and Postdoctoral-Scholars Sponsored

Total number of graduate students: 6 (2 doctoral, 4 master)

Total number of postgraduate scholars: 6

Biographical Sketch of Dr. Manda Clair Jost

Professional Preparation

University of Massachusetts, Amherst	Biology	B. S. 1994
	Anthropology	B. A. 1994
	Film Studies, Interdepartmental	Certificate
Harvard University, Cambridge	Biology	M.S. 1999
Harvard University, Cambridge	Biology	Ph.D. 2002

Appointments

Lecturer in Biological Science, University of Texas at Austin	Fall 2002
Teacher/coordinator for 3rd annual Tree of Life Workshop, Harvard Museum of Natural History	2001 & 2002
Research Associate, Boston Harbor Islands intertidal survey, through the New England Aquarium, Boston	2001
Teaching Fellow, Biological Sciences at Harvard University	1996–2000
Scientific and Educational Consultant on the Natural History of Madagascar, for Holosphere Inc., Point Reyes Station	1999–2000

Two Publications Most Related to this Project

1. Jost, M. C. & K. L. Shaw. In preparation. Phylogeny of Ensifera (Hexapoda: Orthoptera) Using Four Molecular Loci, with Implications for the Evolution of Acoustic Communication. [Also presented as an invited speaker at the Systematics Symposium of the International Orthopterists Meetings in Montpellier, France, 2001.]
2. Cameron, S. A. & M. C. Jost. 1998. Correlates of dominance status among queens in a cyclically polygynous Neotropical bumble bee. Insectes Sociaux 45(2), 1998: 135-149 [Also presented as an invited speaker at the AUSSI meetings in Arkansas, 2000.]

Additional Selected Publications

Synergistic Activities

1. Volunteer research associate for the New England Aquarium, Boston, MA (current).
2. Volunteer educator: Adult mentor for "Eyes to the Future" science program for middle-school girls. 1999-2000. Scientific consultant for Boston area science teachers on using evolution and phylogeny in teaching high-school level biology (2000). Visiting scientist/lecturer to elementary and high schools in the Boston Area (1999–2001).
3. Sole coordinator of independent 'Books for Madagascar' project, which sent half a ton of biology books and texts to the University of Madagascar at Antananarivo. Funded by Harvard University Biological Library. 1999-2000.

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students and postgraduate scholars: 0

Biographical Sketch of Dr. George V. Lauder

Professional Preparation

Harvard University, Cambridge	Biology	A.B. 1976
Harvard University, Cambridge	Biology	M.A. 1978
Harvard University, Cambridge	Biology	Ph.D. 1979

Appointments

Professor, Museum of Comparative Zoology, Harvard University, Cambridge 1999–present

Five Publications Most Related to this Project

(recent publications are available in pdf format at www.oeb.harvard.edu/lauder)

1. Drucker, E. G. & G. V. Lauder. 1999. Locomotor forces on a swimming fish: three-dimensional vortex wake dynamics quantified using digital particle image velocimetry. Journal of Experimental Biology 202: 2393–2412.
2. Drucker, E. G. & G. V. Lauder. 2000. A hydrodynamic analysis of fish swimming speed: wake structure and locomotor force in slow and fast labriform swimmers. Journal of Experimental Biology 203: 2379–2393.
3. Lauder, G. V. 2000. Function of the caudal fin during locomotion in fishes: kinematics, flow visualization, and evolutionary patterns. American Zoology 40: 101–122.
4. Wilga, C. D. & G. V. Lauder. 2002. Function of the heterocercal tail in sharks: quantitative wake dynamics during steady horizontal swimming and vertical maneuvering. Journal of Experimental Biology 205: 2365–2374.
5. Drucker, E. G. & G. V. Lauder. 2002. Experimental hydrodynamics of fish locomotion: functional insights from wake visualization. Integrative and Comparative Biology 42: 243–257.

Five Additional Selected Publications

(recent publications are available in pdf format at www.oeb.harvard.edu/lauder)

6. Lauder, G. V. 1994. Homology, form, and function. pp 151–196. In: Homology: the Hierarchical Basis of Comparative Biology. B. Hall, ed. Academic Press, New York.
7. Lauder, G. V. 1996. The argument from design. pp 55–91. In: Adaptation. M. R. Rose & G. V. Lauder, eds. Academic Press, San Diego.
8. Lauder, G. V. 2000. Biomechanics and behavior: analyzing the mechanistic basis of movement from an evolutionary perspective. pp 19–32. In: Biomechanics in Animal Behavior. P. Domenici & R. W. Blake, eds. BIOS Scientific, OXFORD.
9. Drucker, E. G. & G. V. Lauder. 2001. Locomotor function of the dorsal fin in teleost fishes: experimental analysis of wake forces in sunfish. Journal of Experimental Biology 204: 2943–2958.
10. Nauen, J. C. & G. V. Lauder. 2002. Hydrodynamics of caudal fin locomotion by chub mackerel, Scomber japonicus (Scombridae). Journal of Experimental Biology 205: 1709–1724.

Synergistic Activities

1. Development of flow visualization technique (DPIV) from field of fluid engineering for use in studies of organismal form and function. Articles about this approach have appeared in industry trade journals.
2. Advisor on American Museum of Natural History's new Hall of Ocean Life. Provided advice on three display panels showing presenting the physiology of feeding, respiration and locomotion in fishes.
3. Editorial Board, Journal of Experimental Biology, Journal of Morphology, Physiological and Biochemical Zoology.

Collaborators and Co-Editors

David **Beal**, Massachusetts Institute of Technology, Cambridge; Kathy **Dickson**, California State, Fullerton; Eliot **Drucker**, Harvard University, Cambridge; Lara **Ferry-Graham**, University of California, Davis; Ellen **Freund**, Harvard University, Cambridge; Alice **Gibb**, Northern Arizona University, Flagstaff; Gary **Gillis**, Mt. Holyoke College, South Hadley; James **Liao**, Harvard University, Cambridge; Matt **McHenry**, Harvard University, Cambridge; Jennifer **Nauen**, Harvard University, Cambridge; Michael **Triantafyllou**, Massachusetts Institute of Technology, Cambridge; Eric **Tytell**, Harvard University, Cambridge; Peter **Wainwright**, Harvard University, Cambridge; Jeff **Walker**, University of Southern Maine, Portland; Cheryl **Wilga**, University of Rhode Island, Kingston

Graduate and Postdoctoral Advisors

Karel F. **Liem** (graduate advisor), Harvard University

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 12

Former doctoral students: Miriam **Ashley-Ross**; Brian **Clark**; Amy **Cook**; Alice **Gibb**, Northern Arizona University, Flagstaff; Gary **Gillis**, Assistant Professor, Mt. Holyoke College, South Hadley; Lara **Ferry-Graham**, Postdoctoral Researcher, University of California, Davis; Margaret **Rubega**; Peter **Wainwright**, Professor, Harvard University, Cambridge

Former master students: Erin Schmidt

Current graduate students: Tonia **Hsieh**, Jimmy **Liao**, Eric **Tytell**

Total number of postdoctoral-scholars: 10

Former postdoctoral-scholars: William **Bemis**, Professor, University of Massachusetts, Amherst; Julian **Humphries**; Bruce **Jayne**; Steve **Reilly**; Chris **Sanford**; Cheryl **Wilga**, Assistant Professor, University of Rhode Island, Kingston

Current postdoctoral fellows: Eliot **Drucker**, Ellen **Freund**, Matt **McHenry**, Jen **Nauen**

Biographical Sketch of Francesco Santini

Professional Preparation

Universitá di Pisa, Italy	Biological Sciences	Laurea 1997
University of Toronto	Zoology	

Appointments

Doctoral Candidate, University of Toronto	Zoology	1997–present

Five Publications Most Related to this Project

1. Santini, F. & J. C. Tyler. 2002. Phylogeny and biogeography of the extant species of triplespine fishes (Triacanthidae, Tetraodontiformes). Zoologica Scripta 31: 321–330.
2. Tyler, J. C. & F. Santini. 2002. Review and reconstructions of the tetraodontiform fishes from the Eocene of Monte Bolca, Italy, with comments on related Tertiary taxa. Studi e Ricerche sui Giacimenti Terziari di Bolca, Museo Civico di Storia Naturale di Verona 9: 47–119.
3. Santini, F. & J. C. Tyler. 2002. Phylogeny of the ocean sun-fishes (Molidae, Tetraodontiformes), a highly derived group of teleost fishes. Italian Journal of Zoology 69: 37–43.
4. Tyler, J. C. & F. Santini. 2001. A new species of triacanthid fish of the genus Protacanthodes from the Eocene of Monte Bolca, Italy (Tetraodontiformes). Bollettino del Museo Civico di Storia Naturale di Verona (Geologia Paleontologia Preistoria) 25: 3–9.
5. Santini, F. & E. Stellwag. 2002. Phylogeny, fossils and model systems for the study of Hox genes. Molecular Phylogenetics and Evolution 24: 379–383.

Five Additional Selected Publications

6. Santini, F. & J. Tyler. In preparation. A phylogeny of the families of fossil and extant tetraodontiform fishes (Acanthomorpha, Tetraodontiformes), Upper Cretaceous to Recent. Zoological Journal of the Linnean Society.
7. Santini, F. & E. Stellwag. In preparation. Tetraodontiformes as a model system for the study of morphological complexity and vertebrate axial skeleton development. Journal of Experimental Zoology (Molecular Evolution and Development). Invited paper.
8. Santini, F. & S. Scharf. 2001. Pufferfish and “junk” DNA. Rotunda 34(4): 19.
9. Santini, F. 2002. Phylogenies, and the new evolutionary synthesis. In: Determinism, Holism and Complexity. C. Pellegrini, P. Cerrai & P. Freguglia, eds. Kluwer Academic Publishers. In press.
10. Santini, F. & T. Trepanier. 1998. Biodiversità e biologia conservazionistica: l’importanza dello insegnamento di tematiche ambientali nei corsi di scienze naturali. (Biodiversity and Conservation Biology: the Importance of Teaching Environmental Sciences to High School Students) Naturalmente 12(1): 36–40.

Synergistic Activities

1. Teaching Experience: Teaching assistant for BIO150Y "Organisms in their Environment", introductory course on Evolution, Ecology and Animal Behavior, Departments of Zoology and Botany, University of Toronto (1997–present); Teaching assistant for ZOO 382F “Biology of Fishes” (2000). In 2000, completed “Teaching in higher education”, a graduate course offered by the University of Toronto to Ph.D. students in final year of program.
2. Public outreach on behalf of the Royal Ontario Museum: volunteer at the Display organized by the “Centre for Biodiversity and Conservation Biology”, during the "March Break" activity at the Royal Ontario Museum (1998–1999, 2001); volunteer during set up for the displays organized by the Department of Zoology, University of Toronto, during "U of T day" (1998–2000); participant in the "Close Encounters" program at the Royal Ontario Museum, as representative of the “Centre for Biodiversity and Conservation Biology” (1998–2000).

3. Activities within the University of Toronto: Zoology Union of Graduate Students (ZUGS) President (2000–2001); Coordinator of the Royal Ontario Museum/Department of Zoology Phylogeny Discussion Group (1999–2002); Zoology Union of Graduate Students (ZUGS) Director for the Royal Ontario Museum (1999–2000); Coordinator of the Eco-Evo graduate student seminar series (1999); Zoology Union of Graduate Students (ZUGS) Representative on the Library Committee (1998–1999).
4. Reviewer for the following Journals: Interjournal, www.interjournal.org. Reviewer for the area of "Evolutionary Biology". Bollettino del Museo Civico di Storia Naturale di Verona (Geologia Paleontologia Preistoria). Journal of Biogeography.
5. Special Contributions: Organizer of symposium on "Patterns and Processes in the Evolution of Fishes", held in Toronto, January 4th-8th 2003 during the annual meeting of the Society for Integrative and Comparative Biology.

Collaborators and Co-Editors

Sorin-Dorin **Baciu**; Alexandre F. **Bannikov**; James C. **Tyler**, NMNH (Smithsonian), Washington, D.C.; Richard **Winterbottom**, ROM, Toronto

Graduate and Postdoctoral Advisors

Douglas C. **Currie** (Ph.D. advisor), University of Toronto; Harold H. **Harvey** (PhD. advisor), University of Toronto; Donald **Jackson** (Ph.D. advisor), University of Toronto

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students and postdoctoral scholars: 0

Biographical Sketch of Dr. Edward O. Wiley

Professional Preparation

Southwest Texas State College, San Marcos	B.S. 1966
Sam Houston State University, Huntsville	M.S. 1972
The City University of New York, New York	Ph.D. 1976

Appointments

Professor (Asst., Assoc., Full), Department of Systematics and Ecology, and Curator of Fishes, Museum of Natural History, University of Kansas	1976–present
Research Associate, Division of Fishes, National Museum of Natural History, Smithsonian Institution	1976–present

Five Publications Most Related to this Project

1. Wiley, E. O. & R. H. Hagen. 1997. Mitochondrial DNA sequence variation among the sand darters (Percidae: Teleostei). pp 75–96. In: Molecular Evolution of Fishes. T. Kocher & C. Stepien, eds. Academic Press, New York.
2. Wiley, E. O., G. D. Johnson & W. W. Dimmick. 1998. The phylogenetic relationships of lampridiform fishes (Teleostei: Acanthomorpha), based on a total evidence analysis of morphological and molecular data. Molecular Phylogenetics and Evolution 10(3): 417–425.
3. Tang, K. L., P. B. Berendzen, E. O. Wiley, J. F. Morrissey, R. Winterbottom & G. D. Johnson.1999. The phylogenetic relationships of the Suborder Acanthuroidei (Teleostei: Perciformes) based on morphological and molecular evidence. Molecular Phylogenetics and Evolution 11(3): 415–425.
4. Shaw, K., A. Simons & E. O. Wiley. 1999. Reexamination of the phylogenetic relationships of the sand darters (Teleostei: Percidae). Science Papers of the Museum of Natural History University of Kansas No. 12: 1–16.
5. Wiley, E. O., G. D. Johnson & W. W. Dimmick. 2000. The relationships of acanthomorph fishes: A total evidence approach using molecular and morphological data. Biochemical Systematics and Ecology 28: 319–350.

Five Additional Selected Publications

6. Wiley, E. O. 1981. Phylogenetics. The Theory and Practice of Phylogenetic Systematics. Wiley-Interscience, New York. 439pp.
7. Wiley, E. O. & R. L. Mayden. 1985. Species and speciation in phylogenetic systematics, with examples from the North American fish fauna. Annals Missouri Botanical Garden 72: 596–635.
8. Wiley, E. O. 1992. Phylogenetic relationships of the Percidae (Teleostei: Perciformes): A preliminary hypothesis. pp 247–267. In: Systematics, Historical Ecology, and North American Freshwater Fishes. R. L. Mayden, ed. Stanford University Press, Stanford.
9. Wiley, E. O. & R. L. Mayden. 2000. The evolutionary species concept. pp 70–89. In: Species Concepts and Phylogenetic Systematics. Q. D. Wheeler & R. Meier, eds. Columbia University Press, New York.
10. Coleman, K. A. & E. O. Wiley. 2001. On species individualism: A new defense of the species-as-individuals hypothesis. Philosophy of Science 68(4): 498–517.

Synergistic Activities

1. As part of the FishNet project, I am involved in development an integrated system that uses specimen data, environmental coverages, and the genetic algorithm GARP that will allow investigators to predict the niches and biogeographic ranges of freshwater and marine species within a GIS environment. This integration has already proven practical for predicting the possible introduction and subsequent spread of introduced pest species in North America. Our work with the Japanese on bass introductions demonstrates a parallel use for aquatic organisms.

2. I have continued to participate in development of innovative teaching methods at the University of Kansas through participation in curriculum development and introduction of Internet resources into the classroom. Our current project is development of a proposal to enhance the ability of Graduate Teaching Assistants to be more effective in the classroom.

Collaborators and Co-Editors

James S. **Albert**, Florida Museum of Natural History; Henry **Bart**, Tulane University; P. B. **Berendzen**, University of Minnesota; Daniel R. **Brooks**, Toronto University; George H. **Burgess**, Florida Museum of Natural History; Berry **Chernoff**, Field Museum of Natural History; Keith **Coleman**, University of Kansas; Walter **Dimmick**, University of Kansas; William N. **Eschmeyer**, California Academy of Sciences; Bo **Fernholm**, Swedish Museum of Natural History; William L. **Fink**, University of Michigan; John P. **Friel**, Cornell University; Victoria **Funk**, Smithsonian Institution; Karsten **Hartell**, Harvard University; Phillip A. **Hastings**, Scripps; Dean **Hendrickson**, Texas Memorial Museum; Doug **Hoese**, Australian Museum; G. David **Johnson**, Smithsonian Institution; John H. **Lundberg**, Academy of Natural Science; Richard L. **Mayden**, St. Louis University; J. F. **Morrissey**, Hofstra University; Guillermo **Orti**, University of Nebraska; T. W. **Pietsch**, University of Washington; Richard **Pyle**, Bishop Museum; Scott **Schaefer**, American Museum of Natural History; Kate A. **Moots** (ne. Shaw), Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands; Douglas **Siegel-Causey**, Harvard University; Kevin L. **Tang**, University of Kansas; Christine **Thacker**, NHM of Los Angeles County; Anna **Weitzman**, Smithsonian Institution; Richard **Winterbottom**, Royal Ontario Museum

Graduate and Postdoctoral Advisors

Darrell **Hall**, Sam Houston State University (retired); Donn E. **Rosen**, American Museum of Natural History (deceased)

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of former graduate students: 10

Nancy Holcroft **Benson**, Postdoctoral Researcher, University of Kansas; Ping-Fu **Chen**, University of Kansas; Michael **Ghedotti**, Regis University; R. L. **Mayden**, University of Alabama; Tim **Schmidt**, Texas A&M University; Kate Shaw **Moots**, Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands; Kristine **Rhodes**, University of Kansas; Andrew **Simons**, Bell MNH, University of Minnesota; J. D. **Stewart**, NHM of Los Angeles County; Kevin **Tang**, University of Kansas

Total number of postgraduate scholars: 0

Biographical Sketch of Dr. Richard Winterbottom

Professional Preparation

Queen's University, Ontario	Biology	Ph.D. 1971
Smithsonian Institution, Washington, D.C.	Postdoctoral Fellow	1971–1972
National Museum of Natural Sciences, Ottawa	NRC Postdoctoral Fellow	1972–1973

Appointments

Cross-appointed Professor, Department of Zoology, University of Toronto	1990–present
Senior Curator, Centre for Biodiversity & Conservation Biology, Royal Ontario Museum	1984–present
Full Curator, Department of Ichthylology & Herpetology, Royal Ontario Museum	1984–1997

Five Publications Most Related to this Project

1. Winterbottom, R. 1974. The familial phylogeny of the Tetraodontiformes (Pisces, Acanthopterygii), as evidenced by their comparative myology. Smithsonian Contributions to Zoology 155: 201 pp, 184 figs.
2. Winterbottom, R. & J. C. Tyler. 1981. Family Balistidae. FAO Species Identification Sheets, East Central Atlantic, FAO, Rome. 10 pp.
3. Winterbottom, R. & J. C. Tyler. 1983. Phylogenetic relationships of aracanin genera of boxfish (Ostraciidae, Tetraodontiformes). Copeia 4: 902–917, 12 figs.
4. Tyler, J. C., B. O'Toole & R. Winterbottom. In press. Phylogeny of the genera and families of zeiform fishes and their relationships with tetraodontiforms and caproids. Smithsonian Contributions to Zoology. 205 pp, 102 figs, 2 tbls.
5. Tyler, J. C. & R. Winterbottom. 1999. A review of the Oligocene spikefish genera Acanthopleurus and Cryptobalistes (Tetraodontiformes: Triacanthidae). Paläontologische Zeitschrift (Stuttgart), 73(3/4): 351–367.

Five Additional Selected Publications

6. Winterbottom, R. 1974. A descriptive synonomy of the striated muscles of the teleostei. Proceedings of the Academy of Natural Sciences, Philadelphia 125(12): 225–317, 56 figs.
7. Winterbottom, R. 1971. A reinterpretation of the mechanism of extension of the tetraodontid pufferfish postcleithral apparatus, with notes on the oblique eye muscles of the diodontids (Plectognathi). Notulae Naturae 440: 1–7, 3 figs.
8. Tang, K. L., P. B. Berendzen, E. O. Wiley, J. F. Morrisset, R. Winterbottom & G. D. Johnson. 1999. The phylogenetic relationships of the suborder Acanthuroidei (Teleostei: Perciformes) based on molecular and morphological evidence. Molecular Phylogenetics and Evolution 11(3): 415–425.
9. Guiasu, R. C. & R. Winterbottom. 1993. Osteological evidence for the phylogeny of Recent genera of surgeonfishes (Percomorpha, Acanthuridae). Copeia ??: 300–313.
10. Winterbottom, R. 1992. Evolution of Naso thynnoides and the status of N. minor. Japanese Journal of Ichthyology 38(4): 375–378.

Synergistic Activities

1. I have led numerous collecting/training trips, including to Nha Trang, Vietnam, coral reefs and mangroves (2002); Sodwana Bay, South Africa, reefs (2001); northern Vietnam mangroves (2000); Cac-Ba, near Haiphong, Vietnam (1997); to Townesville and Lizard Island, Australia (1994); Phuket, Thailand (1993); Noumea, New Caledonia (1991); Moorea, Society Islands (1989); Seychelles Islands (1989); Comores (1988).
2. Since 1969, I have led/co-led numerous expeditions, including: a 4-week long, 10-person expedition to Dumaguete, Philippines to collect specimens of fishes, plants and invertebrates for the ROM's planned Gallery of Fishes (1987); week-long feasibility study to explore the aquarium fish potential of the Grenadines (1984); an ichthyological expedition to Fiji involving ROM and members of the Canadian Armed Forces to collect ~1 tonne of fish and report on the fisheries of Dravuni (1983). In 1979, I participated in a Joint Services Research Expedition to the Chagos Archipelago, Central Indian Ocean. Some 31,000 specimens were collected, representing about 600 species, including 20 to 40 undescribed species. In 1973/1976, I led six expeditions in South

Africa to build up the Smith Institute's collections of inter- and sub-tidal fishes, determine zoogeographic ranges and transition zones, and pinpoint ecologically dominant species of fish for further study. Areas visited covered most of the South Africa coastline (Cape Point, Tsitsikama, southern Transkei, northern Transkei, Natal, and Kwazulu or Zululand). I accessioned, identified and catalogued all the resulting material. In 1969, I led an expedition to Bimini, Bahamas to collect marine fishes for the National Museum of Canada and the Royal Ontario Museum, and to carry out experiments on acanthurids and tetraodontids.

3. Since 1983, I have served on numerous ROM Committees: Science Advisory for ROM Foundation grant requests (1995–present); Sciences Publications (Chair of Editorial Committee, 2001-present); Life Sciences Publication Series (Editorial Board (1999–present), Senior Editor (1982-1983), Assistant Editor (1979–1982)); Training and Development (Chair, 1999); Merit Review (Chair, 1996–2000); Sciences Co-operative Field Studies (Chair, 1989–1993); Science Representative, Mankind Discovering Gallery (1983–1990); Trustee, Department of Mammalogy (1986–1987, 1991); Natural Sciences Fieldwork Fund (1984–1990); Gallery Review Commission (1986); Science Representative, Gallery Development Orientation Team (1984–1985); ROM Curatorial Association (ROMCA) (Vice-President, 1982–84).
4. At the University of Toronto I teach courses (e.g., undergraduate Ichthyology and graduate-level Speciation) and have served on various committees.
5. Recent professional activities include: Assistant Editor, Indo-Pacific Fishes Series, Bishop Museum, Hawaii (1983–present); Conseil de Redaction, Revue Francaise d'aquariologie (1996–present); Member of the Taskforce on Canadian Biodiversity (1992–1995); General Ichthyology Editor, Copeia (1991–1996); Member of the Board of Governors, American Society of Ichthyologists and Herpetologists (1978–1983, 1987–1992); Associate Editor, Systematic Zoology (1986–1990); Associate Editor, Canadian Journal of Zoology (1984–1987); International Indo-Pacific Fish Conference, Organizing Committee Tokyo, Japan, (1984–1985).

Collaborators and Co-Editors

P. B. **Berendzen**; G. David **Johnson**, NMNH; J. F. **Morrisset**; Francesco **Santini**, University of Toronto; K. L. **Tang**; James **Tyler**, NMNH; Ed O. **Wiley**, University of Kansas

Graduate and Postdoctoral Advisors

A. J. **Keast** (Ph.D. advisor), Queen's University; McAllister

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 19

Former doctoral students: A. **Bok**; Calvin **Borden**; M. S**. Christensen**; G. **Klassen**; R. D. **Moor**; P.H. **Skelton,** Professor, JLB Smith Institute of Ichthyology, Grahamstown, South Africa

Former master students: G. S. Axelrod, G. S. Butler, K. Doyle, C. Godkin, R. Guiasu, W. Holleman, E. Long (withdrew), N. Lovejoy, B. O'Toole, R. Wang

Current graduate students: D. **Halas**, Francesco **Santini**

Total number of postgraduate-scholars sponsored:

Biographical Sketches of Project Consultants and Students

Cristina Cox Fernandes
William N. Eschmeyer
Peter L. Forey
Lance Grande
Eric J. Hilton
Paul H. Humann
Francis Juanes
Stephen A. Karl
Jeffrey M. Leis
Keiichi Matsuura
Masaki Miya
Geoffrey E. Morse
Benjamin B. Normark
Alan M. Richmond
Tyson R. Roberts
Jeffrey Todd Streelman
Tierney Thys
Peter C. Wainwright

Biographical Sketch of Dr. Cristina Cox Fernandes

Professional Preparation

Universidade Gama Filho, Rio de Janeiro	Biology	B.S. 1982
Instituto Nacional de Pesquisas da Amazônia and Fundação Universidade do Amazonas Manaus, Amazonas	Freshwater Biology and Fisheries	M.Sc. 1989
Duke University, Durham	Zoology	Ph.D. 1995

Appointments

Researcher, Coordenação de Pesquisas em Biologia Aquática, Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Brazil	1986–2000
Visiting Scholar, Department of Ecology and Evolutionary Biology, University of Arizona	1998–2000
Adjunct Research Assistant Professor, Biology Department, University of Massachusetts, Amherst	2000–present
Research Associate, University of Massachusetts Museum of Natural History, Amherst	2000–present

Five Publications Most Related to this Project

1. Lundberg, J. G., C. Cox Fernandes, J. S. Albert & M. Garcia 1996. Magosternarchus, a new genus with two new species of electric fishes (Gymnotiformes: Apteronotidae) from the Amazon River Basin, South America. Copeia 3: 657–670.
2. Cox Fernandes, C. 1998. Sex-related morphological variation in two species of Apteronotid fishes (Gymnotiformes) from the Amazon River Basin. Copeia 3: 730–735.
3. Cox Fernandes, C. 1999. Detrended Canonical Correspondence Analysis (DCCA) of the electric fish assemblages in the Amazon. Chapter 3. In: Proceeding of the International Symposium of Biology of Tropical Fishes, A. L. Val & V. M. F. Almeida-Val, eds. INPA, Manaus.
4. Cox Fernandes, C., J. G. Lundberg & C. Riginos, eds. 2002. The largest of all electric-fish snouts: hypermorphic facial growth in male *Apteronotus hasemani*, and comments on the nominal species A. anas (Gymnotiformes: Apteronotidae). Copeia 1: 52–61.
5. Cox-Fernandes, C. & J. Podos. In press. Sobre a descarga do orgão elétrico do sarapó *Apteronotus hasemani* (Gymnotiformes: Apteronotidae). Book chapter: História natural da biota Amazônica. Edited by Renato Cintra, Universidade do Amazonas. pp 180–192.

Five Additional Selected Publications

6. Cox Fernandes, C. & B. de Merona. 1988. Lateral migrations of fish on a floodplain system in the Central Amazon (Careiro Island - Lake Rei), Br. Preliminary analysis. Memoria de la Soc. Cien. Nat. La Salle. Suplemento 2, Vol. XLVII 409–432.
7. Bittencourt, M. M. & C. Cox Fernandes. 1990. Pesca Comercial na Amazônia Central: uma atividade sustentada por peixes migradores. Ciência Hoje 11(64): 20–24.
8. Cox Fernandes, C. & P. Petry. 1991. A importância da várzea no ciclo de vida dos peixes migradores na Amazônia. pp 315–320. In: Bases Científicas para Estratégias de Preservação e Desenvolvimento da Amazônia: Fatos e Perspectivas. A. Val, E. Figliulo and E. Feldberg, eds.
9. Cox Fernandes, C. 1997. Lateral migrations of fishes in Amazon floodplains. Ecology of Freshwater Fish 6: 36–44.
10. Buhrnheim, C. M. & C. Cox Fernandes. 2001. Seasonal variation of fish communities in Amazonian rain forest streams. Ichthyological Exploration of Freshwaters. 12(1): 65–78.

Synergistic Activities

1. I participate in day to day teaching and training of graduate and undergraduate students in the Bemis lab. I will serve on the dissertation committee for Kerin Claeson.
2. I teach courses on an "as needed" basis for the Department of Biology at the University of Massachusetts, Amherst. For example, in Spring 2002, I taught 50% of the general ecology course to undergraduates.
3. I serve as Research Associate of the Ichthyology Collection at the University of Massachusetts and I help to curate and manage materials of freshwater fishes.

Collaborators and Co-Editors

José **Alves-Gomes**, Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Brazil; William **Bassham**, University of Massachusetts, Amherst; Cristina M. **Bürnheim**, University of Amazonas, Manaus, Brazil; Ricardo **Campos da Paz**, Universidade Federal do Rio de Janeiro, Brazil; Kent **Dunlap**, Trinity College, Connecticut; John G. **Lundberg**, Philadelphia Academy of Natural Sciences; Jeffrey **Podos**, University of Massachusetts; Lucia **Rapp Py-Daniel**, Instituto Nacional de Pesquisas da Amazônia (INPA), Manaus, Brazil; Cynthia **Riginos**, Duke University;

Graduate and Postdoctoral Advisors

John G. **Lundberg**, Philadelphia Academy of Natural Sciences

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students and postgraduate scholars: 0

Biographical Sketch of Dr. William N. Eschmeyer

Professional Preparation

University of Michigan	Zoology, Fisheries	B.S. 1961
Ohio State University	Franz T. Stone Biological Lab.	Summer 1961
University of Miami	Marine Sciences, Ichthyology	Ph.D. 1967

Appointments

Senior Curator, Department of Ichthyology, California Academy of Sciences	1983–present
Director of Research, Department of Ichthyology, California Academy of Sciences	1977–1983
Curator (Assistant, Associate, Chief), Department of Ichthyology, California Academy of Sciences	1967–1977

Four Publications Most Related to this Project

1. Eschmeyer, W. 1990. Catalog of the Genera of Recent fishes. Special Publication of the California Academy of Sciences. vi + 697 pp. (some parts with co-authors).
2. Eschmeyer, W. 1990. Genera of Recent fishes and the International commission involving fishes. pp 7–669. In: Catalog of the Genera of Recent Fishes.
3. Eschmeyer, W. 1990. Opinions and other actions of the International Commission involving fishes. pp 671–697. In: Catalog of the Genera of Recent fishes. W. Eschmeyer, B. Weitbrecht & W. F. Smith-Vaniz).
4. Eschmeyer, W., ed. 1998. Catalog of Fishes. Special publication No. 1 of the Center for Biodiversity Research and Information, California Academy of Sciences. 2905 pp + CD [www version appeared in 1997]. Authorship as follows:
   Species of Fishes. W. Eschmeyer, C. J. Ferraris, Jr., M. D. Hoang & D. J. Long. pp 25–1820.
   Genera of Fishes. W. Eschmeyer, with assistance from R. M. Bailey. pp 1821–2174.
   Species in a Classification. W. Eschmeyer. pp 2175–2443.
   Genera in a Classification. W. Eschmeyer. pp 2449–2494.
   Literature Cited. W. Eschmeyer, M. D. Hoang, C. J. Ferraris & D. J. Long. pp 2501–2847.
   Appendix A. Species and genera of fishes and the International Code of Zoological Nomenclature. W. Eschmeyer. pp 2847–2878.
   Appendix B. Opinions and other actions of the International Commission involving fishes. W. Eschmeyer, B. Weitbrecht & William F. Smith-Vaniz. pp 2883–2905.

Five Additional Selected Publications

5. Randall, J. E. & W. N. Eschmeyer. In press. A review of the genus *Scorpaenopsis* (family Scorpaenidae), with description of new species. Indo Pacific Fishes.
6. Eschmeyer, W. N. 1997. A new species of Dactylopteridae (Pisces) from the Philippines and Australia, with a brief synopsis of the family. Bulletin Marine Science 60(3): 727–738.
7. Paxton, J. R. & W. N. Eschmeyer, eds. 1994. Encyclopedia of Fishes. Weldon Owen Pty Limited (marketed now by Academic Press).
8. Eschmeyer, W. N. & E. S. Herald 1983. A field guide to Pacific Coast fishes. Peterson Field Guide Series. Houghton Mifflin Co., Boston. 336 pp, 48 pls.
9. Eschmeyer, W. N. 1965. Western Atlantic scorpionfishes of the genus *Scorpaena*, including four new species. Bulletin Marine Science 15(1): 84–164 (thesis).

Synergistic Activities

1. I am the editor and primary author of the 2905-page, three-volume reference entitled *"Catalog of Fishes."* Ichthyologists generally and some taxonomists in other disciplines are aware of this volume, the associated Internet version, and its incorporation in FishBase. This work treats over 50,000 described species of fishes, their authorship, date, current status of names, 16,000 references, 10,000 genera (first published in 1990), and current references treating the taxa.

2. I am an expert in taxonomic principles and the Code of Zoological nomenclature. I am Vice President of the International Commission of Zoological Nomenclature, and have written an interpretation of the Code.
3. I have worked in many collections worldwide in search of literature and type specimens. I was

given the Gibbs award by the American Society of Icthyologists and Herpetologists in 1999 for "an outstanding body of published work in systematic ichthyology.
4. Tomio Iwamoto and I started the informative "Newsletter of Systematic Ichthyology" in 1978.
5. I have authored and edited popular books.

Collaborators and Co-Editors

C. F. **Ferraris**, Jr., California Academy of Sciences; R. **Froese**, Kiel, Germany; M. D. **Hoang**, California Academy of Sciences; D. J. **Long**, California Academy of Sciences; S. G. **Poss**, no affiliation; J. E. **Randall**, British Museum; S. S. **Shanks**, California Academy of Sciences

Graduate and Postdoctoral Advisors

Thesis Advisor and Postdoctoral-Scholars Sponsored

Total number of graduate students and postgraduate scholars: 0

Biographical Sketch of Dr. Peter Lawrence Forey

Professional Preparation

London University	Botany, Zoology, Geology ancillary	B.Sc. 1967
London University (Queen Elizabeth College)	Vertebrate Paleontology	Ph.D. 1971

Appointments

Researcher, Fossil Fishes (The Natural History Museum) Unified Band 2 (Individual Merit Promotion), London	2001–present
Adjunct Professor, Department of Biology, University of Massachusetts, Amherst	2001–present
Research Associate, Massachusetts Museum of Natural History, Amherst	2001–present

Five Publications Most Related to this Project

1. Forey, P. L. 1973. A revision of elopomorph fishes, fossil and recent. Bulletin of the British Museum (Natural History) (Geology), London. Supplement 10: 1–222.
2. Forey, P. L. 1977. The osteology of *Notelops* Woodward, *Rhacolepis* Agassiz and *Pachyrhizodus* Dixon (Pisces: Teleostei). Bulletin of the British Museum (Natural History) (Geology), London, 28(2): 123–204.
3. Forey, P. L., D. T. J. Littlewood, P. Ritchie & A. Meyer. 1996. Interrelationships of elopomorph fishes. Pp. 175-191. In: Stiassny, M. L. J., L. Parenti & D. Johnson, eds. Interrelationships of Fishes. Academic Press, San Diego.
4. Bemis, W. E. & P. L. Forey. 2000. Occipital structure and the posterior limits of the skull in actinopterygians. pp 350–369. In: Major Events in Early Vertebrate Evolution. P. E. Ahlberg, ed. Paleontology, Phylogeny, Genetics and Development. Systematics Association Special Volume Series 61. Taylor and Francis, London.
5. Cavin, L. C. & P. L. Forey. 2001. Osteology and systematic affinities of *Palaeonotopterus greenwoodi* Forey 1997 (Teleostei: Osteoglossomorpha). Zoological Journal of the Linnean Society 133: 25–52.

Five Additional Selected Publications

6. Forey, P. L. 1988. Golden Jubilee for the coelacanth *Latimeria chalumnae*. Nature, London 336: 727–763.
7. Forey, P. L. & P. Janvier. 1993. Agnathans and the origin of jawed vertebrates. Nature, London 361: 129–134, 4 figures.
8. Forey, P. L. 1998. History of the Coelacanth Fishes. Chapman and Hall, London. pp 1–419.
9. Forey, P. L. & L. Grande. 1998. An African twin to the Brazilian *Calamopleurus* (Actinopterygii: Amiidae). Zoological Journal of the Linnean Society 123: 1–17.
10. Donoghue, P. J., P. L. Forey & R. J. Aldridge. 2000. Conodont affinity and chordate phylogeny. Biological Reviews 75: 191–251.

Synergistic Activities

1. I curate one of the largest collections of fossil fishes in the world and annually host many visitors and students who use the collection.
2. For the last three years, I have traveled to collect fishes with W. E. Bemis, E. J. Hilton and others. Our base is the Dauphin Island Sea Lab, Dauphin Island Alabama, where we build a temporary lab each year and collect hundreds of fishes (more than 80 species in 2001) from the Alabama Deep Sea Fishing Rodeo. This annual field trip has allowed us to sample and array of actinopterygian taxa, which we prepare as skeletons for systematic osteological research and tissues for DNA sequence study. It is this collecting trip and the many interesting observations we have made during our work together that inspired us to plan this new research on actinopterygian phylogeny.

3. Since 1985, my major teaching assignments have been: Cladistics, MSc Taxonomy, Natural History Museum and Imperial College (annually, 1997–present); Vertebrate Paleontology. Imperial College (annually, 1994–present); Vertebrate Zoology. University College (4 lectures annually, 1998–present); Vertebrate Zoology. Cambridge University (2 lectures with labs annually, 1998–present).

Collaborators and Co-Editors

Per E. **Ahlberg**, NHM, London; R. U. **Aldridge**, University of Leicester, Leicester; William E. **Bemis**, University of Massachusetts, Amherst; L. Mus. **Cavin**, Dinosaur; P. U. **Donoghue**, Birmingham; T. **Elliott**, NHM; Richard **Fortey**, NHM, London; Brian **Gardiner**, Kings College, London; Lance **Grande**, FMNH, Chicago; Eric J. **Hilton**, FMNH, Chicago; Christopher **Humphries**, NHM, London; David **Johnson**, NHM (Smithsonian), Washington D.C.; Ian **Kitching**, NHM, London; Ervins **Luksevics**, Latvian MNH; Norman **Macleod**, NHM; Lars **Werdelin**, Swedish MNH; C**. Williams**, NHM; D. **Williams**, NHM, London; I. Latvian **Zupins**, NHM, London

Graduate and Postdoctoral Advisors

Brian **Gardiner** (Ph.D. Supervisor), Kings College, University of London; Humphrey **Greenwood** (Ph.D. Supervisor), The Natural History Museum, London; Colin **Patterson** (Ph.D. Supervisor), The Natural History Museum, London

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of doctoral students: 8

Per **Ahlberg**, NHM, London; L. **Cavin**, Dinosaur; S. **Davis**; J. **Day**; Eric **Hilton**, FMSN, Chicago; J. **Jeffery**; K. **Monsch**; M. **Veran**, Musee National d'Histoire Naturelle, Paris

In addition, I have taught and supervised approximately 100 M.S. students

Biographical Sketch of Dr. Lance Grande

Professional Preparation

Normandale Community College, S. Bloomington	General Business	A.A. 1973
University of Minnesota, St. Paul	Geology	B.S. 1976
University of Minnesota, St. Paul	Geology	M.S. 1979
University of Minnesota, St. Paul	Zoology	M.S. 1979
City University of New York, New York	Biology	M.Ph. 1982
City University of New York and American Museum of Natural History, New York	Evolutionary Biology	Ph.D. 1983

Appointments

Curator, Field Museum of Natural History, Department of Geology, Chicago	1992–present
Associate Curator, Field Museum of Natural History, Department of Geology, Chicago	1988–1992
Assistant Curator, Field Museum of Natural History, Department of Geology, Chicago	1983–1988
Chairman, Scholarship Committee, Field Museum of Natural History, Chicago	1990–present
Chairman, Scientific Advisory Counsel, Field Museum of Natural History, Chicago	1999–Present
Adjunct Professor of Biology, University of Massachusetts, Amherst	1992–present
Adjunct Professor of Biology, University of Illinois at Chicago, Chicago	1991–present
Member, Committee on Evolutionary Biology, University of Chicago, Chicago	1984-present
Research Associate, Department of Vertebrate Paleontology, AMNH, New York	1984–present

Five Publications Most Related to this Project

1. Grande, L. & W. E. Bemis. 1991. Osteology and phylogenetic relationships of fossil and Recent paddlefishes (Polydontidae) with comments on the interrelationships of Acipenseriformes. Society of Vertebrate Paleontology, Memoir 1, Supplement, Journal of Vertebrate Paleontology 11: i–viii, 1–121.
2. Bemis, W. E. & L. Grande. 1992. Early development of the head of the paddlefish, *Polyodon spathula*. General observations and comments on staging. Journal of Morphology 213: 47–83.
3. Grande, L. & W. E. Bemis. 1996. Interrelationships of Acipenseriformes, with comments on "Chondrostei". pp 85–115. In: Interrelationships of Fishes. M. L. J. Stiassny, L. R. Parenti & G. D. Johnson, eds. Academic Press, San Diego.
4. Grande, L. & W. E. Bemis. 1998. A comprehensive phylogenetic study of amiid fishes (Amiidae) based on comparative skeletal anatomy. An empirical search for interconnected patterns of natural history. Society of Vertebrate Paleontology, Memoir 4, Journal of Morphology 18: 1–690.
5. Grande, L., F. Jin, Y. Yabumoto & W. E. Bemis. 2002. †*Protopsephurus liui*, a well-preserved paddlefish (Acipenseriformes: Polyodontidae) from the early Cretaceous of China. Journal of Vertebrate Paleontology 22(2): 209–237.

Five Additional Selected Publications

6. Grande, L. 1985. Recent and fossil clupeomorph fishes with materials for revision of the subgroups of clupeoids. Bulletin of the American Museum of Natural History 181: 231-372.
7. Grande, L. & O. Rieppel, eds. 1994. Interpreting the Hierarchy of Nature: From systematic patterns to evolutionary process theories. Academic Press, San Diego.
8. Grande, L. 1996. Using the extant *Amia calva* to test the monophyly of Mesozoic groups of fishes. pp 181–190. In: Mesozoic Fishes—Systematics and Paleoecology. G. Arratia & G. Viohl, eds. Verlag Pfeil, München.
9. Grande, L & W. E. Bemis. 1999. Historical biogeography and historical paleoecology of Amiidae and other halecomorph fishes. pp 413–424. In: Mesozoic Fishes 2—Systematics and Fossil Record. G. Arratia & H.-P. Schultze, eds. Verlag Pfeil, München.
10. Liem, K. F., W. E. Bemis, W. F. Walker, Jr. & L. Grande. 2001. Functional Vertebrate Anatomy. An evolutionary perspective. 3rd edition. Harcourt College Publishers, Philadelphia. pp 1–703.

Synergistic Activities

1. Since the 1970's, I have lead more than 20 collecting and training trips to the Eocene Green River deposits of Fossil Lake in Southwestern Wyoming collect fossil vertebrates, invertebrates and plants for research teaching and exhibition; students trained on these trips have continued their studies in ichthyology and paleontology.
2. I curate one of the largest collections of fossil fishes in the United States and annually host many visitors and students who use the collection.
3. I am engaged in textbook writing and development (e.g., Liem, Bemis, Grande and Walker, 2001) and regard textbook improvement as a fundamental component of student training.
4. I have designed and supervised the installation of public exhibits related to the evolution of fishes at Fossil Butte National Monument, Field Museum of Natural History, and other institutions.
5. I have taught at the University of Chicago (e.g. Phylogeny of Fishes (1987, 1988), Systematic Ichthyology (1989, 1990), Research at Field Museum (1990, 1994), Evolution and Osteology of Teleost Fishes (1991)) and at the University of Illinois at Chicago (e.g. Biohistory: Ontogeny, Phylogeny and Paleontology (1991, 1993), Systematic Ichthyology (1992), Systematics (1998)).

Collaborators and Co-Editors

William E. **Bemis**, University of Massachusetts, Amherst; Marcelo **Carvalho**, AMNH, New York; Jin **Fan**, Beijing; Peter **Forey**, NHM, London; Terry **Grande**, Loyola University, Chicago; Karel **Liem**, Harvard University, Cambridge; Li **Guo-Qing**, University of Alberta, Edmonton; Eric J. **Hilton**, FMNH, Chicago; John **Maisey**, AMNH, New York; Norbert **Michlich**, Hessian State Museum, Darmstadt; Mario **de Pinna**, Universidade de Sao Paulo; Warren F. **Walker**, Oberlin College (retired); David **Ward**, Kent; Mark V. H. **Wilson**, University of Alberta, Edmonton; Yoshitaka **Yabumoto**, Kitakyushu MNH, Fukuoka

Graduate and Postdoctoral Advisors

Gareth **Nelson** (Ph.D. reader), AMNH (retired); Don **Rosen** (Ph.D. advisor), AMNH (deceased)
Bobb **Schaeffer** (Ph.D. reader), AMNH (retired); C. Lavett **Smith** (Ph.D. reader), AMNH (retired)

Thesis Advisor and Postgraduate-Scholar Sponsor (those in residence not listed)

Total number of former graduate students: 4

Former doctoral students: Jane **Norman;** Kenshu **Shimada**, Visiting Assistant Professor, University of Illinois, Chicago

Former master students: Chris **Fielitz**, Krista **Lee**

Total number of former postdoctoral scholars: 1

Former postdoctoral scholars: Mario **de Pinna**, Universidade de Sao Paulo

Biographical Sketch of Dr. Eric James Hilton

Professional Preparation

University of Massachusetts, Amherst	Wildlife Biology	B.A. 1996
University of Massachusetts Amherst	Organismic & Evolutionary Biology	M.S. 1999
University of Massachusetts, Amherst	Organismic & Evolutionary Biology	Ph.D. 2002
Field Museum of Natural History, Chicago	Postdoctoral Fellow	2002–present

Appointments

Field Museum of Natural History, Chicago	Geology Department Associate	2000–2001

Five Publications Most Related to this Project

1. Hilton, E. J. & W. E. Bemis. 1999. Skeletal variation in shortnose sturgeon (*Acipenser brevirostrum*) from the Connecticut River: Implications for comparative osteological studies of fossil and living fishes. pp 69–94. In: Mesozoic Fishes 2 - Systematics and Fossil Record. G. Arratia & H.-P. Schultze, eds. Verlag Dr. Friedrich Pfeil, München.
2. Hilton, E. J. 2001. The tongue bite apparatus of osteoglossomorph fishes: Variation of a character complex. Copeia 2001(2): 372–382.
3. Hilton, E. J. 2002. Osteology of the extant North American fishes of the genus *Hiodon* Lesueur 1818 (Teleostei: Osteoglossomorpha: Hiodontiformes). New Series, 100: 1–150.
4. Hilton, E. J., L. Grande & W. E. Bemis. In press. Morphology of †*Coccolepis bucklandi* Agassiz 1843 (Actinopterygii) from the Solnhofen lithographic limestone deposits (Late Jurassic, Germany). Mesozoic Fishes 3 – Systematics, Paleoenvironments and Biodiversity. A. Tintori & G. Arratia, eds. Verlag Dr. Friedrich Pfeil, München. 50 manuscript pages, 14 figures, 6 tables. Revised manuscript returned December 14, 2002.
5. Hilton, E. J. 2003. Comparative osteology and phylogenetic systematics of fossil and living bony-tongue fishes (Actinopterygii, Teleostei, Osteoglossomorpha). Zoological Journal of the Linnean Society 137: 1–100.

Additional Selected Publications

6. Hilton, E. J. 2002. Observations on rostral canal bones of two species of *Acipenser* (Actinopterygii, Acipenseriformes). 2002(1): 213–219.
7. Hilton, E. J. 2002. REVIEW OF: Mesozoic Fishes: Systematics and Paleoecology. Copeia 2002( ): 539–542.

Synergistic Activities

1. Since 1998, I have participated in and co-led an annual two-week field trip to the Dauphin Island Sea Lab, Dauphin Island, Alabama, to collect and prepare fish skeletons and tissues for DNA work. Specimens collected during this period provide the core sample for the work proposed in this proposal and will be an essential part of future work in actinopterygian systematics.
2. Since 2001, I served on the Editorial Board for Copeia and have reviewed several manuscripts for Copeia.
3. Since 1996, I have worked to help develop the Massachusetts Museum of Natural History at the University of Massachusetts, Amherst. I have served on the Steering Committee and worked in many capacities to help this effort.
4. Teaching experience: Biology of Marine Vertebrates, Co-instructor (2000); Ichthyology Teaching Assistant (1997, 1999); Comparative Vertebrate Anatomy, Teaching Assistant (1997, 1999); Herpetology, Teaching Assistant (1998); Introductory Biology, Teaching Assistant (1996).

Collaborators and Co-Editors

William E. **Bemis**, University of Massachusetts, Amherst; Peter L. **Forey**, NHM, London; Nathan J. **Kley**, FMNH, Chicago; Lance **Grande**, FMNH, Chicago; Alan M. **Richmond**, University of Massachusetts, Amherst

Graduate and Postdoctoral Advisors

William. E. **Bemis** (graduate advisor), University of Massachusetts, Amherst; Elizabeth. L. **Brainerd** (graduate reader), University of Massachusetts, Amherst; Peter L. **Forey** (graduate reader), MNH, London, Lance **Grande** (graduate reader and postdoctoral advisor), FMNH, Chicago; Boyd E. **Kynard**, National Biological Survey (graduate reader)

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 1

Amande **Fabiano**, Loyola University, Chicago (Terry Grand, major advisor)

Total number of postgraduate scholars: 0

Biographical Sketch of Paul H. Humann

Professional Preparation

Wichita State University, Witchita	Biology	B.A.
Washburn University, Topeka	Law	J.D.

Appointments

Co-owner: New World Publications, Jacksonville	present

Five Publications Most Related to this Project

1. Humann, P. & N. DeLoach. 2002. Reef Fish Identification—Florida, Caribbean, Bahamas, 3rd edition. New World Publications, Jacksonville.
2. Humann, P. & N. DeLoach. 2001. Reef Creature Identification—Florida, Caribbean, Bahamas, 2rd edition. New World Publications, Jacksonville.
3. Humann, P. & N. DeLoach. 2001. Reef Coral Identification—Florida, Caribbean, Bahamas, 2nd edition. New World Publications, Jacksonville.
4. Humann, P. 1994. Reef Fish Identification—Galapagos. 2nd edition in preparation. New World Publications, Jacksonville.
5. Humann, P., H. Hall & N. McDaniel. 1996. Coastal Fish Identification—California to Alaska. New World Publications, Jacksonville.

Five Additional Selected Publications

6. Humann, P. & N. DeLoach. 1995. Snorkeling Guide to Marine Life—Florida, Caribbean, Bahamas. New World Publications, Jacksonville.
7. Humann, P. In preparation. Reef Fish Identification—Tropical Pacific.
8. Humann, P. In preparation. Reef Fish Identification—Baja to Panama.

Synergistic Activities

1. I have photographed and authored over a dozen books on marine life, and written numerous magazine articles on diving.
2. I teach courses in photography of marine life and lead diving expeditions.
3. I created a marine life learning center on the web (www.fishid.com).

Collaborators and Co-Editors

Ned **DeLoach**, Howard **Hall**, Neil **McDaniel**.

Graduate and Postdoctoral Advisors

Not relevant to this field of work.

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students and postdoctoral scholars: 0

Biographical Sketch of Dr. Francis Juanes

Professional Preparation

McGill University, Montreal, Quebec	Biology	B.Sc. 1982
Simon Fraser University, Burnaby, B.C.	Biological Sciences	M.Sc. 1987
State University of New York, Stony Brook	Marine Sciences	Ph.D. 1992
Univeristy of British Columbia, Vancouver	Postdoctoral Fellowship	1992–1993

Appointments

Associate Professor, Department of Natural Resources Conservation, University of Massachusetts, Amherst	1999–present
Associate Professor, Department of Natural Resources Conservation, University of Massachusetts, Amherst	1993–1999

Five Publications Most Related to this Project

1. Scharf, F. S., J. A. Buckel & F. Juanes. 2002. Size-dependent vulnerability of juvenile bay anchovy (Anchoa mitchilli) to bluefish predation: does large body size always provide a refuge? Marine Ecology Progress Series 233: 241–252.
2. Hanrahan, B. & F. Juanes. 2001. Estimating the number of fish in Atlantic bluefin tuna schools using models derived from captive school observations. Fishery Bulletin 99: 420–431.
3. Juanes, F., J. A. Buckel & F. S. Scharf. 2001. Predatory behaviour and selectivity of a primary piscivore: comparing fish and non-fish prey. Marine Ecology Progress Series 217: 157–165.
4. Juanes, F., B. Letcher & G. Gries. 2000. Ecology of stream fish: insights gained from an individual-based approach to juvenile Atlantic salmon. Ecology of Freshwater Fish 9: 65–73.
5. Tupper, M. & F. Juanes. 1999. Effects of a marine reserve on recruitment of grunts (Pisces: Haemulidae) at Barbados, West Indies. Environmental Biology of Fishes 55: 53–63.

Five Additional Selected Publications

6. Juanes, F., J. A. Buckel & F. S. Scharf. 2002. Feeding ecology of piscivorous fishes. Chapter 12, pp267–283. In: The Handbook of Fish and Fisheries: The Biology, Conservation, and Management of Exploited Species, Vol. 1—Biology of Fishes. P. J. B. Hart & J. D. Reynolds, eds. Blackwell Scientific Publications, Oxford.
7. Yako, L., M. Mather & F. Juanes. 2002. Mechanisms for migration of anadromous herring: providing an ecological basis for an effective conservation plan. Ecological Applications 12: 521–534.
8. Nitschke, P., M. Mather & F. Juanes. 2002. Evidence for density-dependent mortality in recruitment of a temperate reef fish, cunner Tautogolabrus adspersus, among similar reefs in the vicinity of an anthropogenic disturbance. Marine Ecology Progress Series 226: 165–178.
9. Juanes, F. 2001. Mediterranean marine protected areas. Trends in Ecology and Evolution 16: 169–170.
10. Martinez, J. L., S. Gephard, F. Juanes, J. Perez & E. Garcia-Vazquez. 2001. Genetic and life history differentiation between donor and derivative population of Atlantic salmon. Transactions of the American Fisheries Society 130: 508–515.

Synergistic Activities

1. Graduate Program Director, Wildlife & Fisheries Conservation Graduate Program.
2. Co-Director, NSF UMEB Program at the University of Massachusetts, Amherst.
3. Admissions Committee member, University of Massachusetts Intercampus Graduate Program in Marine Science.
4. Acting Director, Five College Coastal and Marine Science Program (2003).
5. During my tenure at the University of Massachusetts, I have interacted with undergraduate students in a variety of ways: as a teacher (>1500), as an academic advisor (>150), as the Departmental Honors Coordinator (>20) and as research advisor on Independent Studies (14), Honors Committees (2) and as an Honors thesis chair (2). I have had productive relationships with those students that have worked in my lab. In addition to guiding their research projects and providing career advice, I have helped them apply for research funding (through the Five College Coastal and Marine Sciences Program and the Hudson River Foundation) and present

their research at scientific meetings, and have encouraged them to prepare their results for publication. Most of these students have gone on to careers in biology or graduate school. I consider these undergraduate students full members of my lab with all the expectations and benefits accorded to my graduate students.

Collaborators and Co-Editors

Ben **Letcher,** U.S. Geological Survey; Martha **Mather**, U.S. Geological Survey; Rodney **Rountree**, University of Massachusetts, Dartmouth; Eva **Garcia-Vazquez,** University of Oviedo

Graduate and Postdoctoral Advisors

David **Conover** (Ph.D. advisor), State University of New York, Stony Brook; Brian **Hartwick** (M.S. advisor); Simon Frasier University, Curnaby, B.C.; Carl **Walters** (postdoctoral advisor), University of British Columbia, Vancouver

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 17

Former doctoral students: Dana **Blasco**, Gabe **Gries**, Brian **Hanrahan**, David **Howe**, Rebecca **Jordan**, Peter **MacNeil**, Aly **McKnight**, Paul **Nitschke**, Fred **Scharf**, Lisa **Yako**

Current graduate students: Paul **Clark**, Peter **Clarke**, Chris **Grogan**, John **Manderson**, Mike **Marino**, Gonazlo **Mendez**, Sonia **Rodriguez**

Total number of postgraduate scholars: 4

Former postgraduate scholars: Brad **Blackwell,** Jeff **Buckel**, Karen **Kellogg**, Mark **Tupper**

Biographical Sketch of Dr. Stephen A. Karl

Professional Preparation

Cleveland State University	Biology	Transferred 1979
University of California, Santa Barbara	Marine Biology	B.A. 1981
University of California, Davis CA	Genetics	Transferred 1987
University of Georgia, Athens, GA	Genetics	Ph.D. 1992
Rutgers, Ctr. Theo. Appl. Genetics	Post-Doctoral Fellow	1992–1993

Appointments

Associate Professor, University of South Florida	1999–present
Assistant Professor, University of South Florida	1994–1999
Research Assistant, Hubbs-Sea World Research Institute, San Diego, CA	1983–1986
Field Research Assistant, Marine Review Committee, San Diego, CA	1983–1983
Database Manager, Neushul Mariculture Inc., Santa Barbara, CA	1982–1983

Five Publications Most Related to this Project

1. Streelman, J. T., M. Alfaro, M. W. Westneat, D. R. Bellwood & S. A. Karl. 2002. Evolutionary history of the parrotfishes: biogeography, ecomorphology, and comparative diversity. Evolution 56: 961–971.
2. Schulze, S. R, S. A. Rice, J. L. Simon & S. A. Karl. 2000. Evolution of poecilogony and the biogeography of North American populations of the polychaete, Streblospio. Evolution 54: 1247–1259.
3. Streelman, J. T., R. Zardoya, A. Meyer & S. A. Karl. 1998. Multilocus phylogeny of Cichlid fishes (Pisces: Perciformes): Evolutionary comparison of microsatellite and single-copy nuclear loci. Molecular Biology and Evolution 15: 798–808.
4. Streelman, J. T. & S. A. Karl. 1997. Reconstructing labroid evolution with single-copy nuclear DNA. Proceedings of the Royal Society, London, Series B 264: 1011–1020.
5. Karl, S. A., S. Schutz, D. Desbruyères, R. C. Vrijenhoek & R. Lutz. 1996. Molecular analysis of gene flow in the hydrothermal-vent clam, Calyptogena magnifica. Molecular Marine Biology and Biotechnology 5: 193–202.

Five Additional Selected Publications

6. Karl, S. A. & D. S. Wilson. 2001. Phylogeography and Systematics of the Mud Turtle, Kinosternon baurii. Copeia 101: 797–801.
7. Karl, S. A. & B. W. Bowen. 1999. Evolutionary significant units versus geopolitical taxonomy: Molecular systematics of an endangered sea turtle (genus Chelonia). Conservation Biology. 13: 990–999
8. Hare, M. P., S. A. Karl & J. C. Avise. 1996. Anonymous nuclear DNA markers in the American oyster and their implications for the heterozygote deficiency phenomenon in marine bivalves. Molecular Biology and Evolution 13: 334–345.
9. Zardoya, R., D. M. Vollmer, C. Craddock, J. T. Streelman, S. A. Karl & A. Meyer. 1996. Evolutionary conservation of microsatellite flanking regions and their utility in resolving the phylogeny of cichlid fishes (Pisces: Perciformes). Proceedings of the Royal Society, London, Series B 263: 1611–1618.
10. Karl, S. A. & J. C. Avise. 1992. Balancing selection at allozyme loci in oysters: implications from nuclear RFLPs. Science 256: 100–102.

Synergistic Activities

1. Associate Editor for Evolution, January 2000–December 2003.

2. Reviewer for numerous manuscripts and grants from national and international organizations: National Science Foundation, National Ecological Observatory Workshop, 10–11 March 2000. National Science Foundation Dissertation Improvement Grant Panelist, February 1998. National Science Foundation, Population Biology Grant Panelist, October 17–19 October 2001.

Collaborators and Co-Editors

M. **Alfaro**, University of Chicago, Chicago; D. R. **Bellwood**, James Cook University, Australia B. W. **Bowen**, University of Florida; M. **Cattell**, Unaffiliated, VA; H. **Dewar**, Pfleger Institute of Environmental Research, CA; M. **Garzon**, University of Memphis; N. **Jonoska**, University of South Florida; A. **Meyer**, University of Konstanz, Germany; S. A. **Rice**, University of Tampa, Tampa; M. **Saito**, University of South Florida; S. R. **Schulze**, University of South Florida; J. L. **Simon**, University of South Florida; J. T. **Streelman**, University of New Hampshire; T. **Thys**, Sea Studios, CA; D. M. **Vollmer**, State Universtiy of New York; R. C. **Vrijenhoek**, Monteray Bay Research Institute; M. W. **Westneat**, University of Chicago, Chicago; D. S. **Wilson**, California State University, Chico; R. **Wilson**, California State University, Long Beach; R. **Zardoya**, Museo Nacional de Ciencias Naturales, Spain

Graduate and Postdoctoral Advisors

John C. **Avise** (thesis advisor); Robert C. **Vrijenhoek** (postdoctoral advisor)

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 13

Former doctoral students: M. **Cattell**, Unaffiliated, VA; K. **Jansen**, U. VA, Wise; J. T. **Streelman**, U. New Hampshire

Former master students: M. Roberts, U. South Carolina; S. Schulze, U. Georgia; M. Stone, Unaffiliated

Current graduate students: A. Bass, USF ; C. Curtis, USF; K. Hayes, USF; A. McMillen-Jackson, USF and DEP; E. Severence, USF; T. Swartz, USF; M. Tringalli, USF and DEP

Total number of postgraduate scholars: 1

Biographical Sketch of Dr. Jeffrey Martin Leis

Professional Preparation

University of Arizona	Zoology	B.S. 1971
University of Hawaii	Biological Oceanography	Ph.D. 1978
	NSF Post-graduate Fellowship	1972–1975
Australian Museum, Sydney	Marine Science, Queen's Postdoctoral Fellow	1979–1981

Appointments Since 1980

Principal Research Scientist, Ichthyology, Division of Vertebrate Zoology, Australian Museum, Sydney	1988–present
Scientific Officer, Ichthyology, Division of Vertebrate Zoology, Australian Museum, Sydney	1985–1988
Research Fellow, Ichthyology Department, Australian Museum, Sydney	1984–1985
Research Associate, Ichthyology Department, Australian Museum, Sydney	1980–1983

Five Publications Most Related to this Project

1. Leis, J. M. 1977. Development of the eggs and larvae of the slender mola, Ranzania laevis (Pisces, Molidae). Bulletin of Marine Science 27(3): 448-466.
2. Leis, J. M. 1978. Systematics and zoogeography of the porcupine-fishes (Diodon, Diodontidae, Tetraodontiformes) with comments on egg and larval development. U.S. Fishery Bulletin 76(3): 535-567.
3. Leis, J. M. 1981. Family Diodontidae. In: FAO Species Identification Sheets for Fisheries Purposes: the Eastern Atlantic Ocean. FAO, Rome.
4. Leis, J. M. & J. E. Randall. 1982. Chilomycterus spilostylus, a new species of Indo-Pacific burrfish (Pisces, Tetraodontiformes, Diodontidae). Records of the Australian Museum 34(3): 363–371 and colour plate.
5. Aboussouan, A. & J. M. Leis. 1984. Balistoidei: Development. pp 450–459. In: Ontogeny and Systematics of Fishes. H. G Moser, W. J. Richards, D. M. Cohen, M. P. Fahay, A. W. Kendall & S. L. Richardson, eds. American Society of Ichthyologists and Herpetologists, Special Publication 1.

Five Additional Selected Publications

6. Leis, J. M. 1984a. Family Diodontidae. In: FAO Species Identification Sheets for Fisheries Purposes: The Western Indian Ocean. FAO, Rome.
7. Leis, J. M. 1984b. Tetraodontoidei: Development. pp 447–450. In: FAO Species Identification Sheets for Fisheries Purposes: The Western Indian Ocean. FAO, Rome.
8. Leis, J. M. 1984c. Tetraodontiformes: Relationships. pp 459–464. In: FAO Species Identification Sheets for Fisheries Purposes: The Western Indian Ocean. FAO, Rome.
9. Leis, J. M. 1986. Family Diodontidae. pp 903–907. In: Smith's Sea Fishes. M. M. Smith & P. C. Heemstra, eds. McMillian South Africa, Johannesburg.
10. Leis, J. M. In press. Family Diodontidae. FAO Species Identification Sheets for Fishery Purposes, Western Central Atlantic.

Synergistic Activities

1. Member, New South Wales Minister for Fisheries Advisory Council for Fisheries Conservation (1999–present).
2. Current research focuses on a revision of the fishes of the family Diodontidae on a world-wide basis; and further study of systematics of fish larvae; and the ecology, behavior and distribution of reef fish larvae (study of the distributions of fish larvae around coral reef and coastal systems and how these relate to currents, with the goal of determining the geographical size of population units and strategies of larval dispersal). Recent fieldwork studied larval fish behaviour and distribution along the New South Wales coast (2001–present), Great Barrier Reef, Lizard Island Region and Coral Sea (1979–2001); and Tuamotu Islands and Rangiroa Atoll (1996 & 1998).
3. Since 1969, I have collected adult and larval fish; e.g., Tuamotu Islands (1994), Central coastal Queensland and the far northern Great Barrier Reef and Coral Sea (1993), French Polynesia (1989), Philippines and Southern Japan (1981 & 1985), FNQ cruise from Townsville to Cape York

(1979), Coastal California(1977-1978), Equatorial Pacific (DOMES cruises, 1975–1976), Hawaii (1971–1976), Golfo de California, Mexico (1969–1978).

4. From 1984–2000 I have co-convened/co-chaired numerous workshops and symposium; e.g., mini-symposium on Larval Fish Dispersal and Settlement (9th International Coral Reef Symposium, Bali, October 2000); Symposia on Larval Fish Biology (5th International Indo-Pacific Fish Conference, Noumea, November 1997); Annual Meetings, Australian Society for Fish Biology (Sydney, July 1995); Symposium on the Ecology, Behaviour and Evolution of Larval Fishes (Fourth International Indo-Pacific Fish Conference, Bangkok, November 1993); International Larval Fish Conference (Sydney, June 1995); Symposium on Fish Larvae and Systematics (International Larval Fish Conference, Sydney, June 1995); Workshop on Larval Dispersal and Recruitment (Annual Meeting of the Australian Marine Sciences Association, Townsville, May 1987); Symposium on Ecology and Evolution of Larval Fishes (Second International Conference on Systematics and Evolution of Indo-Pacific Fishes, Tokyo, July 1985); Workshop on Current Topics in Ecology of Coral Reef Fishes (Australian Institute of Marine Science, Townsville, October 1984).
5. I serve as Chair of the Editorial Committee for Records of the Australian Museum (1997–present), and on the Advisory Board for Ichthyological Research (1996–present). I regularly review manuscripts for the Journal of Marine and Freshwater Research, Bulletin of Marine Science, Copeia, Coral Reefs, Deep-Sea Research, Environmental Biology of Fishes, Journal of the Marine Biological Association of the United Kingdom, Ichthyological Research, Marine Biology, Marine Ecology Progress Series, U.S. Fishery Bulletin and other journals. I regularly review grant proposals for the Australian Research Council, U.S. National Science Foundation, and other funding agencies.

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students:

Total number of postgraduate scholars:

Biographical Sketch of Dr. Keiichi Matsuura

Professional Preparation

Tokyo University of Fisheries, Tokyo	Scientific Fisheries	B.A. 1971
Hokkaido University, Hakodate, Hokkaido	Scientific Fisheries	M.S. 1973
Hokkaido University, Hakodate, Hokkaido	Scientific Fisheries	Ph.D. 1978

Appointments

Chief Curator, National Science Museum, Tokyo	1995–present
Associate Professor, University of Tokyo	1994–present
Senior Curator, National Science Museum, Tokyo	1988–1994
Curator, National Science Museum, Tokyo	1979–1987

Five Publications Most Related to this Project

1. Matsuura, K. 2001. Triacanthodidae, pp 3902–3904; Triacanthidae, pp 3905–3910; Balistidae, pp 3911–3928; Ostraciidae, pp 3948–3951; Triodontidae, p 3953; Tetraodontidae, pp 3954–3957. In: *FAO Species Identification Guide for Fishery Purposes*. *The Living Marine Resources of the Western Central Pacific*, Volume 6. Bony Fishes Part 4 (Labridae to Latimeriidae), Estuarine Crocodiles, Sea Turtles, Sea Snakes and Marine Mammals. K. E. Carpenter & V. H. Niem, eds. FAO, Rome.
2. Sagara, T., K. Matsuura, A. Sato & J. Shimura. 2002. Development of a specimen map browser using a robust geo-coding algorithm. *Database Society of Japan Letters* 1: 39–42.
3. Matsuura, K. & H. Senou. 2002. Fish databases in Japan with special reference to fish-image database and its role in biodiversity study. *Res. Rep. Natn. Env. Stud., Japan,* 171: 220–227.
4. Matsuura, K. 2002. A review of two morphologically similar puffers, Chelonodon laticeps and C. patoca. *National Science Museum Monograph*, 22: 175–180.
5. Matsuura, K. & J. C. Tyler. 1995. Triggerfishes and their Allies. pp 227–231. In: *Encyclopedia of Fishes*.. J. R. Paxton & W. N. Eschmeyer, eds. Academic Press, London.

Five Additional Selected Publications

6. Matsuura, K. & J. C. Tyler. 1997. Tetraodontiform fishes, mostly from deep waters, of New Caledonia. Resultats des Campagnes MUSORSTOM, Vol. 17. *Memoires du Museum National D'Histoire Naturelle* 174: 173–208.
7. Matsuura, K. 1994. Arothron caeruleopunctatus, a new puffer from the Indo-western Pacific. *Japanese Journal of Ichhtyology* 41: 29–33.
8. Matsuura, K. 1992. A new sharpnose puffer, Canthigaster punctata (Teleostei: Tetraodontidae), from the Mascaren Submarine Ridge, western Indian Ocean. *Bulletin of the National Science Museum, Tokyo, Serial A* 18: 127–130.
9. Matsuura, K. 1990. The pufferfish genus Fugu Abe, 1952, a junior subjective synonym of Takifugu Abe, 1949. *Bulletin of the National Science Museum, Tokyo, Serial A* 16: 15–20.
10. Matsuura, K. 1979. Phylogeny of the superfamily Balistoidea (Pisces: Tetraodontiformes). *Mem.oirs of the Faculty of Fisheries Hokkaido University* 26: 49–169.

Synergistic Activities

1. Since 1973 I have conducted fieldwork, including the Japan-Vietnam Joint Expedition for Biodiversity Studies of Shallow Water Animals (2001–2002); projects for the Japan Society for Promotion of Science (multilateral project on Sulawesi Island, Malaysia (2001), project on Sulawesi Island, Indonesia (2000), project on Ambon and Seram Islands, Indonesia, (1997–1998), project on Lombok Island, Indonesia (1995-1996)); Japan-China Joint Expedition for Biodiversity Studies of Marine Animals, Hainan Island, China (1996-1997); and Ichthyological Expeditions for the National Science Museum (1983–1995).
2. Since 1982, I have served as editor for scientific journals, including *Ichthyological Research* (Editor-in-chief, 1992–1997) and the *Japanese Journal of Ichthyology* (Editor, 1982–1987).

3. I hold leadership positions in professional societies, including the Ichthyological Society of Japan (President, 2002; President-elect, 2000–2001) and the Union of Japanese Societies for Systematic Biology (Vice president, 2002).
4. I am a member of the Global Biodiversity Information Facility (NODES Committee and Science Sub-committee "Digitization of Natural History Collections (2002)) and the 5th Indo-Pacific Fish Conference Scientific Committee (1995–present).

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Thesis Advisor and Postgraduate-Scholar Sponsor

Biographical Sketch of Dr. Masaki Miya

Professional Preparation

Tokai University	Oceanography	B.S. 1982
University of Tokyo	Fisheries Sciences	M.S. 1984
University of Tokyo	Fisheries Sciences	Ph.D. 1987

Appointments

Senior Research Scientist, Dept of Zoology, Natural History Museum & Institute, Chiba	1998–present
Adjunct Professor, Graduate School of Natural Sciences, Chiba University	1997–present
Research Scientist, Dept of Zoology, Natural History Museum & Institute, Chiba	1987–1998

Five Publications Most Related to this Project

1. Inoue, J. G., M. Miya, K. Tsukamoto & M. Nishida. 2001. A mitogenomic perspective on the basal teleostean phylogeny: Resolving higher-level relationships with longer DNA sequences. *Molecular Phylogenetics and Evolution*, 20(2): 275–285.
2. Miya, M., A. Kawaguchi & M. Nishida. 2001. Mitogenomic exploration of higher teleostean phylogenies: A case study for moderate-scale evolutionary genomics with 38 newly-determined complete mitochondrial DNA sequences. *Molecular Biology and Evolution*, 18(11): 1993–2009.
3. Miya, M., H. Takeshima, H. Endo, N. B. Ishiguro, J. G. Inoue, T. Mukai, T. P. Satoh, M. Yamaguchi, A. Kawaguchi, K. Mabuchi, S. M. Shirai & M. Nishida. 2003. Major Patterns of higher teleostean phylogenies: A new perspective based on 100 complete mitochondrial DNA sequences. Molecular Phylogenetics and Evolution, 26(1): 121–138.
4. Ishiguro, N., M. Miya & M. Nishida. 2003. Basal euteleostean relationships: A mitogenomic perspective on the phylogenetic reality of the "Protacanthopterygii." Molecular Phylogenetics and Evolution. (In press).
5. Saitoh, K., M. Miya, J. G. Inoue, N. B. Ishiguro & M. Nishida. 2003. Mitochondrial genomics of ostariophysan fish: Perspectives on phylogeny and biogeography. *Journal of Molecular Evolution* (In press).

Five Additional Selected Publications

6. Miya, M. & M. Nishida. 1997. Speciation in the open ocean. Nature, 389: 803–804.
7. Yamaguchi, M., M. Miya, M. Okiyama & M. Nishida. 2000. Molecular phylogeny and larval morphological diversity of the lanternfish genus Hygophum (Teleostei: Myctophidae). Molecular Phylogenetics and Evolution, 15(1): 103–114.
8. Miya, M. & M. Nishida. 2000. Use of mitogenomic information in teleostean molecular phylogenetics: A tree-based exploration under the maximum-parsimony optimality criterion. Molecular Phylogenetics and Evolution, 17(3): 437–455.
9. Kawaguchi, A., M. Miya & M. Nishida. 2001. Complete mitochondrial DNA sequence of Aulopus japonicus (Teleostei: Aulopiformes), a basal Eurypterygii: Longer DNA sequences and the higher-level relationships. Ichthyological Research, 48(3): 213–223.
10. Ogiwara, I., M. Miya, K. Ohshima & N. Okada. 2002. V-SINEs: A new superfamily of vertebrate SINEs that are widespread in vertebrate genomes and retain a strongly conserved segment within each repetitive unit. Genome Research, 12(2): 316–324.

Synergistic Activities

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Thesis Advisor and Postdoctoral-Scholars Sponsored

Biographical Sketch of Geoffrey E. Morse

Professional Preparation

Carleton College, Northfield	Biology	B. A. 1992
Harvard University, Amherst	Organismic and Evolutionary Biology	Ph.D. 2003
University of Massachusetts, Amherst	Organismic and Evolutionary Biology	2002–present

Appointments

ALAS Coordinator (Arthropods at La Selva, Costa Rica) for Bruchinae	2000–present

Five Publications Most Related to this Project

1. Morse, G. E. & B. D. Farrell. 2001. The comparative population structure of sister species of Acacia seed beetles. Proceedings of the Annual Meeting of the Society for the Study of Evolution, Knoxville (awarded Ernst Mayr Prize for top paper in student competition).
2. Morse, G. E. 2001. Ecological and evolutionary diversification in the seed beetles. Seminar given at Entomology Department Seminar Series, University of Massachusetts, Amherst.
3. Morse, G. E. & B. D. Farrell. 2000. Speciation and host plant specialization in Acacia seed beetles. Proceedings of the Annual Meeting of the Entomological Society of America, Montreal (awarded President's Prize for top paper in student competition).
4. Morse, G. E. & B. D. Farrell. 1999. Diversification and the evolution of diet breadth in the seed beetle genus Stator. Proceedings of the Annual Meeting of the Society for the Study of Evolution, Bloomington.
5. Morse, G. E. & B. D. Farrell. 1999. Diversification and the macroevolution of host affiliation in seed beetles (Coleoptera: Bruchidae): Insights from molecular systematics. Proceedings of the Annual Meeting of the Entomological Society of America, Atlanta.

Five Additional Selected Publications

6. Morse, G. E. & B. D. Farrell. 2001. Evolución de interacciones ecológicas entre los brúquidos (Coleoptera: Chrysomelidae: Bruchinae) y sus plantas huespedes: una perspectiva cladística. Paper delivered at invited symposium at the III Reunión Argentina de Cladística y Biogeografía, Mendoza, Argentina.
7. Morse, G. E. & B. D. Farrell. 1997. The molecular phylogenetics of the Bruchidae. Proceedings of the Annual Meeting of the Entomological Society of America, Nashville.
8. Morse, G. E., C. D. Johnson & B. D. Farrell. 1997. The evolution of host use in the seed beetle group Stator. Proceedings of the Annual Meeting of the Society for the Study of Evolution.
9. Kitching, R. L., H. Mitchell, G. Morse & C. Thebaud. 1997. Determinants of species richness in assemblages of canopy arthropods in rainforests. In: *Terrestrial Invertebrates of Tree Canopies*. N. Stork & J. Adis, eds. Chapman & Hall, London.
10. Messina, F. J., S. L. Gardner, & G.E. Morse. 1991. Host-discrimination by egg-laying beetles: Causes of population differences. *Animal Behaviour* 41: 773–779.

Synergistic Activities

1. My primary synergistic activities have been in developing professional and academic contacts throughout Latin America during the course of my fieldwork. hese have evolved into close collaborations with Dr. Jesús Romero Nápoles of the Colegio de Postgraduados in Montecillo, México, with Dra. Susana Muruaga de L'Argentier of the Universidad Nacional de Jujuy in Argentina, with Dr. Arturo L. Terán of the Instituto Miguel Lillo in Tucumán, Argentina, with the Smithsonian Tropical Research Institute and Dr. Donald Windsor in Panama, with INBIO in Costa Rica as the ALAS coordinator of the Bruchidae, with Catherine Duckett of the Universidad de Puerto Rico, Rio Piedras, San Jose, with Dr. Guido Perreira and Dr. José Clavijo Albertos of the Universidad Central de Venezuela in Caracas, Venezuela, and with the Universidad Politecnica de Quito, Ecuador. This has included giving an invited talk, completely in Spanish, at a scientific symposium in Mendoza, Argentina.
2. Throughout all of this I have developed a comprehensive database of the bruchid seed beetles, including a thorough inventory of literature, published specimen records, museum specimen records, typological information, ecological information, keys, descriptions, illustrations, and

photographs. I have shared the information from this database extensively with many of the people listed above, as well as with biological information databases associated with INBIO in Costa Rica, STRI in Panama, and UNAM in Mexico. In addition, this database is currently being prepared for web publication so that this bioinformatic data will be available to a general audience.

3. Other synergistic activities include a love of teaching, for which I won multiple awards during my tenure as a graduate student at Harvard University; the curation and databasing of one of the largest private Coleoptera collections in the United States, owned by David Rockefeller; two terms as president of the oldest entomological club in the United States, the Cambridge Entomological Club; and student organizer of the seminar series of the Department of Organismic and Evolutionary Biology at Harvard University.

Collaborators and Co-Editors

C. Dan **Johnson**, Northern Arizona University; Dr. Susana **Muruaga de L'Argentier**, Universidad Nacional de Jujuy, Jujuy, Argentina; Jesús Romero **Nápoles**, Universidad de Postgraduados, Montecillo, Mexico; Donald **Windsor**, Smithsonian Tropical Research Institute, Panama

Graduate and Postdoctoral Advisors

Brian **Farrell** (Ph.D. advisor), Harvard University, Cambridge; Benjamin **Normark** (Postdoctoral advisor); University of Massachusetts, Amherst; Naomi **Pierce** (Ph.D. reader), Harvard University, Cambridge; John **Wakeley** (Ph.D. reader), Harvard University, Cambridge

Thesis Advisor and Postgraduate-Scholar Sponsor

Biographical Sketch of Dr. Benjamin Bo Normark

Professional Preparation

Yale University, New Haven	Linguistics	B.A. 1985
Cornell University, Ithaca	Ecology and Evolutionary Biology	Ph.D. 1994
University of Arizona, Tucson	Molecular Evolution, Sloan Fellow	1994–1996
Natural History Museum, London	NSF International Research Fellow	1996–1997
Museum of Comparative Zoology, Harvard University, Cambridge	Postdoctoral Fellow	1997–2000

Appointments

Professor of Biology, University of Massachusetts, Amherst	1998–present
Assistant Professor of Entomology, University of Massachusetts, Amherst	August 2000

Five Publications Most Related to this Project

1. Normark, B. B., A. R. McCune & R. G. Harrison. 1991. Phylogenetic relationships of neopterygian fishes, inferred from mitochondrial DNA sequences. Molecular Biology and Evolution 8: 819–834.
2. Normark, B. B. & A. A. Lanteri. 1998. Incongruence between morphological and mitochondrial-DNA characters suggests hybrid origins of parthenogenetic weevil lineages (genus Aramigus). Systematic Biology 47: 475–494.
3. Normark, B. B., B. H. Jordal & B. D. Farrell. 1999. Origin of a haplodiploid beetle lineage. Proceedings of the Royal Society of London, Series B: Biological Sciences 266: 2253–2259.
4. Normark, B. B. 2000. Molecular systematics and evolution of the aphid family Lachnidae. Molecular Phylogenetics and Evolution 14(1): 131–140.
5. Farrell, B. D., A. S. Sequeira, B. O'Meara, B. B. Normark, J. H. Chung & B. H. Jordal. 2001. The evolution of agriculture in beetles (Curculionidae: Scolytinae and Platypodinae). Evolution 55: 2011–2027.

Five Additional Selected Publications

6. Normark, B. B. & N. A. Moran. 2000. Testing for the accumulation of deleterious mutations in asexual eukaryote genomes using molecular sequences. Journal of Natural History 34: 1719–1729.
7. Judson, O. P. & B. B. Normark. 2000. Sinless originals. Science 288: 1185–1186.
8. Normark, B. B. 1999. Evolution in a putatively ancient asexual lineage: recombination and rapid karyotype change. Evolution 53: 1458–1469.
9. Normark, B. B. 1996. The evolution of parthenogenesis in the Aramigus tessellatus species complex (Coleoptera: Curculionidae): Evidence from mitochondrial DNA sequences. Evolution 50: 734–745.
10. Judson, O. P. & B. B. Normark. 1996. Ancient asexual scandals. Trends in Ecology and Evolution 11: 41–46.

Synergistic Activities

1. I was the first member of R. G. Harrison's lab group at Cornell to adopt PCR and DNA sequencing, in 1989; we designed some of the first PCR primers for insect mitochondrial DNA, and always gave away our primers and primer sequences freely to colleagues. Hence, these primers have become work-horses of insect molecular systematics worldwide (see C. Simon et al., 1994, Annuals of the Entomological Society of America 87: 651-701; Caterino et al., 2000, Annual Review Entomology 45: 1-54).
2. Curator, Entomology Museum, University of Massachusetts, Amherst. I am in the process of reviving a significant regional insect collection that has been dormant for decades; I have obtained from my department $5000/year for maintenance and improvement of the collection. In conjunction with an insect systematics course, I have students working to preserve the collection against dermestids, sort and integrate new material, and compile a computer database of holdings, which will eventually be available on the web.
3. Member, Steering Committee, Massachusetts Museum of Natural History. Under the leadership of W. Bemis, we are working towards the establishment of a major new museum of natural history to be based in western Massachusetts. We are raising funds (several million dollars so far)

and are integrating the management of several diverse collections across the University of Massachusetts.

4. Development of database of insect genetic system diversity. I have been invited to contribute a review to the Annual Review of Entomology for 2003, to be entitled 'Phylogeny and evolution of alternative genetic systems in insects,' and have begun compiling the relevant literature into a database. For obligate parthenogenesis alone, there are probably thousands of reports for different species scattered across the cytogenetic, ecological, taxonomic, and agricultural literatures, which have never been enumerated or integrated into a single bibliographic reference. I will post it on the web as an appendix to my review, and will continue to update it. I expect it to become the global clearinghouse for information on alternative reproductive systems in insects.
5. Development of molecular methods of armored scale identification. The remarkable reduced morphology of scale insects will always be a fascinating subject of study in its own right. However, given the labor involved in preparing taxonomically useful slide-mounts of scales, and the decreasing difficulty and cost of DNA sequencing, it may soon become practical to identify scales by their DNA. I have obtained a USDA Hatch grant to develop collections of frozen specimens and DNA, and to develop databases of diagnostic sequences for a wide range of armored scale insects, with an eye to molecular identification, as well as to produce data for molecular-systematic studies.

Collaborators and Co-Editors

R. L. **Blackman**, Natural History Museum, London; H. R. **Braig**, University of Wales, Bangor,; J. H. **Chung**, Harvard University, Cambridge; L. **Claps**, Instituto Miguel Lillo, Tucuman, Argentina; B. D. **Farrell**, Harvard University, Cambridge; T. **Fukatsu**, National Institute of Bioscience and Human-Technology, Tsukuba, Japan; P. J. **Gullan**, University of California, Davis; B. H. **Jordal**, University of Bergen, Bergen, Norway; O. P. **Judson**, Universite Montpellier, Montpellier, France; A. A. **Lanteri**, Museo de La Plata, La Plata, Argentina; D. R. **Miller**, USDA, Beltsville; N. A. **Moran**, University of Arizona, Tucson; B. **O'Meara**, Harvard University, Cambridge; A. S. **Sequeira**, Harvard University, Cambridge; J. M. **Spence**, Natural History Museum, London; R. **Stouthamer**, University of California, Riverside; B. **Turner**, King's College, London; R. **Van Driesche**, University of Massachusetts, Amherst

Graduate and Postdoctoral Advisors

Richard G. **Harrison**, Chair, Department of Ecology and Evolutionary Biology, Cornell University

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 3

Former graduate students: M. E. **Gruwell**, L. M. **Provencher**, B. **Sello**

Total number of postdoctoral-scholars: 0

Biographical Sketch of Dr. Alan M. Richmond

Professional Preparation

University of Massachusetts, Amherst	Zoology	B.S. 1987
University of Massachusetts, Amherst	Forestry & Wildlife Management	M.S. 1990
University of Massachusetts, Amherst	Biology	M.S. 1995
University of Massachusetts, Amherst	Biology	Ph.D. 1999

Appointments

Lecturer, Biology Department, University of Massachusetts, Amherst	1995–present
Curator, Herpetology, Biology Department, University of Massachusetts, Amherst	1984–present
Proprietor, Alan M. Richmond, Environmental Consulting.	

Five Publications Most Related to this Project

1. Richmond, A. M., 1997. A catalogue of turtles of northeastern North America with State, Federal, I.U.C.N., and Cites assignations. pp viii–ix. In: Status and Conservation of Turtles of the Northeastern United States, T. F. Tyning, ed. Serpents Tale Press, Lanesboro.
2. Richmond, A. M. & B. Kynard. 1995. Ontogenetic behavior of shortnose sturgeon Acipenser brevirostrum. Copeia: 172–182.
3. Smith, D. G. & A. M. Richmond, 1986. Two fish species, Prosopium cylindraceum and Lota lota, in Connecticut: native or introduced? Natural History Notes, Connecticut Geological and Natural History Survey 2: 1–3.
4. Summers, A. P., K. F. Darouian, A. R. Richmond & E. L. Brainerd, 1998. Kinematics of aquatic and terrestrial prey capture in Terrapene carolina, with implications for the evolution of feeding in cryptodire turtles. Journal of Experimental Zoology 281: 280–287.
5. Mandica, M. & A. Richmond 2000. Scaphiopus holbrookii (Eastern Spadefoot) distribution record. Herpetological Review 31(2): 110.

Two Additional Selected Publications

6. Richmond, A. M. 2000. The Mudpuppy: our largest salamander. Massachusetts Wildlife Vol. XLX: 9–15.
7. Richmond, A. M., T. F. Tyning & A. P. Summers. 1999. Bufo americanus (American Toad) depth record. Herpetological Review 30(2): 90–91.

Synergistic Activities

1. Geographic Distribution Editor for Society for the Study of Amphibians and Reptiles (2001–present).
2. Assembled and maintain living herpetological teaching collection of approximately 130 specimens (1992–present).
3. Member of University of Massachusetts Institutional Animal Care and Use Committee (1996–present, Chair 2000).

Collaborators and Co-Editors

Elizabeth L. **Brainerd**, University of Massachusetts, Amherst; Anthony **Herrel**, University of Antwerp, Belgium; Eric J. **Hilton**, FMNH, Chicago; Nathan **Kley**, FMNH, Chicago; Mark **Mandica**, no longer working in immediate field; James **O'Reilly**, Miami University, Tampa; Adam **Summers**, University of California, Irvine

Graduate and Postdoctoral Advisors

William E. **Bemis** (Ph.D. advisor), University of Massachusetts, Amherst; Henry **Booke** (M.S. reader), retired; Elizabeth L. **Brainerd** (Ph.D. reader), University of Massachusetts, Amherst; Boyd E. **Kynard** (M.S. advisor, Ph.D. reader), National Biological Survey, Turners Fall; Michael **Ross** (M.S. reader), National Biological Survey, Turners Fall; Michael **Sutherland** (Ph.D. reader), University of Massachusetts; Steve **Tilley** (Ph.D. reader), University of Massachusetts, Amhers

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 0

Total number of postgraduate scholars: 0

Biographical Sketch of Dr. Tyson R. Roberts

Professional Preparation

Stanford University,	Biology	B.A. 1961
Stanford University	Biology	Ph.D. 1968

Appointments

Research Associate in Ichthyology, California Academy of Sciences, San Francisco	present
Assistant Curator of Fishes, Museum of Comparative Zoology, Harvard University	1969-1975

Five Publications Most Related to this Project

1. Roberts, T. R. 1975. Geographical distribution of African freshwater fishes. Zoological Journal of the Linnean Society 57(4) 249–319.
2. Roberts, T. R. 1978. An ichthyological survey of the Fly River, Papua New Guinea, with descriptions of new species. Smithsonian Contributions to Zoology 281: vi+72pp.
3. Roberts, T. R. 1982. Revision of the Southeast Asian freshwater pufferfish genus *Chonerhinos* (Tetraodontidae), with descriptions of new species. Proceedings of the California Academy of Sciences 43(1): 1–16.
4. Roberts, T. R. 1986. Tetraodontidae, in Checklist of the Freshwater Fishes of Africa (CLOFFA), ORSTOM, Paris, etc. 2.
5. Roberts, T. R. 1998. Systematic revision of freshwater pufferfishes of the genus Tetraodon in the Mekong basin, with descriptions of two new species. Ichthyological Research (Tokyo) 45(3): 225–234.

Five Additional Selected Publications

6. Roberts, T. R. 1998. Systematic observations on the medaka or ricefish genus Oryzias, with descriptions of new species. Ichthyological Research (Tokyo) 45(3) 213–224.
7. Roberts, T. R. 1992. Revision of the Old World family Notopteridae (featherback fishes). Ichthyological Explorations Freshwaters 2: 361–383.
8. Roberts, T. R. 1994. Osphronemus exodon, a new species of giant gouramy with extraordinary dentition from the Mekong. Natural History Bulletin of the Siam Society. 42: 67–77.
9. Roberts, T. R. & I. O. Baird. 1996. Traditional fisheries and fish ecology on the Mekong River at Khone Waterfalls in southern Laos. Natural History Bulletin of the Siam Society. 43: 219–262.
10. Roberts, T. R. 1986. Danionella translucida, a new genus and species of minute danioin cyprinid fish from Burma. Environmental Biology of Fishes 16(4): 231–241.

Synergistic Activities

1. I conduct extensive fieldwork on several continents; e.g., between 1999 and 2002 I conducted fieldwork in Myanmar (with Myanmar Department of Fisheries), Cambodia (with Cambodia Department of Fisheries), Bangladesh (with Bangladesh Department of Fisheries), China, and Lake Tanganyika in Tanzania and Zambia.
2. Research in Department of Vertebrate Paleontology, Kenya National Museum; in Cambridge University Library; and in natural history museums in Vienna, Paris, London, Leiden, Amsterdam, San Francisco, Washington, DC and Berlin
3. I have been very active in working to conserve fishes of the Mekong River threatened by dam construction in southeast Asia. During 1995–1998 I conducted environmental impact assessments of hydropower projects in Sekong (Xe Nam-Noi-Xe Pian) and Nam Theun (Theun-Hinboun, Nam Theun 2, Nam Theun 3) basins in Laos.

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students:

Biographical Sketch of Dr. Jeffrey Todd Streelman

Professional Preparation

Bucknell University, Lewisburg	Biology	B.S. 1993
University of South Florida, Tampa	Biology	Ph.D. 1998
University of New Hampshire, Durham, NH	Molecular Evolution	1999–2000
UNH Hubbard Center for Genome Studies	Genomics and Genetic Mechanisms	2001–present

Appointments

Instructor, Tropical Field Biology. University of Massachusetts, Amherst and St. John, US Virgin Islands. 2000–present

Five Publications Most Related to this Project

1. Streelman, J. T., C. Puchulutegui, A. L. Bass, T. Thys, H. Dewar & S. A. Karl. 2003. Microsatellites for the world's heaviest bony fish, the giant Mola mola. Molecular Ecology Notes. In press,
2. Streelman, J. T. & P. D. Danley. The stages of vertebrate evolutionary radiation. 2003. Trends in Ecology and Evolution. In press.
3. Streelman, J. T., M. Alfaro, M. W. Westneat, D. R. Bellwood & S. A. Karl. 2002. Evolutionary history of the parrotfishes: biogeography, ecology and comparative diversity. Evolution 56: 961–971.
4. Streelman, J. T. & T. D. Kocher. 2000. From phenotype to genotype. Evolution and Development 2: 166–173.
5. Streelman, J. T. & S. A. Karl. 1997. Reconstructing labroid evolution with single-copy nuclear DNA. Proceedings of the Royal Society, London, Series B. 264: 1011–1020.

Five Additional Selected Publications

6. Streelman, J. T. & T. D. Kocher. 2002. Microsatellite length variation is associated with prolactin expression and growth response of salt-challenged tilapia. Physiological Genomics 9: 1–4.
7. Carleton, K. L., J. T. Streelman, B.-Y. Lee, N. Garnhart, M. R. Kidd & T. D. Kocher. 2002. Rapid isolation of CA microsatellites from the cichlid genome. Animal Genetics 33: 140–144.
8. Albertson, R. C., J. T. Streelman & T. D. Kocher. In review. Genetic basis of adaptive differences in the cichlid head. Journal of Heredity.
9. Streelman, J. T., R. Zardoya, A. Meyer & S. A. Karl. 1998. Multi-locus phylogeny of cichlid fishes: evolutionary comparison of microsatellite and single-copy nuclear loci. Molecular Biology and Evolution 15: 798–808.
10. Streelman, J. T. & S. A. Karl. 1997. Paradigms and the rise (or fall) of molecular biology. Nature Biotechnology 15: 696–697.

Synergistic Activities

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Stephen A. **Karl** (Ph.D. advisor); Thomas D. **Kocher** (postdoctoral advisor), UNH Hubbard Center for Genome Studies; Philip J. **Motta** (Ph.D. advisor)

Thesis Advisor and Postgraduate-Scholar Sponsor

Biographical Sketch of Dr. Tierney Thys

Professional Preparation

Brown University, Providence	Biology	B.A. 1988
Duke University, Durham	Zoology	Ph.D. 1998

Appointments

Chief Science Editor, Sea Studios Foundation, Monterey	1998–present
Invited teaching assistant and researcher: Bermuda Biological Station	1992
Resident researcher Monterey Bay Aquarium, Monterey	1991, 1993

Five Publications Most Related to this Project

1. Love, M. & T. Thys. 1993. Molas, Ocean Realm, November: 42–48.
2. Thys, T. 1994. Swimming Heads, Natural History, August: 36–39.
3. Thys, T. 1995. Ocean Sunfish. Aqualife, December 12: 146–149 (in Chinese).
4. Streelman, J. T., A. L. Bass, H. Dewar, T. Thys & S. A. Karl. In review. Microsatellite markers for the ocean sunfish, Mola mola. Molecular Ecology Primer Notes.
5. Thys, T. M., B. W. Hobson & H. Dewar. 2001, Marine animals—the next generation of Autonomous Underwater Vehicles? Oceans, November.

Five Additional Selected Publications

6. Bass, A. L., J. T. Streelman, T. Thys, H. Dewar & S. A. Karl. In preparation. Molecular phylogenetic relationship of the genera *Masturus*, *Mola*, and *Ranzania* (Molidae).
7. Thys,T., H. Dewar, S. A. Karl, J. T. Streelman, A. L. Bass, D. Herdson, M. deMaine, M. Johnson, S. Hwang, I. C. Liao, H. Y. Yan, M. Shie, G. Sweeney, N. Nasby, J. O'Sullivan, C. Farwell & T Tobayama. In preparation. Global distribution of the giant ocean sunfish: Past and present.
8. Dewar, H., T. Thys, J. O'Sullivan, C. Farwell, T. Tobayama, I. C. Liao, S. Hwang, S. A. Karl, J. T. Streelman, A. L. Bass & M. deMaine. In preparation.Tracking the giant ocean sunfish in the Pacific.
9. Thys, T. & M. Johnson. 1999. El Ninos little hitchhikers. Ocean Realm, Autumn.
10. Johnson, M. & T. Thys. 1996. The sunfish. Korean Geo, 2: 86–98. (in Korean).

Synergistic Activities

1. I consult and produce scientific books and documentaries. For example, I was science consultant and contributor for *Destination Deep Sea*, National Geographic Society; I co-produced with National Geographic for the PBS entitled "The Shape of Life"—an 8 hour documentary series and outreach project chronicling the rise of the animal kingdom. Currently, I am creating producing a multi-part documentary series and outreach project on global environmental change funded in part by NSF and Packard Foundation and being co-produced with National Geographic for PBS.
2. I have conducted fieldwork in Argentina, Australia, Bermuda, Costa Rica, Hawaii, India, Japan, Philippines, Solomon Islands, South Africa, Taiwan, Venezuela; acting as expedition leader in Hualien, Taiwan tagging giant ocean sunfish (2000, 2001, 2002); in Table Bay, South Africa tagging giant ocean sunfish with Two Oceans Aquarium (2000); and in Orinoco basin, Venezuela collecting Amazonian fishes with Dr. Hector Lopez, University of Caracas (1994).
3. I recently created an Undergraduate On-line Biology course, Animal Diversity for Archipelago Inc. division of Harcourt e-learning, Monterey CA. From 1996 to 1998 I taught courses in Developmental and Comparative Anatomy of the Vertebrates.
4. Since 2000 I have been invited to speak at various institutions, including the Smithsonian Friday lecture series (2003), Mote Marine Lab (2001, 2002), Moss Landing Marine Lab (2001), Student Oceanography Club, Monterey Bay Aquarium (2001), Docent training, Monterey Bay Aquarium (2000), Society of Comparative and Integrative Biology, Chicago (2000).
5. I helped build and promote 'Deep Flight' one-person submarine for Deep Ocean Engineering, San Leandro, California.

Collaborators and Co-Editors

Graduate and Postdoctoral Advisors

Mark **Bertness** (Undergraduate advisor); Stephen A. **Wainwright** (Graduate advisor)

Thesis Advisor and Postdoctoral-Scholars Sponsored

Biographical Sketch of Dr. Peter C. Wainwright

Professional Preparation

Duke University	Zoology	B.S. 1980
University of Chicago	Anatomy	Ph.D. 1988
University of California, Irvine	Postdoctoral Research,Comparative Physiology	1988–1990

Appointments

Professor of Evolution and Ecology, U. California, Davis	2002–present
Associate Professor, Evolution and Ecology, U. California, Davis	1999–2002
Associate Professor of Biological Science, Florida State University	1996–1998
Assistant Professor of Biological Science, Florida State University	1991–1996
Assistant Professor of Biological Sciences, Florida International University	1990–1991

Five Publications Most Related to this Project

1. Wainwright, P. C. & J. P. Friel. 2000. Effects of prey type on motor pattern variance in tetraodontiform fishes. Journal of Experimental Zoology 286: 563–571.
2. Friel, J. P. & P. C. Wainwright. 1999. Evolution of complexity in motor patterns and jaw musculature of tetraodontiform fishes. 1998. Journal of Experimental Biology 202: 867–880.
3. Friel, J. P. & P. C. Wainwright. 1998 Evolution of motor pattern in Tetraodontiform fishes: Does muscle duplication lead to functional diversification? Brain, Behavior and Evolution 53: 159–170.
4. Friel, J. P. & P. C. Wainwright. 1997. A model system of structural duplication: Homologies of the adductor mandibulae muscles in tetraodontiform fishes. Systematic Biology. 46: 441–463.
5. Wainwright, P. C. & R. G. Turingan. 1997. Evolution of pufferfish inflation behavior. volution. 51: 506–518.

Five Additional Selected Publications

6. Hulsey, C. D. & P. C. Wainwright. 2002. Mapping mechanics into morphospace: disparity in the jaws of labrid fishes. Proceedings Royal Society, London, Series B 269: 317–326. (http://www.pubs.royalsoc.ac.uk/proc_bio/proc_bio.html)
7. Sanford, C. P. J. & P. C. Wainwright. 2002. Use of sonomicrometry demonstrates link between prey capture kinematics and suction pressure in largemouth bass. Journal of Experimental Biology 205: 3445–3457.
8. Wainwright, P. C. & R. G. Turingan. 1997. Evolution of pufferfish inflation behavior. Evolution 51: 506–518. (http://www.jstor.org/journals/00143820.html)
9. Friel, J. P. & P. C. Wainwright. 1997. A model system of structural duplication: Homologies of the adductor mandibulae muscles in tetraodontiform fishes. Systematic Biology 46: 441–463. (http://www.jstor.org/journals/10635157.html)
10. Wainwright, P. C. & S. M. Reilly, eds. 1994. Ecological morphology: integrative organismal biology. University of Chicago Press, Chicago.

Synergistic Activities

1. Associate editor: Evolution (1/2002–present), American Naturalist (7/2002–present), Assistant editor Systematic Biology (1995–97); Service with Society of Integrative and Comparative Biology (vertebrate divisional chair 1997–99, systematics divisional program officer 1992–95); AAAS council delegate (1998–01).
2. I was the coordinator during 1998 for NSF-Funded program in Apprentices in Environmental Biology for Florida State University undergraduates from underrepresented groups. Taught two courses and oversaw independent research of four students.
3. Developed new graduate level short course, Bodega Applied Phylogenetics Workshop and co-taught it in 2000, 2001, and 2002. Course includes six computer labs for use of phylogenetic software. tudent attendees over three years have come from nine countries, in addition to the United States.
4. Since 1991 I have recruited one Pacific Islander postdoctoral fellow, one female postdoctoral fellow, two female graduate students, and have supervised research by eleven female

undergraduates.

Collaborators and Co-Editors

David **Bellwood**, James Cook University; Daniel **Bolnick**, University of California, Davis; Andrew **Carroll**, University of California, Davis; Lara **Ferry-Graham**, University of California, Davis; John **Friel**, Cornell University; Chris **Fulton**, James Cook University; Andrew **Hoey**, James Cook University, Robert **Hueter**, Mote Marine Lab, Darrin **Hulsey**, University of California, Davis; Gary **Mittelbach**, Michigan State University; Philip **Motta**, University of South Florida; Craig **Osenberg**, University of Florida; Chris **Sanford**, Hofstra University; Steve **Schenk**, Darton College; Samantha **Shaw**, University of Alabama; Richard **Svanback**, University of Umea; Tom **Waltzek**, University of California, Davis; Mark **Westneat**, Field Museum of Natural History; Cheryl **Wilga**, University of Rhode Island.

Graduate and Postdoctoral Advisors

Albert **Bennett** (postdoctoral advisor), University of California, Irvine
George **Lauder** (PhD advisor), Harvard University

Thesis Advisor and Postgraduate-Scholar Sponsor

Total number of graduate students: 10

Daniel **Bolnick**, University of California, Davis; Rose **Carlson**, University of California, Davis; David **Collar**, University of California, Davis; Andrew **Carroll**, University of California, Davis; Justin **Grubich**, Florida State University; Darrin **Hulsey**, University of California, Davis; Steve Schenk, Darton College; Thomas Waltzek; University of California, Davis

Total number of postgraduate scholars: 5

Michael **Alfaro**, University of California, Davis; Lara **Ferry-Graham**, University of California, Davis; John **Friel**, Cornell University; Michael **McCay**, University of California, Davis

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate, identify the location and pertinent capabilities of each.

All offices and laboratories in the Department of Biology are computer-networked. Our main departmental computer room, the Biology Computer Resource Center (BCRC), supports student, staff and faculty teaching as well as research. The BCRC has a full-time professional director, 25 Macintosh computers, a Sun workstation, a slide scanner, a film printer, a Phaser color printer, an 11″x17″ printer, computer projection systems, etc.

The Bemis laboratory has a Wild stereo microscope (M5) mounted on a table-top boom and equipped with drawing and camera tubes at the main dissecting station. Next to it is a Wild PhotoMakroscop, with substage illumination and a digital camera (4.3mp). Two additional Wild dissecting microscopes and five fiber optic illuminators are available for use wherever needed in the laboratory. A Zeiss Axioskop with camera system and two binocular heads is the major compound microscope in the Bemis lab. An array of objective lenses from 1.25X to 100X is available for the Axioskop. Bemis has a 4″x5″ camera equipped with a 90mm Rodenstock lens used for black and white analog photography. A large (8′) camera stand in the lab can mounts a second 4.3mp digital camera, a Wild M5 or the 4″x5″ camera. The camera stand has a high-intensity halogen lighting system, including an 18″ x 24″ sub-specimen illumination box useful for photographing skeletons. The in-lab darkroom for black and white photography is equipped with an Omega enlarger that we use for printing 4″x5″ negatives.

The Brainerd laboratory has Sonometrics 6 channel sonomicrometry unit; 12 channel AM Systems AC amplifiers for EMG; 6 channel Grass P511J AC amplifiers for EMG; Kodak Ektapro high speed video system; two Sony and one JVC miniDV camcorders; two Sony miniDV editing decks; Nikon and Wild dissecting microscopes with boom stands.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual/subaward arrangements with other organizations.

The Department of Biology has excellent machine and electronic shops available on an "as-needed" basis for research and teaching assistance. Imaging and some microscopy will take place in the University's Central Microscopy Facility Facility, an NSF supported core facility that has a Balzers Critical Point drier and JEOL JSM SEM equipped for digital imagestorage, a Zeiss LSM510 META confocal microscope, and Spot digital photomicroscopy system.

The Graduate Program in Organismic and Evolutionary Biology (OEB) and Department of Biology at the University offer a complete series of courses for vertebrate biologists (Comparative Anatomy, Vertebrate Paleontology, Systematics and Evolution, Ichthyology, Herpetology, Ornithology and Mammalogy) on a regular basis. Our vertebrate faculty members are very research-active (e.g., six of the eight tenure stream faculty studying vertebrates currently have NSF grants; five postdoctoral scholars and Research Assistant Professors work in conjunction with these faculty; and we have two full-time professional staff members who oversee day-to-day management of the University's vertebrate collections). These resources make the University of

Massachusetts an increasingly important and active training site for graduate students and postdoctoral fellows in vertebrate biology.

The Biology Departmental Office and the Secretary to the Chair of Biology will manage all business matters related to this project. In the Biology Departmental Office, our Departmental Manager and four members of the Professional Staff are responsible for hiring of student and professional employees on grant funds, ordering of supplies on grant funds, etc. The Secretary to the Chair of Biology is responsible for appointments of graduate students for grant funded projects.

This section provides Results from Prior Support for each member of the Management Team and each Senior Investigator for this project. References cited are grouped together at the end.

I. Results from Prior Support – William E. Bemis held an NSF Predoctoral Fellowship and served as PI or co-PI for BSR-8806539, BSR-9119561, DEB-9220938, DEB-9743016, DEB-9707705, and DEB-0075460; DEB-0128929 began in September 2002. Reports are on file for previous and current research awards. Two students supervised by Bemis held DDI grants (Findeis, BSR-8901132; Hilton, DEB-0073066); NSF supported two symposia organized by Bemis (BSR-8401117; BSR-9108599). Major products include anatomical and systematic monographs on coelacanths, paddlefishes, bowfins, gars (current DEB support; Grande & Bemis, *in prep*.), and osteoglossomorphs. Other results of prior support are monographs, articles and book chapters on comparative anatomy, embryology, neuroanatomy, skeletal development, and systematics of other fossil and living fishes. Singled out for comment is the 700-page monograph on bowfins published as a *Memoir of the Journal of Vertebrate Paleontology* (Grande & Bemis, 1998). It presented a systematic osteological study of all 28 species (27 fossil, 1 living) then known in Amiidae, revising all genera and recognizing for the first time a monophyletic subfamily that ranged in the Cretaceous from Mexico and Brazil to Spain, Africa and Israel. Phylogenetic analysis made it possible to examine general problems in skeletal development, evolution, systematics, historical biogeography and historical ecology. Janvier (1998) and Gardiner (1999) reviewed the bowfin monograph for *Science* and *Copeia*, respectively. NSF support helped Bemis sponsor Drs. D. Didier and J. Shardo as Postdoctoral Scholars; facilities developed with NSF support attracted Dr. A. Simons to a Darwin Postdoctoral Fellowship at UMass. These postdoctoral trainees established their own research programs in ichthyology and systematics. Many graduate and undergraduate students participated in prior NSF sponsored research. NSF awards helped Bemis develop a broad training program on morphology and systematics of fishes, exemplified by trainee publications such as Bemis et al. (1997), Hilton & Bemis (1999) and Hilton (2002a) on sturgeons; Hilton (2002b, 2003) on osteoglossomorphs; and Hilton, Grande & Bemis (in press). NSF support helped Bemis improve his ability as an illustrator; research makes him a better classroom instructor, and helped motivate him to co-author with Grande six chapters for a comparative anatomy text (Liem et al., 2001). Because of research activity, Bemis received two top UMass honors (Conti Faculty Fellowship, 2000 and Distinguished Faculty Lectureship, 2001).

II. Results from Prior Support — Elizabeth L. Brainerd is PI for IBN-9875245 (04/99–03/04) entitled "Lung Ventilation in Lizards and the Evolution of Amniote Respiratory Mechanisms." This CAREER award has funded research in the comparative physiology and biomechanics of respiration in tetrapods and educational activities in physiology and introductory biology teaching. I completely revised my upper-level comparative physiology course to be inquiry and project based, and designed a new lab component that includes small-group research projects. I co-teach an introductory biology course for 350 students and use a web-based class preparation system specifically designed to make large courses more interactive (http://bcrc.bio.umass.edu/courses/spring2002/biol/biol101section2/). During the grant period I have also supervised the independent projects of ten undergraduate students in my lab, including five honors theses and five students supported by REU supplements to this award. Nine publications to date have come directly from work funded by this award (Druzisky & Brainerd, 2001; Owerkowitcz, Brainerd & Carrier, 2001; Bennet, Simons & Brainerd, 2001; Simons, Bennett & Brainerd, 2000; Brainerd & Simons, 2000; Brainerd, 2000; Owerkowicz, Farmer, Hicks & Brainerd, 1999; Simons & Brainerd, 1999; Brainerd, 1999), with ten additional publications resulting from work in my lab during the grant period (Azizi, Gillis & Brainerd, 2002; Kley & Brainerd, 2002; Brainerd, Slutz, Hall & Phillis, 2001; Federle, Brainerd, McMahon & Holldobler, 2001; Kley & Brainerd, 1999; Azizi & Landberg, 2002; Kley, 2001; Summers & Ferry-Graham, 2001; O'Reilly, Summers & Ritter, 2000; Summers, 2000). Our work on gular pumping in monitor lizards was published in Science and featured in a "Real People Doing Real Science" section of Raven and Johnson's introductory biology textbook. We created a public library (http://www.bio.umass.edu/biology/brainerd/svp-index.php) of digital video clips from our work on gular pumping, buccal oscillation and gular flutter. Also see http://www.bio.umass.edu/biology/brainerd/index.php.

III. Results from Prior Support — W. Bruce Croft is PI for EIA-9983215 (07/01/00–06/30/04) entitled "A Language Modeling Approach to Metadata for Cross-Database Linkage and Search." The University of Massachusetts group is collaborating with a group at CMU to develop approaches to providing effective access to distributed, heterogeneous databases. Our focus is on techniques that automatically generate database descriptions (content metadata) and use these descriptions to identify relevant resources. There has been much recent discussion of metadata and how it can be used to describe the content of Web-based resources. Our research approaches include Question Answering (QA) which provides an enhancement to traditional information retrieval, by eliminating the step of having a user read through a document for an information need. This could greatly reduce time searching for facts using the Internet. In the area of structured database searching, we are testing techniques for generating automatic metadata representations of tabular data and relational databases. This metadata is then used to retrieve tables in

response to queries with information retrieval approaches. We have implemented a demonstration of this approach that searches tabular data extracted from the Department of Commerce Web sites. We are currently working on experiments that examine different approaches to representing row and column data.

The use of link structure has now become common in Web search engines. The PageRank algorithm used by Google is particularly well known. The link structure is used to identify popular or 'authoritative' Web sites. We are examining an alternative approach to using link structure where the text on related pages is used to 'smooth' the representation of a Web page. This can be used to generate metadata in the following way. There are many portals in Government and related Web sites. The home pages for these portals are not very descriptive of the contents of their databases. By using the text on pages linked to these portal sites, we hope to generate much better representations of their content. We are currently developing a mathematical model for this approach, and have begun to carry out experiments where we are comparing the PageRank algorithm for ranking sites to an algorithm that uses 'anchor text' on incoming links to generate a ranking. A web-based demonstration of the Question Answering system can be found at http://canberra.cs.umass.edu/~reu2/index.html. To date, three publications have resulted from this project (Callan, Powell, French & Connell, 2001; Pinto, Branstein, Coleman, King, Li, Wei & Croft, 2002; Li, 2002).

IV. Results from Prior Support — Manda Clair Jost was co-PI for DEB 0073187 (2000–2002) entitled "Dissertation Research: Heterochrony in Insects: Phylogeny and Evolution of Acoustic Characters in the True Crickets (Orthoptera: Grylloidea)" (N. Pierce, K. Shaw, and M. Jost). Manda Jost's doctoral dissertation estimated phylogenetic relationships in the Ensifera (Hexapoda: Orthoptera) and the Grylloidea (Orthoptera: Ensifera) using sequence data from 3 ribosomal loci, and both maximum parsimony and Bayesian inference methods. Phylogenetic estimates were used to test evolutionary hypotheses by character evolution simulations, relative rates tests, and phylogeny-based comparative methods including independent contrasts and concentrated changes. The results showed that specialized acoustic morphology has been lost multiple times in parallel, most frequently together with a total reduction or loss of wings and auditory organs. Independent contrasts analyses for ontogenetically-ordered character states found strong evidence for developmental constraints between multiple morphological characters, consistent with the evolutionary process of paedomorphosis. This result is also supported by additional morphological, ontogenetic, phylogenetic, and ecological lines of evidence. The significance of this project was that it used new phylogenetic trees to test novel hypotheses in a well-studied group, finding good evidence for an important evolutionary process (heterochrony) that is rarely invoked in studies of insects. It also established a new link between the evolution of acoustic morphology and the evolution of flightlessness and aptery, the latter of which has been studied extensively by other researchers using both genetic and endocrinological approaches. Six manuscripts are in preparation from this research, including two papers on phylogenetic relationships of Ensifera and Grylloidea (co-authored by Kerry Shaw); two papers on the evolution of acoustic characters in Grylloidea; and two taxonomy papers that will describe in total eleven new species discovered during the course of the project.

V. Results from Prior Support — George V. Lauder is PI for NSF IBN-9807012 (1998–2002) “Functional Morphology of Aquatic Locomotion in Fishes: Function of Median Fins”and NSF IBN 0090896 (01/01/01–06/31/03) entitled “Experimental Hydrodynamics and Evolution: Locomotor Design and Function of Pectoral Fins in Fishes.” In the past five years, research has focused on applying engineering techniques to the study of locomotor function and evolution in fishes with the aim of (i) developing and validating a quantitative two-dimensional flow visualization system for the study of locomotor function and design in fishes, (ii) implementing this technique in studies of the structure and force of the wake produced by median and paired fins, and (iii) laying groundwork for future comparative hydrodynamic research on steady and unsteady locomotor behaviors across phylogenetically diverse fishes.

A modern flow visualization technique called Digital Particle Image Velocimetry (DPIV) for the first time, has allowed empirical and quantitative measurements of the two-dimensional water velocity flows in the wake of swimming animals. From these data, a number of important fluid dynamic quantities can be calculated: vorticity, circulation, wake momentum, and the magnitude and orientation of fluid forces developed over the course of the fin beat cycle. Using DPIV, we conducted the first empirical analysis of the vortex wake and associated fluid forces produced by a fish swimming with its paired fins (Drucker & Lauder, 1999). Building on this work, we have analyzed speed effects on the pectoral fin vortex wake (Drucker & Lauder, 2000), maneuvering locomotion (Drucker & Lauder, 2001b), and the function of the dorsal fin (Drucker & Lauder, 2001a). We have also undertaken a broad comparative and evolutionary analysis of the pectoral and caudal fin vortex wakes of sharks (Wilga & Lauder, 2000; Wilga & Lauder, 2001; Wilga & Lauder, 2002), sturgeon (Wilga & Lauder, 1999; Liao & Lauder, 2000), mackerel (Nauen & Lauder, 2001; Nauen & Lauder, 2002a), and trout (Nauen & Lauder, 2002b). This latter paper demonstrates the possibility of using stereo-DPIV techniques to quantify the vortex wake of freely-swimming fishes. Review papers synthesizing our results include Lauder (2000), Drucker & Lauder (2002), Lauder & Drucker (2002),

and Lauder et al. (2002). A variety of videos relating to our DPIV work on fish locomotion as well as .pdf files of recent papers can be found on our lab web page: http://www.oeb.harvard.edu/lauder/.

VI. Results from Prior Support — Edward O. Wiley has received five grants in support of research, DEB 81-03532, BSR 87-22562, DEB-9207600, 9317881, and 9985737 (SGER). The results of DEB-9317881 (1994–1997) entitled "A Phylogenetic Analysis of Higher Teleost Fishes (Acanthomorpha) Based on Morphological and Molecular Data" are reported below. The major analysis consisted of a combined DNA and morphological study of 25 species of acanthomorph fishes representing all major groups and two outgroup taxa. The results, reported in Wiley et al. (2000) are largely congruent with the hypothesis of acanthomorph relationships proposed by Johnson & Patterson (1993). The relationships of paracanthopterygian fishes (cods and relatives), not dealt with by Johnson & Patterson (1993) were totally different than previous hypotheses. Our use of 28S rDNA yielded largely uninformative or misleading signal**.** Support for many nodes was very low due to a combination of a low number of target species and the relatively uninformative nature of the sequence data at this higher level of analysis. We had better success with studies at lower taxonomic levels by substituting 16S mtrDNA for 28S rDNA. Ten papers (Wiley, Johnson & Dimmick, 1998; Tang, Berendzen, Wiley, Morrissey, Winterbottom & Johnson, 1999; Wiley, Johnson & Dimmick, 2000; Tang, 2001; Berendzen & Dimmick, in press; Jang-Liaw, Tang, Hui & Shao, in press; Dimmick, Johnson & Wiley, submitted; Grose, submitted; Grose, submitted; Tang, McNyset & Holcroft, submitted)) are directly related to the grant and acknowlede support. A doctoral dissertation, entitled "Molecular systematics of the Atherinomorpha (Teleostei), with an emphasis on the Atheriniformes", was completed in 2001 by Michael Grose. On-going doctoral dissertation project, entitled "Phylogenetic relationships of the anemonefishes", by Kevin Tang uses data collected during the project. We have reported the results of our research directly related to the grant and acknowledging grant support on 11 occasions at national and international meetings (see http://web.nhm.ukans.edu/fishes/NSF/).

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Evan Hadingham
Senior Science Editor
NOVA

1/6/03

TO WHOM IT MAY CONCERN:

This letter is to express NOVA's interest in Prof. William Bemis' major proposal to the National Science Foundation on assessing the biodiversity of pufferfishes and allies as part of the Planetary Biodiversity Inventory initiated by the National Science Foundation. A substantial PBS documentary on inventorying biodiversity has yet to appear, and although our discussions are in an early phase, Prof. Bemis' research may provide a good foundation for such a project.

Recently Prof. Bemis provided invaluable help to us in helping to review and upgrade the content of a show we acquired from the BBC on the discovery of the coelacanth. We have found him to be an excellent academic collaborator, sensitive to the needs of the media. It's on the basis of this experience that we are interested in becoming involved in his ambitious biodiversity project.

NOVA documentaries remain among the highest-rated prime-time programs on PBS, reaching a nationwide audience of around 8 million, and are seen in nearly 100 countries around the globe. Every program also has specially designed outreach content on the NOVA Online web site, which receives up to a million hits a month. NOVA Teachers Guides, with curriculum material centering around each NOVA show, reach 90,000 US teachers a month.

We at NOVA would be grateful for any efforts you can make to support Prof. Bemis in producing this potentially exciting and worthwhile documentary. Please contact me for any further information.

(Submitted electronically)

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Introduction – Management of this project involves: 1) personnel actions (e.g., appointment of a Research Assistant Professor); 2) specific charges to five working groups; 3) distribution of funds; 4) organization of five Annual Meetings; and 5) establishment and maintenance of electronic communication among participants. This document describes how we will manage these and related tasks. Additional information relevant to project management is found in the Budget Section and in Section 4 of the Project Description.

Personnel Responsible for All Major Tasks – We define three categories of project personnel: 1) **Management Team**, 2) **Senior Investigators**, 3) **Project Consultants & Students** (Table MP-1). Each person is also a member of one or more of our five working groups (Figure MP-1). William Bemis and Elizabeth Brainerd will lead the **Management Team** and serve as **Co-Executive Officers**. We are tenured faculty in Biology at the University of Massachusetts, Amherst (UMass). We have managed large NSF research awards, trained doctoral and post-doctoral students, directed major on-campus programs (e.g., the 70-member interdepartmental Graduate Program in Organismic and Evolutionary Biology), and organized topical symposia as well as large international scientific meetings. Bemis has edited multi-author volumes on fishes (e.g., lungfishes and sturgeons) and written revisionary systematic monographs (e.g., paddlefishes and bowfins). Brainerd has led several collaborative NSF projects, such as the Undergraduate Mentoring in Environmental Biology Program (UMEB) at UMass. Together, Bemis and Brainerd will oversee all aspects of the PBI: Pufferfishes and coordinate research activities and communications among project personnel. We also will serve (with others) as co-chairs of three of the project's five Working Groups (see Project Description, pp. 12-13) and co-edit the revisionary monograph for this project, "***Tetraodontiform Fishes.***" To assist us in these executive responsibilities, we will hire for the five-year term Ralf Britz as a Research Assistant Professor of Biology to serve as **Project Manager**. Britz will assist us with graduate training, and travel as needed to achieve inter-institutional integration and to explore new opportunities that may arise during the project. The fourth member of our Management Team will be a **Postdoctoral Researcher 1** to focus on informatics. We will hold an international search to fill this postdoctoral position during Year 1.

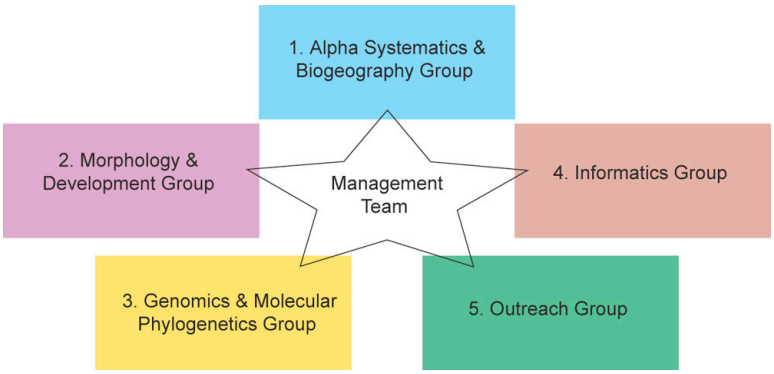

Figure MP-1. Working groups for PBI: Pufferfishes and Allies – Tetraodontiformes – As a Model Group for Planetary Biodiversity Inventories.

Seven **Senior Investigators** also will serve major roles in the project. Five are tenured faculty or curator (Bruce Croft, UMass; Dave Johnson, NMNH; George Lauder, MCZ/Harvard; Ed Wiley, University of Kansas; and Rick Winterbottom, Royal Ontario Museum). The sixth and seventh Senior Investigators are Manda Jost (Postdoctoral Researcher at the University of Texas, Austin, where she has new NSF support for research on tetraodontiform systematics and evolution) and Francesco Santini (Graduate Student at the University of Toronto studying Tetrodontiformes). We invited each Sen-

ior Investigator to identify specific research areas to pursue in detail, and these studies will form part of the new research effort. Our team of Senior Investigators is expected to remain stable during the five-year term of the project. Each will contribute a paper to "***Tetraodontiform Fishes.***" Five of the seven Senior Investigators will serve as a co-chair of a Working Group. Each Senior Investigator will receive annual research support from the project budget; requirements vary but are in the range of $30–50,000 per year, typically to support graduate students in their laboratories. Accordingly, we have supplied in our application materials complete background information regarding these Senior Investigators (i.e., an NSF Biosketch, Results from Prior NSF Support, and Current and Pending Support information where applicable).

Table MP-1. Project Personnel for PBI: Tetraodontiform Fishes.

Category	Name	Affiliation	Role/Expertise
1. Management Team (4 total)	W.E. Bemis	UMass, Amherst	Co-Executive Officer
	E.L. Brainerd	UMass, Amherst	Co-Executive Officer
	R. G. Britz	UMass, Amherst[1,2]	Project Manager
	Postdoctoral[3]	UMass, Amherst	Informatics Specialist
2. Senior Investigators (7 total)	B. Croft	UMass, Amherst	Informatics
	D. Johnson	NMNH, Washington	Morphology & systematics
	M Jost[2]	UT, Austin	Molecular systematics
	G.V. Lauder	MCZ, Cambridge	Morphology & systematics
	F. Santini[4]	UToronto, Toronto	Morphology & systematics
	E.O. Wiley	UK, Lawrence	Molecular systematics & ecology
	R. Winterbottom	ROM, Toronto	Morphology & systematics
3. Project Consultants & Students (19 total; note that this list does not include new students to be brought on board if project is funded)	N. H. Benson[2]	UK, Lawrence	Molecular systematics
	C. Cox Fernandes	UMass, Amherst	Morphology & systematics
	W. Eschmeyer	CAS, San Francisco	Systematics & informatics
	P.L. Forey	MNH, London	Morphology & systematics
	L. Grande	FMNH, Chicago	Morphology & systematics
	E. Hilton	FMNH, Chicago	Morphology & systematics
	P. Humann	New World Pubs.	Photography & systematics
	F. Juanes	UMass, Amherst	Conservation biology
	S. Karl	USouth Florida	Molecular systematics
	J. Leis	AustMus, Sydney	Development & systematics
	K. Matsurra	NSM, Tokyo	Morphology & systematics
	M. Miya	MHMus&Inst, Chiba	Molecular systematics
	G. Morse	UMass, Amherst	Bioinformatics
	B. Normark	UMass, Amherst	Molecular systematics
	A. Richmond	UMass, Amherst	Survey data organizer
	T. Roberts	CAS, San Francisco	Morphology & systematics
	J.T. Streelman	UNH, Durham	Molecular systematics
	T. Thys	Seas Studios Foundation	Ecology & behavior
	P. Wainwright	UCal, Davis	Morphology & systematics

[1] Currently based at the National Museum of Natural History but will be appointed at UMass, Amherst as a Research Assistant Professor for the five years of this project.
[2] Current Postdoctoral Researcher studying tetraodontiform systematics.
[3] Postdoctoral Researcher to be appointed on basis of a search conducted in Year 1.
[4] Current Doctoral Candidate studying Tetraodontiformes for dissertation research.

Project Consultants and Students are persons who have expressed strong interest in the research, pledged support in the form of advice, access to materials or specimens in their care, and willingness to participate in aspects of the project. Project Consultants and Students will have limited management duties, but will be invited to attend all Annual Meetings of the team and to contribute papers to "***Tetraodontiform Fishes***." Additional students at different institutions are expected to join the team if the project is funded. Project Consultants and Students will receive support for attending the Annual Meetings or conducting specific research projects, so we supplied their Biosketches.

We also will invite many other colleagues to attend our annual meetings. Some are researchers who do not yet wish to formally participate in this project (although they expressed support and some interest in attending the Annual Meetings). We hope that some may decide to contribute to "***Tetraodontiform Fishes***" or to formally participate in other ways. Secure funding will help us to develop these contacts.

Training Activities – Graduate student and postdoctoral training is integral to this project. For example, Bemis, Brainerd and Britz will supervise two doctoral students in the Graduate Program in Organismic and Evolutionary Biology at UMass as well as Postdoctoral Researcher 1. Following a pattern of training already used by Bemis, each student will spend > 1 month per year collecting and preparing fishes in the field, and make study visits to ~5 domestic and ~2 international research collections of Recent and fossil fishes per year. Each doctoral student will serve as a teaching assistant for Ichthyology (Biology 542) and Comparative Anatomy (Biology 521) at least once during their degree work. In the third or fourth year of work, each student will be encouraged to spend at least one other semester in residence at an appropriate research collection (e.g., CAS, FMNH, KU, Smithsonian) working closely with another researcher on the project. This inter-institutional approach to training has proven to be very effective in the past, and we will work to broaden this approach to include all participants and institutions. Other team members also expect to admit and to train new doctoral students during the five-year period of the award, and we have budgeted funds to help them to do this. We expect that much interchange of students among institutions will develop naturally, fostered by student attendance at and full participation in our Annual Meetings. We will especially emphasize opportunities to bring students from overseas to laboratories and collections in the United States and *vice versa*.

Timetable – The overall project time line showing Planning Meetings and Annual Meetings as well as other major events is summarized in Figure MP-2.

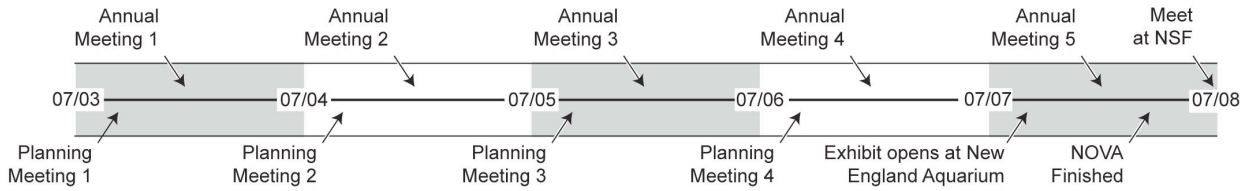

Figure MP-2. Overall time line for PBI: Tetraodontiformes.

As an example of an annual schedule, Planning Meeting 1 will be held over a two-day period at UMass and by teleconference approximately six weeks after an award is made

(for purposes of this example, we are assuming an award date of July 1, 2003). All members of the Management Team (Bemis, Brainerd and Britz) and Senior Investigators (Croft, Johnson, Jost, Lauder, Santini, Wiley and Winterbottom) will attend or be present via teleconference to discuss all aspects of the project, and delineate and finalize assignments and goals for Year 1. By the end of Planning Meeting 1, we will have finalized the charges to each of the five working groups and prepared our first interim report to NSF. Major administrative objectives for Year 1 include appointment of Britz as Research Assistant Professor of Biology, search for and appointment of the Postdoctoral Researcher for Informatics, and recruitment of new doctoral students. Distribution of Participant Support Costs and initial rounds of travel for participants and students also will begin. In January 2004, our first four-day Annual Meeting will take place in Key West. The program will feature presentations on the diversity, phylogeny and genomic organization of tetraodontiforms as well as progress papers, position papers, and discussion of plans with the New England Aquarium and NOVA staff. Group dive trips will be held, as well as an optional overnight visit to protected reefs at the Dry Tortugas National Park. The meeting will conclude with a review of the charges to the working groups and preparation of the second interim report to NSF. In April 2004, Bemis and Brainerd will prepare the third interim report to be sure that all work in participant laboratories is proceeding according to plan; we will adjust and update the charges to working groups as needed. In July 2004, we will prepare our first annual report, which will include progress measured by Annual Milestones.

Annual Milestones – The Management Team and Senior Investigators will craft very specific charges to each working group and update these charges as needed following each quarterly review. This is the best mechanism for keeping a large group of participants on track and in close communication with each other. (This is the model that Bemis has used to successfully manage the workload of large university councils and committees that he has chaired in recent years.) Careful minutes will be taken during all Planning Meetings. Records of progress and all changes in charges will be distributed via http://www.bio.umass.edu/biology/bemis/PBI/Open_communications.htm. Key annual milestones for the project include the Planning Meeting and the Annual Meeting for each year as shown in Figure MP-2. But the most important measures concern the research productivity of participants and the working groups to which they contribute. For example, key measures of progress by Working Group 1 (Alpha Systematic & Biogeography) can be easily enumerated: What percentage of type descriptions has been digitized and posted on the project's website? What percentage of the type specimens has been located and photographed? What percentage of specimens in collections have had identification verification, and how many of these have geo-reference data? In order for this project to show steady progress, we would anticipate that at least 25% of the work for Working Group 1 should be completed by the end of Year 1 (i.e., 100 of the 400 described species would have their type description and other basic data posted on the project's website). We consider these to be examples of realistic goals that can be readily measured to evaluate our progress.

Plans for Maintaining and Enhancing Leadership of Key Members and Communication Among All Team Members – Managing this project is similar in many respects to managing a large national scientific meeting in that a variety of interests must be accommodated smoothly so that the desired integration of researchers is achieved. Much like any scientific society, it is essential to have key leaders completely invested not only

in the day-to-day research work for the project but also in the project's larger goals. For example, while it may be possible for an individual participant to make great headway in their particular area of expertise, their cooperation with other personnel is what will distinguish this project from a collection of separate research inquiries. The most effective way to develop such cooperation among researchers – particularly systematists, who are not used to working together in large groups – is not to force too much at the outset. Instead, collaboration, and the cooperation that results from it, needs to be allowed to grow as a result of personal interactions among project personnel: if you bring these people together in one place then they will interact with each other in ways that will be larger than the sum of the individual research efforts. This is why our approach emphasizes a Planning Meeting each year for the Management Team and Senior Investigators, an Annual Meeting for all participants, and international travel to maximize contact among project personnel.

A related issue is the flexibility of funding that we have designed into this project from the start. For example, our ability to move funds into exciting research areas and collaborations that may emerge as a result of developing personal research contacts at meetings will help to foster many new areas of inquiry. In this regard, the role of the Management Team will be to listen, detect and identify those emerging collaborations worthy of additional support. The flexibility of the Participant Support Cost category and our Office of Grant and Contract Administration at the University of Massachusetts, Amherst, will make it possible for us to be more nimble and creative than would otherwise be the case.

Outreach Efforts to Disseminate Results – In addition to peer-reviewed scientific publications that participants will produce during the award, we also will generate a comprehensive project monograph *"Tetraodontiform Fishes,"* that we will distribute free to all members and institutional subscribers to Copeia. (This resembles the model used by Grande & Bemis (1991, 1998) for memoirs to the Journal of Vertebrate Paleontology).

Web-revision of Tetraodontiformes is a major objective of this work. We will provide web-based species checklists and a comprehensive catalog of species; query-based range map searches using FishNet/Species Analyst; collection inventories using MANTIS or similar tools; interactive keys (linked to photographs of living and preserved specimens and morphological photographs and diagrams with labeling layers); and links to our authorities on particular groups. We also will provide links to character data matrices so that a query can generate an analysis of relationships.

Curatorial, Computational, and Sequencing Facilities and Resources – Many curators and collection personnel will participate on this project (Table MP-1 and Biosketches). New materials collected by participants will be deposited in permanent collections of their choice and all records will be made available on the web. Participants are responsible for their own permitting arrangements and compliance to relevant rules and governments and rights of private landowners. All newly collected specimens are to have fully geo-referenced data; tissue samples are to be retained for every specimen (our standard practice is to preserve tissues in the field in 95% ETOH; see Bemis et al., submitted). Computational facilities (i.e., servers) will be maintained in the UMass Amherst Biology Department. Sequencing for this project will be conducted at several laboratories, Miya (Tokyo), Jost (UT Austin), Karl (USF), Normark (UMass) and Wiley (Kansas).