Fisheries

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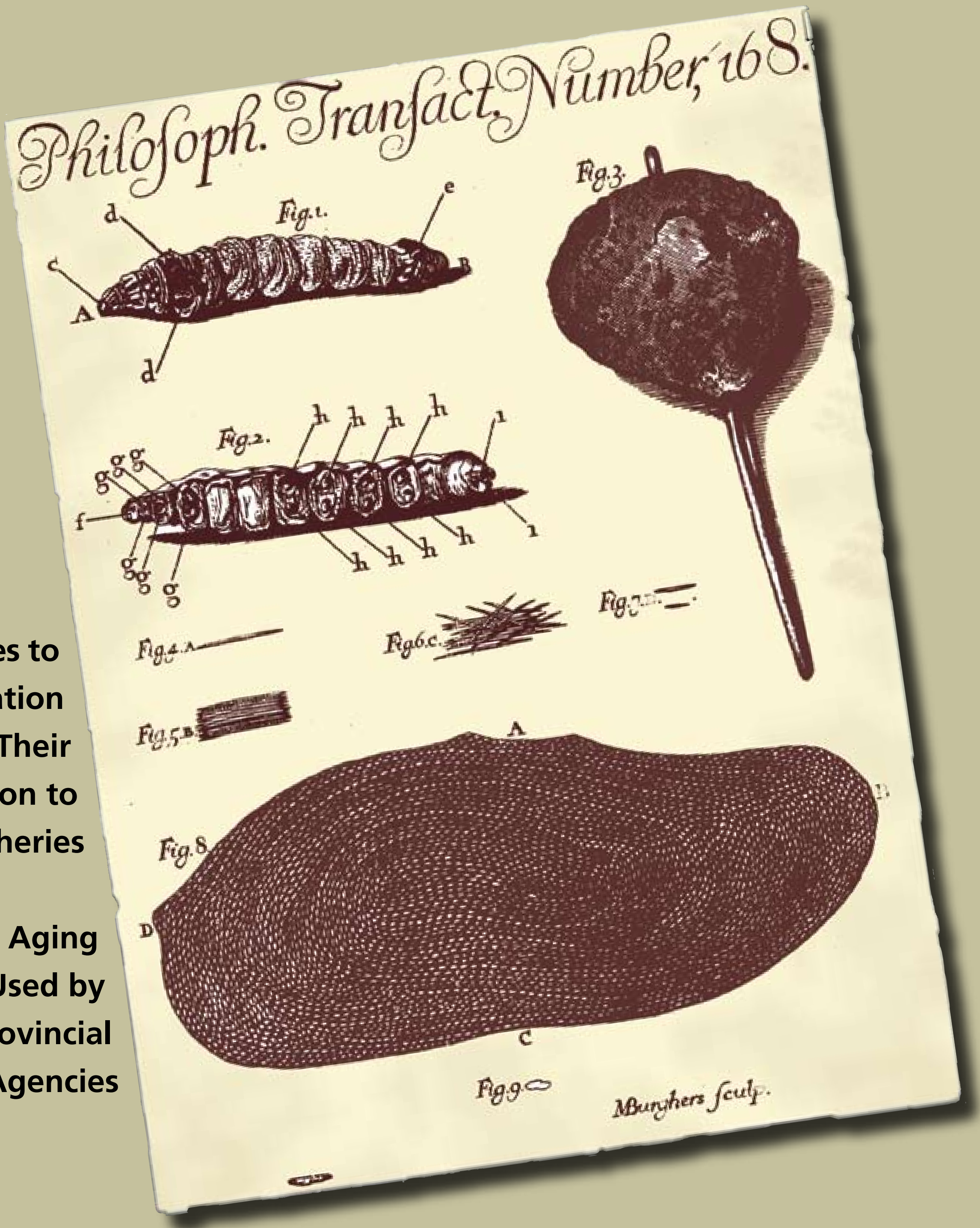

Earliest References to Age Determination of Fishes and Their Early Application to the Study of Fisheries

Freshwater Fish Aging Procedures Used by State and Provincial Fisheries Agencies

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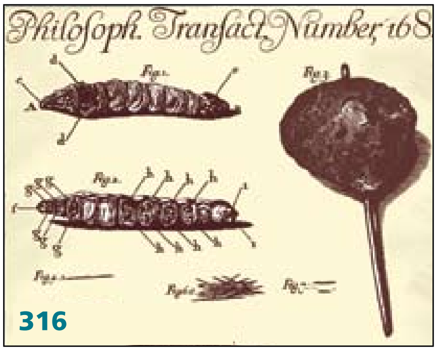

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COVER: The plate illustrating Leeuwenhoek's 1680s original theory that rings on the scale of eel were formed annually and could be used for determining age.
CREDIT: Philosophical Transactions of the Royal Society of London.

Jennifer L. Nielsen

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Talent du jour: what's in a name?

In the new world of $1,000 genomes and integrated climate change research, will fisheries still be able to attract the best and brightest?

Traveling around as president of AFS has given me a unique view of fisheries issues across a wide spectrum of our membership. One conversation that has come up time and again during my travels is the shifting trends at many colleges and universities in the way they organize and implement fisheries science. Many schools are leaving the tradition of a "Fisheries Department" behind and folding their graduate fisheries curricula into interdisciplinary programs for aquatic ecology, conservation biology, or ecosystem studies. Twenty-five years ago, graduate programs in fisheries were viewed as programs providing knowledge and applications for employment in fish harvest, culture, or extraction management. These programs were often thought to be light on science and research and heavy on credentials and training that enhance regional fisheries employment. This was true for other natural resource programs such as forestry and range management that have also undergone reexamination at most schools where they were taught. AFS members who serve on fisheries faculties are worried about their programs languishing in the face of integrated science.

AFS was recently tasked to look at fisheries graduate educational opportunities throughout the United States, focused on one objective in the recent reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act. The reauthorization requests information on the perception that there is a shortage of post-baccalaureate degrees in subjects related directly to traditional fisheries science. A survey on this issue is being implemented for AFS by Kevin Hunt, Mississippi State University. In preliminary development, Hunt's survey looked at 92 fisheries graduate programs in 45 states. Only 29 (32%) of these graduate degrees currently reside in university programs that still contain the words "fish" or "fisheries" in their title. This begs the question of where "fisheries" science stands in these programs. Universities and faculty are struggling in their efforts to redefine their fisheries programs without losing the core curricula and culture of learning that defines fisheries education today, while exploring new opportunities and technologies dedicated to resource management science.

Today's natural resource programs are changing, faced with elevated public interest in the environment; active controversies over sustainable resources, conservation, and allocation; and the need for rigorous science. University administrators have watched as recruitment to fisheries programs declined through the 1990s. Ecosystem management of natural resources is the buzzword of the day and new students in resource management demand a broad approach. Administrations responded to what the student body of the twenty-first century wanted in a natural resource program—and that was clearly something more than the legacy of fisheries exploitation and harvest management.

What exactly are the current needs in fisheries education and what does this trend in resource education portend for universities, students, and especially for AFS membership? In an effort to look further into this issue, I talked to the leaders of two long-term, highly respected fisheries schools that recently struggled with this transition: David A. Armstrong, director, Aquatic and Fisheries Sciences, University of Washington (UW); and Karl E. Havens, chair, Fisheries and Aquatic Sciences, University of Florida, Gainesville (UF). It is interesting that both schools came to very similar decisions on their fisheries programs, including a similar change in their programs' names.

Armstrong and Haven have overlapped significantly in their efforts to revitalize languishing fisheries programs at their universities. They both felt their schools were "sending the wrong message" to undergraduates interested in continuing their education in natural resources but not necessarily in a strict "fisheries" curricula. Both schools sought to retool their majors in fisheries, but retain the conduit for employment into professional programs leading to viable careers in fisheries. They felt that the current job market is such that a M.S. degree is required for entry-level positions at fisheries management agencies, state and federal. They also sought a broad training in biology, ecology, and conservation for their students to provide the knowledge, skills, and competencies needed to complete a graduate program in fisheries. Both schools have linked their fisheries degrees to broader communication and analytical skills thought to be a critical for graduate education at their universities.

Decisions made in the development of their current fisheries programs were to:

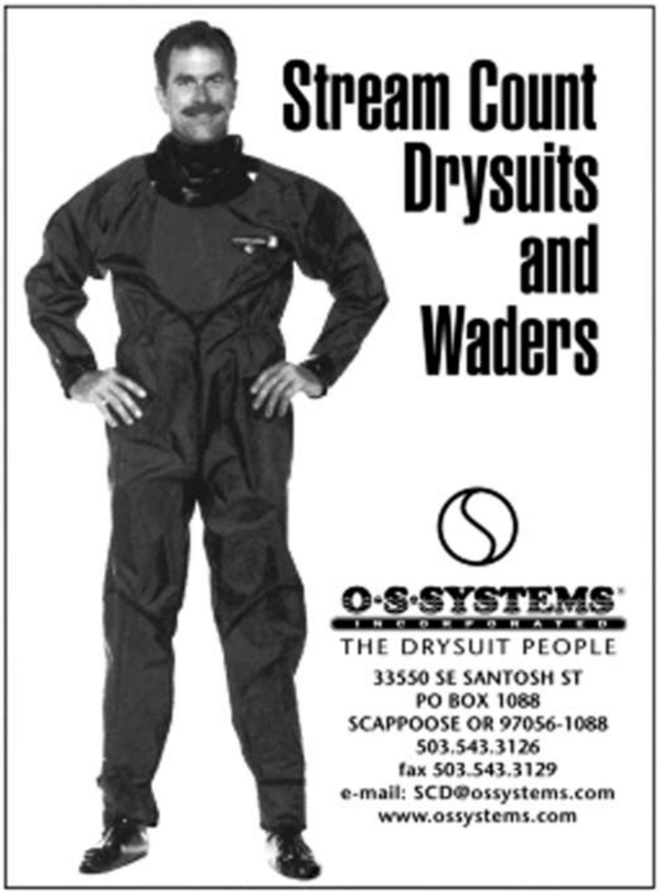
- Include courses on conservation and management of natural environments important to aquatic species, not just fish and fisheries.
- Emphasize ecology, life history, adaptations, and impacts of anthropogenic activity in aquatic ecosystems.
- Develop new crossover opportunities with mainstream ecology, encouraging interdisciplinary majors.

Continued on page 352

NEWS: FISHERIES

VHS virus detection fact sheet

A new fact sheet by scientists from the U.S. Geological Survey's (USGS) Western Fisheries Research Center describes the best methods for resource managers and others to detect and confirm a new and virulent strain of viral hemorrhagic septicemia (VHS) virus in fish, including popular game fish and bait fish. The recent spread of this sometimes devastating new strain—called VHSV Genotype IVb–has resulted in very large die-offs of thousands of fish in four of the five Great Lakes since 2005. The VHSV Genotype IVb has an exceptionally broad host range—thus far, the strain has been isolated from more than 25 species of finfish. The disease causes internal bleeding in fish, but is not believed to be harmful to people. Regulatory agencies in the United States and Canada have already placed restrictions on the movement of fish or fish products that could pose a risk for the spread of VHSV to regions outside of the currently known geographic range. These restrictions include requirements for viral examinations by standard methods.



The new USGS fact sheet reviews important factors in how to isolate VHSV Genotype IVb using cell culture assays and its identification by the polymerase chain reaction (PCR) assay. The fact sheet can be downloaded at http://biology.usgs.gov/faer/.

Record Gulf dead zone predicted

A team of scientists from the National Oceanic and Atmospheric Administration (NOAA), the Louisiana Universities Marine Consortium, and Louisiana State University is forecasting that the "dead zone" off the coast of Louisiana and Texas this summer has the potential to be the largest since shelf-wide measurements began in 1985. The dead zone is an area in the Gulf of Mexico where seasonal oxygen levels drop too low to support most life in bottom and near-bottom waters. It is caused by a seasonal change where algal growth, stimulated by input of nutrients such as nitrogen and phosphorus from the Mississippi and Atchafalaya rivers, settles and decays in the bottom waters. The decaying algae consume oxygen faster than it can be replenished from the surface, leading to decreased levels of dissolved oxygen.

This summer's zone may be as large as 8,500 square miles, an area about the size of New Jersey. Since 1990, the average annual hypoxia-affected area has been approximately 4,800 square miles; the "dead zone" measured 6,662 square miles in 2006. Although NOAA has predicted an active hurricane season for 2007, if no strong storms stir up the waters, this year's dead zone could equal the largest recorded and stretch into the continental shelf waters of Texas. This area is of particular concern because of its potential to affect valuable fisheries in the Gulf of Mexico.

RBFF Anglers' Legacy having financial impact

The Recreational Boating and Fishing Foundation's (RBFF) Anglers' Legacy program is having a positive financial impact on the fishing and boating industry, according to new survey results. In a survey of more than 7,500 Anglers' Legacy ambassadors who have taken a pledge to take one new person fishing each year, the data reveal an ambassador generates an initial average $120 in fishing tackle and equipment sales, and $166 in boating supplies such as gasoline and boating accessories. Nearly two-thirds of ambassadors purchased fishing licenses for the people they took fishing (3.2 on average).

"Right now, we're approaching 10,000 ambassadors, which translates into a potential of $1.2 million for fishing and $1.66 million for boating," said RBFF President and CEO Frank Peterson. "With the help of our industry partners, those numbers can only get better. If Anglers' Legacy can reach one million pledges, that could mean $286 million for the fishing and boating industries. That's a lot of money supporting the programs that protect the future of the resource and the sport."

Guangdong(Zhanjiang) International Prawn Exhibition
Guangdong (ZhanJiang) International Aquatic Products & Reservation and Transportation Equipment Expo.
Guangdong (ZhanJiang) International Aquatic Breeding, Processing Technology and Equipment Expo..
To focus on fishery festival ; To gain global business opportunity
■Zhanjiang City, with three sides surrounded by sea, faces to the north fishing ground. With its sufficient fishery products and its unique environment, it plays an important role in China fishery. It is the biggest prawn breeding, processing and exporting base of China, and its output covers 40% of Chinese Prawn.
■It ranks itself among the high standard exhibitions, occupying over 10,000 square meters,with more than 500 booths. Right now there are over 300 companies have participated.
■It will focus on present the new techniques and results of aquiculture and aquatic processing. For convenience sake, this exhibition center will be divided in to six areas: Aquiculture, Aquatic processing, Aquatic products, Logistics, Trading, and Technique Consultation.
2007
ZHANJIANG
8.24–8.26
■China-Japan-Korea Non-governmental Fishery Consultation and the Surrounding Countries Aquatics Trading Development Forum will also be held during the exhibition.
■Big fishery powers such as Norway, Iceland, Korea, Japan, Chile, Argentina will be invited, to promote worldwide fishery communication and cooperation, to make the exhibition a worldwide fishery trading feast.
Exhibition time: August24th ~26th ,2007
Exhibition place: Zhangjiang International Exhibition Center·Guangdong·China
Sponsor: Guangdong Provincial Oceanic and Fishery Administration of China; People's Government of Zhanjiang City
Co-sponsor: Oceanic and Fishery Administration of Fujian Province; Aquatic products and Stockbreeding Bureau of Guangxi Chuang Municipality
Hainan Ocean and Fishery Office
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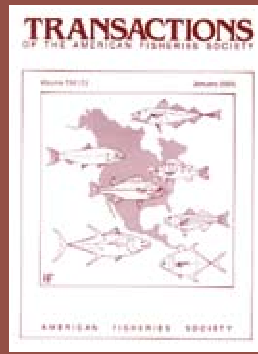

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[Note] **Effects of Road Decommissioning on Stream Habitat Characteristics in the South Fork Flathead River, Montana.** Magnus McCaffery, T. Adam Switalski, and Lisa Eby, pages 553-561.

[Note] **A New Low-Cost Instream Antenna System for Tracking Passive Integrated Transponder (PIT)–Tagged Fish in Small Streams.** Morgan H. Bond, Chad V. Hanson, Robert Baertsch, Sean A. Hayes, and R. Bruce MacFarlane, pages 562-566.

Effects of Habitat Volume and Fathead Minnow Introduction on Larval Survival of Two Endangered Sucker Species in Upper Klamath Lake, Oregon. Douglas F. Markle and Larry K. Dunsmoor, pages 567-579.

[Note] **Comparison between Model-Predicted and Field-Measured Stream Habitat Features for Evaluating Fish Assemblage–Habitat Relationships.** Travis O. Brenden, Lizhu Wang, Richard D. Clark, Jr., Paul W. Seelbach, and John Lyons, pages 580-592.

Spawning by Female Chinook Salmon Can Be Detected by Electromyogram Telemetry. Barry A. Berejikian, Robert C. Endicott, Donald M. Van Doornik, Richard S. Brown, Christopher P. Tatara, and Jeffery Atkins, pages 593-605.

Genetic Diversity within Fragmented Cutthroat Trout Populations. V. L. Pritchard, K. Jones, and D. E. Cowley, pages 606-623.

Incidence of Hybridization between Naturally Sympatric Westslope Cutthroat Trout and Rainbow Trout in the Middle Fork Salmon River Drainage, Idaho. Christine C. Kozfkay, Matthew R. Campbell, Steven P. Yundt, Michael P. Peterson, and Madison S. Powell, pages 624-638.

Cold Summer Temperature Regimes Cause a Recruitment Bottleneck in Age-0 Colorado River Cutthroat Trout Reared in Laboratory Streams. Mark A. Coleman and Kurt D. Fausch, pages 639-654.

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Regional Synchrony of Brown Trout and Brook Trout Population Dynamics among Michigan Rivers. Troy G. Zorn and Andrew J. Nuhfer, pages 706-717.

A Structured Approach for Developing Indices of Biotic Integrity: Three Examples from Streams and Rivers in the Western USA. Thomas R. Whittier, Robert M. Hughes, John L. Stoddard, Gregg A. Lomnicky, David V. Peck, and Alan T. Herlihy, pages 718-735.

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Coherence of Atlantic Cod Stock Dynamics in the Northwest Atlantic Ocean. Brian J. Rothschild, pages 858-874.

Earliest References to Age Determination of Fishes and Their Early Application to the Study of Fisheries

James R. Jackson
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ABSTRACT: Age data are routinely used in fish population studies today. While various works have touched upon aspects of the history of fish aging techniques, there does not appear to be a single source that attempts to summarize the earliest literature on age determination of fishes in a broad historical context. The Fisheries Management Section formed the ad hoc Assessment of Fish Aging Techniques Committee in 2006, with development of such a review as a goal. The earliest references to rings on the hard structures of fish by Leeuwenhoek and Hederström date to the seventeenth and eighteenth centuries. Scientific validation of annuli on the scales of fish did not take place until the late 1800s, with the work of Hintze and Hoffbauer. The work of Reibisch on otoliths and Heincke with other hard structures quickly followed. These later studies on fish aging techniques came at a time when large-scale studies of fish populations were gaining momentum. While the new aging methods were adopted rapidly by many fisheries workers, debates about their validity were not uncommon. A notable example took place between Hjort and Thompson, centering on Thompson's doubts concerning the validity of scale-based ages in Hjort's seminal 1914 paper.

Referencias elementales para la determinación de edad en peces y sus primeras aplicaciones en el estudio de las pesquerías

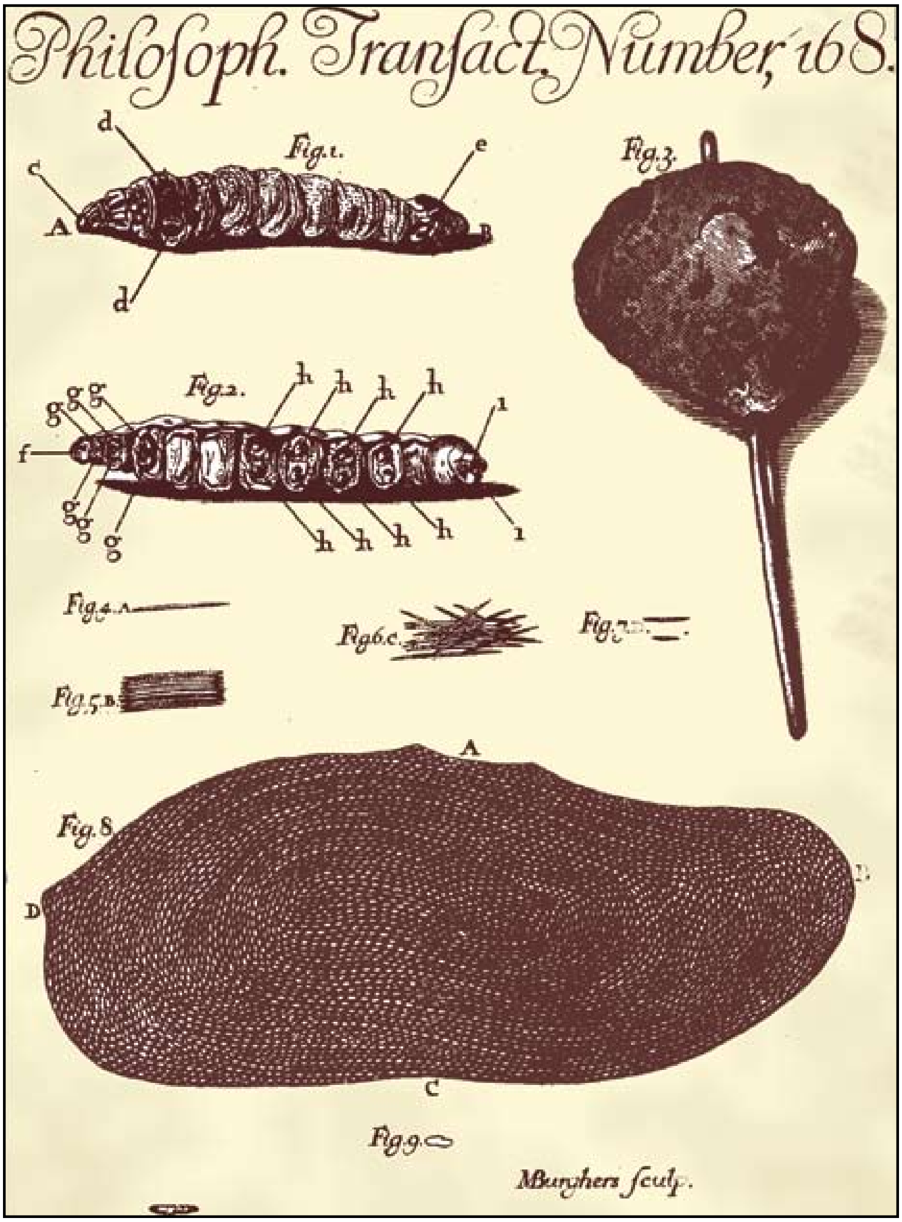
RESUMEN: En la actualidad, los datos de edad son comúnmente utilizados en estudios poblacionales de peces. Si bien existen varios trabajos que abordan aspectos relacionados a la historia de las técnicas para determinar la edad en peces, parece no haber una sola referencia en la que, bajo un contexto histórico, se sintetice la información de los primeros estudios sobre este tema. Para tal fin, en 2006, La Sección sobre Manejo de Pesquerías estableció el Comité para la Evaluación de Técnicas de Determinación de Edad en Peces. Las primeras referencias acerca de anillos de crecimientos en estructuras duras en peces, de Leeuwenhoek y Hederström, se remontan a los siglos XVII y XVIII. La validación científica de los anillos presentes en las escamas de los peces no se dio sino hasta finales de 1800, con el trabajo de Hintze y Hoffbauer, seguido por los estudios de Reibisch sobre otolitos y otras estructuras duras. Estos trabajos se dieron al mismo tiempo en el que los estudios a gran escala de biología poblacional de peces ganaban inercia. Mientras que los nuevos métodos para determinación de edad fueron rápidamente adoptados por varios estudiosos de las pesquerías, crecieron los debates acerca de su validez. Un ejemplo fue la controversia suscitada entre Hjort y Thompson, generada por las dudas de Thompson acerca de la validez de los datos de edad publicados en un artículo de Hjort en 1914, obtenidos a partir de la lectura de escamas.

The use of age information is an integral part of fisheries today. Hilborn and Walters (1992:167) state that "the most valuable information obtained from sampled catch, at least for temperate waters, is age." The development and acceptance of methods for age determination in fishes represents a critical early stage in fisheries science, and at times was fraught with more controversy than today's wide usage of the methods would suggest. In 2006, the Fisheries Management Section of the American Fisheries Society formed the ad hoc Assessment of Fish Aging Techniques Committee to assess the status of aging of freshwater fishes in North America (see Maceina et al. this issue). As part of the committee's goals, an historical survey of the earliest references to aging of fishes and their initial application to fisheries studies was undertaken. Earlier works on fish aging have touched on aspects of the history of the field, often focusing on specific structures or species (e.g., Van Oosten 1929; Menon 1950), but many of these works appear in outlets that are not easily accessible. I am not aware of a single source that attempts to summarize the earliest works on age determination in fishes in their historical context, including their acceptance and initial application to the study of fisheries in the early years of the 1900s. The objective of this article is to provide such a summary and serve as a reference for those wishing to access original sources. In most cases, primary source material has been used by the author, but in those cases where original documents were unavailable, original citations are still provided for historical purposes, with acknowledgement of the secondary source for the citation.

Aristotle (ca. 340 B.C.) may have been the first to speculate upon the use of hard structures to determine fish age, claiming in his *Historia Animalium* that "the age of a scaly fish may be told by the size and hardness of its scales" (Thompson 1910:Book

VIII, Section 30). However, it was not until the development of the microscope that more detailed studies of scale structure took place. Antoni van Leeuwenhoek of Holland, who used his experience counting threads in cloth at a dry goods store with magnifying glasses to develop improved lenses that he used to construct microscopes, became one of the leading microscopists of the 1600s. Leeuwenhoek possessed a wide-ranging curiosity that included issues surrounding demographics of animal populations (Egerton 1968). Curiously, Leeuwenhoek's studies of fish scales appear to have been at least in part inspired by Biblical strictures against eating fish without scales. His earliest writings on fish scales appeared in a letter to the Royal Society of London, and focused on the European eel (*Anguilla anguilla*) and the burbot (*Lota lota*), which he was drawn to as a result of their reported lack of scales "which two sorts of fish, the Jews will not eat, as forbidden by the Law of Moses." (Leeuwenhoek 1685:893). Leeuwenhoek found scales on both eel and burbot and undertook a study of the fine structure of eel scales, which included his observation of "circular lines" (Leeuwenhoek 1685:894; Figure 1). Leeuwenhoek observed that "altho [sic] all the scales, are not just of the same shape, I have yet observed, in many of them, as I judged, the same number of circular lines. From whence I conclude, that every year, the scale encreased [sic] one circular line..." (Leeuwenhoek 1685:894-895). A more detailed version of Leeuwenhoek's studies of fish scales, published in a volume of collected writings, included a description of the ring pattern on the scales of carp (*Cyprinus carpio*), as well as his speculation that the ring pattern resulted from the growth of new, larger scales underneath older scales. However, he nonetheless correctly inferred the timing of the formation of darker areas as occurring during the season of slowed growth, as he had previously observed in trees (Leeuwenhoek 1798).

Figure 1. The plate accompanying Leeuwenhoek's original theory that rings on the scale of eel were formed annually and could be used for determining age. Leeuwenhoek's illustration of scale patterns is presented as Fig.8, Fig. 9 shows an eel scale to scale (Leeuwenhoek 1685).



It seems that Leeuwenhoek's work went largely undiscovered by fisheries workers, as the attribution for the first reliable age determination more often is credited to Hans Hederström (e.g., Ricker 1975). Hederström, a Swedish clergyman, was drawn to his studies of fish aging by reports of a 267-year-old pike (*Esox lucius)* known as Heibrun's pike (Hederström 1759; Casselman 1974). Hederström asked, "Is it in agreement with the order established within the animal kingdom that nobler and more useful animals should have such a short span of life compared with that of the pike?" (Hederström 1759:161). Trusting that the Creator might provide some means of determining the age of fish, as was the case with trees, Hederström examined the vertebrae of pike and concluded that the rings that could be discerned on them were growth rings that could be used to determine the fish's age. His reasoning revealed a thoroughly scientific approach, and included verification that (1) both sides of a vertebra had the same number of rings, (2) all vertebrae in an individual possessed the same number of rings, (3) larger fish had more rings on their vertebrae than smaller fish, and (4) the number of rings matched the age of fish "known either from experience or from other circumstances" (Hederström 1759:162). Hederström went on to present length-at-age data for pike that agree well with modern estimates and also reported that he had confirmed the applicability of using rings on vertebrae for determining the age of a variety of other species, including European perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), bream (*Abramis brama*), chub (*Leuciscus cephalus*), cod (*Gadus morhua*), European eel, and burbot.

While Hederström alluded to the use of known-age fish to verify his conclusions of annually-formed rings on fish vertebrae, fully-documented validations of the formation of annuli in the hard structures of fish did not appear in the literature until 100 years later. Robert Pell (1859) reported that his examination of the scales of yellow perch (*Perca flavescens*) and the vertebrae of sucker (*Catastomus* spp.) he had reared in ponds for two years exhibited two "rings or circles," and he concluded that the rings could be used to determine the age of all fish (Pell 1859:347). G. Hintze (1888, as cited and summarized in Van Oosten 1929) presented the results of his studies of the scales of known-aged carp from commercial ponds. Hintze presented illustrations of scales of age 1–4 carp, clearly showing addition of annuli, but with an erroneous interpretation of an accessory annuli in the age-2 fish that Van Oosten (1929) speculated may have lessened the impact of his work.

It was not until 1898, more than 200 years after Leeuwenhoek's original theories about the significance of patterns on fish scales, that the matter was finally subjected to thorough and critical study by C. Hoffbauer. Like Hintze, Hoffbauer studied carp from commercial ponds. His initial and most frequently cited paper was published in 1898, and was followed by more detailed studies in 1900 (Hoffbauer 1898 [Figure 2], 1900a; 1900b). Hoffbauer carefully observed the development of scales through the year, noting that during the season of growth, marginal, concentric rings were easily discernable and widely spaced, but as growth slowed and ultimately ceased during the winter they became more closely compacted, with a subsequent renewal of the pattern of widely-spaced circuli when growth resumed. He correctly concluded that the darker areas formed by closely-arranged circuli during the winter could be interpreted as representing annual marks and therefore used to age fish. Hoffbauer followed the formation of annuli on carp up to age 3, and then went on to examine the effects of environmental conditions on scale development. Among his findings were observations that scales from undernourished carp were characterized by less clearly defined and more closely arranged annuli. Further experimentation confirmed that spacing of annuli was correlated with the growth rate of fish, with fast growth resulting in more widely spaced annuli. Hoffbauer's later work included application of his new techniques to goldfish (*Carassius auratus*), largemouth bass (*Micropterus salmoides*), European perch, pike, and salmon (*Salmo* spp.). J. Stuart Thomson, with encouragement and support from Walter Garstang and E. J. Allen at the Plymouth Laboratory of the Marine Biological Association of the United Kingdom, extended Hoffbauer's work with freshwater fishes to important commercial marine species. His detailed work with pollack (*Pollachius pollachius*), poor cod (*Trisopterus minutus*), whiting (*Merlangius merlangius*), haddock (*Melanogrammus aeglefinus*), and cod convinced him that Hoffbauer's findings could be applied to marine species (Thomson 1902, 1904).

Investigations into the potential of structures other than scales for aging fish followed soon after Hoffbauer's publication. Johannes Reibisch, working with the Commission for the Scientific Investigation of German Seas at Kiel, quickly tried to apply Hoffbauer's findings in his studies of plaice (*Plueronectes platessa*), but was soon frustrated by the difficulty in accurately identifying annuli on scales. His experiences led him to look at another structure, and in 1899 he published the first paper on the utility of otoliths for determining the age of fish (Reibisch 1899, Figure 3).

Crowding of the rings in the otoliths of older plaice led Friedrich Heincke, also with the German Commission at Kiel, to examine the usefulness of a variety of fish bones for age determination. Working with gadids and flatfish, Heincke found annuli in the vertebrae, opercula, and several bones in the pectoral girdle (Heincke 1905, as cited and summarized in Menon 1950), and it is his work that is most often cited in conjunction with Hoffbauer and Reibisch as completing the early studies establishing scales, otoliths, and bones as viable aging structures (e.g., Allen 1917; Ricker 1975). Menon (1950) credits Tereschenko (1913), who was working with roach, with the first use of cleithra for aging and Holtzmayer (1924) with first using fin rays as part of his work with sturgeon (*Acipenser* spp.). So within 250 years

Figure 2. Illustration of annuli on the scales of carp from Hoffbauer (1898).

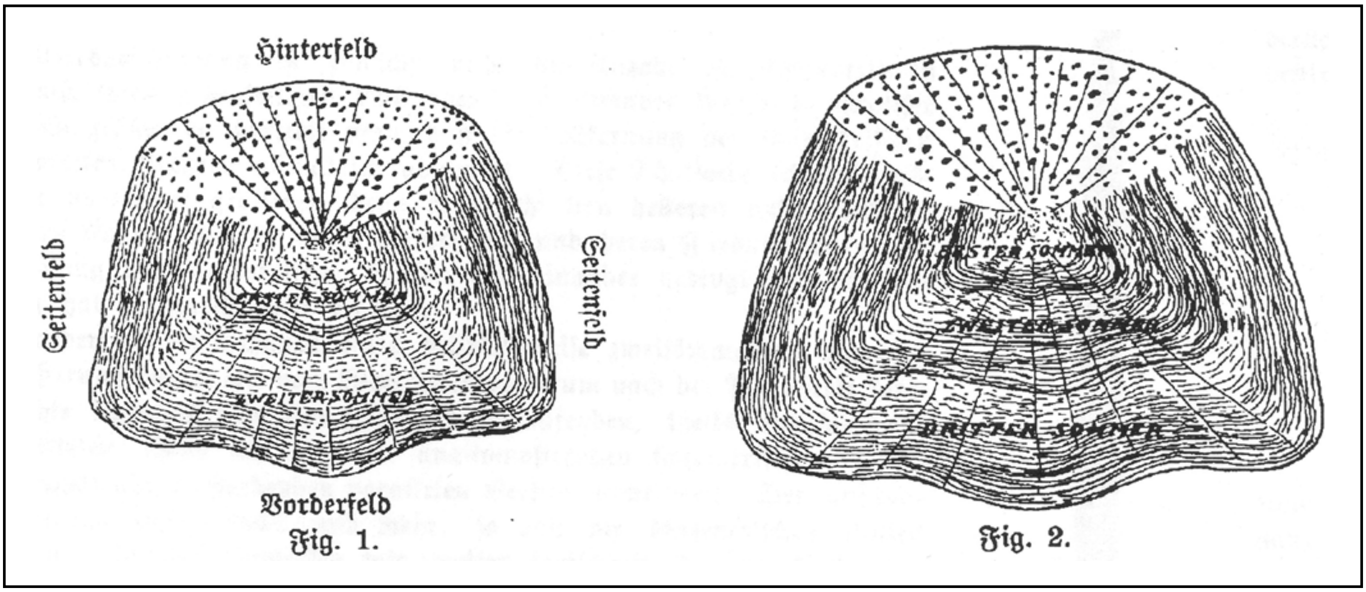
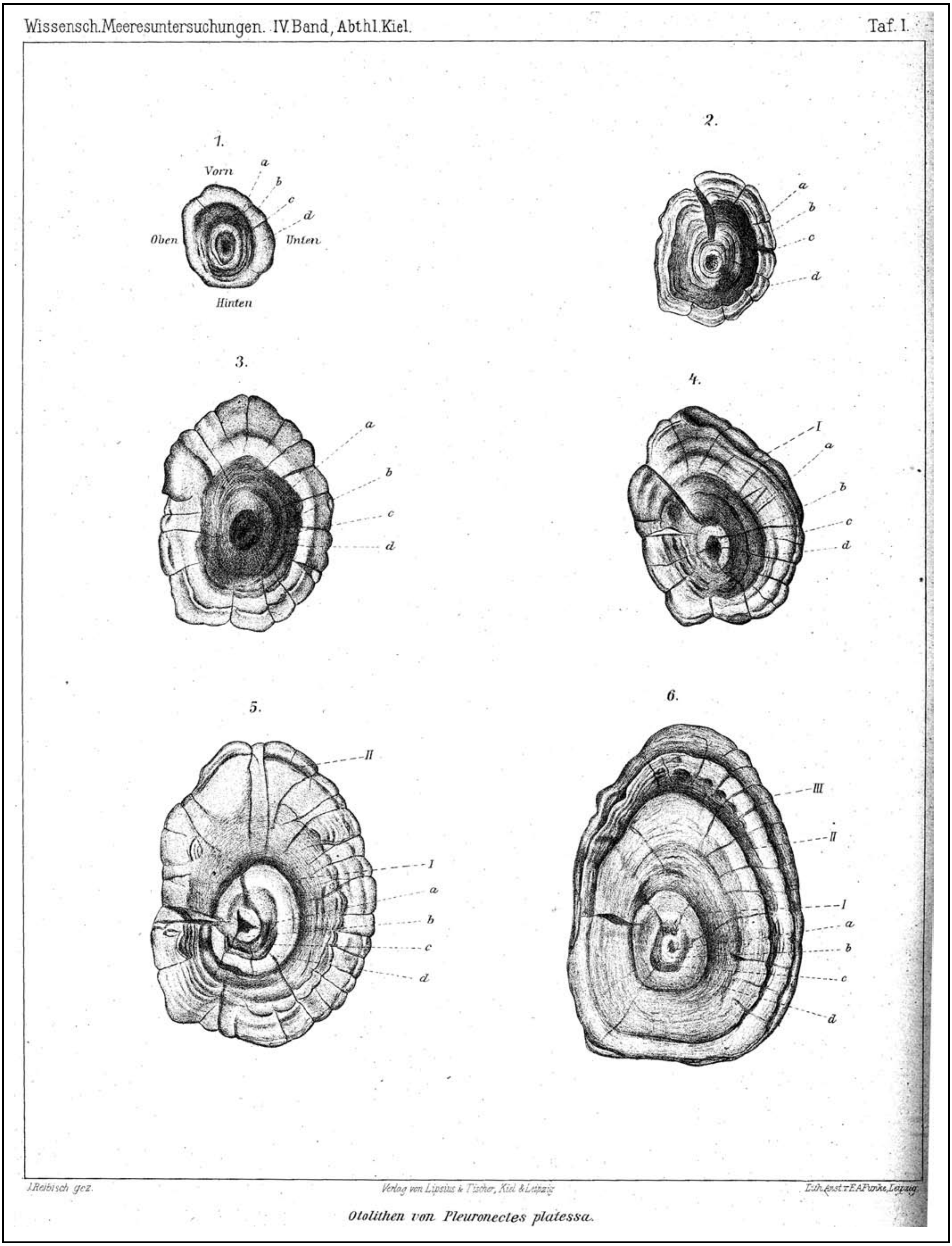


Figure 3. Plate illustrating annuli on otoliths of plaice (Reibisch 1899).



of Leeuwenhoek's first published observations of annuli on scales, those structures relied upon for the majority of aging of freshwater species in North America had been introduced to the literature (Maceina et al. this issue).

The findings of Hoffbauer and Reibisch could not have been better timed for notice and near-immediate application to the questions of fisheries. Fluctuations in the commercial catches of sea fishes had begun to attract serious attention in the later decades of the 1800s. Analyses of commercial catches and the initiation of large-scale fishery-independent surveys would soon take fisheries research in a direction where age-based data could lead to seminal breakthroughs that would change the way fish population dynamics were viewed.

Questions about age-specific processes would arise soon after systematic analyses of fisheries catches began. In the absence of wide-spread knowledge of the potential utility of hard structures for age determination, it is not surprising that early efforts at assigning ages to fish by fisheries workers were based on length information. While Carl Georg Johannes Petersen is most often credited with first proposing length-based methods for age determination (e.g., Allen 1917; Ricker 1975), his work appears to have been preceded by Joseph T. Cunningham. Cunningham, working at the Marine Biological Association's Plymouth Lab, attempted to use lengths from known-aged fish he reared in aquaria to assign ages to wild-caught fish, focusing on flatfish and cod (Cunningham 1891, 1892). Cunningham's efforts were not rewarded by clear-cut results: "It is evident there is considerable variation in the rate of growth in nature, from the difficulty of distinguishing in a large number of fish those of one year's, two years', and three years' growth" (Cunningham 1891:97).

C. G. J. Petersen, director of the Danish Biological Station, may be best remembered today for his pioneering efforts with fish marking and the mark-recapture population estimate method that bears his name (it has been argued that Petersen never used his marking methods to conduct a population estimate, with priority instead going to Knut Dahl, a member of Johan Hjort's staff in Norway; Le Cren 1965). Petersen's work using lengths to assign ages to blenny (*Zoarces viviparus*) received more notice than Cunningham's, but was characterized by the same difficulties (Petersen 1892, summarized by Ricker 1975). Petersen constructed what are now known as length-frequency graphs, proposing that the peaks, or modes, that were evident across the range of smaller to larger size classes represented progressively older age-classes of fish. Petersen's approach suffered the same sensitivity to variability in growth rates as had Cunningham's less quantitative presentation. Modes became difficult to differentiate for older age-classes and overlap in lengths of fish between the modes made confident assignment of ages to fish based on length alone problematic (see Allen 1917; Smith 1994).

Following the papers of Hoffbauer and Reibisch, fish aging began to be featured in many of the fisheries assessments in the early 1900s. Michael Graham, the research director at Lowestoft responsible for recruiting and mentoring, among others, Raymond Beverton and Sidney Holt, recalled that the "majority of workers showed no scepticism [sic]" (Graham 1943:134). Graham included among those who were skeptical C. J. G. Petersen, who during lunch "once asked an ardent believer in the new method if it included the rings on the slice of beetroot on his plate" (Graham 1943:133-134). The validity of aging techniques was questioned by some workers, in some cases pointedly (e.g., Williamson 1918), and refinements of methods continued. These debates did not, according to existing contemporary accounts, slow the incorporation of aging into studies of most of the major fisheries (see Allen 1917; Van Oosten 1929).

A notable early debate concerning the application of age data centered on the work of Johan Hjort, a respected figure in Norwegian fisheries studies who assumed a lead role in the International Council for the Exploration of the Sea when it was established in 1902 (Rozwadowski 2002). Hjort recounts having seen Heincke present results of his work on fish aging to the council in 1904, after which Hjort arranged to visit Heincke at his laboratory to learn more (Hjort 1914). Hjort soon put his assistants to work developing an extensive aging program, settling on scales as his primary tool. His goal was to frame his fisheries research in light of the science he referred to as "vital statistics," or what we would now call demographics, with the explicit intention of collecting "representative statistics" that would allow insights into "1. Birth-rate. 2. Age-distribution. 3. Migration" (Hjort 1914:11).

Hjort presented his plans for the use of scale-based age determinations in assessing herring populations to the council in 1910, initiating a debate about the validity of the scale method that was spearheaded by D'Arcy Wentworth Thompson, the British delegate to the council (Smith 1994; Rozwadowski 2002). Thompson's concerns carried the day, and Hjort's proposed program of study was not supported by the council. Hjort continued his work anyway. Hjort's assistant, Einar Lea, who was by this time leading the lab's scale studies, continued to present results of their work and invited other scientists to demonstrations of the method, and ultimately the council appointed Hjort as chair of a committee charged with further assessments of the new method, a committee on which Thompson was not included (Smith 1994; Rozwadowski 2002).

The results of Hjort's research program were laid out in his 1914 monograph *"Fluctuations in the great fisheries of northern Europe viewed in light of biological research"* (Hjort 1914; Figures 4–5). Today this paper is most often cited in reference to Hjort's hypothesis that the concept of a critical period in the early life history of fish developed by Fabre-Domergue and Biétrix (1897) in aquaculture settings could apply to wild fish populations. However, Sinclair and Solemdal (1988) point out that the contemporary impact of Hjort's research related to his use of age data to link variability in landings to variable recruitment within fish populations. While commonly accepted today, Hjort's insights were revolutionary in their time, and would lead to fundamental changes in how fish populations were studied and fisheries managed.

Hjort's paper received a glowing notice in the journal *Nature* from E. J. Allen: "There can be little doubt that this report by Dr. Hjort will mark an epoch in the history of scientific fishery investigation" (1914:672). The praise was not unanimous. D'Arcy Wentworth Thompson, best known as a biomathematician and author of the classic *On Growth and Form*, responded to Allen's review expressing his inability to accept Hjort's conclusions (Thompson 1914a, b). Thompson did not accept Hjort's conclusions that the 1904 year class dominated the Norwegian spring herring fishery for more than 5 years. His doubts were based in part on his feeling that the "assumption" that the ages of herring were indicated by rings on the scales was far from proven and also on his belief

Figure 4. Photograph of a herring scale from Hjort (1914).

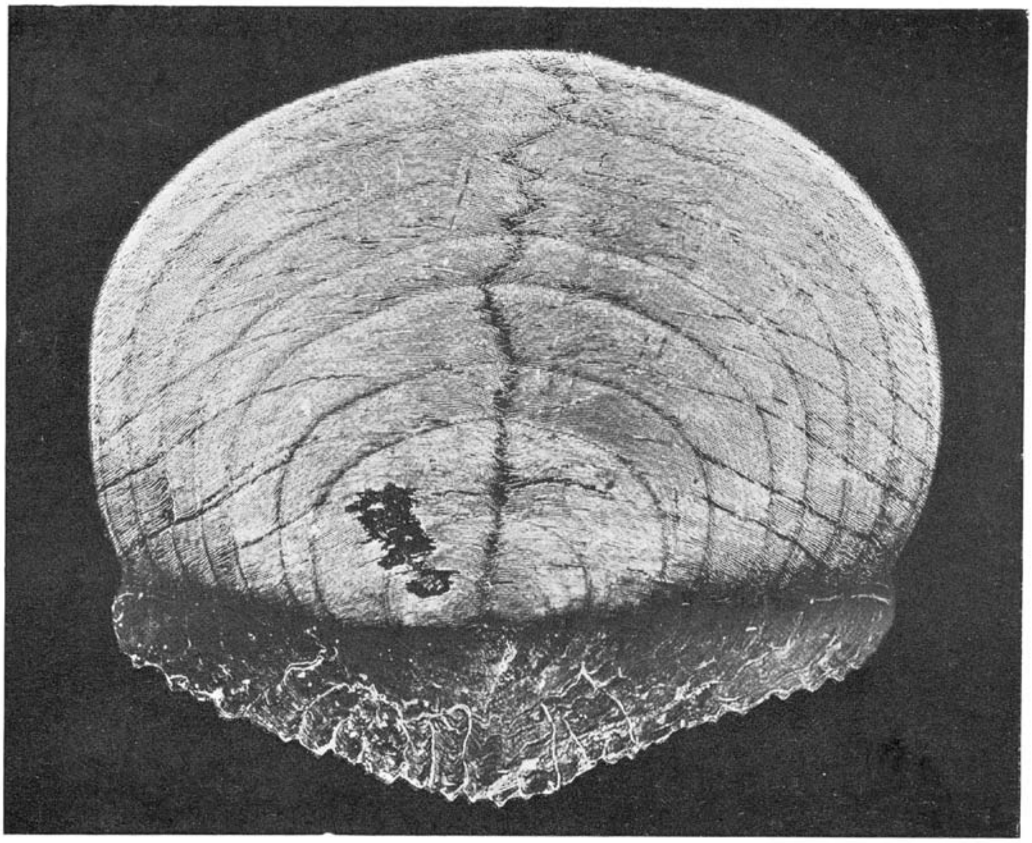


Fig. 9. Herring scale with 8 winter rings inside the edge (Lea phot.).

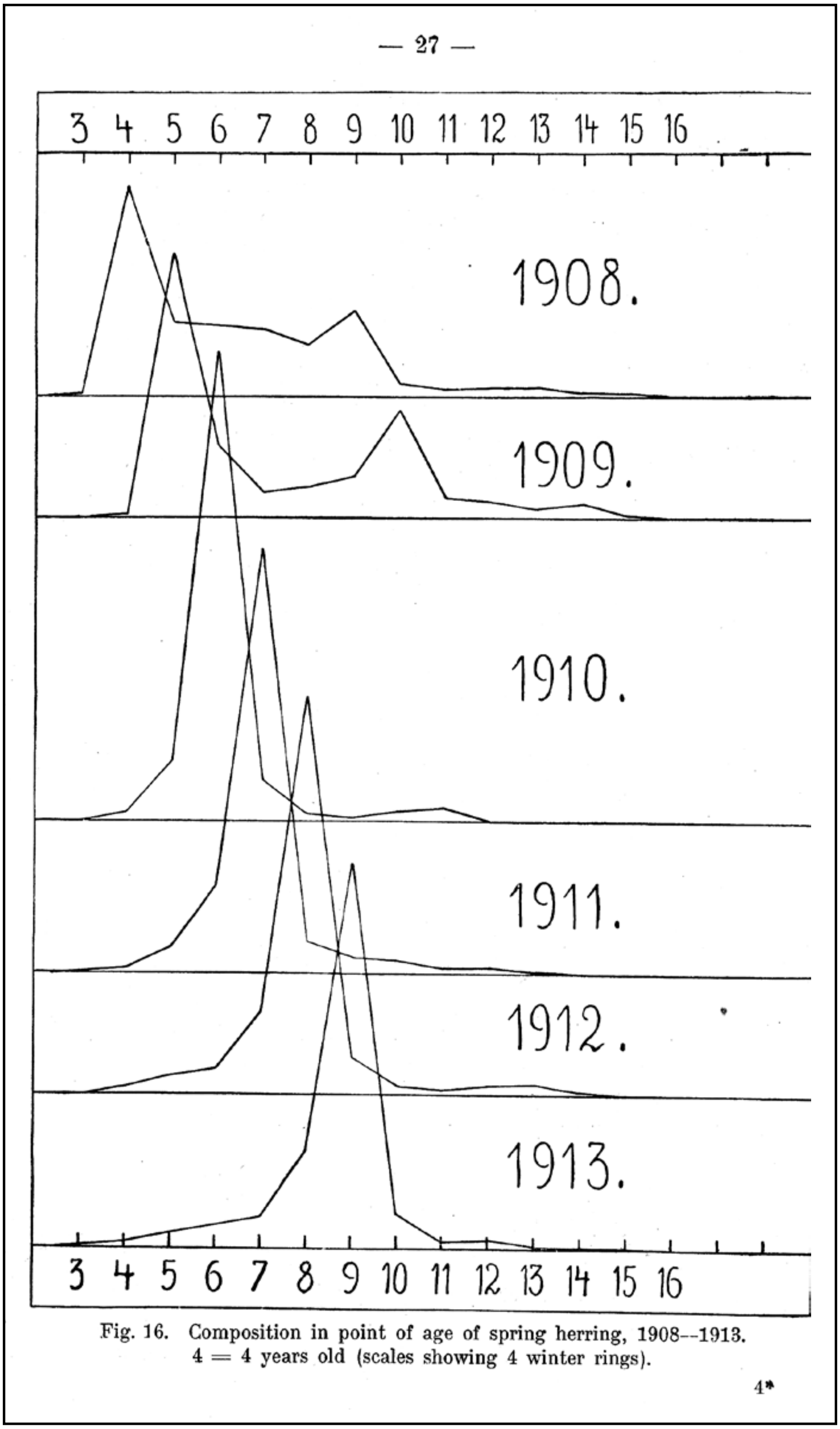
that same-aged fishes tended to shoal together. Thompson noted that the frequency distribution of herring age groups in Hjort's data "ranged themselves with great apparent regularity in a unimodal skew-curve." (Thompson 1914a:60). He argued that the conclusions drawn from Hjort's age distributions were "statistically improbable," and used that improbability to conclude that the rings on herring scales were unlikely to vary in number as a function of age: "Just as the individual herrings vary in a normal fashion about a certain modal size, so do they also vary, in the number of their scale-rings, about a certain modal number." (Thompson 1914a:60). Thompson finished by describing Hjort's efforts to interpret his data as "a clear case of a biological problem, based upon statistics, surrounded by mathematical difficulties, where the biologist cannot possibly be sure of his ground until he has enlisted the help of the mathematical statistician" (Thompson 1914a:61).

Hjort enlisted his assistant Einar Lea, who had conducted the bulk of the aging studies on herring and had previously published his methods in detail, in his response to Thompson's criticisms (Hjort and Lea 1914). They began by reiterating their methods for age determination using scales and emphasizing the amount of evidence from other sources that the method was valid. They then addressed Thompson's statistical concerns by presenting comparisons of a normal curve to their age-frequency curve, concluding that "the dissimilarity of the two curves is, in fact, so great as to exclude any idea of the age-curve following the usual law of biological variation" and that "it seems to us impossible to explain the observed facts as a result of common variation, even if the help of a mathematical statistician were enlisted." (Hjort and Lea 1914:256). Thompson's follow-up letter, raised additional concerns about sampling issues and sample sizes in Hjort's studies, and reiterated his "unaltered incredulity" (Thompson 1914b:363). History would bear out the soundness of Hjort's science, although Thompson would remain firm in his skepticism about the reliability of scales for aging herring until 1930, when he publicly announced his conversion at an ICES meeting (Smith 1994). Thompson's arguments did bring attention to the need to obtain samples from multiple locations and schools of fish if the intention was to characterize the age composition of the entire stock (Smith 1994). Perhaps ironically, just three years after his debates with Hjort, Thompson's analyses of the length composition from his commercial port sampling of haddock catches would add to the growing body of evidence that fish populations exhibited large natural fluctuations in recruitment (Smith 1994).

The incorporation of age data in studies of freshwater fish populations progressed more slowly than it did in the studies of marine populations. Carlander (1987) theorized that the delay was partly attributable to limited communication among freshwater and marine fisheries scientists, but was in large part due to the focus on stocking and habitat in freshwater management rather than on issues of harvest and yield where age data were particularly valuable. A. G. Huntsman of the Fisheries Research Board of Canada was keeping abreast of the developments in Europe, however, and in 1918 presented a paper to the Royal Society of Canada on its potential applications, soon followed by a similar presentation to the American Fisheries Society (Huntsman 1918, 1919). Carlander (1987) credits Huntsman's papers with bringing aging methods to the attention of North American workers, and the first papers in the *Transactions of the American Fisheries Society* applying the methods to freshwater studies appeared in 1924. Borodin (1924) used scales to assess American shad (*Alosa sapidissima*) in the Connecticut River, and a study of the use of otoliths in the same system followed soon after (Barney 1924). A search of articles in the *Transactions* reveals only one other application of aging to fish studies in the 1920s, but an increase to 84 in the 1930s, 74 during the 1940s, 112 during the 1950s, followed by rapid increases to 231 in the 1960s and 370 during the decade of the 1970s.

The foundations for routine incorporation of age data into fish population assessments were well-established by the early years of the 1900s. The structures used to perform the majority of current agency aging of freshwater fishes in North America had all been introduced into the literature prior to 1925. New techniques frequently encounter resistance upon their initial application, and fish aging was no exception. While contemporary accounts suggest that aging techniques were adopted quickly and widely after their discovery by the fisheries profession, controversies, both private and public, did occur. Hopefully, the preceding review of the earliest works on fish aging and their early impact on fisheries research will help readers appreciate the foundations upon which current aging programs have been built, and serve as a useful documentation of the primary literature for those techniques covered in the review of current practices presented by Maceina et al. (this issue).

Figure 5. Age frequency graphs of herring based on scale ages from Hjort (1914).



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FEATURE:
FISHERIES RESEARCH

Current Status and Review of Freshwater Fish Aging Procedures Used by State and Provincial Fisheries Agencies with Recommendations for Future Directions

ABSTRACT: In 2006, the Fisheries Management Section of the American Fisheries Society formed the ad hoc Assessment of Fish Aging Techniques Committee to assess the current status of aging freshwater fish in North America. For seven species groups that included black bass (*Micropterus* spp.), crappie/sunfish (*Pomoxis* spp./*Lepomis* spp.), catfish (Ictaluridae), morinids, percids, salmonids, and esocids, a survey of U.S. and Canadian fisheries agencies (*N* = 51 agencies responding) revealed that scales, otoliths, and spines were the most common structures used to age fish. Latitudinal clines existed for some of the structures that were examined, with scales typically used more in northern latitudes than otoliths. Many agencies conducted some validation of age estimation techniques and most assessed precision at least for some of the age samples collected. Providing personnel with training to age fish was common. Reasons for the structures used and the types of inferences and information generated from age data were reported. Scales were the most common structure used to age esocids, black bass, crappie/sunfish, and moronids, but only 27% of all respondents felt that scales accurately aged fish to the maximum age. Alternatively, most agencies felt that otoliths provided accurate estimates. From a review of published papers, otoliths were more accurate when compared to other aging structures and showed higher precision. Most agencies conducted back-calculation of lengths from annuli that provided additional information on growth, even though back-calculation procedures contain complex and inconsistent interpretation and computation issues. Currently, many studies are being conducted where known-age fish were chemically or physically marked, stocked, then recaptured after a number of years which can furnish data for age validation. Recommendations include the development of a known-age reference database to allow sharing of information, publication of validation studies, and careful considerations for conducting back-calculation of lengths from presumed annuli.

Estado actual y revisión de procedimientos para determinar edad en peces dulceacuícolas, utilizados por agencias estatales y municipales de pesquerías, con recomendaciones para trabajos futuros

RESUMEN: En 2006, La Sección sobre Manejo de Pesquerías estableció de manera expedita el Comité para la Evaluación de Técnicas de Determinación de Edad en Peces con el fin de conocer el estado actual de las técnicas utilizadas para la lectura de edad en los peces dulceacuícolas de Norteamérica. Un estudio prospectivo realizado a las agencias de pesquerías de los Estados Unidos de Norteamérica y Canadá (*N* = 51 agencias respondieron) reveló que las escamas, otolitos y espinas fueron las estructuras más utilizadas para la lectura de edad en siete grupos de especies que incluían a la lobina negra (*Micropterus* spp.), mojarras (*Pomoxis* spp./*Lepomis* spp.), bagre (Ictaluridae), morónidos, pércidos, salmónidos y esócidos. Existe una gradiente (clinal) latitudinal para algunas de las estructuras que son examinadas: las escamas, más que los otolitos, son mayormente utilizadas hacia el norte. Varias agencias hicieron validaciones de técnicas para estimación de edad y la mayoría evaluó la precisión, al menos, de algunas de las muestras colectadas. La capacitación de personal para la lectura de edad, fue un rasgo común. También se reportaron las razones por las cuales se utilizó cierta estructura en lugar de otra, así como los tipos de inferencia e información derivada de los datos de edad. Las escamas fueron las estructuras más utilizadas para determinar la edad en esócidos, lobina negra, mojarras y morónidos, pero solo el 27% de las agencias consideró que la edad máxima podía ser determinada con mayor precisión utilizando las escamas. Alternativamente, la mayoría de las agencias consideró que a través de los otolitos se obtienen estimaciones precisas. Sobre la base de una revisión de trabajos publicados, se encontró que usando otolitos, en comparación a otras estructuras que sirven para determinar la edad, podían derivarse estimaciones más precisas. Casi todas las agencias se valieron del retro-cálculo de longitudes a partir de anillos que podían proveer información adicional sobre crecimiento, pese a que este procedimiento implica interpretaciones intrincadas e inconsistentes y cálculos complejos. Con la finalidad de generar datos útiles para la validación de la edad, actualmente se están realizando muchos estudios en los cuales a peces de edad conocida, se les marca física y químicamente, se les libera y recaptura después de unos años. Se recomienda desarrollar una base de datos de edades conocidas que sirva para compartir información, publicación de estudios sobre validación así como para conocer aspectos fundamentales que deben considerarse al hacer un retro-cálculo de longitudes a partir de anillos.

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INTRODUCTION

Fishery biologists commonly collect and process calcified structures from freshwater fish to estimate age. Age data are regularly used to assess fish population dynamics (growth, mortality, and recruitment) and stock structure, and are an essential component of age-structured population models (Beverton and Holt 1957; Ricker 1975). Many fishery texts devote chapters to discussion of techniques for aging fish and methods to conduct back-calculation to estimate previous lengths-at-age, but few of these texts thoroughly address the need to validate the accuracy of presumed annuli or the importance of assessing the precision of age assignments between or among readers (Beamish and McFarlane 1983, 1995; DeVries and Frie 1996). In addition, few published studies consider age data as estimated values. In this profession, we have typically assumed age data are accurate, and this assumption has been long supported by our text books and publications.

Given the importance of age data in fisheries studies and the increase in published papers on species-specific age estimation and application of age data over the past two decades, a summary of which structures and methods used to estimate age of freshwater fish in North America is warranted. To fulfill this need, the Fisheries Management Section with support of the Fisheries Administration Section of the American Fisheries Society formed the Assessment of Fish Aging Techniques Committee (ad hoc) in 2006. The tasks of the committee were to: (1) survey state and provincial freshwater fisheries agencies regarding the structures and procedures used to age freshwater fish; (2) conduct a literature review on fish aging techniques, primarily examining previous efforts to describe accuracy (validation), precision, and the back-calculation of lengths from presumed annuli; and (3) provide recommendations for aging techniques that will improve accuracy and provide direction for future research. Including federal, tribal, university, and private agencies in the survey was deemed impracticable as identifying all these groups and obtaining a fair representation would be difficult. The results of the tasks assigned to this committee are presented in this article.

PROCEDURES USED BY STATE AND PROVINCIAL FISH AGENCIES TO AGE FRESHWATER FISH

In February 2006, an eight-question survey was sent to state and provincial fisheries chiefs in the United States and Canada via e-mail. The survey contained questions regarding the percentage of sampled fish populations that were aged, the approximate frequency that certain structures were used to age fish, opinions on aging accuracy, precision and validation of different aging structures, training, use of back-calculation, and types of information and analyses generated from age data.

A total of 45 state and 6 provincial agencies responded to the survey; 2 states within this sample reported that they did not routinely estimate the age of freshwater fish. We asked agencies to report frequency of use of scales, otoliths, spines, cleithra, fin rays, vertebrae, and other structures to age seven important recreational and, in some instances, commercial fish groups that included black bass (*Micropterus* spp.), crappie/sunfish (*Pomoxis* spp. and *Lepomis* spp.), catfish (Ictaluridae), salmonids, percids, moronids, and esocids. The relative importance of each structure for each fish group was computed by multiplying frequency of occurrence of use by the percent effort using that structure; thus relative importance values sum to 100% for each species group. Scales and otoliths were the most commonly used structures to age fish (Table 1, Figure 1) and many agencies used more than one structure to estimate ages for the same species group (Table 1). Scales were more commonly (relative importance 58–65%) used to age black bass, crappie/sunfish, and moronids than otoliths (33–41%), but scale and otolith use to age salmonids and percids was nearly equal (Figure 1). The relative importance of pectoral spines was about twice that of otoliths for aging catfish (Figure 1). Scales, followed by cleithra, were the predominant structures used to age esocids (Figure 1).

Significant latitudinal clines in the relative importance of scales and otoliths to age black bass, crappie/sunfish, and moronids were evident, with otoliths more commonly used in southern states and scales used in more northern states and provinces (Figure 2). Similarly, effort directed at aging catfish using otoliths and pectoral spines was negatively and positively correlated, respectively with latitude (Figure 2). For salmonids and percids, the use of otoliths (r = -0.22 to 0.26; $P > 0.1$) and scales (r = 0.05 to 0.07; $P > 0.5$) to age these fish did not vary with latitude. The use of cleithra to age esocids slightly increased with latitude ($r = 0.46$; $P < 0.05$), and otolith use weakly decreased ($r = -0.36$; $P = 0.06$) with latitude.

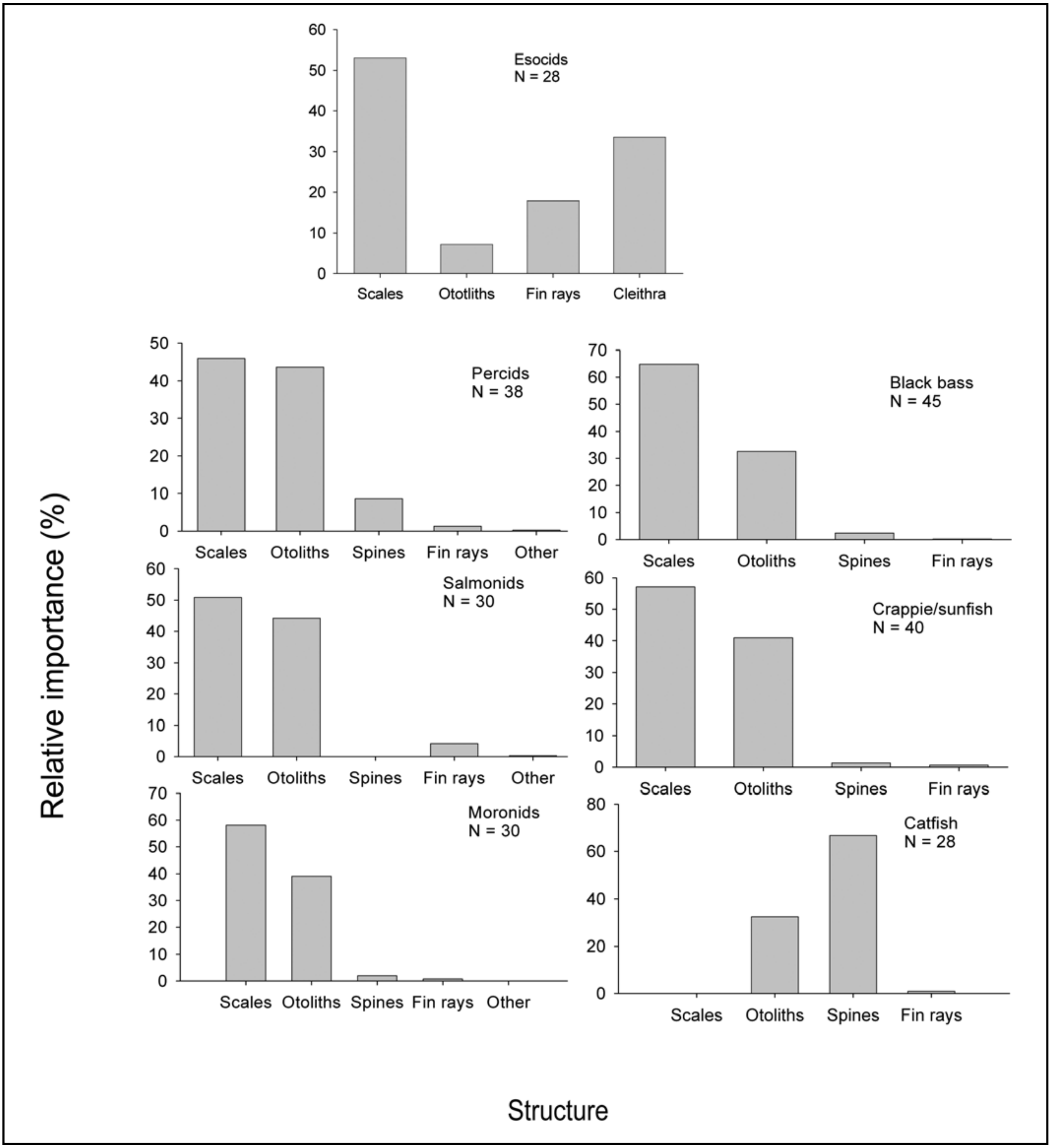
Respondents were asked to indicate the maximum age they believed could be accurately estimated from scales for the applicable species groups. The median maximum age of scale accuracy varied between 5–6 years among 5 species groups (Figure 3). Opinions on maximum ages that could be accurately determined generally ranged from 3 to 9 years for all groups except esocids, where higher maximum reliable ages were more commonly reported. From some of the references listed in Table 4, other references, and our personal observations and communications, maximum age of these North American fish is generally positively related to latitude and some of these species can obtain presumed longevity of 9–15 years for smaller bodied species (Hales and Belk 1992; Soupir et al. 1997; Sammons et al. 2006; Maceina and Sammons 2006) and up to 20–25 years for larger bodied species (Casselman 1974; Erickson 1983; Green and Heidinger 1994).

Table 1. Frequency of aging structures used by 43 U.S. states and 6 Canadian provinces. Number in parenthesis represents the number of states and provinces where this structure was used exclusively.

Structure	Black bass	Crappie/ sunfish	Catfish	Salmonid	Percid	Moronid	Esocid
Scales	34(13)		26(12)	22(10)	25(8)	20(13)	21(9)
Otoliths	27(11)	25(15)	13(7)	20(7)	29(10)	16(9)	4(2)
Fin rays	1	1	1	2	1	1	5
Spines	4	1	21(14)		8	2	
Cleithra							15(5)
Vertebrae				2			
Other				1	1		
Total number of agencies	45	40	28	30	38	30	28

Most agencies (76%) assessed the precision of age estimates either between or among readers for the structures examined and commonly used two blind (independent) readers, with these readers consulting to resolve differences in age assignment (Figure 4). For some agencies, assessment of precision was not standardized, and double-blind, triple-blind, and group reading (simultaneous examination of structures by two or more readers) were commonly-used procedures (Figure 4). However, precision was not assessed for all aging efforts within an agency's jurisdiction (Figure 4). More than half of the agencies (59%) reported conducting some validation of annuli, primarily by stocking fish of known age that were either chemically or physically batch marked and then subsequently recaptured. Not all species groups or structures were

Figure 1. Relative importance of different structures used to age seven species groups of freshwater fish. Relative importance was computed as the occurrence of use for a structure multiplied by the percent effort of use for that particular structure.



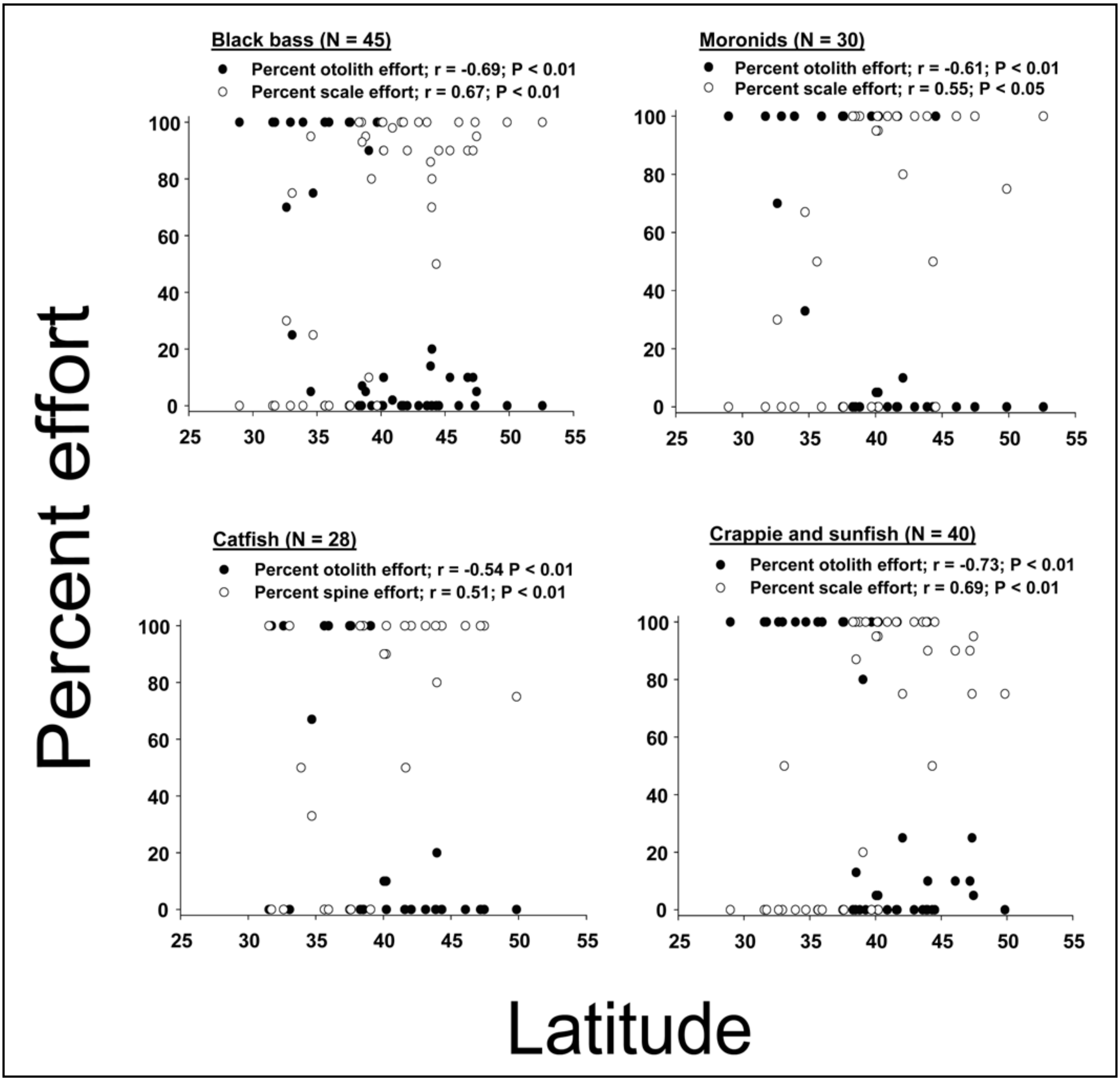
validated as stocking was limited and was species specific.

About 80% of all agencies provided training to personnel to age fish, with 74% of the agencies providing one-on-one training to a single individual through experienced staff. Standardized or formal training and some combination of standardized/individual training was offered to personnel in the remaining agencies. Known-age and reference-aging structures were reported by only 14 of the 38 agencies that offered training.

Nearly every agency that aged fish used this information to assess growth (100%), mortality (86%), and/or recruitment (82%). Analyses of age data were commonly used in the regulation decision-making process (92%) and in research (82%). Additionally, among 49 respondents, 79% conducted back-calculation of lengths from presumed annuli in at least some of the fish populations where age estimates were made. Back-calculation was routine in some agencies as about half (47%) these agencies computed back-calculated lengths for 40 to 100% of the populations that were sampled and aged. Thirty-five of 38 agencies reported that scales (66%) followed by otoliths (43%) were the most common structures used for conducting back calculation.

Finally, for scales, fin rays, and spines, 83% of the agency respondents indicated the non-lethality of collection was a strong consideration for using these structures. However, of these respondents, only 38% acknowledged that these non-lethal structures were accurate for a limited age

Figure 2. The percent effort of using scales, otoliths, and spines to age four major fish species groups plotted against latitude. Latitude was determined from the center of each state and province.



range (primarily young fish). Only 27% of respondents felt scales were accurate aging structures for older aged fish. Most agencies that collected structures that were lethal to fish including cliethra (*N* = 5) and otoliths (*N* = 35) felt these structures provided accurate ages.

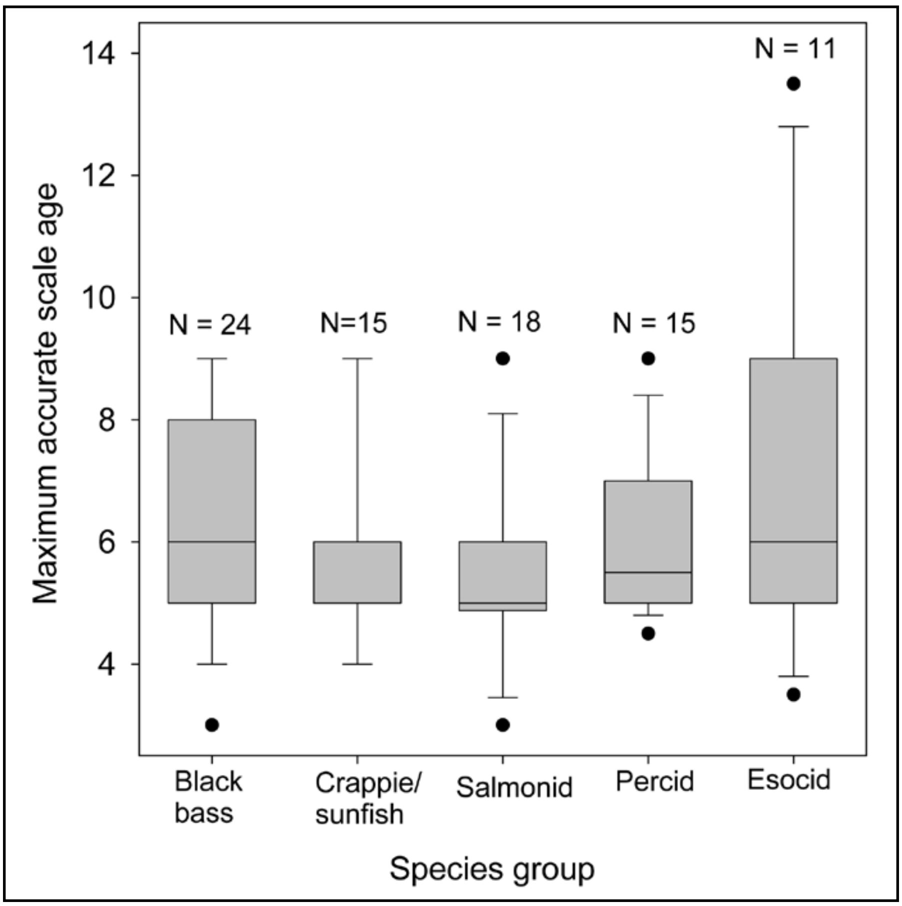
LITERATURE REVIEW: ACCURACY AND PRECISION OF AGES ESTIMATES AND BACK-CALCULATION OF LENGTH

Accuracy and precision of age estimates

Age estimates contain error. Thus, a need exists to assess and understand the magnitude, relevance, and sources of these errors (Beamish and McFarlane 1995; Campana 2001). Campana (2001) separated age estimation error into two components, process error and interpretation error. Process errors occur because some bony structures do not form periodic marks that correspond to annular cycles of growth or, if formed, these annular marks may not be discernible when using a particular technique. Process errors are best assessed through validation (e.g., use of known-age fish) to determine if interpreted annuli are accurate.

Interpretation error is associated with individual subjectivity in identifying annuli. Errors associated with interpretation are best assessed through quality control monitoring, although frequently only precision can be evaluated. Precision simply represents the reproducibility or consistency of repeated measurements on a given structure. Thus, age estimates can be highly reproducible, but inaccurate (Campana et al. 1990; Campana and Moksness 1991). Therefore, estimates of precision cannot be substituted for measures of accuracy. Discussions regarding the consequences of both process error and interpretation error can be found throughout the literature (e.g., Beamish and McFarlane 1983, 1995; Campana 2001). To ensure the accuracy of age estimates, freshwater fisheries biologists should implement techniques to minimize both sources of error. Below, we summarize relevant literature and provide a review of validation and quality control (precision) techniques.

Figure 3. Respondents opinion of the maximum age that could be accurately determined from scales from five major fish species groups where it was recognized that the absolute true maximum age could not be determined. Shaded areas represent the 25th and 75 percentiles, error bars are the 10th and 90th percentile values, and dots represent corresponding minimum and maximum ages. The horizontal line is the median response.

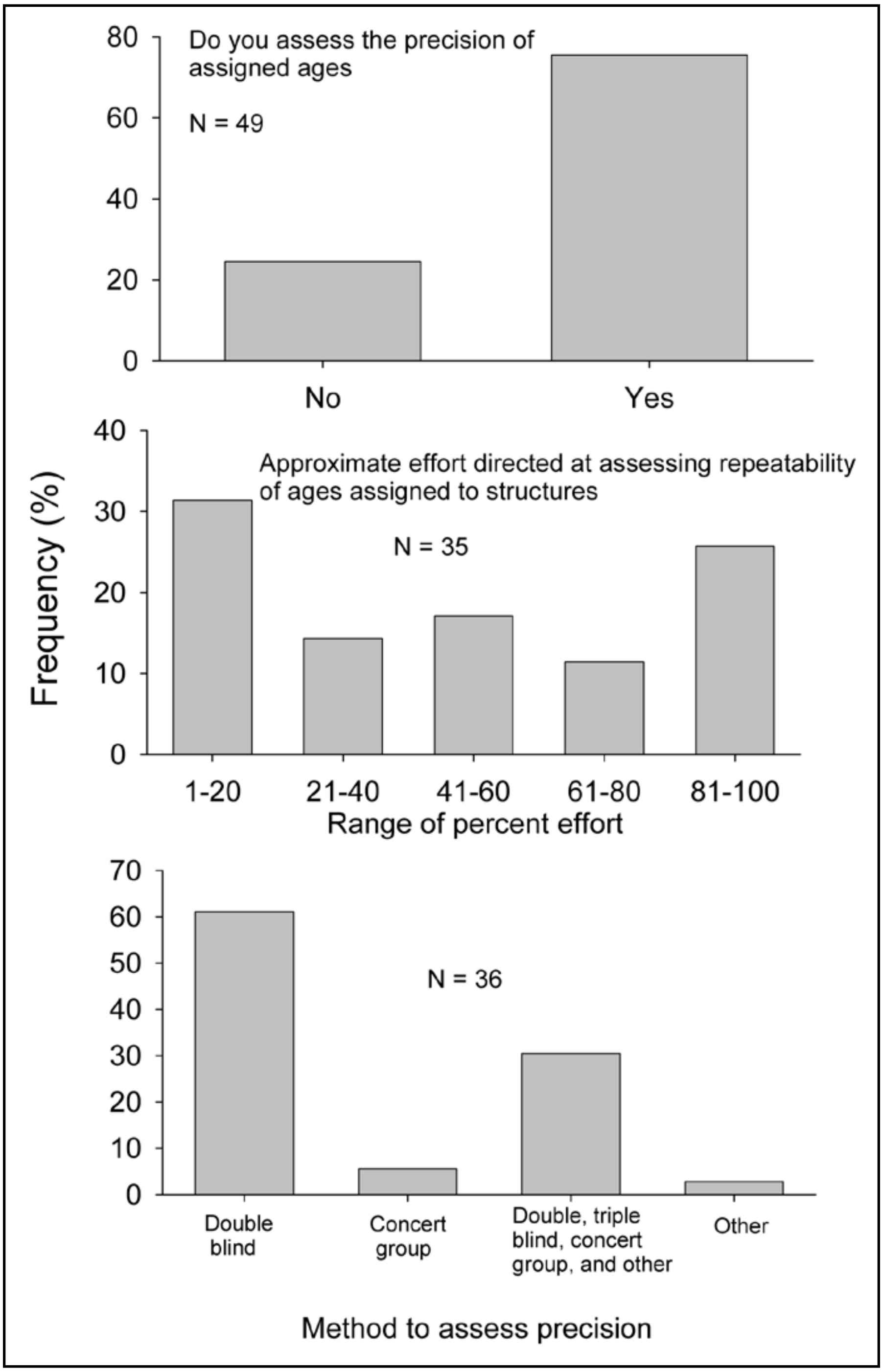


Validation represents an effort to assess process error and often has the objective of "determining the accuracy" of a particular age estimation technique. While many methods have been used to validate age estimation techniques (see review by Campana 2001), we categorize validation techniques into three general types: (1) techniques that validate absolute age and the formation of annular increments as well as a readers' ability to accurately interpret annuli utilizing known-age fish (e.g., Erickson 1983; Heidinger and Clodfelter 1987; Fitzgerald et al. 1997; Buckmeier et al. 2002; Ross et al. 2005); (2) techniques that validate the formation of annular increments and the readers' ability to accurately interpret annuli utilizing marked fish of unknown age that have been at liberty for a known time (e.g., Babaluk and Campbell 1987; Babaluk and Craig 1990; Mantini et al. 1992; Hining et al. 2000) and (3) techniques that attempt to validate the formation of annular increments and the readers' ability to accurately interpret annuli utilizing unmarked fish of unknown age (e.g., marginal increment analysis; Maceina and Betsill 1987). Techniques that validate absolute age are considered optimal; however, techniques that validate annulus formation utilizing marked fish, especially those marked with chemicals (e.g., with tetracycline compounds), can be used as a surrogate if annulus formation is validated for all age groups. Although useful in describing the timing of annulus formation, techniques such as marginal increment analysis rarely offer true validation because few studies have followed the strict protocols recommended by Campana (2001). Techniques including length-frequency analysis, matching back-calculated lengths with previously estimated lengths, and the progression of strong year classes through time, were not considered by Campana (2001) as true methods of validation, but these methods and marginal increment analysis do provide some evidence of annuli accuracy.

Determining the accuracy of a particular technique for all applications may appear to be an impossible standard, as the degree of accuracy associated with a particular technique is almost certain to vary across individual readers and populations. Francis (1995) stated that "the validation of an aging procedure should be aimed at how accurate the procedure is, rather than whether it is accurate." Ideally, a technique that consistently produces a high level of accuracy in at least several evaluations is desirable. However, multiple validation studies for a particular species are rare (Tables 2 and 3). Nevertheless, we attempted to summarize validation studies for freshwater fishes.

We limited the focus of our summary to the seven categories of fishes utilized in our age survey. We recognize that ages are estimated for other species, but suggest that the majority of age estimation occurring in North America is focused on these species. We considered a technique valid for a specified age if the authors reported at least 80% agreement with known age. Although arbitrary, we believe 80% offers a minimum level of quality consistent with many standard fishery assessments. When reported, we also used the 80% level in summarizing those studies validating annulus formation. Large variations in the reporting of techniques and data were evident. In some cases, almost no actual data were reported, while in other instances data were not specifically presented by age class. In addition, it was often difficult to determine how the authors dealt with the bias of knowing the age of the fish in the study. Consequently, variability observed across studies made generalizations difficult and our summary represents our best interpretation of the information as it was presented.

Figure 4. Percent of respondents that assessed precision of ages estimates (top), the effort directed at assessing the repeatability of age assignment (middle), and methods to assess precision (bottom).



Validation of age estimation techniques has been conducted for at least some species in each of the seven categories of fishes we reviewed, though many species commonly aged (e.g., blue catfish *Ictalurus furcatus*, brown trout *Salmo trutta*, white bass *Morone chrysops*, spotted bass *Micropterus punctulatus*, and yellow perch *Perca flavescens*) apparently lack published validation (Tables 2 and 3). In general, most techniques have only been validated for young fish and were based on relatively small sample sizes. Multiple structures have been validated for several species, with otoliths being more accurate than other structures when direct comparisons were conducted (Table 2; e.g., Heidinger and Clodfelter 1987; Secor et al. 1995; Buckmeier et al. 2002; Cooper 2003; Ross et al. 2005). Attempts to validate scales and fin rays for several species apparently failed primarily due to process error (Mann and Beaumont 1990; Rien and Beamesderfer 1994; Fitzgerald et al. 1997; Whiteman et al. 2004; McBride et al. 2005), whereas none of the otolith studies reviewed reported failure. The opinions expressed by the agencies surveyed generally agreed with the published literature. Most (82%) felt otoliths and cleithra provided accurate age estimates whereas only 27% felt scales were accurate. When used, scales were usually only considered accurate for young fish.

To fully assess age estimation error, the accuracy of individual readers must also

Table 2. Summary of age ranges that have been validated for common freshwater fishes using known-age fish. Common species and groups of freshwater sport fishes that no validation studies were found are also included to demonstrate need. Only ages that were reported to be at least 80% accurate were included. Superscripted numbers refer to citations in Table 4. Superscripted letters refer to footnotes below table.

Species	Otoliths	Scales	Spines	Fin rays	Vertebrae	Cleithra	Opercula
Bullheads							
Channel catfish[a]	0-3[4]		0-3[4,24,29]		0-3[1]		
Blue catfish							
Flathead catfish			0-5[31]				
Northern pike		0-1[10]					0-1[10]
Muskellunge		0-2,4[16]		0-7[16]			
Pickerels							
Rainbow trout[a]	0-3[7]	0-1[7]					
Brown trout							
Brook trout							
Lake trout							
Chinook salmon	0-5[22b]						
Coho salmon							
Striped bass[a]	0-7[13,28b]	0-4[13c]					
White bass							
Redbreast sunfish							
Bluegill	0-1[26]						
Redear sunfish							
Pumpkinseed							
Rock bass							
Smallmouth bass[a]	0-4[13]						
Spotted bass							
Largemouth bass	0-16[5,15,30]	0-4[23c,24]					
White crappie[a]	0-5[25]	0-5[25]					
Black crappie[a]	0-5[25]	0-5[25]					
Yellow perch							
Sauger							
Walleye[a]	0-4[9,13]	0-3[9]					

[a]Studies that examined more than one structure and found otoliths to be more accurate
[b]Validated in saltwater
[c]Average accuracy 80%, not reported for individual age classes

Table 3. Summary of structures that annulus formation has been validated for at least some age classes. Common species and groups of freshwater sport fishes that no annulus validation studies were found are also included to demonstrate need. Methods used for annulus validation include known-age fish (K), mark-recapture(R), and marginal increment analysis (M). Superscripted numbers refer to citations in Table 4.

Species	Otoliths	Scales	Spines	Fin rays	Vertebrae	Cleithra	Opercula
Bullheads							
Channel catfish	K[4]		K[4,24,29]		K[1]		
Blue catfish							
Flathead catfish			K[31]				
Northern pike		K[10],R[10,17],M[19]		R[3]		R[3,6,17]	K[10]
Muskellunge		K[16]		K[16]			
Pickerels							
Rainbow trout	K[7],R[14]	K[7]					
Brown trout							
Brook trout	R[12]						
Lake trout							
Chinook salmon	K[22]						
Coho salmon							
Striped bass	K[13,28]	K[13]					
White bass							
Redbreast sunfish	R[20]						
Bluegill	K[26],R[20],M[11]						
Redear sunfish	R[20]						
Pumpkinseed							
Rock bass							
Smallmouth bass	K[13]						
Spotted Bass							
Largemouth bass	K[5,15,30],M[8,30]	K[23,24],R[21]					
White crappie	K[25],M[18]	K[25]					
Black crappie	K[25],M[27]	K[25]					
Yellow perch							
Sauger							
Walleye	K[9,13]	K[9]					R[2]

be assessed due to the subjectivity associated with age estimation. For example, Buckmeier (2002) found variability of age estimates was high among individuals using validated techniques to estimate the age of known-age largemouth bass even after receiving training. Unfortunately, monitoring of this type is rarely conducted due to the relative scarcity of reference collections of known-age fish. As a weak surrogate for this type of quality control, many agencies (76% of those surveyed) do assess the precision of age estimates among readers. Until known-age fish become more readily available, assessing precision may be the only form of quality control that can be conducted.

Traditionally, percent agreement has been used as a measure of precision. This method has inherent problems because of inconsistencies among species and among ages within a species. Percent agreement of 95% can represent poor precision in short-lived species (e. g., 4 years), whereas 95% agreement within 5 years can be good precision in a long-lived species (Beamish and Fournier 1981). Alternative measures of precision have been proposed by Beamish and Fournier (1981) and Chang (1982). These two methods not only assess reader disagreement, but also include the magnitude of reader differences in age assignment.

Precision assessments were more prevalent than validation studies in the published literature for all seven categories of fishes assessed in our survey. Typically, otolith age estimates were more precise than scale age estimates for black basses (Besler 2001; Maceina and Sammons 2006), crappies (Schramm and Doerzbacher 1985; Boxrucker 1986; Hammers and Miranda 1991), salmonids (Sharp and Bernard 1988; Baker and Timmons 1991), percids (Robillard and Marsden 1996; Kocovsky and Carline 2000; Isermann et al. 2003; Maceina and Sammons 2006), sunfish (Hoxmeier et al. 2001), and moronids (Welch et al. 1993). However, precision was similar between otoliths and scales for crappies (Kruse et al. 1993) and white bass (Soupir et al. 1997) in South Dakota and between cleithra and scales for northern pike (*Esox lucius*) in Ontario (Laine et al. 1991). Precision of otolith age estimates was better than spine-based estimates for ictalurids (Nash and Irwin 1999; Buckmeier et al. 2002; Maceina and Sammons 2006) and for walleyes (*Sander vitreous;* Erickson

Table 4. Citations referenced in Tables 2 and 3.

Superscript	Citation
1	Appelget and Smith 1951
2	Babaluk and Campbell 1987
3	Babaluk and Craig 1990
4	Buckmeier et al. 2002
5	Buckmeier and Howells 2003
6	Casselman 1974
7	Cooper 2003
8	Crawford et al. 1989
9	Erickson 1983
10	Frost and Kipling 1959
11	Hales and Belk 1992
12	Hall 1991
13	Heidinger and Clodfelter 1987
14	Hining et al. 2000
15	Hoyer et al. 1985
16	Johnson 1971
17	Laine et al. 1991
18	Maceina and Betsill 1987
19	Mann and Beaumont 1990
20	Mantini et al. 1992
21	Maraldo and MacCrimmon 1979
22	Murray 1994
23	Prather 1967
24	Prentice and Whiteside 1975
25	Ross et al. 2005
26	Schramm 1989
27	Schramm and Doerzbacher 1982
28	Secor et al. 1995
29	Sneed 1951
30	Taubert and Tranquilli 1982
31	Turner 1980

1983; Marwitz and Hubert 1995; Kocovsky and Carline 2000; Isermann et al. 2003).

Back-calculation of length

Many (79%) of the agencies responding to the survey reported using back-calculation procedures to estimate lengths of fish at earlier ages and for many agencies, back-calculation was routinely conducted when age samples were collected. From the survey, scales followed by otoliths were the most common structures used to conduct back-calculation. Back-calculation of lengths from presumed annuli can provide growth information for time periods when no direct sampling occurred, and allows comparison of growth rates among fish populations sampled at different times and/or locations. Growth studies using back-calculated lengths were first published for North American freshwater fish in the 1920s (Carlander 1987). Since then, the methods for back-calculating length-at-annulus have been widely applied, occasionally critiqued, and re-applied to fisheries across North America. Although back-calculated estimates are commonly done, the techniques used are varied and poorly understood, with little agreement on which computational methods are best (Summerfelt and Hall 1987; Francis 1990; Pierce et al. 1996).

The direct proportion method (i.e., the Dahl-Lea method) and the intercept-corrected direct proportion method (i.e, the Fraser-Lee method) are two of the most commonly used back-calculation methods for freshwater fish. These two methods were used in 55 of 94 articles published in American Fisheries Society journals between 1990 and 2005 that used back-calculation. Other techniques for back-calculation, such as regression (Mottley 1942), non-linear (Francis 1990) or polynomial regression (Maceina and Betsill 1987; Secor and Dean 1992) models have been scrutinized and found to perform poorly (Carlander 1981; Gutreuter 1987; Francis 1990; Schramm et al. 1992) or have not been widely applied in North America. Of the 94 articles that we reviewed, only 7 applied the use of regression to back-calculate growth (not including papers that compared regression to other back-calculation techniques). To circumvent the problem of choosing the "correct" back-calculation formula, Weisberg and Frie (1987) introduced the concept of using actual increments measured from structures as a surrogate of growth and incorporated environmental and age effects into a multi-way analysis of variance. Three criteria for the validation of a back-calculation procedure identified by Francis (1990) are: (1) the radius of a structure annulus is the same as the radius of the structure at the time the annulus was formed (2) the time of annulus formation is correct and (3) the formula used accurately relates structure radius and body size for each fish. Campana (1990) found back-calculated lengths consistently underestimated previous lengths-at-age (Lee phenomenon) due to decoupling of somatic and otolith growth in older fish and the application of an incorrect back calculation formula (Fraser-Lee). Because proper validation requires the tracking of individual fish over time, these criteria cannot be met in many instances. Klumb et al. (1999) stated that these three requirements can only be met in mark and recapture, laboratory, or pond studies. Thus for many studies, estimates of back-calculated lengths may be error prone and suspect.

Back-calculated lengths must be recognized as estimates and will possess some inherent level of error. Potential sources of bias and error include: (1) previous lengths are estimated only from surviving fish and may only describe growth of these fish and not the entire cohort; (2) the relation between body length and size of the calcified structure may not be proportional or linear during all or part of the life of an individual, biasing estimates of back-calculated lengths unless the correct relation is applied; (3) annuli may be incorrectly identified; (4) measurements to presumed annuli may not be consistent among readers and for fish within a population, and may vary among collection locations; and (5) fish length measurements at time of capture may be in error.

An underlying assumption for back-calculating is accurately describing the relation between somatic growth and hard part growth. When a linear relationship exists, the body length-to-hard part regression provides the intercept value that is used in the Fraser-Lee equation. The intercept for the Fraser-Lee method has often been interpreted as the length of the fish when the hard part first forms; thus, the Fraser-Lee method is often employed when the hard parts are not present at hatching, such as with scales. This makes biological sense because a fish that develops hard parts after hatching will have some positive length when that hard part develops. However, regressing body length on hard part radius produces an intercept that is statistically, not biologically derived. DeVries and Frie (1996) noted that a statistically-derived intercept (including negative values) can be appropriate for accurately back-calculating growth, but may not have a biological interpretation. Hile (1970) recommended that intercepts be derived for unique stocks of fish, pointing out that a species body-scale curve rarely exists. Carlander (1982) acknowledged Hile's statement, but promoted the use of standard intercepts because body-scale regressions often lack younger age groups, and that "slight variation in estimating the slope from medium to large fish can cause significant deviation in the intercept, and, thus, the calculated lengths of the first few years of life." Standard intercepts, such as those proposed by Carlander (1982) and Beck et al. (1997) have been widely used in back-calculations in North America. Ricker (1992) advocated for the Fraser-Lee method with an intercept that was determined by a symmetrical regression technique, such as geometric mean regression. Campana (1990) demonstrated the computation of a biological intercept in a modified Fraser-Lee back-calculation procedure that corrects for changes in the otolith:body length relation and will approximate otolith size during hatching or fish swim-up. Fish biologists using structures such as otoliths, cleithra, or spines, have reported inconsistent relationships between somatic growth and hard part growth with slow-growing fish having larger otoliths than fast-growing fish of a similar size (Maceina and Betsill 1987; Campana 1990; Casselman 1990).

A single computational method for back-calculating growth does not nor should exist. Fishery biologists should be cognizant of the factors that influence back-calculation and select the most appropriate method for the data. When undertaking a back-calculation study, our committee recommends caution and a suite of questions should be answered:

1. What is the purpose and goal of conducting back-calculation and how are the data to be used?
2. Will the sampling techniques produce a random, unbiased sample?
3. Which hard part will be used to estimate age?
4. Can ages accurately be assigned to that hard part?
5. Can annular increments accurately be measured?
6. Along what axis should measurements be taken?
7. Is the body length-to-hard part relation linear?
8. Which back-calculation formula should be used?
9. Has the chosen formula been validated for the species, age groups, and hard part chosen?

RECOMMENDATIONS AND FUTURE DIRECTIONS

Our survey only included state and provincial agency responses, but obviously a wide variety of other professional fish organizations estimate the age of fish and responses of these groups may vary from our results. However, our survey included a wide geographic sample and based on the regional distribution of the committee, we feel these responses were representative of aging activities in the United States and Canada. Aging of fish is common in our profession and currently the accuracy of annulus formation has not been verified for many species for which ages are estimated. Misconceptions do exist as some structures have been used to age fish for over 50 years, and the accepted and common reference of these structures has been published in fishery texts, reports, and peer-reviewed journals. Yet undoubtedly, inaccurate age assignment still exists due to both process and interpretation errors. In our survey, we observed the conflict (dilemma) fishery biologists face of accepting inaccurate age data to prevent fish sacrifice, but at times some biologists recognize that sacrificing fish is necessary to obtain age structures that they feel are more accurate. Inaccurate age assignment and particularly the underestimation of true age for example, can lead to erroneous population assessment, mismanagement, and the over harvest of an exploited fishery resource (see Beamish and McFarlane 1995).

We recommend a concerted effort be made by all fishery biologists to carefully evaluate the accuracy of their age data, including both age estimates and back-calculations of lengths. The apparent availability of known-age fish detected in our survey should allow for the development of known-age reference data bases containing numerous species groups over different geographic areas. We also recommend that validation studies be continued for both annulus formation as well as back-calculation of length and these results communicated and published in the peer-reviewed literature. Certainly, precision of age estimates also should be assessed in all aging studies and formal, standardized training should be offered to personnel when needed. Aging of fish is a well-established procedure with a long history of application, but improvements and new insights can only be realized if workers continue to consider their own techniques carefully and share their findings.

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FORUM:
FISH HABITAT

Dams and Fish/Shrimp Migrations in Mesoamerica—Worldwide Implications

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INTRODUCTION

There are ever so many reasons to question dam proposals in developing countries. Issues of social justice and indigenous rights are often raised. Shaky economic assumptions are frequently exposed. The ecological damage is well-documented. An endless list of site-specific issues can arise—for example, the submergence of archaeological resources of the Rio Usumacinta watershed in Guatemala and Mexico or the Ilisu valley in Turkey should proposed dams go forward.

But there is only one issue that applies across the board, to every dam ever proposed: all dams act as barriers to the movement of aquatic animals, and "fish ladder" type technology is, at best, a partial solution. No discussion of any dam scheme is complete without an assessment of which species of fish and other aquatic creatures need to move up and down the river past the dam site. Yet, except in those cases involving high-profile commercial or recreational fisheries, this issue often goes unremarked.

No dam assessment is complete without an effort to collect all relevant biological information. By "relevant" we mean not only the environmental impact studies which are often mandated for the areas directly impacted by the dam, reservoir, and associated infrastructure, but information about long reaches of river up and downstream of the dam site. Most dam proposals do not include such studies.

This is a global issue, but applies with particular force to islands and narrow land masses, such as the Mesoamerican isthmus, where rivers are characteristically short. The experience in the Changuinola/Teribe watershed of Bocas del Toro Province, Panama, described herein, details the critical nature of this problem. As aquatic conservation biologists, we are embarrassed that so many of our professional colleagues are asleep on this issue. River activists concerned with dams have also largely neglected to take advantage of this universal issue. It is time for a worldwide wake-up call on this critical problem.

DAM PROPOSALS IN PANAMA

Our involvement in dam issues in Mesoamerica grew out of a stream biomonitoring program in the Talamanca region of Costa Rica where, so far, we are not faced with specific dam proposals. In November 2004, the biomonitoring team was asked to give a series of workshops for leaders of the Naso and Ngobe indigenous groups from Bocas del Toro Province, just across the Rio Sixaola in Panama. Our original focus was on issues like deforestation, organic pollution, and overfishing—the kinds of problems rural communities have a hand in creating and can learn to resolve.

But just prior to the workshops, a historic event occurred. The Naso (the only hereditary monarchy in the Western Hemisphere) deposed their king for signing off on a proposal for a hydroelectric dam to be built on a tributary of the Rio Teribe, in Naso territory. We soon learned that the neighboring Ngobe tribe, located just over the hill along the Rio Changuinola (to which the Teribe is tributary), were facing three dam proposals. All this was in an area so remote that some of the workshop attendees had to walk three days to reach the nearest bus stop.

The cultural rights and economic issues were being addressed by the Naso, Ngobe, and Alianza para la Conservacion y el Desarrollo, a small Panamanian non-governmental organization; there was little for us to do at that level beyond being sympathetic. But fundamental biological issues were not being raised, a fact later confirmed when we reviewed the weak environmental impact assessments for the four dams.

So we modified our workshops to include a strong emphasis on the role of barriers to the movement of aquatic animals. A key word to understand in this situation is "diadromy." Some aquatic animals are relatively sedentary; others are highly migratory. Some migrate within freshwater, but for many, free transit between fresh and salt waters is an essential feature of their life cycle. Such animals are referred to as "diadromous." You might be familiar with the spawning migrations of the diadromous salmon of the U.S. Pacific Northwest and

The diadromous *Joturus pichardi* (hog mullet, also known as bobo in Costa Rica, bocachica in Panama, or cuyamel in northern Central America) is the most highly esteemed freshwater food fish in the greater Talamanca region. There are no complete studies of its life history.

the role of dams in decimating many of these salmon runs. But from an ecosystem point of view, it can be argued that diadromy is even more important in places like Panama than in the North Pacific.

Because the Mesoamerican isthmus is so narrow, but also because during geological time this region was frequently cut off from the large North and South American land masses, relatively few purely freshwater fish were able to colonize the area. A high percentage of the "freshwater" fauna of the isthmus is obliged to spend part of its life in the ocean and estuaries. Seemingly paradoxically, the higher one goes in a watershed, the greater the dominance of diadromous forms. In our research in Costa Rica, we have found that 70–94% of individual fish (and all of the usually abundant shrimps) in small upland streams far from the sea are diadromous species.

A DIADROMOUS DIET

The diadromous species happen to include almost all the larger bodied fish utilized as food by the Naso and the Ngobe. As for ecological importance, anyone who has ever observed the phenomenon of the "tismiche," when giant mixed schools of larval shrimp and gobies pass upstream like dark clouds, cannot doubt the importance of diadromy in maintaining the food chain of rivers draining into the Caribbean. We have no hard numbers, but it is certain that the greater part of the animal biomass (the total weight of living animals) is composed of diadromous species.

There was no documentation of the fish and shrimp communities in the upper reaches of the Changuinola-Teribe watershed, but we were able to train Naso and Ngobe biodiversity field workers to do biological surveys in the upper watershed. Their findings backed our assumptions about the high proportion of diadromous species. For example, in the reach that would be impounded by the proposed Bonyic Dam, 95% of the fish and all of the shrimp were diadromous. (These findings contributed to a decision by the Inter-American Development Bank to discontinue consideration of funding Bonyic, citing "potential impacts on stream ecosystems," but that is just one source of financing for one of the dams.)

Most of the sites monitored by the indigenous field workers were within the La Amistad International Peace Park and Biosphere Reserve, a World Heritage site. The first stated purpose of the creation of La Amistad was to "protect a significant sample of the biological diversity of one of the richest faunal and floral zones which still remains relatively unaltered in the Republic of Panama." Construction of the lowermost dam on the Changuinola, known as Chan-75, would eventually compromise that biodiversity by eliminating all diadromous species from 848 km of permanent streams within La Amistad. Not every river can claim an internationally renowned protected area in its watershed, but the potential for ecosystem damage is similar in every case.

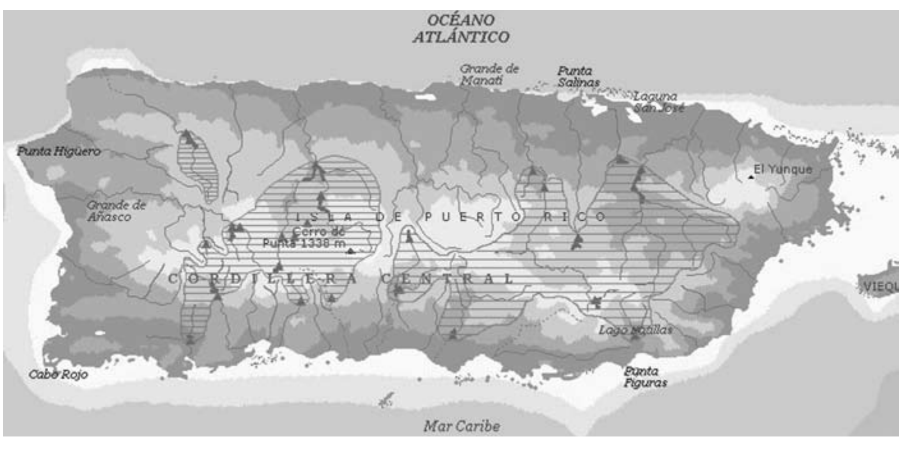
THE CURRENT CRISIS IN MESOAMERICA

When we began to look for precedents, we were startled to find no research at all from Mesoamerica (which still has relatively few dams). We did discover relevant studies from the West Indian islands of Puerto Rico, Guadeloupe, and Curaçao, where the native diadromous fauna is similar to that of Mesoamerica—and where it has been decimated in all three cases. Perhaps the best example is from Puerto Rico, which, as part of the United States, was a victim of early enthusiasm for dam construction. Most major rivers in Puerto Rico are dammed, with the result that the majority of the freshwater fish and shrimps have disappeared from many of the island's river stretches above dams. This situation has provided a "laboratory" for predicting ecosystem effects elsewhere in the region. Changes documented by researchers in Puerto Rico, in addition to the virtual disappearance of fish and shrimp, include increases in sedimentation and algal growth and dramatic changes in the aquatic insect community upstream, with severe damage to fisheries downstream.

A recent study by Conservation Strategy Fund documented plans for no less than 381 new dams between southern Mexico and the Panama/Colombia border. These and other infrastructure projects are clearly part of the "globalization" phenomenon, fueled by the various hemispheric free trade agreements.

WORLDWIDE IMPLICATIONS

River protectors everywhere need to connect the dots, and spread the word about how damming rivers with diadromous species is creating a global biodiversity crisis. Concern over the role of dams as barriers to animal migration is a valid component of every anti-dam case. Even far inland, or in rivers already blocked by some dams where diadromy is not an issue, there is the matter of "potamadromy" (migrations within freshwater). No dam study is complete without collecting all the available biological information on migratory species, no biologist is exempt from responsibility for making this information publicly available, and no activist should be reluctant to be the first to raise this issue.



Map of Puerto Rico showing major rivers, sites of large dams (>15 m high) and the area of the island (22%) where the native freshwater fish and shrimp fauna has been essentially eliminated due to the barrier effect of dams and reservoirs.

FORUM: FISH HABITAT

Fisheries of the Yangtze River Show Immediate Impacts of the Three Gorges Dam

Songguang Xie, Zhongjie Li, Jiashou Liu, Shouqi Xie, Hongzhu Wang, and Brian R. Murphy

Xie, Li, Liu, Xie, and Wang are with the State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, People's Republic of China. Murphy is with the Department of Fisheries and Wildlife Sciences and Conservation Management Institute, Virginia Polytechnic Institute and State University, Blacksburg. Murphy can be contacted at murphybr@vt.edu.

Three Gorges Dam (TGD), currently the largest hydropower project in the world, was completed in June 2006 but has been impounding and altering river flow since 2003. Large dams impact river ecosystems and services, and aquatic biota are affected by flow and temperature modifications, water chemistry changes, and migration blockage (McAllister et al. 2001; Nilsson et al 2005). Xie (2003) warned specifically of potential impacts of TGD to ancient fish species of the Yangtze, and Fu et al. (2003) similarly warned of impacts to a broad array of native species. Consistent with these predictions, four major commercial carp species (silver carp *Hypophthalmichthys molitrix*, bighead carp *Aristichthys nobilis*, grass carp *Ctenopharyngodon idella*, and black carp *Mylopharyngodon piceus*) are now showing effects of altered river ecology below the dam.

Public release of data from ongoing studies of TGD impacts is generally restricted until 2009 by the central government, but some preliminary results have been posted to a TGD-monitoring program website (Anonymous 2006). Annual harvest of these commercial carps below TGD during 2003–2005 was 50–70% below a 2002 pre-dam baseline (Table 1). Even more alarming is a decline of up to 95% in the abundance of drift-sampled carp eggs and larval carp over the same period; undoubtedly carp harvest will decline even more in the next few years as recruitment-to-catchable stocks declines. Reproduction of the carps is likely being affected by TGD-altered river temperatures and annual flow regimes that have modified seasonal cues for migration and reproduction. Figure 1 shows that the annual flow regime below TGD, as modified by dam operations, is a fairly close approximation of normal flow patterns. However, there are subtle changes that seemingly are having rapid and drastic impacts on resident fishes. TGD operations slightly increase flow downstream before the normal spring/summer flow increase (Figure 1), in order to increase reservoir storage capacity and reduce downstream flooding during the coming summer rainy season. This flow increase may stimulate carps to initiate upstream spawning runs (Anonymous 1976) in late spring before eggs are suitably mature. Concurrently, TGD's hypolimnetic discharge lowers downstream river temperatures year-round, and likely retards in-vivo egg maturation during winter and spring even further. In fall,

Table 1. Annual commercial harvest (x 1,000 metric tons) of four species of carp (silver, bighead, grass, black), and numbers (millions) of drift-sampled carp (*Cyprinidae*) eggs and larvae below the Three Gorges Dam (Yangtze River, People's Republic of China) before (1997 and 2002) and after (2003–2005) river impoundment began (adapted from Anonymous 2006; time units for drift sampling were not reported).

Year	1997	2002	2003	2004	2005
Commercial harvest	NA	3360	1350	1010	1680
Eggs and larvae	250	190	40.6	33.9	10.5

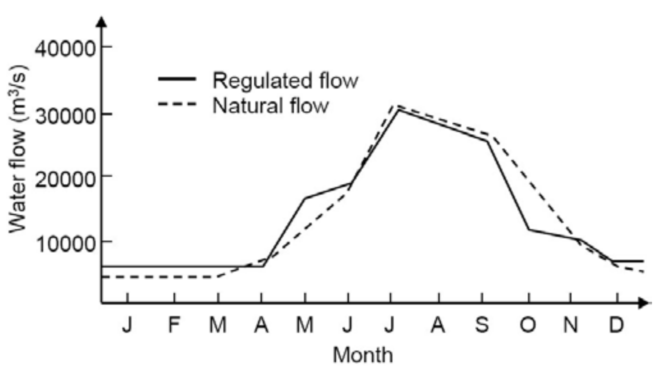


Figure 1. Annual flow regime of the Yangtze River is modified by the Three Gorges Dam (adapted from Anonymous 1997).

dam operations begin to reduce discharge through the dam earlier than the natural dry-season flow decrease in order to store water for peak power production over the winter (Figure 1). Again, carps stimulated by these abnormally early flow reductions may migrate from feeding areas in floodplain lakes back to the mainstem river (Anonymous 1976) before rebuilding energy stores needed for overwintering and successful reproduction during the subsequent spring. The precipitous decline of carp recruitment in the Yangtze River demonstrates that even seemingly subtle changes to river flow regimes may have drastic ecological effects.

Planning is underway for more than 20 additional hydropower dams in the Yangtze basin (Chen et al. 2006) to support burgeoning economic development in China. Design and operational changes from the TGD model must be considered if basin-wide impacts on commercial and subsistence fisheries, and subsequent socioeconomic detriments, are to be avoided.

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NEWS:
AFS UNITS

Bioengineering Section
New Emerging Technology Committee

The Bioengineering Section has announced the formation of an ad hoc Emerging Technology Committee. This committee will provide strategic support and technical guidance for those who are pursuing either the development of new fish passage and intake protection technologies or the use of existing technologies in unusual and innovative conditions (e.g., as fish collection devices or as barriers to fish passage). The new committee will accomplish this by assisting innovators, reviewing concepts, fostering communication, providing a forum for highlighting new technologies, and identifying potential funding sources. A development workgroup under the chairmanship of Lynn Reese of the U.S. Army Corps of Engineers (USACE) with support from Ned Taft (Alden Research Laboratory), Jock Conyngham (Engineer Research and Development Center, USACE), Doug Dixon (Electric Power Research Institute), Larry Swenson (National Marine Fisheries Service), and Marcin Whitman (California Department of Fish and Game) has drafted interim bylaws describing its mission, objectives, operating structure, and technology evaluation criteria. The current workgroup will serve as the initial ad hoc committee. The committee will begin operation in 2007 with plans for quarterly (seasonal) meetings by conference call, except during the AFS Annual Meeting when the committee will meet in person. The committee will organize and implement, when needed, a technical session at the AFS Annual Meeting during which time technology innovators will be provided an opportunity to present their ideas to the AFS membership and conference attendees. During its initial operation as an ad hoc committee, the interim bylaws will be evaluated and revised as necessary. Committee membership will rotate beginning in 2008, at which time new members with education in fisheries science and professional experience in the development, evaluation, and use of fish passage, protection and restoration technologies will be called upon to serve. For additional information on this committee, contact Marcin Whitman, current Section president, at MWhitman@dfg.ca.gov or Lynn Reese, committee chair, at Lynn.A.Reese@usace.army.mil.

—Marcin Whitman

Ball State, Lake Superior State, and Purdue Universities Student Subunits
Host raffle at joint Chapter meeting

The Indiana, Michigan, and Ohio Chapters held their annual technical meeting at Pokagon State Park in Angola, Indiana, on 14 and 15 February 2007. Despite the "blizzard" conditions experienced in the Midwest that week, turnout was great. The Student Subunits of Ball State, Lake Superior State, and Purdue hosted the annual raffle which netted "fistfuls" of money for each student group. Showing off the benefits of their hard work are Jennifer Pritchett, Ball State incoming president; Bob Mueller, outgoing Ball State president; and Brianne Lunn, Lake Superior State incoming president. The funds will support a variety of student activities throughout the year, including attendance at next year's meeting.

—Tom Lauer

East Carolina University Student Subunit Wins student organization award

For the second year in a row, the East Carolina University Student Subunit of the American Fisheries Society (ECU-AFS) has been awarded the Student Organization of the Year on the ECU campus for the 2006–2007 academic year. The ECU-AFS organization this year was led by Rebecca (Becky) Deehr, a Ph.D. student in the Coastal Resources Management program. Currently there are 25 undergraduate and graduate students participating in the organization.

This honor is no easy feat, as the competition involves over 280 student

Education Section
Proposes Society resolution on science education

The Education Section has proposed a resolution of the American Fisheries Society concerning the teaching of alternatives to evolution. If approved by the Governing Board at the AFS Annual Meeting in San Francisco, the resolution will be voted on by the membership at the Business Meeting on Tuesday, 4 September, at the San Francisco Marriott. The text of the resolution and the background material are available at: www.fisheries.org/units/education/index.htm.

—Jill Hardiman

ECU-AFS organizes the annual Big Sweep of Greenmill Run for the campus.

organizations, some of which are service oriented. The award is presented to the organization that demonstrates service and leadership to the university and makes a significant contribution through consistent and sustained activities that benefit the community. This year, for the first time, the organizations' faculty advisor, Roger Rulifson (Biology, Institute for Coastal and Marine Resources) was named as the Advisor of the Year for the 2006–2007 academic year. Rulifson has successfully advised and served ECU-AFS since its inception in 1998, participating in many service events, bringing in exciting speakers, and motivating members to be successful.

Achievement awards are not new to these 25 student members of ECU-AFS. In addition to winning this prestigious award last academic year, the ECU-AFS organization won the Best Student Subunit Award two years in a row from the Southern Division of AFS, and in the fall of 2006 won the AFS Best Student Subunit Award, which was presented to Becky Deehr and ECU-AFS representatives in Lake Placid, New York. For more information about the ECU Student Subunit, check out their website at www.ecu.edu/org/.afs.

—Roger Rulifson

Becky Deehr holds the ECU Best Student Organization of the Year Award for 2006-2007, and Roger Rulifson holds the Best Faculty Advisor for an organization award.

Montana Chapter
Holds annual meeting in Missoula

The Montana Chapter pulled off another successful meeting (our 40th) in February 2007, in Missoula. The meeting theme "Revisiting and Reinvigorating the Source of Our Passion and Professionalism" generated great participation and discussion. Nearly 250 people attended the meeting, and a record number (over 50) of presentations were given—15 by student presenters (also a record). The meeting began with inspiring talks in the plenary session by former nine-term Congressman Pat Williams and Montana Fish, Wildlife and Parks biologist Chris Clancy that covered both the challenges we face as natural resource managers and praise for those committed to protecting and enhancing the fisheries in our state and beyond. The general meeting had provoking symposia ranging from lake trout status and management, to installing or removing barriers, to the conservation of Arctic graying, as well as outstanding contributed paper sessions on fish management, ecology, and techniques.

Preceding the conference was an outstanding continuing education workshop organized by Continuing Education Chair Lisa Eby and Past President Kate Walker—"How to Move Fish, Water, and Wood Through Culverts"—that was attended by over 100 professionals from diverse backgrounds, including hydrologists, fish biologists, and engineers. This workshop demonstrated tremendous potential for outreach by the Montana Chapter to professionals working with Montana's natural resources who do not normally attend AFS meetings.

At the business meeting, Carter Kruse, Turner Enterprises, was elected to serve as president elect of the Montana Chapter. Kruse begins his term in September.

Being able to acknowledge and honor the work done by individuals across the state is unique and important role of the Chapter, and this year was no exception. In addition to awards, we acknowledged the contributions by the outgoing Excom officers, Past President Kate Walker and Secretary Treasurer Matt Jaege; both will be missed on the Excom. We provided 10 individuals and a group with the following awards:

- **Kiza Gates** (Montana State University) was awarded the Best Student Presentation for her talk, "Movement of Anglers and Sediment Transport: Implications for Moving Aquatic Nuisance Species."
- **Eric Roberts** (Montana Fish, Wildlife and Parks) was the first recipient of the new Best Professional Presentation Award for his paper, "Changes in Angler Use Following an Unauthorized Walleye Introduction in Canyon Ferry Reservoir."
- **Dale Koelzer** and **Roger Nelson** were awarded Outstanding Landowner Awards.
- **Tom Pruitt and Staff** from the Ennis National Fish Hatchery were awarded the Outstanding Group Achievement Award
- **Greg Tollefson**, Five Valleys Land Trust, was awarded the 2006 Natural Resource Professional Award.
- **Lisa Eby**, University of Montana, was awarded the 2006 Educator Award.
- **Michael Howell** from the *Bitterroot Star* was awarded the 2006 Outdoor Writer Award.
- **Rick Barrows**, U.S. Department of Agriculture, and **John Vincent**, Gallatin County Commissioner, were awarded Outstanding Individual Achievement Awards.
- Awards Chair Travis Horton presents **Steve Leathe** (below) with the coveted "2006 Outstanding Fishery Professional Award."

—Travis Horton

OBITUARY:
DAVID GUY PARTRIDGE

GEORGIA DNR FISHERIES BIOLOGIST

On 16 February 2007, David Guy Partridge, 41, died in an automobile accident on an icy road attempting to avoid a deer on a snowy night near his home of Wall Lake, Iowa. Partridge worked for the Georgia Department of Natural Resources (GDNR) in Albany as a senior fishery biologist. He was responsible for coordinating sampling in reservoirs and rivers, supervising personnel, and overseeing hatchery operations and contract research in his region.

Partridge was born in Cedar Rapids, Iowa, and grew up in rural west-central Iowa, spending many hours fishing and hunting. In 1988, he graduated with a B.A. in business from the University of Northern Iowa, but soon realized that he wanted to do something in the fisheries profession. In 1990, he obtained a B.S. degree in fisheries and wildlife biology from Iowa State University. After gradation, he worked for about three years as a fisheries technician for the Illinois Natural History Survey, and then decided to advance his career opportunities and entered the graduate program at Auburn University, Alabama. At Auburn University, he received a M.S. in fisheries in 1997 and by then already had joined the staff of the GDNR. He became an AFS member in 1992. Partridge provided much of his new knowledge, creativity, and natural resource common sense to the agency, implementing more efficient and accurate methods to sample and assess fish populations. He quickly became a leader in the agency and fellow professionals relied on his opinions. Partridge even assisted former President Jimmy Carter in Plains, Georgia, with improving his pond for sport fishing.

Although Partridge was on a fast track and promising career ladder, he left the agency after 10 years to reconnect with his family, friends, and the state of Iowa land he loved so much. Throughout his life, Partridge was a passionate outdoors person, and hunted and fished whenever and wherever he could. Back in Iowa, he pursued his hobbies, with trips back to the Southeast, North Dakota, and Canada. He was also involved in community service activities and appeared he was going to pursue another career path in land, aquatic, and wildlife conservation in Iowa.

Whatever Partridge did in life, he pursued that activity with enthusiasm, energy, and a smile. He blended his professional career with his outdoor ambitions and promoted and communicated wise natural resource use with the public. He was simply a great person to be around—either at work, in the field, or doing something in the woods or on the water, it was always a good experience. He was one of those unique individuals that impacted everyone he knew.

In his memory, the David G. Partridge Memorial Fisheries Scholarship has been established to support graduate students at Auburn University in fisheries management, ecology, and conservation biology to help these students continue in the career path and ideals that he exemplified. More information on contributing to this scholarship can be obtained by contacting Graves Lovell (Graves.Lovell@dcnr.alabama.gov) or Mike Maceina (maceimj@auburn.edu).

Dave Partridge—fishery biologist, angler, hunter, conservationist, and devoted family man and friend—will be missed. We will always remember those early mornings when he would call out, "Oh buddy, daylight's burning!" as we started off on another great day.

—Mike Maceina,
Graves Lovell,
and Todd Partridge

Proportional Size Distribution (PSD): A Further Refinement of Population Size Structure Index Terminology

Christopher S. Guy, Robert M. Neumann, David W. Willis, and Richard O. Anderson

Guy is the assistant unit leader at the Montana Cooperative Fishery Research Unit, Bozeman. The Unit is jointly supported by Montana Department of Fish, Wildlife and Parks; Montana State University; and the U.S. Geological Survey. He can be reached at cguy@montana.edu. Neumann is managing editor at *In-Fisherman* magazine, Baxter, Minnesota. Willis is a distinguished professor in the Department of Wildlife and Fisheries Sciences at South Dakota State University, Brookings. Anderson is a retired professor located in Missouri City, Texas, and was the founder of size structure indices.

It has been little over a year since we proposed a new terminology for proportional stock density (PSD) and relative stock density (RSD; Guy et al. 2006). In that article, we stated that we would provide a follow-up piece regarding comments we received on the proposed terminology. We received 15 responses. Ten respondents agreed with the name change, one was indifferent, and four were opposed.

More interesting than the "agree or disagree" votes were the comments associated with the responses. For example, one person suggested that we use the term percent instead of proportion given that size structure values are multiplied by 100. Two people suggested that we drop the acronyms associated with length categories, such as Q-P for quality-to-preferred-length, in favor of actual length values. A few individuals thought that the name change was "small potatoes" and that a change would not increase the utility of the indices. Conversely, others liked the name change because it would help them better convey information to anglers. That is, size is what primarily interests anglers, not stock density. Further, several respondents agreed that the change would help with communication among scientists and make teaching the concept of size structure indices easier.

We considered all comments carefully in our contemporary decision. We were persuaded to continue with new terminology and revised our proposal because of comments from Richard Anderson, who initially developed PSD and RSD. Anderson proposed the term: "proportional size distribution," which he suggested would be more descriptive and accurate than proportional or relative stock density. We thought this was a better choice than ideas proposed in Guy et al. (2006) given it retains the use of PSD. Further, we decided to drop the term relative stock density because it was redundant with PSD (Table 1). We could not incorporate all the comments and suggestions that we received, and believe that we have crafted a simple, sensible compromise.

We do not take the name change lightly and would not have proposed such a change had we not strongly believed that it would benefit the profession at all levels (i.e., from teaching undergraduate students about the concept to improving communication among practicing professionals). The history regarding the development of size structure indices (e.g., Willis et al. 1991; Anderson and Neumann 1996) need not be lost in the new terminology. Obviously, we do not want the profession to forget why size structure indices were originally developed, because understanding the meaning and history behind them is obviously more important than the name.

...others liked the name change because it would help them better convey information to anglers. That is, size is what primarily interests anglers, not stock density. Further, several respondents agreed that the change would help with communication among scientists and make teaching the concept of size structure indices easier.....

Table 1. Old (proportional stock density [PSD]; relative stock density [RSD]) and new (proportional size distribution [PSD]) terminology for size-structure indices. Note that PSD = RSD-Q in the old terminology.

TERMINOLOGY

Current	New
PSD	PSD
RSD-P	PSD-P
RSD-M	PSD-M
RSD-T	PSD-T
RSD S-Q	PSD S-Q
RSD Q-P	PSD Q-P
RSD M-T	PSD M-T

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COLUMN: MEET A YOUNG PROFESSIONAL

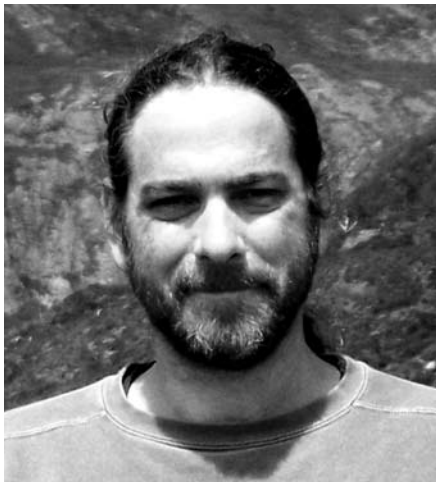
Todd Gedamke, Research Fisheries Biologist

NMFS SOUTHEAST FISHERIES SCIENCE CENTER, MIAMI, FLORIDA

Fisheries: Why did you choose a career in fisheries?

Gedamke: My life has been a natural progression from an excited 10-year-old exploring the marshes of the Long Island Sound and diving in the Caribbean to a career in fisheries. I started my formal training at Colgate University, where I not only gained a solid background in biology, but was also able to spend a semester at sea with the Sea Education Association program in Woods Hole. It was there, and probably whilst onboard the *R/V Westward*, that it became clear that marine science was where I belonged. Following my undergraduate degree, I gained priceless hands-on experience working as an educator and assistant aquarium curator for the University of Georgia, as a fisheries observer for the National Marine Fisheries Service (NMFS) in the Bering Sea, as the director of a loggerhead sea turtle research project in Georgia, and also researching hawksbill sea turtles in Antigua.

Sometime, while I was knee-deep in pollock on the deck of a commercial factory trawler in the Bering Sea, I became fascinated by the sheer magnitude of the fishery and the research and management that was involved in the process. It was then that I decided to pursue a graduate degree in fisheries. My desire to work in this area stemmed not from a radical crusade to save the Earth but rather from a practical standpoint. It became obvious to me that as our society grows and technology allows for more efficient harvesting of marine resources, that knowledge would be the key. The issues are complex and only through an understanding of the dynamics of these marine systems can management measures be developed that take into consideration the concerns of both the environmentalists and fishing communities. With this in mind, and my love of seafood, I matriculated into the fisheries program at the Virginia Institute of Marine Science (VIMS) and began my career in fisheries.



Fisheries: Did you have a mentor and if so, how did they help you get where you are?

Gedamke: My early development can be solely attributed to my father's passion for life and inherent desire to always question, seek out answers, and solve problems. Without this influence I wouldn't be where I am today.

In the world of marine science, my first role model was Jack Musick from VIMS. I met him at a Sea Turtle Symposium soon after I completed my undergraduate degree and was impressed by the balance he maintained between the different aspects of his personality and the thirst for both practical and theoretical experiences. I was sure he could write a manuscript while tending a longline and I saw a little of myself in him.

Although Jack put graduate school and VIMS on my radar, Bill DuPaul accepted me into the program and immediately got me involved in research on the sea scallop fishery. Bill's ability to work directly with the industry and focus his research efforts on management needs was impressive. I learned not only about fisheries research but also about the surrounding politics and management process.

And finally there is John Hoenig. I sought out his quantitative expertise while working on my master's degree and we've been working together ever since. John continually impresses me with his ability to break down complex problems into their fundamental components. He exposed me to the quantitative aspects of fisheries science, ignored my calculus phobias, taught me to write, and generally opened my eyes to areas that I had left unexplored. John took me under his wing, offered me a fellowship through the NMFS Southeast Fisheries Science Center and, in the end, gave me the skills and confidence to succeed in the world of quantitative fisheries science.

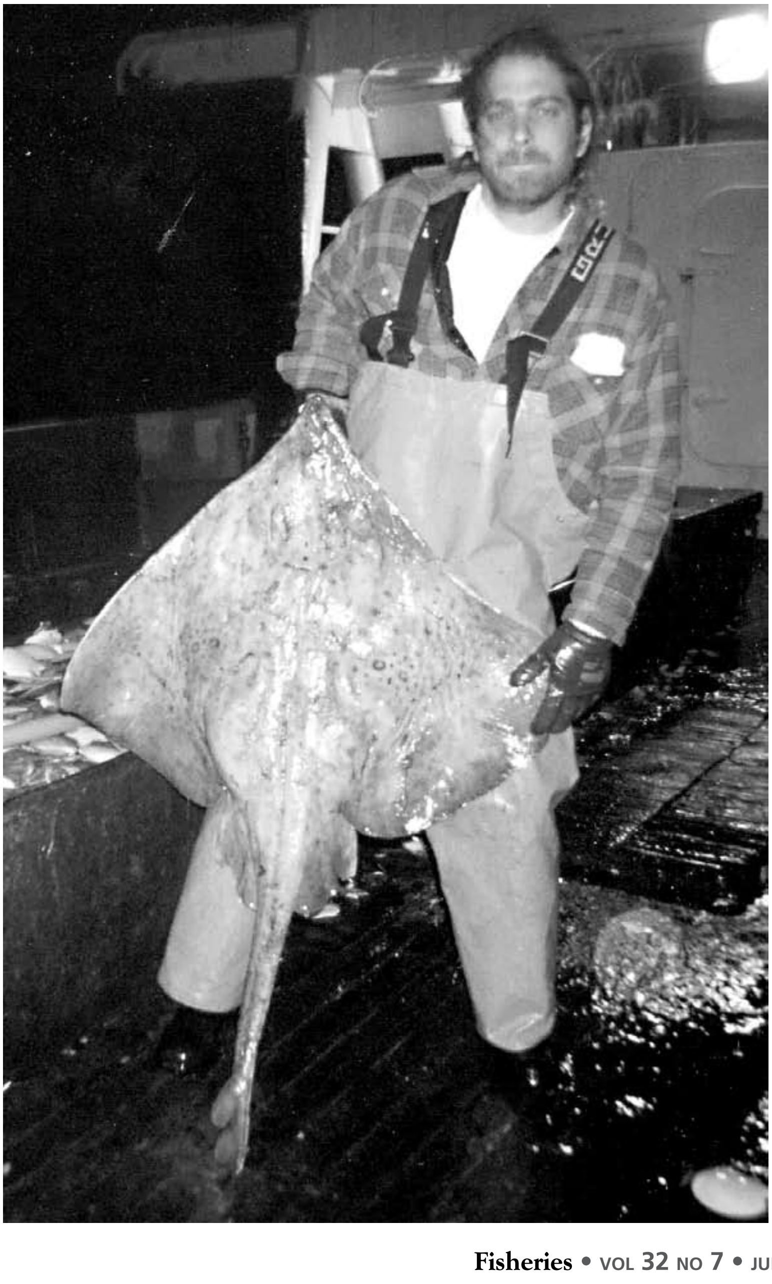
I feel lucky to have known and worked with them all and they have shaped me into what I am today.

Fisheries: What issues are you currently working on and what are your greatest challenges/accomplishments?

Gedamke: Recently, my focus has been on stock assessment and the development of stock assessment methodologies. My current research began following an article published in *Science* which claimed that the barndoor skate (*Dipturus laevis*) might be on the brink of extinction.

The challenge was to recognize the potential of the limited data and develop new approaches for use in data-limited situations. I began working with the Beverton-Holt mortality estimator based on mean lengths. This method has minimal data requirements but has the underlying assumptions of constant mortality and constant recruitment. I, with John Hoenig, developed a variant of this method which does not require the restrictive assumption of equilibrium conditions (i.e., constant mortality). We then took this one step farther by incorporating a time series of recruitment into the analysis. We also generalized an approach which uses catch rates from multiple years to estimate survival rates.

With these new tools, we have been able to conclude that the current mortality rate on the U.S. barndoor skate population is low and, at least in the area we studied, there is no current threat to the species. But far more exciting has been the experience of seeing the new methods applied to goosefish, sea scallops, and groupers. The lesson has been to start simple and think general.



Fisheries: What would you credit for jump-starting your career?

Gedamke: The short answer is my graduate work at VIMS and the guidance of my mentors. VIMS prides itself on advisory work as well as education and research. Faculty and students interact continually with government scientists and fisheries management agencies like NMFS, the Atlantic States Fisheries Management Committee, and the Virginia Marine Resources Commission. This provides VIMS students with invaluable practical experience. In my case, NMFS scientists took a personal interest in me and in my work and offered advice, data, collaborative research opportunities, advice, and more advice.

Fisheries: How do you see fisheries science changing during your career?

Gedamke: The main thing I see changing is in the amount and quality of information that is available. Technological advancements and long-term research programs will continue to add to our knowledge base and our overall understanding of marine ecosystems. This will not only allow existing methodologies to be fine-tuned but also foster the development of more complex and realistic analytical techniques (i.e., ecosystem-based models, multispecies models, and a greater incorporation of spatial and environmental variability).

Fisheries: What would you like to change if you could?

Gedamke: If I could change one aspect of fisheries science, it would be the working relationship between the fishing industry and scientists. Onboard commercial vessels, I learned to speak the language of the fishing community and heard a pervasive distrust of fishery managers. This is unfortunate. Those who have spent their lives at sea have a wealth of experiences and an understanding of the fishery that cannot be gained any other way. I think that the cooperation between the fishing community, researchers, and managers and the exchange of both practical and theoretical knowledge will greatly benefit all of those involved.

Fisheries: Please describe your AFS involvement.

Gedamke: I became a member of AFS in 2001 and have presented my research at a couple of Annual Meetings. I have had four manuscripts accepted by AFS journals and a fifth is in revision. Just over a year ago I was asked to be an associate editor of the *North American Journal of Fisheries Management.* Working with Carolyn Griswold and the rest of the AFS editorial staff has been extremely rewarding and enjoyable.

Aug 5-10—2007 **Joint Annual Meeting of the Ecological Society of America and the Society for the Ecological Restoration,** Brisbane, Australia. See www.riversymposium.org.

Aug 12-18—**30th Congress of the International Association of Theoretical and Applied Limnology: Redefining Theoretical and Applied Limnology in the 21st Century,** Montreal, Canada. See www.sil2007.org.

Aug 14-16—**Salmonid Restoration Federation Central Coast Field School: Culvert and Road Drainage Practices to Protect and Benefit Steelhead and Water Quality in the Central Coast Region,** Arroyo Grande, California. Contact Nicole, 805/473-8221.

Aug 15-16—**European Aquaculture Society: Aqua Nor Forum 2007,** Trondheim, Norway. See www.easonline.org/home/en/default.as.

Aug 22-24—***Salvelinus confluentus* Curiosity Society Annual Meeting,** Perkins Lake, ID. Contact Dan Kenney, dkenney@fs.fed.us, 208/622-0094.

Sep 2-6—**American Fisheries Society 137th Annual Meeting,** San Francisco, California. See www.fisheries.org/sf/.

Sep 11-13—**Second Global Conference on Large Marine Ecosystems,** Qingdao. China. See www.ysfri.ac.cn.?GLME-Conference2Qingdao/homepage.htm.

Sep 11-15—**Fish Stock Assessment Methods for Lakes and Reservoirs Conference: Towards the True Picture of Fish Stock,** Ceske Budejovice, Czech Republic. See www.fsamlr2007.czweb.org.

Sep 15—**Ocean Conservancy's 22nd Annual International Coastal Cleanup.** See www.oceanconservancy.org/iccmedia.

Sep 17-21—**Northwest Environmental Training Center: Introduction to Engineered Log Jam—Technology and Applications for Erosion Control and Fish Habitat,** Olympic Peninsula, Washington. See www.nweec.org.

Sep 16-21—**Association of Fish and Wildlife Agencies,** Louisville, Kentucky. See www.fishwildlife.org/annualmeet.html.

Sep 17-21—**International Council for the Exploration of the Sea,** Helsinki, Finland. See www.ices.dk.

Sep 18-21—**International Conference on Freshwater Habitat Management for Salmonid Fisheries,** University of Southampton, UK. See www.salmonidhabitat.co. Contact Lynn Field, admin@salmonidhabitat.com.

Oct 2-3—**Second Thermal Ecology and Regulation Workshop,** Westminster, Colorado. See www.rd.tetratech.com/EPRIThermalWorkshop.com. Contact Bob Goldstein, rogoldst@epri.com, 650/855-2593.

Oct 8-11—**Second International Symposium on Tagging and Tracking of Marine Fish with Electronic Devices,** San Sebastian, Guipuzcoa, Pais Vasco, Spain. See http://unh.edu/taggingsymposium/.

Oct 9-10—**Symposium on Anadromous Salmonid Tagging and Identification Techniques in the Greater Pacific Region,** Portland, Oregon. See www.rmpc.org/2007-marking-symposium.html Contact george_nandor@psmfc.org 503/595-3100.

Oct 9-10—**Seattle-Bioneers Conference 2007,** Seattle, Washington. See www.nwetc.org.

Oct 9-12—**International Symposium: Wild Trout IX,** West Yellowstone, MT. www.wildtroutsymposium.com/. Contact Dirk Miller, Dirk.Miller@wgf.state.wy.us, 307/777-4556.

Oct 15-17—**Aquaculture America 2008,** Lake Buena Vista, Florida. See www.sustainableaquaculture.org.

COLUMN
PRESIDENT'S HOOK

Continued from page 316

- Develop dynamic curricula through new faculty hires as full-time positions become available.
- Set trends in new directions in information use and management, i.e., "bioinfomatics" has replaced "fish food science" classes at UW and while there is a new emphasis on geospatial analyses at UF.
- Develop new and effective tools for fisheries assessment—hydroacoustics, genetic stock identification using single nucleotide polymorphisms (SNPs), electronic data storage tags.
- Develop extensive, rigorous quantitative programs and modeling applications.
- Develop new curricula in fisheries ecosystem management, including training in natural resource law and social economics.
- Conduct rigorous science with published outcomes that contribute to basic research and management applications in fisheries science.

We are all aware of the dual roles that colleges and universities provide as both scientific and social institutions. Traditional fisheries schools are experiencing a transition and redirection much like other natural resource disciplines that have experienced changes in trends and applications with changing social needs. This seems to be a healthy change, at least at the two fisheries schools I spoke to. Enrollments in the schools of Aquatic and Fishery Science (UW) and Fishery and Aquatic Sciences (UF) have increased substantially in recent years.

The drive for interdisciplinary research in the applied sciences marks a fundamental, critical, and in some cases even radical transition to a new literacy in fisheries science. Stepping beyond the rubric of extraction and allocation in fisheries science takes much more than just a name change, however. We cannot forget that knowledge and tools dedicated to extraction and allocation are still important skills critical to sustainable fisheries. Clearly fish and fisheries, what ever they are called, will play a vital cultural, economic, and social role in human society for a long time to come. The American Fisheries Society can support the framework for this transition in traditional fisheries programs by providing publication and networking tools for our new and diverse student membership, training and educational opportunities for our members, and development of programmatic reviews and policy statements that reflect the needs of our increasingly integrative membership. Fisheries science, by any name, will remain critical to sustainable resource management now and into the future.

LETTER: TO THE EDITOR

AFS Socioeconomics Section Members Clarify Opinions on the Proposed AFS Policy Statement on Economic Growth

As concerned members of the AFS Socioeconomics Section (SES), and in response to the comment of John Whitehead in the May 2007 issue of *Fisheries*, we want to clarify our opinions on the draft AFS policy statement on economic growth and fish conservation.

First, we commend the AFS Governing Board and Resource Policy Committee (RPC) for presenting AFS members with the draft policy statement. Without the statements of professional natural resources societies regarding the impacts of economic growth on fish and wildlife, we allow politicians, economists, and business interests to have free rein over the issue. Far too often we've heard the results in the form of rhetoric such as, "There is no conflict between growing the economy and protecting the environment." Such rhetoric has led to a wasteful consumer ethic and to macroeconomic policies resulting in the decline of aquatic ecosystems and fisheries, among other forms of environmental deterioration.

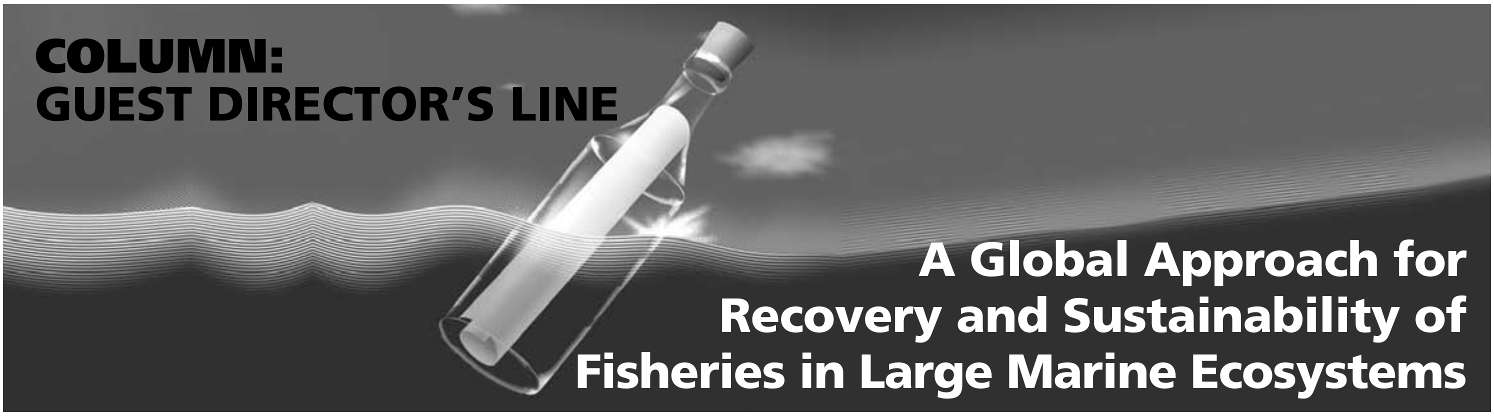
Given the contrasting underpinnings of orthodox (neoclassical) and heterodox (biophysical, ecological, etc.) economics, we accept the fact that consensus on every aspect of this issue is unattainable. Many of us want stronger wording about the inherent conflict between economic growth and fish conservation than appears in the RPC draft, and we have provided our suggestions through appropriate channels. An example is the role of microeconomic and macroeconomic policies in conserving fish and the ecosystems they depend upon. The draft policy statement calls for the application of microeconomic policy tools to what is, in the end, a macroeconomic matter: economic growth.

We recognize value in microeconomic policy reform for the sake of efficiently allocating resources, including fisheries. For that reason, especially, we have welcomed the contributions of neoclassical economists to fisheries management, and we can even accept a certain amount of microeconomic language in a policy statement on economic growth. However, tweaking microeconomics simply is not sufficient to effect the fundamental economic changes necessary to enhance fish conservation substantially. Expecting microeconomics alone to fix a macroeconomic problem is like arranging the china shop while letting in the bull. Therefore, we think the policy statement must address macroeconomic reform as well.

Whitehead's disclaimer that his "views are not representative of *every* member of the Socioeconomics Section" (emphasis added) is correct, strictly speaking. However, this is misleading to the naïve reader, as it suggests that those who hold contrary views are a very small minority. To the contrary, we have found it quite easy to identify numerous SES supporters of the proposed policy statement. Indeed, we believe that the majority of SES members would actually favor the policy statement advanced by the RPC, or else remain neutral on the subject. That said, an accurate opinion tally from the SES is no longer especially important. Rather, we believe it is time for the opinions of the RPC, Governing Board, and AFS membership at large to prevail, and not the opinion of the SES or a minority therein.

Neoclassical economists are well-known for advocating laissez-faire and economic growth. It is time for fisheries ecologists to weigh in on the impacts of economic growth on fish conservation—and what to do about it—rather than leaving this issue in the hands of neoclassical economists. Considering the mounting empirical evidence, coupled with official positions already taken by other professional societies (The Wildlife Society, American Society of Mammalogists, U.S. Society for Ecological Economics, and others), an AFS position on economic growth is long overdue. We believe the RPC's draft statement is a good starting point, and look forward to constructive, thoughtful commentary from the rest of AFS regarding this important policy issue.

—Steve Coghlan, University of Maine, Orono;
Paul Angermeier, Virginia Polytechnic University, Blacksburg;
Joseph Cech, University of California, Davis;
Kin Daily, Ecological Services, Inc., Bay City, Oregon;
Tom Lang, University of Arkansas at Pine Bluff;
Karin Limburg, State University of New York College of Environmental Science and Forestry, Syracuse;
Michael Litwin. U.S. Fish and Wildlife Service, Bloomington, Indiana;
Jerry Mead, University of Pennsylvania, Philadelphia;
Geoffrey Patton, Wheaton, Maryland, and
Phil Pister, Desert Fishes Council, Bishop, California.



COLUMN: GUEST DIRECTOR'S LINE

A Global Approach for Recovery and Sustainability of Fisheries in Large Marine Ecosystems

K. Sherman and A. Duda

Sherman is the director of National Oceanic and Atmospheric Administration Northeast Fisheries Science Center Narragansett Laboratory, Narragansett, Rhode Island. He can be contacted at ksherman@ mola.na.nmfs. gov. Duda is senior advisor on international waters, Global Environment Facility, Washington, DC.

LARGE MARINE ECOSYSTEMS

Large marine ecosystems (LMEs) are natural regions of ocean space encompassing coastal waters from river basins and estuaries to the seaward boundary of continental shelves and the outer margins of coastal currents. They are relatively large regions of 200,000 km^2 or greater, the natural boundaries of which are based on four ecological criteria: bathymetry, hydrography, productivity, and trophically related populations (Sherman 1994; Sherman and Duda 2005). The LMEs are areas of the world oceans most stressed from habitat degradation, pollution, and overexploitation of marine resources. Ninety percent of the usable annual global biomass yield of marine fish and other living marine resources is produced in 64 LMEs (Figure 1) identified within, and in some cases extending beyond, the boundaries of the exclusive economic zones of coastal nations located around the margins of the ocean basins (Sherman 1994; Garibaldi and Limongelli 2003).

Levels of primary production are persistently higher around the margins of the ocean basins, within the boundaries of the LMEs, than in the open-ocean pelagic areas (Figure 2). Urban centers with high population density characterize many of these coastal ocean areas and contribute to nutrient over-enrichment that has its greatest impact on natural productivity cycles through eutrophication, anoxic conditions, and dead zones from high levels of nitrogen and phosphorus effluent from estuaries (Kroeze and Seitzinger 1998). Toxins in poorly treated sewage discharge, harmful algal blooms, and loss of wetland nursery areas to coastal development are ecosystem-level problems that also need to be addressed (GESAMP 1990).

Since 1995, the Global Environment Facility (GEF) has provided substantial funding to support country-driven projects for introducing multi-sectoral ecosystem-based assessment and management practices for LMEs located around the margins of the oceans. At present, 116 developing countries are engaged in the preparation and implementation of GEF-LME projects, totaling $650 million in start-up funding. A total of 16 projects including 85 different developing countries have been approved by the GEF Council, and another 9 projects involving an additional 31 different countries have GEF international waters projects under preparation (www.iwlearn.net).

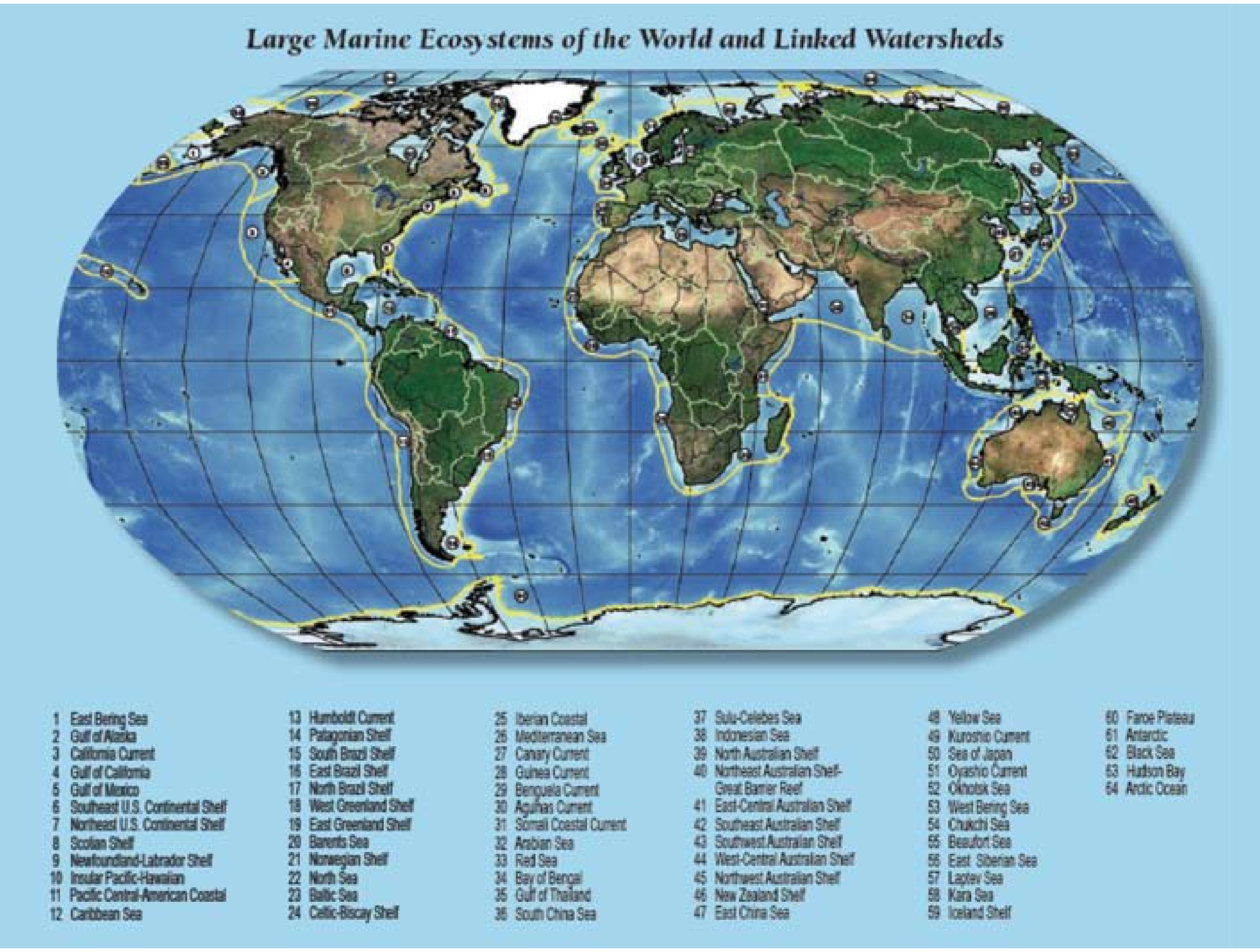
A five-module indicator approach to assessment and management of LMEs has proven useful in ecosystem-based projects in the United States and GEF-supported projects elsewhere (Figure 3). The modules are adapted to LME conditions through a transboundary diagnostic analysis process to identify key issues, and a strategic action program development process for the groups of nations or states sharing an LME to remediate the issues (Wang 2004). These processes are critical for integrating science into management in a practical way, and for establishing appropriate governance regimes. In a number of these projects, science advisory bodies are utilized to continue providing a science base for management decision-making.

The GEF-LME projects presently funded or in the pipeline for funding in Africa, Asia, Latin America, and Eastern Europe represent a growing network of marine scientists, marine managers, and ministerial leaders who are pursuing ecosystem and fishery recovery goals. The annual fisheries biomass yields from the ecosystems in the network are significant at 44.8% of the global total, and are a firm basis for movement by the participating countries toward the 2002 World Summit on Sustainable Development (WSSD) targets for introducing ecosystem-based assessment and management by 2010, and for recovering depleted stocks and achieving fishing at maximum sustainable yield (MSY) levels by 2015 (Sherman 2006). The Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fishery Practice (FAO 2002) is supported by most coastal nations and has immediate applicability to reaching the WSSD fishery goals. The code argues for moving forward with a precautionary approach to fisheries sustainability, using available information more conservatively to err on the side of lower total allowable catch levels than has been the general practice in past decades (Freestone and Hey 1996).

2007–2010 GEF SUPPORT FOR FISHERIES RECOVERY AND BIODIVERSITY CONSERVATION

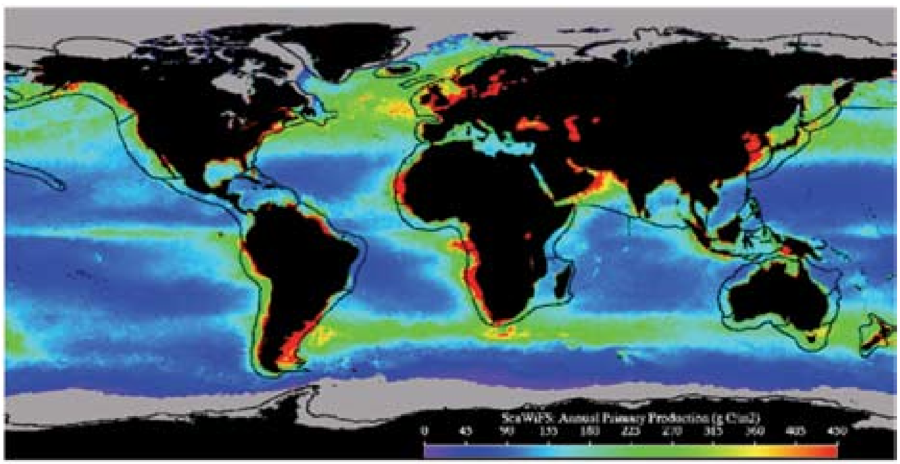
The recent study by Worm et al. (2006) reached the conclusion that cumulative catches within the world's LMEs have declined 13% (10.6 million metric tons) since passing a cumulative maximum in 1994. They argue that species average catches in non-collapsed fisheries were higher in species rich systems and, that species robustness to overexploitation was enhanced in LMEs with high fish species diversity. They further argue that sustainable fisheries management, pollution control, maintenance of essential habitats, and the creation of marine reserves will prove to be good investments in the productivity and value of goods

Figure 1. Global map showing 64 LMEs and linked watersheds.



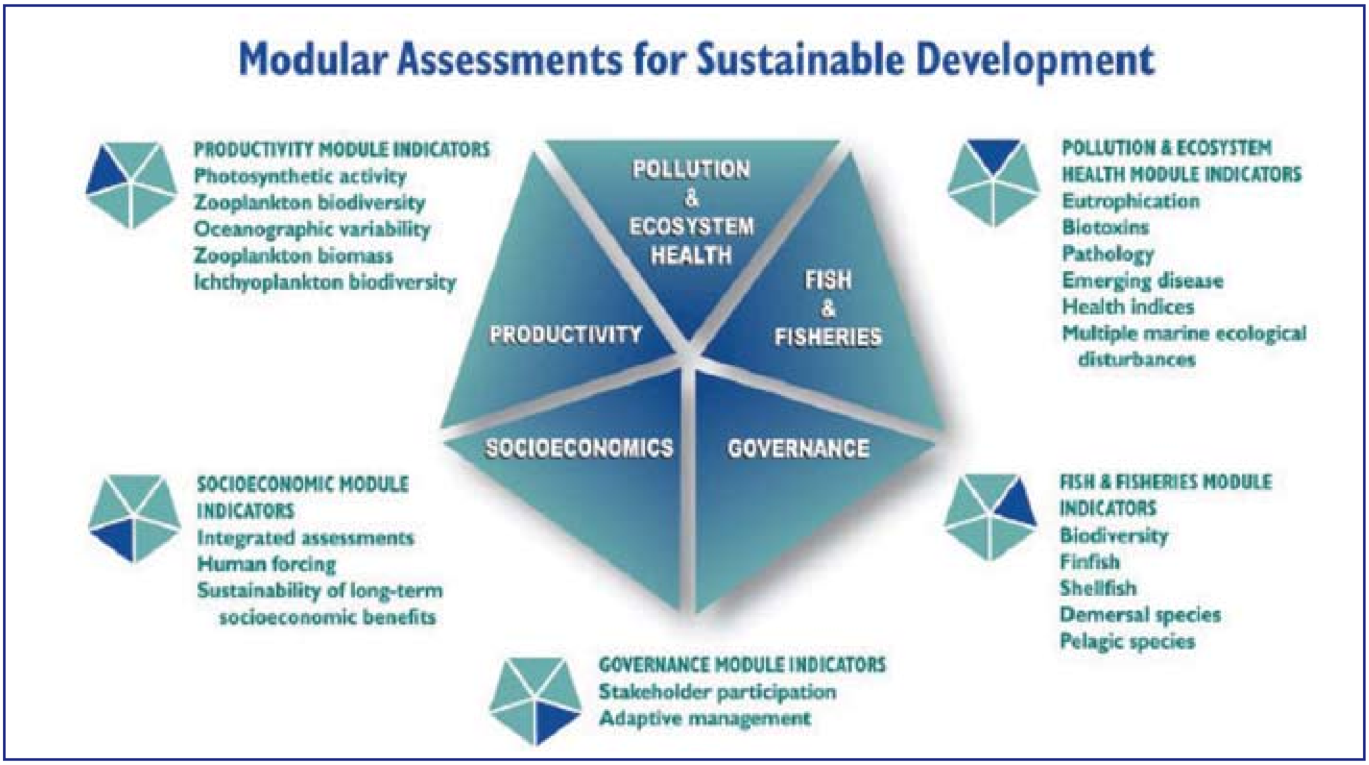
and services that the ocean provides to humanity while business as usual will threaten water quality and ecosystem stability. The $60 billion in international trade in marine fisheries products is at risk from this depletion. In an effort to assist developing countries in moving forward to recover and sustain marine fisheries water quality and habitats, the draft GEF strategy for its International Waters (IW) focal area for the period 2007 to 2010 places a priority on recovering depleted marine fish stocks and implementing selective and less destructive fishing practices than those that are now threatening coastal economies and the communities depending on them, as well as causing adverse impacts on biological diversity. The draft strategy is available on www.iwlearn.net.

Figure 2. Global map showing 64 LMEs and their estimated average annual productivity. (Estimates are based on SeaWiFS satellite data collected between September 1998 and August 1999, and the model developed by Behrenfeld and Falkowski (1997). The color-enhanced image (provided courtesy of Rutgers University) depicts a shaded gradient of primary productivity from a high of 450 $gCm^{-2}yr^{-1}$ in red to < 45 $gCm^{-2}yr^{-1}$ in purple.



The impact of declining fish stocks and destructive fishing practices has serious implications for loss of species and biomass of ecosystem structure, integrity, and stability. Consequently, the GEF International Waters (IW) focal area is joining forces with the GEF Biodiversity focal area during the period of 2007-2010 to catalyze cost-effective solutions. Already, 116 different states have requested GEF help to work with their neighbors in GEF IW foundational capacity building projects for almost one-half (17) of the planet's

Figure 3. LME modules as suites of condition indicators for inputs to integrated ecosystem assessments.



LMEs that are shared by developing countries, in recognition of these social and economic concerns. GEF recommended processes are underway toward development of ministerially-agreed collective programs of action that should benefit from use of marine protected areas (MPAs).

During the period 2007 to 2010, the GEF International Waters focal area plans to support developing countries bordering LMEs in Africa, Asia, Latin America, and Eastern Europe to introduce an ecosystem-based approach for moving toward the restoration and sustainability of depleted fish stocks, over-enriched coastal waters, restoration of habitats, protection of biodiversity, and adaptation to climate change. Participating countries may also be eligible to request GEF funding for addressing land-based sources of marine pollution and habitat conservation, including support for (1) barrier removal in improving wastewater treatment and using low cost constructed wetlands for sewage treatment, (2) wetlands restoration, (3) integrated coastal management and community-based fisheries, and (4) transitional support to fishers for alternative livelihood activities for near-coastal fisheries that are overcapitalized, overfished, and under stock rebuilding management regimes.

LME APPROACH TO WORLD SUMMIT TARGETS

Since 1993, the NOAA Fisheries Service has been cooperating with GEF, the World Conservation Union (IUCN), Intergovernmental Oceanographic Commission, UNESCO, and several other UN agencies, including the United Nations Industrial Development Organization, UN Development Program, UN Environment Program, and FAO, to assist developing countries in planning and implementing ecosystem-based management focused on LMEs as the principal assessment and management unit for near-coastal ocean resources. NOAA contributes scientific and technical assistance and expertise to aid developing countries in reaching the targets of the 2002 WSSD (Duda and Sherman 2002). The targets, agreed on by officials of more than 100 countries, call for the achievement of "substantial" reductions in land-based sources of pollution, introduction of the ecosystems approach to marine resource assessment and management by 2010, designation of a network of marine protected areas by 2012, and the maintenance and restoration of fish stocks to MSY levels by 2015. The GEF-LME strategy supports the WSSD targets for addressing coastal and marine issues by jointly analyzing scientific information on transboundary problems and their root causes, and setting priorities for action on these problems.

Reforms are taking place among the participating countries in operationalizing this ecosystem-based approach to managing human activities in the different economic sectors that contribute to place-specific degradation of the LME and adjacent waters. The WSSD target for introducing ecosystem-based assessment and management practices by 2010 can still be met by many of the countries constituting the existing LME network. It is unlikely that the WSSD target for maintaining and restoring fishery resources to MSY levels by 2015 will be met. However, progress is being made in recovery of depleted fish stocks through mandated reductions in fishing effort (Sherman et al. 2002). With regard to the target for control and reduction of land-based sources of pollution, considerable additional effort will be required to achieve "substantial reductions," whereas good progress has been made in designating MPAs within the GEF-LME project network. The U.S. Ocean Action Plan, published on 17 December 2004 by the Office of the President in response to the U.S. Commission on Ocean Policy's

Final Report (USCOP 2004), supports the LME concept and strategy for ecosystem-based management within the UN regional seas programs and by international fisheries bodies (EOPUS 2004):

Advancing International Oceans Science

Advance the Use of Large Marine Ecosystems. The United States will promote, within the UN Environment Program's regional seas programs and by international fisheries bodies, the use of the Large Marine Ecosystems (LME) concept as a tool for enabling ecosystem-based management to provide a collaborative approach to management of resources within ecologically bounded transnational areas. This will be done in an international context and consistent with customary international law as reflected in 1982 UN Convention on the Law of the Sea.

Additional information on NOAA's contributions to the global LME movement toward ecosystem-based management and resource sustainability is available from the LME Program Office, Northeast Fisheries Science Center, Narragansett Laboratory, Narragansett, Rhode Island, and from the LME website: www.lme.noaa.gov. Additional information on the GEF International Waters Focal Area is found at www.iwlearn.net.

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UPDATE: ANNUAL MEETING

AMERICAN FISHERIES SOCIETY 137th Annual Meeting

AFS Western Division & California-Nevada Chapter Annual Meeting

2007 URBAN FISHING SYMPOSIUM

Recreational fishing traditionally has been one of the most favored participatory outdoor activities in the United States. However, urbanization, urban sprawl, and other factors have caused participation to decline. In addition, recreational fishing participation is consistently lower than the national average for groups such as females, African-Americans, and urban residents. In response to these trends, many state agencies have developed urban fishing programs. However, little information exists to aid in the development, management, and evaluation of theses programs. This Urban Fishing Symposium is the first since 1983, and it will be comprised of invited topics, case studies, and research, with 35 oral and 16 poster presentations. The program thoroughly engages a diverse array of issues relevant to urban fishing program managers, developers, and fisheries administrators, with presentations from across the United States and internationally. Presentations include, but are not limited to, status of urban/community fishing programs nationwide, the role of aquaculture and fish stocking, funding sources, contaminants, program evaluation, alternative programs, marketing and promotion, collaboration, law enforcement, human dimensions, technological applications (including applications of GIS, video recording, and telephone hotlines), and management. Aligned with the AFS 2007 meeting theme of "Addressing Uncertainty and Unintended Consequences in Fish and Fisheries," the Urban Fishing Symposium intends to provide the information necessary to protect against the uncertainty and unintended consequences of neglecting potential angler groups. The "Trout Day" kids fishing event at Lake Merced on Sunday morning will kick-off the symposium by showcasing one aspect of urban fishing in action. The symposium will also include a social event on Tuesday night (see below). The symposium will conclude with a facilitated discussion about the future of urban fishing, research needs, and any other items symposium participants deem important. A product of this symposium will be the Proceedings of the 2007 Urban Fishing Symposium, which will include manuscripts of all oral presentations, management briefs of all posters, and which will be published by AFS. For additional information visit our website at **www.uaex.edu/uapb-student/UrbanFishing/2007.htm.**

SCHEDULE

SUNDAY
6:45 a.m.–1:00 p.m.
"Trout Day" at Lake Merced

MONDAY
1:20–5:20 p.m., Room GG B2
Oral Presentations

4:00–6:00 p.m.
Poster Set-up

6:30–8:30 p.m.
Trade Show and Poster Social

TUESDAY
8:00 a.m.–Noon, Room GG B2
Oral Presentations

9:00 a.m.-5:00 p.m.
Poster Session

6:30--9:30 p.m., Parc 55 Hotel Atrium
Urban Fishing Social

WEDNESDAY
8:00 a.m.–2:20 p.m., Room GG B2
Oral Presentations

2:20–5:20 p.m., Room GG B2
Discussion

9:00 a.m.–5:00 p.m.
Poster Session

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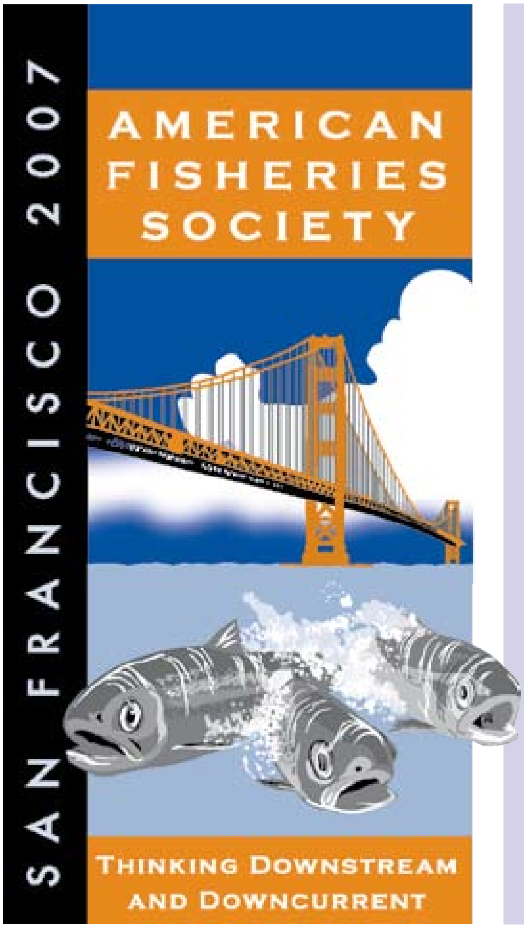


SPONSORS

Trophy Level ($2,500 and up)

American Sportfishing Association
Arkansas Game and Fish Commission
Minnesota Department of Natural Resources
Recreational Boating and Fishing Foundation
U.S. Fish and Wildlife Service, Management Assistance Branch

Memorable Level ($1,000- $2,400)

AFS Fisheries Management Section
AFS Southern Division
Arizona Game and Fish Department
Nebraska Game and Parks Commission
New York State Department of Environmental Conservation

Preferred Level ($999 and below)

AFS Fisheries Administration Section
AFS University of Arkansas at Pine Bluff Student Subunit
Aquatic Resources Education Association
In-Fisherman Inc.
Shakespeare Fishing Tackle

SOCIAL EVENT

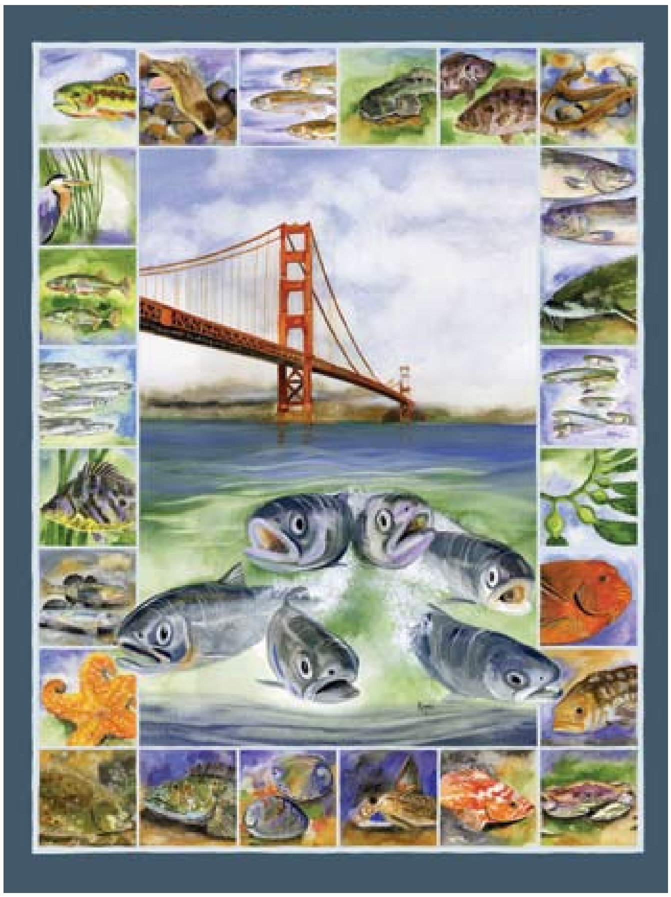
Open to all Urban Fishing Symposium Attendees

This social event will be held Tuesday evening at the Parc 55 Hotel Atrium and Ballroom and is open to all Urban Fishing Symposium attendees and their guests. The Parc 55 is one of the Annual Meeting's overflow hotels and is conveniently located only two blocks from the Marriot. Attendees will dine on an array of regional California cheeses, smoked salmon, antipasto displays, and crudité platters. Thanks to the generosity of the Mad River Brewing Company, attendees will enjoy the award-winning "Steelhead Double IPA."

Urban fishing and aquatic education coordinators are encouraged to display and distribute their program's promotional items as a way for other programs to acquire new marketing ideas.

If you are unsure on how to get to the Parc 55, you can meet up with Southern Division Past President Bob Curry in the Marriot's lobby at 6:15 p.m., and he will lead a group over to the social event.

Take the short walk, enjoy thefresh air, and join us for some fun!



ANNOUNCEMENTS: JOB CENTER

To see more job listings go to www.fisheries.organd click Job Postings.

M.S./Ph.D. Assistantship, Brown Trout Bioenergetics, USGS South Dakota Cooperative Fish and Wildlife Research Unit/South Dakota State University, Brookings.
Responsibilities: Evaluate the effects of an invasive diatom *Didymosphenia geminata* on brown trout foraging ecology in the Black Hills, South Dakota. Interest/experience with bioenergetics modeling, stable isotope analysis, and food web ecology are desired.
Qualifications: B.S./M.S. degree in fisheries science or related field, motivated M.S. or Ph.D. student, strong written and oral communication skills, and competitive GPA and GRE scores.
Salary: Research stipend ($16,000–20,000). Includes out-of-state tuition waiver .
Closing date: 1 September 2007.
Contact: Submit a letter of interest, resume, names and addresses of three references, copies of academic transcripts and GRE scores to Steven R. Chipps, USGS South Dakota Cooperative Fish and Wildlife Research Unit, Department of Wildlife and Fisheries Sciences, NPBL 2140B, South Dakota State University, Brookings, South Dakota 57007; Steven.Chipps@sdstate.edu; 605/688-5467.

Environmental Biologist Specialist (2 positions), Kentucky Department of Fish and Wildlife Resources, Frankfort.
Responsibilities: Develop stream restoration projects statewide under the in-lieu fee mitigation program. See http://fw.ky.gov/streamandwetlandrestoration. Oversee restoration development, design, and monitoring of projects.
Qualifications: B.S. degree in biological, environmental, or natural science with a minimum of 30 credit hours in biological sciences plus one year of professional experience. See job title code 3061 at http://personnel.ky.gov/employment/classpec/e-cs.htm.).
Salary: $2,937.20–3,890.90 per month dependent on source funding. Grade 14.
Closing date: 17 August 2007.
Contact: Send unofficial college transcripts and a completed/signed application (See http://personnel.ky.gov/employment/onlineap.htm.) to Mike Hardin, KDFWR, #1 Sportsman's Lane, Frankfort, Kentucky 40601. Contact Mike Hardin, Mike.Hardin@ky.gov, 502/564-7109 x365. Applicants and employees in this classification may be required to submit to a drug screening test and background check. EOE M/F/D.

Fisheries Resource Analyst, East Bay Regional Park District, Oakland, California.
Responsibilities: Assist the fisheries manager in implementation of fisheries resource development in 11 freshwater lakes/reservoirs, as well as creeks and bay/delta shorelines. Assist with annual fisheries surveys; studies of specific game fish species; requires safe boat operating as well as fish ID, netting and handling skills; planning and implementing fisheries habitat projects, fishing derbies, special events, and aquatic plant control programs; statistical analysis of fisheries data; prepare professional reports, papers, and Power Point presentations.
Qualifications: B.S. in fisheries or related aquatic resources and one year of experience performing difficult research or work in the fisheries field.
Salary: $4,772–5,187 per month plus excellent benefits.
Closing date: 5 p.m.,15 August 2007.
Contact: East Bay Regional Park District, Human Resources, 2950 Peralta Oaks Ct., Oakland, CA 94605; 510/544-2154; www.ebparks.org or apply online at www.CalOpps.org.

Department Head, Wildlife and Fisheries Sciences, South Dakota State University, Brookings.
Responsibilities: Provides leadership in the Department of Wildlife and Fisheries Sciences including vision for academic and research programs, personnel management, and budget oversight.
Qualifications: An earned doctorate in wildlife and fisheries sciences or a closely related field with five years of full-time relevant experience and strong leadership skills. Strong grant and publication records preferred; demonstrated commitment to conservation, management, and ecology of fish and wildlife resources; and commitment to enhancing educational programs.
Salary: Commensurate with rank and qualifications.
Closing date: 15 August 2007.
Contact: Tom Cheesbrough, Search Committee Chair, Biology and Microbiology Department, South Dakota State University; thomas.cheesbrough@sdstate.edu; 605/688-6141; fax: 605/688-6677.

Postdoctoral Scientist—Fish Ecologist/Ecological Modeler, University of Michigan's Cooperative Institute for Limnology and Ecosystems Research and NOAA's Great Lakes Environmental Research Laboratory, Ann Arbor.
Responsibilities: Participate in funded research projects that will develop and apply various models (individual-based and spatially-explicit bioenergetics,

EMPLOYERS: **To list a job opening on the AFS Online Job Center submit a position description, job title, agency/company, city, state, responsibilities, qualifications, salary, closing date, and contact information (maximum 150 words) to jobs@fisheries.org. Online job announcements will be billed at $350 for 150 word increments. Please send billing information. Listings are free for Associate, Official, and Sustaining organizations, and for Individual members hiring personal assistants. If space is available, jobs may also be printed in *Fisheries* magazine, free of additional charge.**

statistical) to explore the ecological responses of key fish species to hypoxia in Lake Erie and to multiple ecosystem stressors in Saginaw Bay, Lake Huron.
Qualifications: Ph.D. in ecology, fisheries science, or related field. Strong quantitative and written skills. Experience in developing bioenergetics, individual-based, and/or statistical models is strongly preferred.
Salary: $35,000–40,000, plus benefits.
Closing date:15 August 2007.
Contact: Submit cover letter, CV, and names and contact numbers of three references to Tomas Höök, thook@umich.edu; 734/741-2388. EOE.

Assistant Hatchery, Kodiak Regional Aquaculture Association, Kitoi Bay Hatchery (25 miles from Kodiak, Alaska, by floatplane or boat).
Responsibilities: All aspects of hatchery operations, including coho and sockeye rearing and release, maintaining water quality and quantity, and other operational tasks. Schedule and supervise seasonal staff, makes evaluations, share on-call 24-hour site responsibilities, and manage the facility for specified periods.
Qualifications: B.S. in aquaculture, fisheries or related major, with minimum 2 years experience as fish culturist or assistant manager at a salmon hatchery or aquaculture facility. Strong multi-species fish culture background. Experience may be substituted for education on a case-by-case basis. Related prior experience with increasing levels of responsibility, with favorable employer evaluations regarding experience, skills, aptitude, and attitude.
Salary: Salary depends on experience. Generous benefits include furnished housing and utilities, 403(b), insurance, and excellent outdoor recreation.
Closing date: Open until filled.
Contact: Send resume and references to Drew Aro and Kevin Brennan, kraa@gci.net, or call 888/486-6555.

Administrative Officer, Kodiak Regional Aquaculture Association, Kodiak, Alaska.
Responsibilities: Work at a a non-profit corporation that operates two Pacific salmon hatcheries with 12 to 20 permanent and seasonal employees. Assure timely completion of the business of the board of directors including meetings, elections, resolutions, accounts receivable and payable, payroll, and assistance with annual audit. Coordinate human resources activities, maintain records and files, and answer correspondence or direct inquiries to appropriate staff.
Qualifications: A two year degree from an accredited school majoring in accounting, business administration, small business management or related, and two years experience with increasing responsibility. Proficiency with computers and office/accounting software. Education and experience may be substituted.
Salary: Salary depends on experience. Minimum $15.14 per hour, $2,461 per month. Excellent benefit package includes annual and sick leave, 12 paid holidays per year, medical-dental-vision-prescription insurance, and a 403(b) retirement plan with a generous employer contribution.
Closing date: Open until filled.
Start date: 15–30 August 2007 preferred.
Contact: Send resume/references to Kevin Brennan at kraa@gci. net or call 888/486-6555.

Assistant Professor of Fish Physiology/Aquaculture, Fisheries and Illinois Aquaculture Center, Department of Zoology, Southern Illinois University Carbondale.
Responsibilities: 12-month, tenure-track assistant professor, 75% research in the Fisheries and Illinois Aquaculture Center, 25% teaching in zoology. Will be expected to develop an externally funded research program, supervise M.S. and Ph.D. students, and teach environmental physiology of fish and comparative endocrinology or another course in his/her specialty. See announcement at http://fisheries.siu.edu/opport.htm.

Managing Editor

The Walleye Technical Committee (WTC) of the North Central Division of the American Fisheries Society (AFS) is seeking qualified applicants for a short-term managing editor position. The AFS Books Department has accepted our proposal for a book, entitled *The Biology and Management of Walleye and Sauger in North America,* and this full-service publisher will assist with planning, peer review, manuscript development, editorial, production, distribution, and marketing guidance and assistance. Prior to production and printing of the book, the WTC is responsible for completing the manuscript. We will contract a full-time editor to oversee the manuscript completion, with an estimated time for completion of two years. The editor will work with our steering committee throughout the writing and editing process.

Compensation is negotiable.

Interested candidates should contact: Patrick Hanchin
Walleye Technical Committee Chair
hanchinp@michigan. gov
231/547-2914 x227
by 31 August 2007.

Qualifications: Ph.D. in appropriate field, record of peer-reviewed publications and scholarly accomplishments commensurate with experience, demonstrated grant success or strong evidence of funding potential. Preference given applicants with postdoctoral teaching and research experience and membership in the AFS and/or WAS. **Contact:** Forward curriculum vitae, statement of teaching, research interests and plans, transcripts from all institutions attended, representative reprints, and have four letters of reference sent to Christopher Kohler, Fisheries and Illinois Aquaculture Center, MC-6511, SIUC, Carbondale, Illinois 62901. E-mail inquiries (not applications) to ckohler@siu.edu. **Closing date:** Open until filled.

Supervisory Fish (or Fish and Wildlife) Biologist (GS-0482/0401–13), U.S. Fish and Wildlife Service, Mid-Columbia Fisheries Resource Office, Leavenworth, Washington. **Responsibilities:** Address fisheries and aquatic issues in the Upper Columbia basin of central and eastern Washington. As project leader, take responsibility for the overall supervision, planning, and execution of work at the station. The program involves the identification, development/planning, and implementation of investigative projects, habitat restoration projects, and species conservation. **Qualifications:** Must meet basic qualification for a GS-12 biologist. **Salary:** GS-13, starts at $75,414 per year. **Closing date:** 3 August 2007. **Contact:** Jana Grote, Fisheries Supervisor: jana_grote@fws.gov; 503/231-2387. Apply online at http://jobsearch.usajobs.opm.gov. EOE.

2007 Membership Application

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All memberships are for a calendar year. New member applications received January 1 through August 31 are processed for full membership that calendar year (back issues are sent). Those received September 1 or later are processed for full membership beginning January 1 of the followig year.
Fisheries, July 2007