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PHOTO: Jared Flowers

COLUMN: GUEST PRESIDENT'S HOOK

What's Happening Across the Pond: Observations of the Institute of Fisheries Management 2008 Conference in Leeds, England

Ron Essig

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"First-rate" is the description that comes to mind when summing up the 39th annual meeting of the Institute of Fisheries Management (IFM) that I attended 14–16 October 2008 in Leeds, England! I attended this meeting representing the American Fisheries Society (AFS) Fisheries Management Section (FMS) as part of an exchange arrangement with the IFM that the FMS and the Fisheries Administration Section (FAS) have had in place since 2005.

Each of the two AFS Sections alternately sends a representative every other year, so I followed FMS Past President Joe Larscheid who attended the IFM meeting in Minehead, England, in 2006. The 2008 meeting venue was the Royal Armouries Museum which was a special treat in its own right. This museum, which is affiliated with the Tower of London, houses four floors of displays of weapons, armor, and hunting implements going back hundreds of years in Europe and Asia.

The IFM (www.ifm.org.uk) has a membership very similar to the FMS of about 900 professionals who deal with all aspects of fisheries management from fish passage to aquatic resources education. There are 10 established regional branches of IFM within England, Wales, Scotland, Northern Ireland, and the Republic of Ireland that deal with localized issues. The IFM is an organization separate from the Fisheries Society of the British Isles, whose membership mostly comes from academia. A president, chairman, and council govern the IFM. During the meeting, President John Solbe turned over the reins after a six-year term to Peter Bisset. Ian Dolben is the current chairman, following Steve Axford who was chairman for the previous five years and attended the 2007 AFS Annual Meeting in San Francisco. Several of these leaders asked me about Carlos Fetterolf, who visited some years back as an AFS officer. I'm sure thankful that our FMS officer terms are not as long as those of the IFM.

There were more than 150 delegates (attendees) at the IFM meeting from throughout the British Isles. The largest group of delegates worked for the Environment Agency, which is a federal agency charged with managing inland and sea-run fisheries in England and Wales. (There is no equivalent of our state or provincial fisheries agencies.) There was also strong representation by fisheries staff of other British Isles governmental agencies, environmental staff of regional water companies, and consulting firms, with some universities represented. I was one of two international delegates. The other was Herman Wanningen from the Netherlands (herman@wanningen-waterconsult.nl), who is an expert in fish passage and one of the editors of an excellent 2006 publication entitled *From Sea to Source: Guidance for the Restoration of Fish Migration in European Rivers.* This 120-page publication is a terrific synopsis of the state-of-the-art of fish passage in Europe, with contributions from 18 countries.

Since the theme of the conference was "Breaking Down Barriers," I provided a keynote address that focused on three barriers to fisheries in the United States--angling participation, habitat, and funding. I touched on some problems and recent efforts to combat them for each of the three barriers:

- **Angling participation**—I mentioned the national declines in fishing license sales and estimated numbers of anglers since 1991, and how Richard Louv's 2005 book *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder* helped catalyze initiatives to get people outside in nature. Recent efforts to increase angling participation that I touched on are the Recreational Boating and Fishing Foundation and the fact that there are many other federal, state, and local efforts to connect people with nature through fishing.
- **Habitat**—I showed some examples of environmental assaults on fisheries habitat, then I cited the August 2008 *Fisheries* article that documented how 39% of North American freshwater and diadromous fish species are now considered imperiled. I commented on recent efforts to improve aquatic habitat like the National Fish Habitat Action Plan, provision of fish passage and dam removal, and governmental recognition of climate change.
- **Funding**—I explained how state fisheries agencies are heavily dependent on fishing license sales and dedicated federal grant funding. I mentioned the State Wildlife grant program and closed with more detail on the Federal Aid in Sport Fish Restoration program and its critical importance to fisheries management in the United States.

The second major address of the conference entitled "Fish Are the Messenger: People Are the Solution" was delivered by Ian Cowx of Hull University. Cowx shared some of his experiences with fisheries studies in the Mekong River, Asia, where Chinese investors want to construct 10 mainstem dams greater than 50 m high and in Lake Victoria, Africa, where rapidly expanding fishing threatens its Nile perch population. It was for this type of global fisheries work that Cowx was recognized along with Robert Arlinghaus of Germany with the 2008 FMS Award of Excellence. Since Cowx could not attend the annual FMS meeting in Ottawa last August, this IFM conference provided a great opportunity

Continued on page 197

STATE OF THE SALMON

The second State of the Salmon Conference, "Bringing the Future into Focus," was held in Vancouver, British Columbia, during 2–5 February 2009 The conference was exceptionally well attended, with nearly 400 participants travelling from around the world to hear Pacific salmon experts from Korea, Japan, Russia, Canada, and the United States. Topics ranged from local fisheries management to broader ecological issues, in light of the imminent threat of climate change. The conference mood, with its emphasis on effecting change, was set by keynote speaker David Suzuki: "We don't know enough to manage any species. The best we can do is to manage ourselves."

Policy-oriented presentations emphasized the importance of managing for diversity at the population level using tools such as wild salmon policies, strict enforcement of poaching regulations, re-framing the role of hatcheries, and cultivating cross-boundary cooperation in conservation efforts. Science talks explored interrelated themes: the urgent need to account for uncertainties associated with climate change, improved understanding of salmon in the marine environment, and implementation of monitoring programs to measure progress of salmon and habitat conservation activities. The establishment of salmon strongholds also emerged as an important theme of the conference, with presenters illustrating how a Pacific Rim-wide stronghold network could successfully complement and enhance current efforts to protect Pacific salmon in an uncertain future. The Pacific Salmon Stronghold Conservation Act (proposed U.S. federal legislation—see Fisheries 34[1]:29-30) is an important step toward meeting this vision. Full proceedings of the conference are available at: www.stateofthesalmon.org/conference2009.

Additionally, progress was made on the "Goals and Principles for Salmon Conservation," a guidance document intended to help define stewardship requirements to ensure wild salmon thrive around the North Pacific. The overarching goals are:

1. Manage wild salmon populations for abundance, diversity, and the maintenance of ecosystem health;
2. Protect and restore enough habitat to maintain healthy wild salmon stocks and ecosystem processes; and
3. Build institutions, markets, and human communities that support wild salmon and their ecosystems over time.

The State of the Salmon Program (SoS), which organized the conference, drafted the document based on input from key partners. SoS received constructive feedback during the conference, and welcomes additional feedback from anyone. Please visit their website at http://stateofthesalmon.org and answer a brief online questionnaire before 22 May 2009. A summary of the results will be published in a future issue of Fisheries.

—Sarah Louise O'Neal

JOURNAL HIGHLIGHTS: TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY

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UPDATE: LEGISLATION AND POLICY

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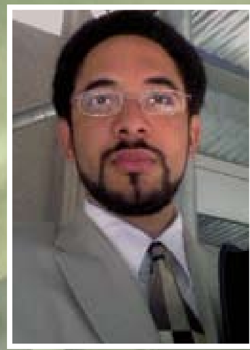

Maximum retainable groundfish levels in Alaska

NOAA Fisheries Service has revised the maximum retainable amounts (MRAs) of groundfish, using arrowtooth flounder as a basis species, in the Gulf of Alaska. This final rule increases the MRAs from 0% to 20% for deep-water flatfish, rex sole, flathead sole, shallow-water flatfish, Atka mackerel, and skates; from 0% to 5% for aggregated rockfish; and from 0% to 1% for sablefish. These MRA percentages establish the amount of a species closed to directed fishing that may be retained onboard a vessel, relative to the amounts of other groundfish open to directed fishing retained onboard the vessel. MRA percentages serve as a management tool to slow down the rate of harvest and reduce the incentive for targeting a species closed to directed fishing. MRAs also allow for retention of incidentally caught species instead of requiring regulatory discards of species closed to directed fishing. The intended effect of this action is to reduce regulatory discards of otherwise marketable groundfish in the arrowtooth flounder fishery.

Omnibus Public Land Management Act of 2009

On 25 March, the U.S. House of Representatives approved the "Omnibus Public Land Management Act of 2009" (H.R. 146), a bipartisan package that combines more than 160 individual measures that enjoyed wide support in the Congress. Among its many provisions, the bill permanently codifies the National Landscape Conservation System, creates 2 million new acres of wilderness across 9 states, establishes 3 new national park units, designates 1,000 miles of wild and scenic rivers, designates a national monument and 3 national conservation areas, protects world-class hunting land in the Wyoming Range, and recognizes new historic sites and heritage areas. The bill was signed into law by President Obama on 30 March 2009.

NOAA Report on U.S. fishing communities

The report *Fishing Communities of the United States, 2006* is NOAA's first national reference guide featuring snapshots of selected fishing communities and ports from the nation's 23 coastal states. The ports that are profiled were chosen by experts around the country, primarily on the basis of commercial fisheries landings in 2006 and the historical significance of fishing in a community. The report's details of the diverse demographics of 222 U.S. saltwater fishing communities will help the agency design management strategies that will lead to more sustainable fisheries.

The report shows that fishing communities range in size from small communities such as Winter Harbor, Maine, pop. 988, to cities such as San Diego, California, pop. 1,223,400. Statewide trends from 1997 to 2006 about the number of building permits issued, fishery disaster declarations made, and unemployment rates are also included. In addition, the report also contains demographic information to present a clearer picture of each coastal town and city and how they compare to other communities in their states and the nation. The report is available online at www.st.nmfs.noaa.gov/st5/publication/fisheries_communities.html.

Proposed ESA listing for Pacific smelt

NOAA's Fisheries Service has proposed listing the Pacific smelt as threatened under the Endangered Species Act. Pacific smelt, known officially as eulachon and sometimes called candlefish or Columbia River smelt, are small ocean-going fish that historically ranged from northern California to the Bering Sea in Alaska. They return to rivers to spawn in late winter and early spring. Recreational fishers catch smelt in dip nets, and typically fry and eat them whole.

Smelt are a culturally significant species to native tribes, traditionally representing a seasonally important food source and a valuable trade item.

In 2007, the Cowlitz Indian tribe in Washington petitioned NOAA's Fisheries Service to list the fish populations in Washington, Oregon, and California. The tribe's petition described severe declines in smelt runs along the entire Pacific Coast, with possible local extinctions in California and Oregon. NOAA Fisheries Services' scientific review found that this smelt stock is declining throughout its range. Further declines are expected as climate change affects the timing of spring flows in Northwest rivers. Those flows are critical to successful Pacific smelt spawning.

The agency said other threats to the fish include water flow in the Klamath and Columbia river basins and bird, seal, and sea lion predation, especially in Canadian streams and rivers. The agency is currently accepting public comments on the proposal, and gathering further scientific information on the species to further explore the reasons for its decline and possible efforts to restore its numbers.

Quesnel Lake, British Columbia

H. J. FLOWERS

Counterintuitive Responses of Fish Populations to Management Actions:
Some Common Causes and Implications for Predictions Based on Ecosystem Modeling

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James F. Kitchell

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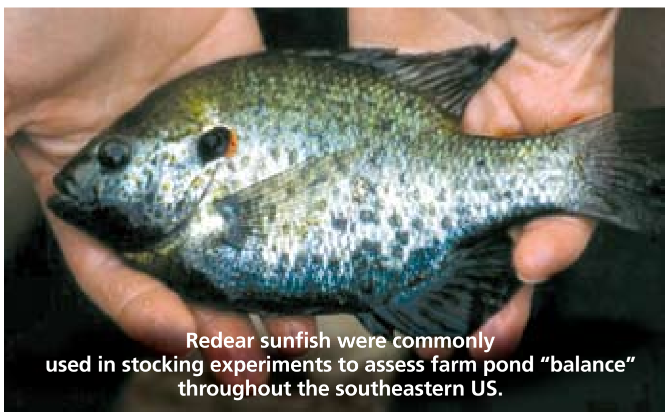
ABSTRACT: Observed ecosystem responses to fisheries management experiments have often been either much smaller or in the opposite direction of the expected responses based on experience or population models. Examples of these responses can be found even for some very simple experimental management manipulations such as predator and prey manipulations in small lakes and ponds to fish population responses to harvest closures. Such counter-intuitive prediction failures offer opportunities to identify key processes and variables that are not widely considered in models used to evaluate ecosystem-based fisheries management policies. A common denominator in the case histories presented are unexpected behavioral responses and strong changes in juvenile survival rates of fish driven by changes in competition, predation, and behavioral responses to predation risk. These factors restructured many of the ecosystems in our simple examples, yet are not widely included in models currently used to evaluate ecosystem-based fisheries management policies. This represents a critical need in the development of modeling tools to evaluate ecosystem-based policies based on an iterative process of model building and model testing, using fisheries management actions as probing tools to learn more about the ecosystems being managed.

Respuestas inesperadas de poblaciones de peces ante acciones de manejo: algunas causas comunes e implicaciones para la predicción basada en modelación de ecosistemas

La respuesta de los ecosistemas ante experimentos de manejo pesquero en ocasiones ha sido limitada e incluso opuesta a aquella que se espera de la experiencia o de acuerdo a modelos poblacionales. Pueden encontrarse ejemplos de esto en manipulaciones experimentales sencillas como en los sistemas depredador-presa en pequeños lagos y estanques, así como la respuesta de las poblaciones de peces a vedas de captura. Estas predicciones fallidas y contra-intuitivas ofrecen una oportunidad para identificar variables y procesos clave que comúnmente no son considerados en los modelos que se usan para evaluar las políticas de manejo pesquero basado en el ecosistema. El común denominador en los casos que aquí se presentan es el comportamiento inesperado y los cambios drásticos en las tasas de supervivencia de individuos juveniles de peces, determinados a su vez por cambios en la intensidad de la competencia, depredación y la conducta al riesgo de depredación. Si bien estos factores reestructuraron muchos de los ecosistemas en nuestros ejemplos, no se incluyen en los modelos que actualmente se emplean para evaluar políticas de manejo de pesquerías con consideraciones a nivel ecosistema. Esto representa una necesidad crítica de desarrollar herramientas de modelación para evaluar políticas pesqueras basadas en el ecosistema. Dicho desarrollo implica un proceso iterativo de creación y falsar de modelos utilizando acciones de manejo pesquero como herramientas para probar y aprender más acerca de los ecosistemas en cuestión.

INTRODUCTION

Most fisheries management actions are motivated by predictions of how a single species will respond to the implemented policy, with little consideration given to the ecosystem as a whole. These predictions are developed in numerous ways, ranging from a single manager making predictions based on their experience and intuition to large international committees considering the latest in complex oceanographic and ecosystem-linked fish-



Redear sunfish were commonly used in stocking experiments to assess farm pond "balance" throughout the southeastern US.

H. J. FLOWERS


Fisheries research camp in Grand Canyon, Arizona


The mouth of the Little Colorado River in Grand Canyon, Arizona.


A Safe Run of Lava Falls, Colorado River, Grand Canyon, Arizona


Humpback chub from the Grand Canyon reach of the Colorado River, Arizona

H. J. FLOWERS

ery models with hundreds of parameters. It is widely expected that in a simple freshwater example the former approach would be most appropriate, while the latter would be adept at providing insight into effective management for complex oceanic fisheries, but how realistic are these expectations? Our ability to make predictions about how an ecosystem would respond to a management action is often not as good as we would hope, regardless of the system or model complexity.

Many fisheries management agencies are currently developing or expanding ecosystem-based management programs, motivated by concerns that fishing has impacts on ecosystems beyond localized depletions of targeted species (Link et al. 2002; Pauly et al. 2002; Christensen et al. 2003; Dulvy et al. 2003; Link 2005; NRC 2006; Murawski 2007). This emphasis on ecosystem-based approaches has been partially set in motion by increased public interest in fisheries impacts on marine systems, fueled by high profile scientific publications (Pikitch et al. 2004; Smith 2007) and major ocean policy reviews by national (U.S. Oceans Commission 2004), international (ICES 2000), and non-governmental organizations (Pew 2003). Concerns over the broader impact to ecosystems from fishing are not new (May 1984), and the issue has not been whether marine fisheries management should consider ecosystem-level effects, but instead how can management actions capture these interactions and develop effective policies to allow sustainable harvest while minimizing indirect effects to the ecosystem (Pauly et al. 2002; NRC 2006)? Freshwater fisheries policies also consider ecosystem-level interactions, with recent emphasis placed on developing a better understanding of the role of habitat manipulations (Minns 1996), water level management (Richter et al. 2003), or changes in stocking policy in enhancing fishery performance (Cowx and Gerdeaux 2004).

Recently the U.S. National Research Council (NRC 2006) synthesized the contemporary scientific debates and policy concerns related to ecosystem-based fisheries management. NRC (2006) defined ecosystem-based fisheries management as "developing ecosystem-level goals that are multispecies focused and that consider multiple kinds of human activities that are tied to healthy marine ecosystems." This definition suggests a process of developing management policies that integrate both consumptive and nonconsumptive uses of marine ecosystems with value judgments on what mix of uses people deem most desirable (NRC 2006).

Management policies, including ecosystem-based fisheries management, can be thought of as a mix of science and judgment and these policies represent a description of how the world works. Each of these descriptions serve as testable hypotheses from which we can construct diagnostic management experiments (e.g., adaptive management) and then compare these experiments to data to reveal the best policy (Holling 1978; Hilborn and Mangel 1997). When these management experiments are absent, we have a long history in fisheries management of constructing mathematical simulation models to evaluate various policy scenarios related to the harvest of single or multiple species, with mixed results in fishery and model performance (Pauly et al. 2002; Walters and Martell 2004; Lotze et al. 2006).

The development of ecosystem-based management policies clearly requires the development of models to test and screen proposed policy scenarios (Walters and Martell 2004) and there is growing debate about what quantitative models should be used to support decision making (Link 2005; NRC 2006; Smith et al. 2007). A range of modeling approaches to examine these policies are currently being tested, including expanded single species assessment models, whole ecosystem biomass or energy flow models (e.g., Ecopath, Atlantis), and very complex system models representing both bottom-up and top-down forces (e.g., SEAPODYM; see Whipple et al. 2000; Lehodey et al. 2003; Christensen and Walters 2004; Link 2005; NRC 2006). The range of choices can make it difficult for public agencies to invest wisely in data collection and model development to meet ecosystem-based fishery mandates (NRC 2006).

One way to develop a better sense of priorities for research investment is to look at past experience to examine why various predictions about the efficacy of particular policy choices turned out to be incorrect and to learn from our mistakes. This article offers a step in that direction by reviewing a set of case examples, where a model was proposed, an experiment carried out, and the results show that the model made incorrect predictions as to how an ecosystem would respond to a management action for various reasons. A surprising feature of these cases is that some of the most extreme failures of our expectations are in very simple systems (i.e., high mountain lakes or small ponds) where we would generally expect our ability to correctly predict ecosystem response would be high—yet the results were contrary to our expectations. Such cases are examples of highly counterintuitive dynamic responses. As governmental fisheries agencies work to meet ecosystem-based fishery mandates, the role of computer models in helping to meet these mandates has also grown. The examples we present serve as cautionary reminders by asking whether these models could have helped us foresee the counterintuitive responses observed in the examples. Our intent is not to dissuade the use of models, but instead to highlight these instances where model predictions and ecosystem responses diverged to promote improvements in model building, our understanding of basic fish ecology, and ultimately our ability to manage aquatic ecosystems.

The following section presents a wide range of case examples from freshwater and marine systems (summarized in Table 1), mainly involving direct manipulation of fish abundances or habitat factors thought to limit abundances of one or more species. We selected these examples because either we were involved in the original experiment or have experience working in very similar ecosystems. We summarize common factors that have caused simple or intuitive models to give incorrect predictions, and the implications of these factors for future development of ecosystem models as the basis for design and test of fisheries policies. We anticipate that there are many examples of these types of counterintuitive responses that are commonly viewed as management "failures," instead of as opportunities to learn from the unanticipated outcome. We hope that this article will serve as motivation to reconsider some of these unexpected outcomes in a variety of ecosystems.

EXAMPLES OF COUNTERINTUITIVE RESPONSE

The examples presented are from systems where we have close knowledge of scientific "experiments" to compare contrasting treatments (before-after or among spatial experimental units), preferably repeated (replicated) enough times to provide evidence that the apparent response was not due to factors other than treatment. These experiments cover a range or marine and freshwater lentic and lotic systems throughout North America. There are few examples in the published literature where both contrast (level of effect) and replication allow unambiguous interpretation of the data. These experiments generally break down into three cases: efforts to improve fishery performance (i.e., abundance or yield), recovering fisheries (i.e., population responses to fishery closures, gear restrictions), or habitat "improvements" (i.e., flow modifications).

CASE GROUP 1: LESSONS FROM TRYING TO IMPROVE FISHERY PERFORMANCE

Reducing brook trout density to improve growth

Study motivation

Brook trout (*Salvelinus fontinalis*) are widely introduced in alpine lakes of the Sierra Nevada Mountains, California, and can spawn successfully in most of the lakes of that region. Typically, in these and similar systems, brook trout overpopulate and deplete available prey resources, which leads to cascading effects throughout the lake foodweb on both predator and prey species (Donald and Alger 1989). If brook trout spawning is habitat limited this can lead to reduced recruitment, lower brook trout densities, higher prey availability, better growth for remaining brook trout, and improved fishing opportunities for anglers (Donald and Alger 1989).

Management action

In keeping with the evidence at hand and conventional wisdom of the time, we reasoned that lower brook trout densities would mean more food available per remaining adult brook trout (Donald and Alger 1989). During the 1980s and early 1990s, two of C.J.W.'s graduate students (Hall 1991; DeGisi 1994) did gillnet depletion experiments to reduce brook trout densities and estimate brook trout abundances in Sierra mountain lakes.

Prediction

These brook trout removal experiments were designed to test a management policy of whether regularly reducing adult brook trout densities could be used to improve brook trout growth and quality of fish for angling.

Counterintuitive response

To our surprise, there was either no growth improvement or even reduced trout growth in the years following 50%–80% density reduction in most of the lakes. Instead, there was dramatic improvement in age 0–1 survival rates, apparently due to reduced cannibalism (data available in the R. A. Myers worldwide stock-recruitment database, www.mscs.dal.ca/~myers/welcome.html). The resulting large juvenile cohorts spread widely over the lake surfaces rather than restricting their activity to littoral areas. It is highly likely these juveniles observed by DeGisi (1994) competed with adults for food resources, and that this competition resulted in much lower food availability to remain-

Table 1. Examples of case histories from a variety of freshwater and marine ecosystems demonstrating counterintuitive responses to expected management actions.

System	Management goal	Predicted response	Treatment	Counterintuitive observed response	Possible cause
Brook trout, Sierra Nevada Mountains	Increase trout growth	Reduce density, increase growth of adult brook trout	Intensive harvest	Reduced growth of adult brook trout	Increased juvenile abundance, competition with adults for available food
Rainbow trout, Bonaparte Plateau	Increase trout growth	Reduce competition	Intensive harvest	Reduced rainbow trout survival	Increased recruitment leading to density dependent mortality in early juveniles
Largemouth bass, southeastern US ponds	Maintain balance of predators and prey for sustained harvest	Increase bass yield	Increase prey abundance	Decreased yield of largemouth bass	Bass recruitment reductions due to competition with adult prey species for zooplankton
Coho salmon, Pacific Northwest	Stocking programs to increase coho salmon harvest	Increase coho salmon landings	Large-scale stocking programs	Declines in coho salmon landings	Enhanced predator abundances, declines in juvenile coho salmon survival
Sockeye salmon, Fraser River and Bristol Bay	Increased sockeye salmon harvest	Increase sockeye salmon recruitment	Increase escapement levels	Decreased sockeye salmon recruitment	Increased predator abundances, declines in juvenile sockeye salmon survival
Northern cod, Newfoundland	Restore northern cod stocks	Eliminate *F*, fishery recovers 6-60 years	16 years of fishery closure	Cod stock has continued to decline, no signs of recovery	Ecosystem now in alternative stable state that does not allow cod recovery
Red snapper, Gulf of Mexico	Decrease juvenile snapper mortality due to by-catch	Increase adult snapper landings	Restrict shrimp fisheries to decrease bycatch	Shrimp fishery may be enhancing red snapper recruitment	Reduced juvenile snapper *M* due to reductions in predators or juvenile habitat
Menhaden, Gulf of Mexico	Protect menhaden from overfishing	Clupeids highly vulnerable to overfishing	Reduce fishing mortality rate	Menhaden populations have increased over the history of the fishery	Reduced adult *M* due to high fishing mortality on menhaden predators
Coho salmon, British Columbia	Protect coho salmon spawning streams	Logging practices negatively impact coho salmon smolts	Experimental forest harvest coupled with intensive fish monitoring	Initial increase in coho smolt production following logging	Increase in coho survival from fry to smolt
Humpback chub, Colorado River, Arizona	Modify dam operations to enhance chub survival	Increases in humpback chub survival and abundance	Water flow schedules modified to stabilize mainstem flows	Declines in humpback chub survival and abundance	Declines in humpback chub survival and abundance along with concurrent increases in nonnative species (parasites, ongoing drought)
Wisconsin ponds and lakes	Prey respond to perceived predators	Behavioral response of prey different when predators are or are not present	Variety of experimental manipulations of predators-prey and access to each other	Prey demonstrate behaviors that would be expected when predators present, even when predators can not feed on prey species	Perceived risk of predation triggers overarching behavioral responses similar to predation effects

ing older fish thus negating the expected improvement in adult fish growth (Myers 2002).

Reducing a potential competitor to improve rainbow trout recruitment

Study motivation

In the Bonaparte Plateau, British Columbia, the only fish species present in some small lakes are rainbow trout (*Oncorhynchus mykiss*) and a predatory, but pygmy race (asymptotic body length around 220 mm) of the northern pikeminnow (*Ptychocheilus oregonensis*). We expected to find complex interactions between these species, such as predation on juveniles of one species by the other, which could possibly create multiple population equilibria (Carpenter 2000) of alternating adult biomass dominance between rainbow trout and pikeminnows. The key assumption for this to occur is that juvenile survival rate should increase in one species when the biomass of the other is greatly reduced, because pikeminnow and rainbow trout are possible competitors and predators based on diet observations from these lakes (N. Taylor and D. O'Brien, University of British Columbia, pers. comm.).

Prediction

Given the results from the brook trout experiments described in the first example (DeGisi 1994), we did not know whether an increase in the juvenile survival rate in one species would lead to an increase in the growth rate of the other because of uncertainty over the level of piscivory in adult rainbow trout or pikeminnow (N. Taylor and D. O'Brien, University of British Columbia, pers.comm.).

Management action

Two recent studies (Taylor 2006; D. O'Brien, University of British Columbia, pers.comm.) tested the assumption that reducing a potential competitor would increase rainbow trout biomass by massively reducing densities of pikeminnow via intensive gillnetting in four lakes and similarly reducing rainbow trout densities in another three lakes. One additional lake served as untreated "controls" for the experiment (eight lakes total).

Counterintuitive response

Mark-recapture data for years following the pikeminnow reduction indicated that juvenile rainbow trout survival rates have been lower in the pikeminnow removal lakes than in the control and rainbow trout removal lakes—exactly the opposite of our expectation. There are several possible explanations for this curious result. The simplest is that pikeminnow mainly prey on rainbow eggs and fry so that improvements (which we could not measure directly) in early life rainbow trout survival ultimately led to higher trout fry densities. These higher rainbow trout densities then led to higher density-dependent mortality rates of juvenile rainbow trout over the size-age range that the authors were able to study with tagging (Taylor 2006; D. O'Brien, University of British Columbia, pers.comm.).

Achieving "balance" in southeastern US farm ponds

Study motivation

A widely studied and difficult challenge in fisheries management, and a great example for research in basic population ecology, has been the search for "balance" in pond and reservoir ecosystems containing Centrarchid fishes from both a management (Swingle 1950; Swingle and Swingle 1967; Anderson 1973; Noble 1986) and ecosystem synthesis perspective (Werner and Gilliam 1984). In general, the objective is to understand the densities, predatory interactions, and behaviors involved that lead to producing populations of predatory basses (mostly *Micropterus salmoides*) capable of sustaining high harvest rates, while preventing overpopulation (of predators or prey) or depletion of prey resources (primarily *Lepomis*, *Dorosoma*, and *Notropis* spp.; Swingle 1950). This objective provided the basis for the construction of literally thousands of small farm ponds throughout the southeastern United States which served as replicate experiments for many early fisheries researchers interested initially interested in managing these ponds for food production and later for recreation (Swingle 1950; Noble 1986). This balancing act involves not only the fishes, but also the interaction between benthic and pelagic primary production (macrophytes and phytoplankton), with macrophytes providing needed cover for juvenile fish (Werner and Gilliam 1984) and phytoplankton providing primary production that fuels the food web components needed by those juveniles (Swingle 1950). These complexities are now interpreted using concepts like trophic cascades (Carpenter and Kitchell 1993a; Stein et al. 1996), strong impacts of behavioral response to predation risk ("indirect trait mediated effects," e.g., Peacor and Werner 2001; Werner and Peacor 2003; Schmitz et al. 2004), changes in behavior and reproductive strategies (Beard and Essington 2000), and multiple stable states where the desired "balanced" state may represent an unstable cusp between undesirable (stunted predator populations with low body condition), but persistent states (Holling 1973; Scheffer 1990; Holling and Meffe 1996; Scheffer et al. 2001).

Prediction

A "balanced" (Swingle 1950) fish community of predator and prey populations to maximize harvest is possible through top-down (regulated and experimental harvest of predators and prey) and bottom-up (fertilization, macrophyte control, forage fish stocking) control.

Management action

Efforts to teeter between two undesirable steady states, overpopulation of predators with low predator body condition vs. overpopulation of prey with low predator recruitment, have included diverse actions ranging from top-down effects related to stocking large predators (to reduce planktivores, increase zooplankton, and enhance water clarity) to large scale bottom-up treatments such as artificial fertilization to increase phytoplankton production and ultimately planktivore abundance for predatory fish. In pond systems, virtually every factor that can be beneficial can also be deleterious in high quantity. For example, extensive macrophyte development can lead to high recruitment of sunfish, which in turn leads to stunting and reproductive failure of basses through predation on their eggs and fry by the sunfish. The stocking of planktivores (e.g., *Dorosoma* spp.) to provide supplemental forage for predators such as largemouth bass can actually reduce bass populations via juvenile planktivores crashing zooplankton populations prior to juvenile bass's ontogenetic switch to zooplankton (DeVries and Stein 1990). This demonstrates that many of the intuitive steps to enhance production has the potential to cause just the opposite effect.

Counterintuitive response

After 50 plus years of experimentation, fisheries management policy in the U.S. southeast is changing from the search for long-term balance through stocking and harvest level manipulations in favor of other policy tools (Noble 2002), like habitat improvement, periodic ecosystem resets (draining or poisoning all or part of the ecosystem; Kim and Devries 2000), deliberate fluctuation of reservoir levels (Keith 1975; Ploskey 1986), and use of very different fish species combinations (e.g., minnows and bass). Yet even with these new approaches, including whole lake forage community manipulations, results counterintuitive to expectations continue to appear (Kim and DeVries 2000; Irwin et al. 2003), highlighting the difficulty of persisting between two alternative stable states (Gunderson and Holling 2002).

Predation effects without predation: impacts of predation risk on pond communities and lake ecosystems

Study motivation

All three of the previous case histories from small ponds and lakes share a common prediction and management action associated with manipulating direct effects of predation. In this case history, we examine results from small lakes where non-lethal effects of predators caused prey-populations to respond behaviorally in the same manner as if predation was occurring (Peacor and Werner 2001; Werner and Peacor 2003; Schmitz et al. 2004). These responses are nearly as high as would be expected if predation were actually occurring.

Prediction

Manipulations of fish communities such as additions or removals of a fish species can be done in experimental lakes to examine predator-prey interactions through traditional approaches, such as diet and prey selection studies and also non-traditional ways such as examining changes in predator or prey behavior. Simple predictions such as reductions in zooplankton in a small pond following high stocking densities of zooplanktivorous fishes or differing prey behavior when predators are included or excluded from prey species are often correct, but the mechanisms for these responses may be different than what was originally expected (Carpenter and Kitchell 1993b).

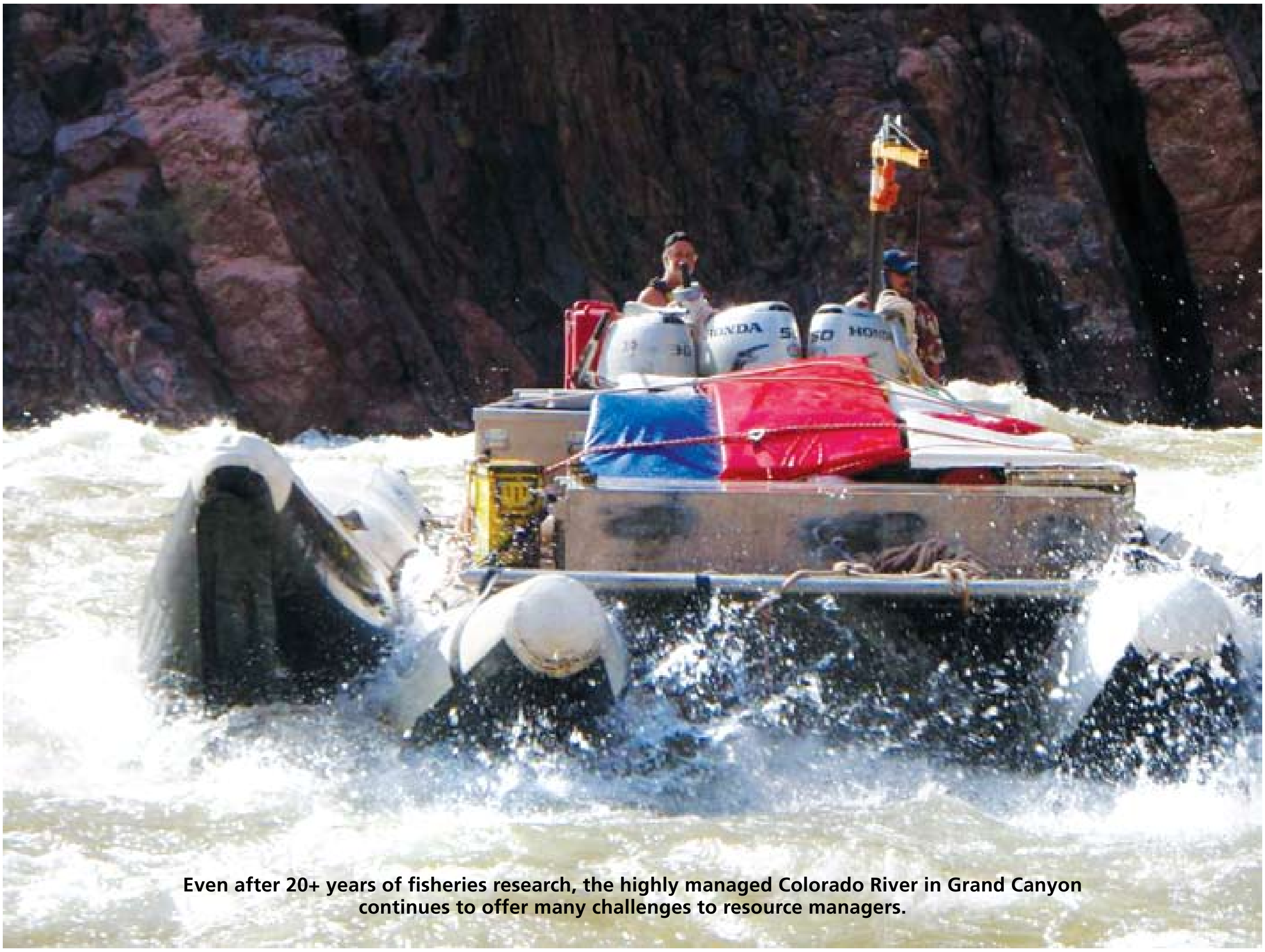
Management action

Carpenter and Kitchell (1993b) assembled a list of 32 specific predictions as part of hypothesis development for experimental lake food web manipulations (Carpenter and Kitchell 1993b). Predictions covered the full range of food web and ecosystem variables from nutrients to apex predator effects. Manipulations involved large-scale changes in food web structure through removal, manipulation, or restoration of fish populations.

Counterintuitive result

Of the 32 predictions documented by Carpenter and Kitchell (1993b), 16 were confirmed, one was equivocal, and 15 proved to be wrong, i.e., were not corroborated by the results. Most of the latter owed to unexpected behavioral responses, most often in the prey species. For example, in a small experimental lake in northern Wisconsin (Peter Lake, see Carpenter and Kitchell 1993a for description), when 90% of the largemouth bass were removed and 49,601 zooplanktivorous minnows added shortly thereafter, the minnows behaved as expected and immediately began exploiting large zooplankton as prey. That lasted about two weeks. Perception of predation risk owing to the remaining bass population rose (as measured by increased emigration rate) and by the end of the first month nearly all of the minnows were densely aggregated in refugia (beaver channels) where they gradually starved or were eaten by birds (He et al. 1993). Neither the models nor the conventional wisdom of the time were successful in anticipating these rapid and dramatic changes owing to the role of behavioral responses in food web interactions.

As a follow-up to observations of fish behavioral responses during previous experiments, He and Kitchell (1990) conducted a whole lake manipulation to measure the relative effects of behavioral responses vs. direct predation effects in a system that contained one species of potential prey fishes, but no piscivores. The lake was divided in half by installing a metal fence from surface to bottom and shore to shore. The fence allowed small fishes to pass through but not pike. Adult northern pike *Essox lucius* were added to one side of the fence in a planned "titration" of geometric increase over the course of a summer. We monitored both sides of the fence using a pre-post manipulation monitoring program to assess the prediction that potential prey would aggregate in littoral refugia and/or leave the side where pike had been added. The response was both more rapid and greater than expected. Emigration began immediately after a few pike were added and was led by those species whose size and morphology made them most vulnerable. Fish not only left the side with pike, but many left the lake through an outlet stream at the pike-free side. Pike did prey on some fishes, but over the course of the summer, emigration accounted for 50–90% of the total change in biomass for individual species when compared to direct predation effects (He et al. 1993). In these examples, neither the models nor the conventional wisdom of the time were successful in anticipating these rapid and dramatic changes owing to the role of behavioral responses in food web interactions.



Even after 20+ years of fisheries research, the highly managed Colorado River in Grand Canyon continues to offer many challenges to resource managers.

Stocking coho salmon smolts to increase harvestable abundance

Study motivation

Coho salmon (*Oncorhynchus kisutch*) have been the target of hatchery stocking programs to increase their abundance in the Pacific Northwest for over 100 years (Anderson 1997; Nichelson 2003). However, results of these stocking programs (as measured by increases in coho salmon catch) are generally poor and research efforts continue to try and understand the cause of these poor returns (Beamish et al. 1997).

Prediction

Food resources were thought to be available in ocean ecosystems to support increased coho salmon populations via intensive stocking efforts. These increased populations could then allow for increased harvest of coho salmon in West Coast fisheries (Walters et al. 1978).

Management action

The numbers of hatchery smolts released yearly in three "replicate" jurisdictions (coastal Oregon, Washington, and British Columbia) could at least double total coho salmon abundance in the ocean, absent any density-dependent survival effects (Walters et al. 1978). Early models for possible trophic impacts or limits of such high stocking rates (e.g., Walters et al. 1978) suggested that there was ample ocean food production to support the increases, even if coho feeding were limited to coastal areas near natal rivers. To take advantage of this perceived abundant ocean food supply, coho salmon hatchery releases increased in the late 1960s and 1970s.

Counterintuitive result

As these releases of coho salmon increased, total ocean coho salmon abundance (as indicated by catches) did initially increase. However, coho salmon catches soon stopped increasing and have declined dramatically in recent years (Bradford and Irvine 1999). The increases in hatchery production were also likely at the expense of both hatchery and wild adult coho salmon as measured by changes in their survival and wild coho escapement rates. If abundant food sources existed, why were there declining survival rates in adult coho salmon? The likely cause is a marine carrying capacity or limit on total adult abundance (Peterman 1991; Levin and Williams 2002). The remaining catches are now dominated by hatchery-produced fish and we now seem to be producing less coho than the natural system did, at substantial public cost. In particular, declines in coho ocean survival rate have continued well after hatchery releases stopped increasing, suggesting that progressive change in some other marine survival factor has been at least partly responsible for the decline of wild stock escapement and total ocean abundance.

Increasing escapement goals for cyclic populations of sockeye salmon to increase harvest levels

Study motivation

Analyses of stock-recruitment data for cyclic sockeye salmon (*Oncorhynchus nerka*) populations of the Fraser River and Bristol Bay led to the conclusion that the cycles might be due in part to depensatory fishing effects that prevent low cycle (abundance) lines from recovering from historical disturbances (Walters and Staley 1987; Eggers and Rogers 1987; Levy and Wood 1992; Myers et al. 1997). Later analyses supported this conclusion and led to recommendations for experimental increases in sockeye salmon escapement (reviewed in Martell et al. 2008).

Prediction

Increasing escapement rates (i.e., number of adults allowed to "escape" past the fishery and spawn) of the low-cycle lines would allow these lines to recover to historical abundances and allow for higher harvest in low-cycle years (Myers et al. 1997).

Management action

Based on the suggestions cited above, sockeye salmon escapement has increased in the largest Bristol Bay stock (Kvichak or Lake Iliamna) since the late 1980s and has also been occurring progressively for several Fraser River stocks, particularly the Horsefly (Quesnel Lake) stock. The goal of the increased escapement rates is to allow the low-cycle lines to recover to historical abundances to allow for higher harvest in low-cycle years (Myers et al. 1997).

Counterintuitive result

Initial responses to increased spawning escapement were as expected—recruitment rates increased and total sockeye salmon production was higher over each 4 or 5 year cycle. But over the last decade, there have been progressive declines in life-cycle survival rates (as measured by log[recruits/spawner]), even for spawning cycle lines that still have quite low spawner numbers. In addition, freshwater juvenile sockeye salmon body growth for the Quesnel stock is very low even in years when juvenile densities are low (when growth is expected to be high). This low growth and survival has occurred concurrently with measured increases in cladoceran copepod abundances (a key juvenile sockeye salmon food source) in Quesnel Lake, apparently associated with increases in marine-derived nutrients due to higher spawner abundances in peak years (C. Walters, personal observation). It appears that higher average abundances of juvenile sockeye (averaged over cycle lines of high and low abundance) is causing a numerical response of predators in the nursery lakes. We speculate juveniles are responding to these predators by reducing feeding and growth rates even in years when intraspecific competition is weak.

The counterintuitive response in this case is particularly worrisome since it implies not only that increased spawning abundance may fail to produce higher recruitments on a sustained basis, but also that higher stock sizes may not be attainable. It may be that the cyclic sockeye salmon populations can cause strong variation among cycle lines so as to allow nursery lake "fallow periods" analogous to crop rotation policies in agriculture (Walters and Kitchell 2001). In addition, a sequence of low sockeye years might reduce the likelihood of predator populations increasing in response to the higher abundance of juvenile sockeye as prey—thus lessening the depensatory effects of increased predation on juvenile sockeye salmon within the nursery lake.

CASE GROUP 2: LESSONS FROM DEVELOPING AND RECOVERING FISHERIES

Restoring the Newfoundland northern cod stock through fishery closures

Study motivation

The collapse of the Newfoundland northern (2J3KL) cod (*Gadus morhuda*) stock is one of the best documented examples of fisheries assessment and management failure. Just before the fishery was closed in 1991, the remaining stock was highly concentrated and was subject to extremely high fishing mortality (Walters and Maguire 1996). Although this stock sustained intensive harvest for hundreds of years, since the closure it has shown no signs of recovery (Lily 2004).

Management action

Despite this high fishing mortality rate, virtually every assessment model for the stock predicted that it would eventually recover (Walters and Maguire 1996; Walters and Martell 2004). The key assessment models used to evaluate this recovery differed only in how fast recovery might occur. Estimates of recovery ranged from 6–8 years, based on the "millions of eggs" assumption that cod recruitment is independent of spawning stock, to 40–60 years, based on assumptions of severe recruitment overfishing and slow rebuilding of spatial stock structure (Walters and Maguire 1996).

Counterintuitive result

To date the stock has not started to recover and has even declined further since the closure (Walters and Martell 2004) which suggests the potential for multiple population equilibria (Holling 1973) and the population being trapped at low abundance. Recruitment rates remain very low, there has been a large increase in natural mortality rate of older cod, and there are few signs of reappearance of the offshore, migratory component of the stock (Anderson and Rose 2001; Lilly 2004; Olsen et al.

Research on juvenile native and nonnative fish in Grand Canyon may help researchers better predict fish population response to management actions.

2004). Thus, in this case, there is no evidence in support of the simple and common assumption that removal or reduction in fishery mortality will cause stock recovery.

Restricting shrimp fisheries to reduce bycatch mortality of red snapper

Study motivation

Fisheries for red snapper (*Lutjanus campechanus*) and shrimp (*Penaeus* spp.) are among the most important recreational and commercial fisheries in the U.S. Gulf of Mexico (Gallaway and Cole 1999; Coleman et al. 2004). Analysis of shrimp trawl bycatch data has shown that the shrimp fishery kills large numbers of age 0–1 red snapper, on the order of 20–25 million juvenile fish per year (Gallaway and Cole 1999); in contrast, the commercial and recreational fisheries now take a total of around 2 million older snappers (NOAA SEDAR 7 2005).

Prediction

Declines in juvenile red snapper mortality through reductions in bycatch of juvenile red snapper in the shrimp fishery, will expedite red snapper stock recovery.

Management action

Recent management policy proposed by various U.S. federal fisheries management councils and agencies has been to encourage and eventually require use of bycatch reduction devices (BRDs), which are designed to substantially reduce unwanted bycatch, maintain shrimp catch rates, and greatly simplify onboard shrimp handling (Gallaway and Cole 1999). Age-structured stock assessment models for red snapper predict that these bycatch reductions will help to make the overall red snapper fishery sustainable at current catch levels, and even increase modestly. There has been some debate about whether the bycatch reduction "benefits" might be partly lost through density-dependent juvenile mortality of red snapper after the age of highest discarding, but that risk has been considered small enough to still make the BRD policy worthwhile (NOAA SEDAR 7 2005).

Counterintuitive result

Recent NMFS stock assessments for this species (NOAA SEDAR 7 2005) present a range of trends in historical recruitment patterns depending on data sources and assessment approac. Models using stock-reduction analysis techniques (Walters et al. 2006), and the full red snapper catch history from the late 1800s to the present, suggest that red snapper recruitment was possibly lower before the development of the shrimp fishery-positive recruitment "anomalies" began in the 1960s when the shrimp fishery became fully developed (NOAA SEDAR 7; Walters et al. 2006). These positive recruitment anomalies suggest that over this time period red snapper recruitment has actually been increasing rather than decreasing. How could this happen? One simple possibility could be increasing survival rates of juveniles due to declines in predators of juvenile red snapper (through direct and indirect effects of fishing). In this way, fisheries may be "cultivating" juvenile red snapper in ways that improve red snapper production through removal of predators or competitors (Walters and Kitchell 2001). Large-scale experiments including spatially closures of some areas to trawling to test these effects are currently being considered by governmental management agencies to better determine the impacts of trawl fishing on juvenile red snapper.

The curious response of menhaden in the Gulf of Mexico to fishery development

Study motivation

Beginning in the late 1940s, a large reduction fishery for menhaden (*Brevoortia patronus*) developed in the Gulf of Mexico, with peak landings approaching a million metric tons during the 1980s and peak fishing mortality rates (*F*) possibly exceeding 1.0 / y (Vaughn et al. 2000, 2007). During the 1990s, menhaden catches in the Gulf of Mexico declined, raising concerns that the stock may be overfished. Menhaden (and other clupeids) show the sort of schooling behavior that can produce strong density dependence in catchability coefficients and rapid, steep increases in *F* during stock size declines, similar to the cod example (Hilborn and Walters 1992).

Prediction

Through a combination of an intense fishery and schooling behavior of menhaden, Gulf of Mexico menhaden fisheries are likely to be overfished.

Management action

Based on experience with other clupeid stocks (i.e., British Columbia herring *Clupea pallasii pallasii* and Peruvian anchovies *Engraulis ringens;* Hilborn and Walters 1992), conventional fisheries experience would typically assume that this stock had likely already been overfished and had declined substantially in recent years.

Counterintuitive result

In a bizarre reversal of typical population responses to harvesting, the Gulf menhaden stock has apparently increased through much of the history of the fishery. Juvenile survey data and catch-at-age models indicate a general upward trend in recruitment since the fishery started (Vaughn et al. 2007). Analysis of the catch-at-age data in Vaughan et al. (2000) indicate that the total mortality rate Z of age 1+ menhaden has actually declined over time, causing a negative regression relationship between Z and fishing effort. One simple explanation for these patterns is that the natural mortality rate M decreased while the fishery was developing; the apparent decrease in M is roughly correlated with decreases in stocks of some major predatory fish, particularly red snapper and groupers (family Serranidae), which were likely caused by fishing—again a cultivation effect (Walters and Kitchell 2001) where fishers are removing natural menhaden predators, causing a decline in menhaden natural mortality.

CASE GROUP 3: LESSONS FROM HABITAT "IMPROVEMENT"

Protecting coho salmon Oncorhynchus kisutch *from impacts of logging*

Study motivation

Throughout the Pacific Northwest, intense debate over the impacts of stream habitat changes caused by logging (siltation, loss of bank cover, channel destabilization, increased nutrients and temperature) has led to the creation of a variety of experimental treatments where logging practices have been prescribed and carried out, and then salmon populations within the watershed closely monitored to discern possible impacts (Holtby 1988; Brown 1994).

Prediction

Governmental management agencies and researchers have expressed concern that that deleterious habitat changes caused by logging such as changes in temperature and sedimentation could result in negative effects to fish populations within the logged watershed (Holtby 1988).

Management action

In the early 1970s, an experimental program was initiated on Carnation Creek, British Columbia, to demonstrate impacts of logging on coastal watersheds and salmon (Hartman and Scrivener 1990; Hartman et al. 1996). The watershed was logged in a careful sequence, while closely monitoring stream habitat variables and anadromous fish abundances.

Counterintuitive result

The expected changes in egg-fry survival were observed, but surprisingly there were responses by different salmonid species. For example, out-migrant chum fry (*Oncorhynchus keta*) and steelhead smolts declined after longing, but coho salmon smolt output increased, rather than the expected decrease (Hartman and Scrivener 1990). This meant there must have been a very substantial increase in juvenile coho survival from the fry to smolt stage, and/or increased proportion of juveniles smolting at age 1 rather than 2 (Holtby 1988). These positive effects have been attributed to increased growth caused by warmer water (Holtby 1988). Similar responses have been observed in other experimental watershed studies (Thedinga et al. 1989), indicating that this may be an important area for additional cooperative

Quesnel River, British Columbia, Canada

research between forest and fisheries management interests—at least with regard to coho salmon—to develop management practices that allow for sustained use of forest and coho salmon resources.

Managing Colorado River flows to restore the endangered humpback chub

Study motivation

The construction and operation of Glen Canyon Dam on the Colorado River turned the river in Grand Canyon from a warm, turbid, strong seasonally fluctuating ecosystem into a cold water ecosystem with large diurnal variations in water flow (Gloss et al. 2005). At least one population of the endangered humpback chub (*Gila cypha*) managed to survive the initial impacts of the dam, likely because it had potadromous behavioral specialization to spawn in a major tributary (Little Colorado River, LCR) with at least some of its juveniles rearing entirely in the LCR (Gloss et al. 2005). Humpback chub population viability has also become one of the centerpieces of a large management program designed to protect the ecological, cultural, and recreational resources of Grand Canyon (Gloss et al. 2005). A key component of the ecological research has been efforts to determine how physical (e.g., cold water, modified flows) and biological (e.g., introduced species) changes in the mainstem Colorado River impact or limit humpback chub populations. In an effort to track humpback chub population responses to management actions such as flow modifications or non-native species removal, an intensive fish tagging and monitoring program was initiated in 1989 to monitor trends in recruitment, adult survival, growth, movement, and abundance of humpback chubs in Grand Canyon (Gloss et al. 2005; Coggins et al. 2006; Coggins 2008a,b).

Prediction

The Glen Canyon Dam Adaptive Management Program was initiated to work with stakeholder groups to develop management plans for the operation of Glen Canyon dam to maximize benefits to resource users and aid in the recovery of the endangered humpback chub. Because of the wide range of cultural, ecological, and recreational values of stakeholders affected by Glen Canyon dam, much research has gone into developing dam operations policies that minimize the conflict between objective functions for each user group (Gloss et al. 2005).

An example policy was carried out in 1991 when modified low-fluctuating flows policy (MLFF) was tested to improve habitat for native fishes and create better recreational conditions for camping beaches in Grand Canyon. This flow policy severely restricted diurnal flow variations in hopes of reducing the impact of flow variation on native fishes by “improving” habitat for juveniles (by creating and stabilizing backwater areas which are warmer than the mainstem river) and adults (by stabilizing mainstem flows; Gloss et al. 2005; Follstad Shah 2007). The expectation was that by improving habitat for native fish, humpback chub populations would begin to increase and eventually be downlisted from the endangered species list.

Counterintuitive result

Humpback chub recruitment estimates from the tagging program, along with catch rate indices from long-term monitoring based on netting, indicate that humpback chub recruitment did not increase following implementation of MLFF, and may have declined (Coggins et al. 2006). Within a few years after implementation of MLFF, exotic salmonids (rainbow trout and brown trout *Salmo trutta*) increased in the Colorado River mainstem around the mouth of the LCR, possibly due to improved nearshore habitat conditions for non-natives coupled with downstream dispersal of rainbow trout from a large tailwater population just below Glen Canyon Dam (Gloss et al. 2005). In 2003, an experimental "mechanical removal" program (intensive electrofishing) was initiated as part of a 16-year experimental plan to test humpback chub population responses to flow experiments, non-native fish removals, and experimental increases in diurnal flow variations. The first of these tests was to remove nonnative fish as a test to see if these exotics were preventing the use of the mainstem Colorado River as a humpback chub juvenile rearing area (Gloss et al. 2005; Melis et al. 2006; Coggins 2008a,b). This program was designed to separate the effects of modified flow regimes from that of exotic trout or changes in water temperature (either experimentally or naturally via drought) on humpback chub populations (Melis et al. 2006; Coggins 2008b).

The sudden, unexpected decline in humpback chub recruitment immediately following the habitat "improvement" (MLFF) may have been purely accidental or a result of a range of factors including hydrology (Valdez and Ryel 1995), temperature (Coggins 2008a), or parasites (Hoffnagle et al. 2006). But there is little doubt that the predator increase has made the mainstem reach near the LCR a much more hostile environment for juvenile chub despite more favorable water flow conditions which helped to motivate the mechanical removal experiment. Index netting and early tag recapture data for chub cohorts produced after mechanical removal have started to show promising signs of recruitment increase (Melis et al. 2006; Coggins 2008b).

IMPLICATIONS FOR ECOSYSTEM MODELING AND MANAGEMENT

Modeling approaches for assessing policies for ecosystem-based management reviewed by NRC (2006) included linking trophic interactions of a few key species within an ecosystem (Punt and Butterworth 1995), simple biomass dynamics models parameterized using methods like Ecopath with Ecosim (EwE; Walters et al. 1997; Whipple et al. 2000; Koen-Alonso and Yodzis 2005), and complex size-age structured models like MSVPA/MSFOR (Anderson and Ursin 1977; Gislason 1991; Sparre 1991; Magnusson 1995; Collie and Gislason 2001). These kinds of ecosystem models have huge data requirements which do not necessarily reduce the uncertainty in their predictions, but could they have helped us foresee the counterintuitive responses observed in the case-histories we reviewed? Are these ecosystems we reviewed much more complex than we thought or do we need to develop a better understanding of how these ecosystems work before they can be effectively managed in a desired state?

There are several common denominators in the case histories we reviewed. Most counterintuitive responses involved unexpected changes in juvenile survival rates, primarily through changes in predation, recruitment (brook trout case history from the Sierras), or behavior (small lake fish communities in Wisconsin). Most case histories also involve changes in trophic interactions, predominantly changes in predation mortality (or threat of predation) on small fishes. None of the case histories we reviewed, except perhaps the initial recruitment decline of humpback chub, appear to involve subtle details of population genetics, bioenergetics, ecophysiology, or habitat modification. The common thread of changes in behavior, recruitment, and changes in survival patterns of juveniles are all intraspecific processes that were not anticipated and are not explicitly considered in single-species assessment models widely used by fisheries managers (Hilborn and Walters 1992).

Unexpected changes in juvenile mortality rates are particularly worrisome from the standpoint of developing more useful ecosystem models to screen policy options. The assumptions about early life survival and recruitment in many multispecies virtual population analysis models (VPA) are either not explicitly described (Jurado-Molina and Livingston 2002), or these models use simple stock-recruitment relationships to describe patterns in the multi-species virtual population analysis (MSVPA) recruitment estimates (Sparholt 1995; Vinther et al. 2001), which may not be able to adequately capture changes in juvenile survival. Other approaches like Ecosim, a component of the Ecopath software (www.ecopath.org; Christensen and Walters 2004), do allow for the use of multi-stanza size-age dynamics that permits the examination of juvenile mortality patterns. Ecosim can also be used to examine and make predictions about specific life history stages that may be particularly sensitive to changes in predation regimes or habitat factors (Walters and Martell 2004; NRC 2006), although the ability of the program to predict a complex ecosystem response to management policies continues to be evaluated (Walters et al. 2005; NRC 2006).

How well would the modeling approaches discussed above and those reviewed by NRC (2006) have done in making the correct predictions in the case histories we reviewed? While it is simple to incorporate different mortality rates for different fish life stages in the model, it is extremely difficult to partition these rates among the factors (i.e., predation, cannibalism, etc.) that we suspect typically cause them. The reason for this difficulty is simple but discouraging: juvenile fish biomasses are typically very small compared to the biomasses of the larger organisms that eat them, so juveniles typically contribute only a very tiny proportion of total predator diets. Such low diet proportions are typically ignored by ecosystem model developers since they may not appear "important" for the predator. Even rigorous diet studies have a low likelihood of capturing such low proportions in situations where predation is known to be a strong regulator of recruitment success (Post et al. 1998). This point has been understood for many years in relation to detecting impacts of cannibalism

(Sheperd and Cushing 1990), but it applies equally well to all predators that may cause changes in juvenile mortality rates.

If an ecosystem model were able to correctly make the predictions observed in these case histories, would a fishery manager or management council have taken those predictions seriously? How would the model predictions have fared in debates about whether to proceed with the experiments? Would having the "right" models as part of the decision making process of whether to conduct the experiment—or in the case of ecosystem based fisheries management, whether to implement a certain policy—change the decisions that were made? Would (or should) decision makers have abandoned Occam's razor in favor of the predictions from complex models? The idea of developing a hypothesis (a conceptual model), designing an experiment around the hypothesis, and then verifying the hypothesis through analysis, testing, and formal model development is certainly not new (Walters 1986; Hilborn and Mangel 1997). It has long been argued that the main value of modeling exercises is to help in designing better "research" programs aimed specifically at documenting possible causes of policy failure (Holling 1978; Walters 1986; Walters and Martell 2004).

There is no simple solution to the question of whether to trust mathematical models we build, or our intuition as to which management policies will be best to meet the stated objectives. Models can be made more elaborate, and data collection can be intensified, but doing only one or the other has both risks and costs. We suggest that the iterative process of conjecture (model building) and testing (experimental data collection) could have helped managers to recognize the two common features in the case histories we reviewed. First, it appears that behavioral responses accelerate and intensify interaction rates that might be too simply represented in biomass or population modeling efforts and would be difficult (if not impossible) to derive from controlled laboratory or mesocosm studies. Testing for behavioral and multi-trophic level ("mini-ecosystems") responses is readily conducted in the laboratory or in mesocosms, but estimation of its role in nature is most appropriate if evaluated at the ecosystem scale (Carpenter 1996). An understanding and representation of behavioral responses such as vulnerability exchange parameters in foraging arena theory is critical in the development of ecosystem models (Walters and Martell 2004). These behavioral responses are clearly demonstrated in the responses of prey to predator risk in the examples we provide (e.g., bass and minnows in northern Wisconsin). Capturing these dynamics with ecosystem models will likely reduce the predator-prey instability common in some ecosystem models, and make appropriate corrections for model predictions that produce higher potential population sizes based on crude, large-scale estimates of prey abundance and production (Walters and Martell 2004).

Second, it appears that both field studies and modeling efforts should focus more on the causes of mortality in juvenile fishes, suggesting a need for researchers to consider a broader range of alternative hypotheses about juvenile recruitment mechanisms. Several of our case histories (brook trout examples from the Sierras, red snapper and menhaden from the Gulf of Mexico) identified unexpected changes in survival patterns of juveniles as a likely reason for the counterintuitive response that was observed. This is not to say that less attention should be focused on other research concerns (e.g., factors regulating larval fish abundance). Instead, we see a need for research on juvenile life stages, simply because while larval fish are subjected to a myriad of uncontrollable and stochastic effects on their survival, selection has favored behavioral responses in juvenile fishes that foster their survival even though they are highly vulnerable to piscivory because of their small size (Walters and Juanes 1993).

We feel that the most instructive outcomes for improving learning and policy development have derived from combinations of two activities. The first are critical evaluations of expected vs. observed outcomes, where we examine the ecosystem response to our management action and compare this response to our prediction. The common thread in our case histories of changes in juvenile survival rates and behaviors could be tested in this framework as alternative hypotheses when management actions do not follow predictions. This approach could lead further research into changes in juvenile fish survival rates or lead to the discovery of other ecosystem interactions which we are not aware of and/or are not including in our current models. This simple exercise is rarely reported in the literature but offers important insight regardless of the management outcome. Second, whole system manipulations often have the potential to produce outcomes at ecosystem scales similar to the scale natural selection has operated on in the past. Whole system manipulations that can include mortality or selective removal caused by fishing (Law 2000) or whole system management actions (e.g., large ecosystem restoration, Florida Everglades) are a force unlike that experienced in the evolutionary history of fishes. Clearly, the most instructive manipulations are those that create the strong contrast required for maximum learning opportunities at the scale pertinent to fishery policy development. In short, fisheries management actions, and the counterintuitive responses that sometimes occur following these actions, should be viewed as a tool that can teach us about both fish population dynamics and the ecosystem context that supports them.

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REFERENCES

Anderson, J. L. 1997. The growth of salmon aquaculture and the emerging new world order of the salmon industry. Pages 175–184 *in* E. K. Pikitch, D. D. Huppert, and M. P. Sissenwine, eds. Global trends: fisheries management.. American Fisheries Society Symposium 20, Bethesda, Maryland.

Anderson, J. T., and **G. A. Rose.** 2001. Offshore spawning and year-class strength of northern cod (2J3KL) during the fishing moratorium, 1994-1996. Canadian Journal of Fisheries and Aquatic Sciences 58:1386-1394.

Anderson, K. P., and **E. Ursin.** 1977. A multispecies extension to the Beverton and Holt theory of fishing; with accounts of phosphorus, circulation and primary production. Meddr Danm. Fisk.-og Havunders. N. S. 7:319-435.

Anderson, R. O. 1973. Application of theory and research to management of warmwater fish populations. Transactions of the American Fisheries Society 102:164-171.

Beamish, R. J., C. Mahnken, and **C. M. Neville.** 1997. Hatchery and wild production of Pacific salmon in relation to large-scale, natural shifts in the productivity of the marine environment. ICES Journal of Marine Sciences 54:1200-1215.

Beard, T. D. and **T. E. Essington.** 2000. Effects of angling and life history processes on bluegill size structure: insights from an individual-based model. Transactions of the American Fisheries Society 129:561-568.

Bradford, M. J., and **J. R Irvine.** 1999. Land use, fishing, climate change, and the decline of Thompson River, British Columbia, coho salmon. Canadian Journal of Fisheries and Aquatic Sciences 57:13-16.

Brown, L. R. P. B. Moyle, and **R. M. Yoshiyama.** 1994. Historical decline and current status of coho salmon in California. North American Journal of Fisheries Management 14:237-261.

Carpenter, S. R. 1996. Microcosm experiments have limited relevance for community and ecosystem ecology. Ecology: 77:677-680.

_____. 2000. Alternate states of ecosystems: evidence and its implications for environmental decisions. *In* M. C. Press, N. Huntley, and S. Levin, eds. Ecology: achievement and challenge. Blackwell Press, London.

Carpenter, S., and **J. Kitchell.** 1993a. The trophic cascade in lakes. Cambridge University Press, Cambridge, England.

_____. 1993b. Simulation models of the trophic cascade: predictions and evaluations. Pages 310-331 *in* S. R. Carpenter and J. F. Kitchell, eds. The trophic cascade in lakes. Cambridge University Press, Cambridge, England.

Christensen, V., S. Gúnette, J. J. Heymans, C. J. Walters, R. Watson, D. Zeller, and **D. Pauly.** 2003. Hundred-year decline of North Atlantic predator fishes. Fish and Fisheries 4:1-24.

Christensen, V., and **C. J. Walters.** 2004. Ecopath with ecosim: methods, capabilities, and limitations. Ecological Modeling 172:109-139.

Coggins, L. G., Jr. 2008 a. Active adaptive management for native fish conservation in Grand Canyon: implementation and evaluation. Doctoral dissertation. University of Florida, Gainesville, Florida, USA.

_____. 2008b. Abundance trends and status of the Little Colorado River population of humpback chub; an update considering 1989-2006 data: U.S. Geological Survey Open-File Report 2007-1402.

Coggins, L. G., Jr., W. E. Pine, III, C. J. Walters, D. R. Van Haverbeke, D. Ward, and **H. C. Johnstone.** 2006. Abundance trends and status of the Little Colorado River population of humpback chub. North American Journal of Fisheries Management 26:233-245.

Coleman, F. C., W. F. Figueira, J. S. Ueland, and **L. B. Crowder.** 2004. The impact of United States recreation fisheries on marine fish populations. Science 305:1958-1960.

Collie, J. S., and **H. Gislason.** 2001. Biological reference points for fish stocks in a multispecies context. Canadian Journal of Fisheries and Aquatic Sciences 58: 2167-2176.

Cowx, I. G., and **D. Gerdeaux.** 2004. The effects of fisheries management practises on freshwater ecosystems. Fisheries Management and Ecology 11:145-151.

DeGisi, J. 1994. Year class strength and catchability of mountain lake brook trout. Msc. thesis, Department of Zoology, University of British Columbia, Vancouver, Canada.

DeVries, D. R., and **R. A. Stein.** 1990. Manipulating shad to enhance sport fisheries in North America: an assessment. North American Journal of Fisheries Management 10:209-223.

Donald, D. B., and **D. J. Alger.** 1989. Evaluation of exploitation as a means of improving growth in a stunted population of brook trout. North American Journal of Fisheries Management 9:177-183.

Dulvy, N. K., Y. Sadovy, and **J. D. Reynolds.** 2003. Extinction vulnerability in marine populations. Fish and Fisheries 4:25-64.

Eggers, D. M., and **D. E. Rogers.** 1987. The cycle of runs of sockeye salmon (*Oncorhynchus nerka*) to the Kvichak River, Bristol Bay, Alaska: cyclic dominance or depensatory fishing? Pages 343–366 *in* H. D. Smith, L. Margolis, and C. C. Wood, eds. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Special Publication Canadian Journal of Fisheries and Aquatic Sciences 96.

Follstad Shah, J. J., C. N. Dahm, S. P. Gloss, and **E. S. Bernhardt.** 2007. River and riparian restoration in the Southwest: results of the National River Restoration Science Synthesis Project. Restoration Ecology 15:550-562.

Gallaway, B. J., and **J. G. Cole.** 1999. Reduction of juvenile red snapper bycatch in the U.S. Gulf of Mexico shrimp trawl fishery. North American Journal of Fisheries Management 19:342-355.

Gislason, H. 1991. The influence of variations in recruitment on multispecies yield predictions in the North Sea. ICES Marine Science Symposium 193:50-59.

Gloss, S. P., J. E. Lovich, and **T. E. Melis.** 2005. The state of the Colorado River ecosystem in Grand Canyon. U.S. Geological Survey Circular 1281.

Gunderson, L. H. and **C. S. Holling eds.** 2002. Panarchy: understanding transformation in human and natural systems. Island Press, Washington, DC.

Hall, D. 1991. Growth, fecundity, and recruitment responses of stunted brook trout populations to density reductions. Ph.D. dissertation, Department of Zoology, University of British Columbia, Vancouver, British Columbia, Canada.

Hartman, G. F., and **Scrivener, J. C.** 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin Fisheries and Aquatic Sciences vol 223.

Hartman, G. F., J. C. Scrivener, and **M. J. Miles.** 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia, and their implication for restoring fish habitat. Canadian Journal of Fisheries and Aquatic Sciences 53(supplement 1): 237-251.

He, X., and **J. F. Kitchell.** 1990. Direct and indirect effects of predation on a fish community: a whole-lake experiment. Transactions of the American Fisheries Society 119:825-835.

He, X., R. A. Wright, and **J. F. Kitchell.** 1993. Fish behavioral and community responses to manipulation. Pages 69-84 *in* S. R.

Carpenter and J. F. Kitchell, eds. The trophic cascade in lakes. Cambridge Univ. Press, Cambridge, England.

Hilborn, R., and **M. Mangel.** 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, New Jersey.

Hilborn, R., and **C. J. Walters.** 1992. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Chapman and Hall, New York.

Hoffnagle, T. L., A. Choudhury, and **R. A. Cole.** 2006. Parisitism and body condition in humpback chub from the Colorado and Little Colorado Rivers, Grand canyon, Arizona. Journal of Aquatic Animal Health 18:184-193.

Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review Ecology Systematics 4:1-24.

Holling, C. S., ed. 1978. Adaptive environmental assessment and management. Blackburn Press, Caldwell, New Jersey.

Holling, C. S., and **G. K. Meffe.** 1996. Command and control and the pathology of natural resource management. Conservation Biology 10:328-337.

Holtby, B. L. 1988. Effects of logging on stream temperatures in Carnation Creek, British Columbia, and associated impacts on the coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 45: 502-515.

ICES (International Council for the Exploration of the Seas). 2000. 100 Years of science under ICES. ICES Marine Science Symposia 2000. Helsinki, Finland.

Irwin, B. R., D. R. DeVries, and **G. W. Kim.** 2003. Responses to gizzard shad recovery following selective treatments in Walker County Lake, Alabama, 1996-1999. North American Journal of Fisheries Management 23:1225-1237.

Jurado-Molina, J., and **P. Livingston.** 2002. Climate-forcing effects on trophically linked groundfish populations: implications for fisheries management. Canadian Journal of Fisheries and Aquatic Sciences 59:1941-1951.

Keith, W. E. 1975. Management by water level manipulation. Pages 489-497 *in* H. Clepper ed. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Kim, G. W., and **D. R. DeVries.** 2000. Effects of a selective gizzard shad reduction on trophic interactions and age-0 fishes in Walker County Lake, Alabama. North American Journal of Fisheries Management 20:860-872.

Koen-Alonso, M., and **P. Yodzis.** 2005. Multispecies modeling of some components of the marine community of northern and central Patagonia, Argentina. Canadian Journal of Fisheries and Aquatic Sciences 62:1490-1512.

Law, R. 2000. Fishing, selection, and phenotypic evolution. ICES Journal of Marine Science 57:659-668.

Lehodey, P., F. Chair, and **J. Hampton.** 2003. Modelling climate-related variability of tuna populations from a coupled ocean-biogeochemical-populations dynamics model. Fisheries Oceanography 12:483-494.

Levin, P. S., and **J. G. Williams.** 2002. Interspecific effects of artificially propagated fish and additional conservation risk salmon. Conservation Biology 16: 1581–1587.

Levy, D. A., and **C. C. Wood.** 1992. Review of proposed mechanisms for sockeye salmon population cycles in the Fraser River. Bulletin Mathematical Biology 54: 241–261.

Lilly, G. 2004. Northern (2J+3KL) cod stock status update. Fisheries and Oceans Canada, Stock Status Report 2004/011. Available at: www.dfo-mpo.gc.ca/csas/Csas/status/2004/SSR2004_011_e.pdf.

Link, J. S. 2005. Translating ecosystem indicators into decision criteria. ICES Journal of Marine Science 62:569-576.

Link, J. S., J. K. T. Brodziak, S. F. Edwards, W. J. Overholtz, D. Mountain, J. W. Jossi, T. D. Smith, and **M. J. Fogarty.** 2002. Marine ecosystem assessment in a fisheries management context. Canadian Journal of Fisheries and Aquatic Sciences 59:1429-1440.

Lotze, H. K., H. S. Lenhian, B. J. Bourque, R. H. Bradbury, R. G. Cooke, M. C. Kay, S. M. Kidwll, M. X. Kirby, C. H. Peterson, and **J. B. C. Jackson.** 2006. Recovery potential of estuaries and coastal seas. Science 312: 1806-1809.

Magnusson, K. 1995. An overview of the multispecies VPA – theory and applications. Reviews in Fish Biology and Fisheries 5:195-212.

Martell, S. J. D., C. J. Walters, and R. Hilborn. 2008. Retrospective analysis of harvest management performance for Bristol Bay and Fraser River sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 65:409-424.

May, R. M., ed. 1984. Exploitation of marine communities. Springer-Verlag, New York.

Melis, T. S., S. J. D. Martell, L. G. Coggins, W. E. Pine, III, and **M. E. Anderson.** 2006. Adaptive management of the Colorado River ecosystem below Glen Canyon Dam, Arizona: using science and modeling to resolve uncertainty in river management. American Water Resources Associate Summer Specialty Conference 1-6.

Minns, C. K., J. R. M. Kelson, and **R. G. Randall.** 1996. Detecting the response of fish to habitat alteration in freshwater ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 53 (Supplement 1):403-414.

Murawski, S. A. 2007. Ten myths concerning ecosystem approaches to marine resource management. Marine Policy 31:681-690.

Myers, R. A. M. 2002. Recruitment: understanding density-dependence in fish populations. *In* P. J. B. Hart and J. D. Reynolds, eds. Handbook of fish biology and fisheries. Blackwell Science Ltd., Malden, Massachusetts.

Myers, R. A. M., J. Bradford, J. M. Bridson, and **G. Mertz.** 1997. Estimating delayed density-dependent mortality in sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 54:2449-2462.

Nichelson, T. 2003. The influence of hatchery coho salmon (*Oncorhynchus kisutch*) on the productivity of wild coho salmon populations in Oregon coastal basins. Canadian Journal of Fisheries and Aquatic Sciences 60:1050-1056.

NOAA SEDAR 7 (Southeast Data, Assessment, and Review). 2005. Stock Assessment report of SEDAR7 Gulf of Mexico Red Snapper, Section 3: stock assessment workshop report. Gulf of Mexico Fisheries Management Council, Tampa, Fl. Available at: www.gulfcouncil.org/downloads/SEDAR7%20AW%20report%20main.pdf.

Noble, R. L. 1986. Management of reservoir fish communities by influencing species interactions. Pages 137-143 *in* G. E. Hall, and M. J. Van Den Avyle, eds. Reservoir fisheries management: strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland.

_____. 2002. Reflections on 25 years of progress in black bass management. American Fisheries Society Symposium 31:419-431.

NRC (National Research Council). 2006. Dynamic changes in marine ecosystems: fishing, food webs, and future options. The National Academies Press, Washington, D. C.

Olsen, E. M., M. Heino, G. R. Lilly, , M. J. Morgan, J. Brattey, B. Emande, and **U. Dieckmann.** 2004. Maturation trends indicative of rapid evolution preceded the collapse of northern cod. Nature 428:932-935.

Pauly, D., V. Christensen, D. Guénette, T. J. Pitcher, U. R. Sumaila, C. J. Walters, R. Watson, and **D. Zeller.** 2002. Towards sustainability in world fisheries. Nature 418:689-695.

Peacor, S. D., and **Werner, E. E.** 2001. The contribution of trait-mediated indirect effects to the net effects of a predator. Proceedings of the National Academy of Sciences 98:3904-3908.

Peterman, R. M. 1991. Density-dependent marine processes in North Pacific salmonids: lessons for experimental design of large-scale manipulations of fish stocks. ICES Marine Science Symposium 192:69-77.

Pew Oceans Commission. 2003. America's living oceans: charting a course for sea change. Pew Oceans Commission, Arlington, Virginia. Available at: http://pewoceanscience.org.

Pikitch, E. K., C. Santora, E. A. Babcock, A. Bakun, R. Bonfil, D. O. Conover, P. Dayton, P. Doukakis, D. Fluharty, B. Heneman,

E. D. Houde, J. Link, P. A. Livingston, M. Mangel, M. K. McAllister, J. Pope, and **K. J. Sainsbury.** 2004. Ecosystem-based fishery management. Science 305:346-347.

Ploskey, G. R. 1986. Effects of water-level changes on reservoir ecosystems, with implications for fisheries management. Pages 86-97 *in* G. E. Hall and M. J. Van Den Avyle, eds. Reservoir fisheries management: strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland.

Post, J. R., E. A. Parkinson, and **N. T. Johnston.** 1998. Spatial and temporal variation in risk to piscivory of age-0 rainbow trout: patterns and population level consequences. Transactions of the American Fisheries Society 127:932-942.

Punt, A. E., and **D. S. Butterworth.** 1995. The effects of future consumption by the Cape fur seal on catches and catch rates of the Cape hakes. 4. Modelling the biological interaction between Cape fur seals *Arctocephalus pusillus pusillus* and the Cape hakes *Merluccius capensis* and *M. paradoxus*. South African Journal of Marine Science 16:355-385.

Richter, B. D., A. T. Warner, J. L. Meyer, and **K. Lutz.** 2003. A collaborative and adaptive process for developing environmental flow recommendations. River Research and Applications 22:297-318.

Scheffer, M. 1990. Multiplicity of stable states in freshwater ecosystems. Hydrobiologia 200/201:475-486.

Scheffer, M., S. R. Carpenter, J. A. Foley, C. Folke, and **B. Walker.** 2001. Catastrophic shifts in ecosystems. Nature 413:591-596.

Schmitz, O. J., V. Krivan, and **O. Ovadia.** 2004. Trophic cascades: the primacy of trait-mediated indirect interactions. Ecology Letters 7:153-163.

Shepherd, J. G., and **D. H. Cushing.** 1990. Regulation in fish populations: myth or mirage? Philosophical Transactions Royal Society London 330:151-164.

Smith, A. D. M., E. J. Fulton, A. J. Hobday, D. C. Smith, and **P. Shoulder.** 2007. Scientific tools to support the practical implementation of ecosystem-based fisheries management. ICES Journal of Marine Science 64:633-639.

Sparholt, H. 1995. Using the MSVPA/MSFOR model to estimate the right-hand side of the Ricker curve for Baltic cod. ICES Journal of Marine Science 52:819-826.

Sparre, P. 1991. Introduction to multispecies virtual population analysis. ICES Marine Science Symposium 193;12-21.

Stein, R. A., M. T. Bremigan, and **J. M. Dettmers.** 1996. Understanding reservoir systems with experimental tests of ecological theory: a prescription for management. American Fisheries Society Symposium 16:12-22.

Swingle, H. S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Alabama Polytechnic Institute, Agricultural Experiment Station Bulletin 271, Auburn, Alabama.

Swingle, H. S., and **W. E. Swingle.** 1967. Problems in dynamics of fish populations in reservoirs. Pages 229–243 *in* Reservoir Fishery Resources Symposium Reservoir Committee, Southern Division, American Fisheries Society, Bethesda, MD.

Taylor, N. 2006. Population dynamics of pygmy pikeminnow in British Columbia mountain lakes. Ph.D. dissertation, Department of Zoology, University of British Columbia.

Thedinga, J. F., M. L. Murphy, J. Heifetz, K.V. Koski, and **S. W. Johnson.** 1989. Effects of logging on size and age composition of juvenile coho salmon (*Oncorhynchus kisutch*) and density of presmolts in Southeast Alaska streams. Canadian Journal of Fisheries and Aquatic Sciences 46:1383-1391.

U.S. Commission on Ocean Policy. 2004. An ocean blueprint for the 21st Century. U.S. Commission on Ocean Policy, Washington, DC. Available at: http://oceancommission.gov.

Valdez, R. A., and **R. J. Ryel.** 1995. Life history and ecology of humpback chub (*Gila cypha*) in the Colorado River, Arizona. Final Report. Contract No. 0-CS-40-09110. Salt Lake City, UT.

Vaughan, D. S., J. W. Smith, and **M. H. Prager.** 2000. Population characteristics of Gulf menhaden, *Brevoortia patronus*. NOAA Tech. Rep. NMFS 149.

Vaughan, D. S., K. W. Shertzer, and **J. W. Smith.** 2007. Gulf menhaden (*Brevoortia patronus*) in the U.S. Gulf of Mexico: Fishery characteristics and biological reference points for management. Fisheries Research83:263-275.

Vinther, M., P. Lewy, L. Thomsen, and **U. Petersen.** 2001. Specification and documentation of the 4M package containing multi-species, multi-fleet and multi-area models. The Danish Institute for Fisheries and Marine Research, Charlottenlund Castle, Charlottenlund.

Walters, C. J. 1986. Adaptive management of renewable resources. Blackburn Press, Caldwell, New Jersey.

Walters, C. J., and **F. Juanes.** 1993. Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taken by juvenile fish. Canadian Journal of Fisheries and Aquatic Science 50:2058-2070.

Walters, C. J., R. Hilborn, R. M. Peterman, and **M. J. Staley.** 1978. Model for examining early ocean limitation of Pacific salmon production. Journal of the Fisheries Research Board of Canada 35:1303-1315.

Walters, C. J and **M. J. Staley.** 1987. Evidence against the existence of cyclic dominance in Fraser River sockeye salmon (*Oncorhynchus nerka*). Pages 375-384 *in* H. D. Smith, L. Margolis, and C. C. Wood, eds. Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Special Publication Canadian Journal of Fisheries and Aquatic Sciences 96.

Walters, C. J., and **J. J. Maguire.** 1996. Lessons for stock assessment from the northern cod collapse. Reviews in Fish Biology and Fisheries 6:125-137.

Walters, C., V. Christensen, and **D. Pauly.** 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. Reviews in Fish Biology and Fisheries 7:139–172.

Walters, C. J., and **J. F. Kitchell.** 2001. Cultivation/depensation effects on juvenile survival and recruitment: implication for the theory of fishing. Canadian Journal of Fisheries and Aquatic Sciences 58:39-50.

Walters, C. J., and **S. J. Martell.** 2004. Fisheries ecology and management. Princeton University Press, Princeton, N.J.

Walters, C. J., V. Christensen, S. J. D. Martell, and **J. F. Kitchell.** 2005. Possible ecosystem impacts of applying MSY policies from single-species assessment. ICES Journal of Marine Science 62:558-568.

Walters, C. J., S. J. Martell, and **J. Korman.** 2006. A stochastic approach to stock reduction analysis. Canadian Journal of Fisheries and Aquatic Sciences. 63:1-12.

Werner, E. E., and **J. F. Gilliam.** 1984. The ontogenetic niche and species interactions in size-structured populations. Annual Reviews in Ecology and Systematics. 15:393-425.

Werner, E. E., and **S. D. Peacor.** 2003. A review of trait-mediated indirect interactions in ecological communities. Ecology 84:1083–1100.

Whipple, S. J., J. S. Link, L. P. Garrison, and **M. J. Fogarty.** 2000. Models of predation and fishing mortality in aquatic ecosystems. Fish and Fisheries 1:22-40.

PERSPECTIVE:
REPLY

Risks of Introductions of Marine Fishes: Reply to Briggs

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ABSTRACT: This is a rebuttal to a publication by John C. Briggs in the April 2008 issue of *Fisheries* in which he suggested introducing fishes and invertebrates from the North Pacific into the North Atlantic to increase diversity toward improving fisheries in the latter. We argue otherwise for reasons that Briggs downplayed or never considered. Using examples of introductions within the Pacific and the Atlantic, and movements of species from the Pacific to the Atlantic, we provide a record of failures and damage or dangers to native species from the few introductions that became successful. We argue that a lack of diversity of fishes and invertebrates in the North Atlantic versus that of the North Pacific is not the problem to be corrected by introductions as Briggs suggested. A record of overfishing and management policies is the problem in the North Atlantic. Introductions from the North Pacific to the North Atlantic are not worth the costs or the environmental risks involved.

Riesgos de la introducción de peces marinos: una réplica a Briggs

RESUMEN: Esta es una réplica al artículo de John C. Briggs, publicado en el número de abril de 2008 de la revista *Fisheries*, en el cual él sugirió introducir peces e invertebrados del Pacífico norte al Atlántico norte con el fin de incrementar la diversidad y mejorar las pesquerías en esta última región. Aquí argumentamos lo contrario por razones que Briggs nunca consideró. Mediante ejemplos de introducciones realizadas dentro del Pacífico y el Atlántico, y de movimientos de especies de un océano al otro, en esta contribución se muestra un registro de casos fallidos o de peligros para especies nativas a partir de las pocas introducciones que se volvieron exitosas. Se argumenta que la poca diversidad de peces e invertebrados en el Atlántico norte versus aquella del Pacífico norte no es un problema que deba corregirse mediante introducción de especies, como lo sugiere Briggs. En el Atlántico norte, la sobrepesca histórica y las políticas de manejo son realmente el problema. Llevar a cabo introducciones del Pacífico norte al Atlántico norte no compensa los costos o los riesgos ambientales que esto implica.

INTRODUCTION

Impetus for this article was a provocative paper by John C. Briggs (2008) advocating transplantations of North Pacific fishes into the North Atlantic for "proactive management" and toward a stock enhancement program. Briggs's proposal was stated to have potential benefit by supplementing diversity, supposedly contributing to stabilization of the ecosystem, increasing biomass, and possibly preventing a future decline of commercial and recreational fishery stocks. He argued that because the North Atlantic has an impoverished fauna compared to that of the North Pacific, benefits from introductions of North Pacific fish and invertebrate species into the North Atlantic outweigh risks, and "the chances of a disastrous results would appear to be exceedingly slim." We found many faults with the premises that Briggs suggested and provide reasons why, using examples of failures and some serious mistakes made with introductions of marine species.

We disagree with most of Briggs's (2008) assumptions regarding introductions and, more importantly, believe he has downplayed or dismissed some serious and perhaps irreversible dangers inherent in marine or other introductions generally. More importantly, the proactive management strategy he proposed does nothing to address underlying causes for the collapse of fish stocks worldwide or specifically in the North Atlantic (Pauly et al. 1998; Pauly and Maclean 2003) that are primarily due to overfishing. We believe it sends the wrong message that this problem can be corrected by introductions that would likely fail, and would require huge expenditures of funds for pre-introduction research and implementation of transplantations on a massive scale. Even assuming the introductions Briggs proposed might achieve the goals he targeted, he ignored what might be long-term ecological effects to the native biota of the North Atlantic.

Briggs (2007, 2008) stated that relatively few introduced marine fishes and invertebrates become pests or are detrimental to native biological communities, and that potential benefits from such introductions might justify the risks. Indeed, the following sentence given in recent popular media indicates that Briggs's management suggestion is being seriously considered: "At the very least, the reader is left wondering if this is an idea whose time has come" (Rodger 2008). What that statement seems to imply is that Briggs (2007, 2008) and Rodger (2008) are unfamiliar with the large, growing body of literature concluding that introductions of nonnative species can result in often unpredicted negative effects to receiving communities and to the biota therein over time.

The premise of Briggs's (2008) argument is flawed in many ways. Intrinsic vulnerability to fishing of different species is largely a function of their adult size and age at first maturity (Cheung et al. 2005), not their taxonomic or biogeographical affinities. The notion that greater taxonomic diversity among fishes in the North Pacific has contributed to greater productivity of the fisheries of that region compared to the relatively low diversity in the North Atlantic is only an assumption on his part, for which he cited no supporting references. That idea ignores the wealth of information and data that have demonstrated that declines of fishery stocks in the North Atlantic are due to widespread overfishing (Christensen et al. 2003) and not to a lack of species diversity.

Relentless technological innovations that rapidly increased fishing capacity and efficiency, ineffective management of shared stocks (species whose ranges span international borders), and the tendency to ignore scientific advice in favor of higher catch quotas have led to this decline (Pauly et al. 2002; Pauly and MacLean 2003). These are the factors that have caused extraordinary high and unsustainable exploitation rates, resulting in stock collapses. Hilborn (2007) showed that the primary determinant of stock recovery is whether they continue to be fished at unsustainable levels. This was avoided to some degree in the North Pacific because management regimes there succeeded in limiting fishing pressure before major collapses occurred. It has been the differential success of management agencies in regulating fishing efforts that underlie the contrasts between North Atlantic and North Pacific, and not the underlying biology of the ecosystems.

It is naïve and probably dangerous to suggest a biological-based "fix" via introductions to a problem that is of a social and political nature. Moreover, the idea that ecosystems with a more diverse fish fauna are more resilient to overfishing is tenuous at best and, in our opinion is unsupported by convincing research. Assuming that transplanted North Pacific fish species became successfully established in the North Atlantic, why would they be less susceptible to overfishing than resident North Atlantic fish species they are intended to supplement or perhaps replace?

We are alarmed that his proposal might be taken seriously, including his view (Briggs 2007) that few marine species introductions have had negative effects on native species, a topic that will be addressed separately by others (J. T. Carlton, Williams College, pers. comm.).

Briggs (2007, 2008) is correct that marine introductions have not so far and might not cause species extinctions, but that is a "straw-man" argument that ignores or downplays cases of serious and perhaps irreversible negative impacts to native biota in novel waters. Extinctions are not the major concern regarding introductions of marine or other non-native species. Rearrangements and perhaps irreversible serious disturbances to receiving communities as a result of introductions that might or might not result in extinctions should be of major concern. Moreover, how should such rearranged systems be managed effectively to produce the results he is seeking?

Briggs (2008) also argued that the historical exchange (ca 3.5 million years ago) of faunas during the so-called Great Trans-Arctic Biotic Interchange resulted in no significant loss of biodiversity, but he seems to ignore the fact that human sociological adjustments to local faunal mixing of the dimension he proposes would take place on a far shorter time scale.

The literature contains many examples of freshwater fish introductions that have had and continue to cause serious problems (Courtenay et al. 1985; Courtenay and Robins 1989; Minckley and Douglas 1991; Kottelat and Freyhof 2007), but herein we focus on introductions involving marine species with a strong admonishment that they not be undertaken.

A BRIEF SUMMARY OF MARINE FISH INTRODUCTIONS FROM THE PACIFIC TO THE ATLANTIC

To our knowledge, the only successful (= totally self-sustaining) fish introduction from the Pacific/Indian Ocean into the Atlantic to date have been that of two species of lionfishes, *Pterois volitans* and *P. miles* (Whitfield et al. 2002; Ruiz-Carus et al. 2006, Whitfield et al. 2007; Hamner et al. 2007; Albins and Hixon 2008). Both species are of subtropical to tropical origin but, unexpectedly, were found established in cooler, deeper waters along the eastern Atlantic coast of the United States (Whitfield et al. 2007). Since becoming established, lionfishes have rapidly extended their ranges widely into northern and central areas of the Caribbean, including shallow, warm waters where they are now common. Lionfishes have become demonstrably invasive, with significant negative impacts to native fishes in the Bahamas (Albins and Hixon 2008).

THE HAWAIIAN EXPERIENCE WITH MARINE INTRODUCTIONS

The indigenous biota of few places on Earth has suffered more from the impact of humans than the Hawaiian Islands, beginning with arrival of the first Polynesians in about 500 AD. More recently, marine organisms have been transported to the islands from fouling on ship's hulls and from release of ballast water.

Lack of concern regarding negative impacts of introductions to the marine environment of the Hawaiian Islands is evident from intentional importations of marine algae, crustaceans, mollusks, and fishes. Thirty-three species of marine fishes have been introduced to the islands (Brock 1952; Maciolek 1984; Randall 1987; Eldredge 1994; Randall 2007). In addition, there are several reports of exotic marine fishes being found in Hawaiian waters as results of releases by aquarists, akin to similar reports of Indo/Pacific fishes introduced to waters of southeastern Florida (Semmens et al. 2004).

Intentional introduction of marine fishes, with approval of the state of Hawaii, were toward objectives of some becoming baitfish for tuna or as food fishes believed to be of greater value than native species, the latter activity intended for proactive management. The Hawaiian Islands have only two native species of groupers (Serranidae)—the rare giant grouper (*Epinephelus lanceolatus*) and an endemic deep-water species, the Hawaiian grouper (*E. quernus*). Hawaii also lacked native snappers of the genus *Lutjanus* (Lutjanidae).

Six species of groupers and three snappers were introduced from French Polynesia to the Hawaiian Islands from 1956 to 1958. Three species are clearly established, two now in alarming numbers. One is the bluestriped snapper (*Lutjanus kasmira*) and the other, the peacock grouper (*Cephalopholis argus*).

The bluestriped snapper has undergone a population explosion throughout the entire Hawaiian Archipelago, likely by leaving predators and competitors behind, but also because of a lack of fishing pressure (Randall 2007; Dierking 2008). Although good-eating, it reaches a total length of only 32 cm. Thus, it has not been widely accepted as a food fish in spite of a relatively low market price. It is unpopular with anglers, not only because of its low value, but also because it ranges to depths greater than 150 m where it is caught by anglers whose intended catches were for valuable deeper water, native lutjanid species of the genera *Etelis* and *Pristipomoides*. The bluestriped snapper is suspected of causing a reduction in populations of some local goatfishes of the genera *Mulloidichthys* and *Parupeneus* via competition for food resources, and as a predator on young of the valuable crustacean *Ranina ranina*, locally known as the Kona crab. One can only worry what further reductions or, at worst, possible extinctions of the Hawaiian marine fauna might eventually result in the future from introduction of this snapper.

Of even greater concern are impacts of the introduced peacock grouper. Its population has been slow to build within the islands, beginning with a major increase on the west coast of the island of Hawaii in recent years. It reaches 60 cm in total length and is esteemed as a food fish in areas where ciguatera fish poisoning does not occur. Nevertheless, in the Hawaiian Islands, about one out of every five caught can cause ciguatera. As a result, few people will risk eating this grouper. Lacking natural predators, its population continues to increase and is building westward in the Hawaiian chain. Studies of its food habits revealed fishes comprise 77.5–95.7% of its prey (Randall and Brock 1960; Helfrich et al. 1968; Harmelin-Vivien and Bouchon 1976; Randall 1980).

Native Hawaiian reef fishes have evolved over many centuries without abundant resident fish predators in their environment. However, long-term projections indicate introductions might lead to population reductions and, at worst, extinctions. Earle (2005) summarized the current view of this introduction with his article titled "Have We Created a Monster?"

SOME PAST AND RECENT INTRODUCTIONS IN THE ATLANTIC

Smith-Vaniz et al. (1999) reported attempted intentional fish introductions to Bermuda from sources in southeastern Florida during the summer of 1924, approved by the legislature of Bermuda, supposedly to supplement and enhance commercial species already present. They documented the lack of establishment or infrequent subsequent capture of all of these attempted introductions. Smith-Vaniz et al. (1999) noted that because the fish fauna of Bermuda originated from Caribbean sources, the intended introduced species might have occurred there naturally had conditions been suitable for them. They also remarked that such additional introductions were misguided attempts to add to the established, natural fish fauna of Bermuda. Introduced lionfishes, however, have been found in Bermudian waters in recent years, likely the result of Gulf Stream gyres that brought them there (Whitfield et al. 2002), but without substantiated evidence of their establishment to date.

WHAT ARE THE ASSUMPTIONS OF SUCCESS VERSUS RISKS?

Baltz (1991) summarized the 120 marine and coastal introductions around the world known at that time, finding that the majority were unintentional releases into coastal estuaries that "profoundly affected the community structure." Most intentional introductions did not establish populations or did not achieve their objectives. The few that became established all had negative effects, including harm to valuable fisheries, introductions of parasites, and perhaps future endangerment of native species. Historically, most intentional attempts at introductions have been to add North Atlantic species to the North Pacific and, with the exception of anadromous species (striped bass, *Morone saxatilis*, and American shad, *Alosa sapidissima*), nearly all failed (Baltz 1991). Introductions have continued, although for most, the source of the introduction and whether or not populations became established remain unknown (Streftaris et al. 2005).

Only the former Soviet Union has attempted to transplant fishes from the North Pacific to the Atlantic. Of 42 attempts, 15 were in waters connected with the open ocean and of these, only 3 became established. Two species, one anadromous and the other secondarily marine, showed evidence of spawning but only persisted as small populations. After repeated introductions in the Barents Sea, the third species, pink salmon (*Oncorhyncus gorbuscha*), survived as a naturally reproducing population that now supports a small fishery but requires periodic replenishment from the North Pacific (Petryashov et al. 2002).

No introductions of North Pacific marine fishes to other open ocean waters have been successful. One example Briggs (2008) mentioned of a "successful" marine introduction was considered by Matishov et al. (2004) to be the "greatest intended large-scale change in the Barents Sea coastal ecosystem." Instead, this clearly illustrates the dangerous unknowns of marine introductions. The red king crab (*Paralithodes camtschaticus*), an endemic North Pacific crustacean, was experimentally introduced to the Barents Sea by the Soviet Union on a small scale in the 1930s in an attempt to provide a target for a local fishery. After very limited success, it was later systematically introduced on a larger scale from 1961 to 1969 (Zelenina et al. 2008). Few crabs were found until the late 1970s, when a reproductive population became established and the crabs began to expand rapidly. By the early 2000s, the stock had established to the point of supporting a substantial fishery and continues to expand south along the coast of Norway, invading new coastal areas. Following patterns of established introductions, the species is likely going through an explosive expansive phase (Matishov et al. 2004). Ironically, because the crab easily entangles in gillnets, it is now considered a "bycatch nuisance" in the fishery and has precipitated calls for its eradication by gillnet anglers (Petryashov et al. 2002).

Due to its recent expansion, little is yet known regarding effects of the crab on the Barents Sea ecosystem (Kuzmin and Sundet 2000). What is known is that the red king crab is a polyphage, feeding on any edible material it can capture by crushing and shredding it with powerful claws. It has been observed feeding on scallops. As the crabs become larger and more abundant, the commercially important scallop *Chlamys islandica* may become threatened with destruction (Jørgensen and Primicerio 2007). The crabs are also known to feed on fishes and fish roe, especially capelin (*Mallotus villosus;* Petryashov et al. 2002). Although capelin are highly fecund, possible disruption of capelin reproduction and future contribution to the food chain may have damaging effects on populations of higher-level predators

Common cod (*Gadus morhua*) has been overfished and stressed. An added stressor may be the provision of a fertile ground for parasites. The red king crab also serves as a carrier for a marine leach, *Johanssonia arctica*, an intermediate host of the blood parasite, *Trypanosoma murmanensis*, which has been implicated in the death of juvenile cod and known to have debilitating effects on adult cod and other fishes (Hemmingsen et al. 2005).

Briggs (2008) seems unaware of the role that the International Council for the Exploration of the Sea (ICES) played regarding introductions of marine species. Sindermann (1992) reported on an aquaculture meeting sponsored by ICES, held in Puerto Rico during the 1980s, on a proposal (due to rising interest in introductions and transfers of marine species for culture purposes) for introductions of marine species. Sindermann and others entitled that session the "International Decade of Indiscriminate Ocean Transfers" (acronym = IDIOT). Little enthusiasm followed that meeting, although the ICES working group on introduced species drafted assessments that led to several guidelines for contemplated marine introductions (Sindermann 1992). Those assessments need further refinement and implementation, especially in view of Briggs's recent (2008) proposal.

Finally, what Briggs (2008) suggested by increasing biodiversity via introductions from the North Pacific to the North Atlantic to improve fisheries ignores increasing evidence that such introductions can create more problems than they might solve. Although some few introduced species have potential to become invasive and increase biodiversity, they "often have a destabilizing effect on natural community abundance patterns and ecosystem services, especially if they become dominant" (Palumbi et al. 2008).

SUMMARY

From the preceding, it should be evident that introductions made with the best of intentions can become biological "time bombs" and can have unpredicted effects on native biota, depending on the species introduced.

We cannot be certain if introduced North Pacific fishes or invertebrates, as Briggs (2008) proposed, might or might not become established in the North Atlantic or become invasive. However, this will not resolve the problem of overfishing and delayed management policies. What is needed is far greater focus by fishery managers, fishers, and the public on the human-associated causes of the problem, and what efforts will be needed, perhaps mandated, to reverse the existing situation (Pauly et al. 2002). Where is the documentation that introductions have benefited human society versus their disruption and damage to aquatic ecosystems? Such issues have never been adequately addressed in the past prior to implementation of introductions. What succeeded or failed via introductions are more important questions. The past record of marine introductions has not been positive. Are intentional introductions of fishes or other marine species truly required anywhere and, if so, why? Are the unknown dangers worth the risks? We think not.

Information, not assumptions without proof of benefits, and full evaluation of potential risks should be major guidelines for fishery managers (Pauly et al. 2002; Simberloff et al. 2005; Hansen and Jones 2008), and biogeographers as well. The bottom line is, do we have enough knowledge and, especially forethought, to properly manage our marine or other fishery resources without recommending intentional introductions that could exacerbate our previously created problems?

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REFERENCES

Albins, M. A., and **M. A. Hixon.** 2008. Indo-Pacific lionfish (*Pterois volitans*) reduce recruitment of Atlantic coral-reef fishes. Marine Ecology Progress Series 367:233–238.

Baltz, D. M. 1991. Introduced fishes in marine systems and inland seas. Biological Conservation 56:151–177.

Briggs, J. C. 2007. Marine biogeography and ecology: invasions and introductions. Journal of Biogeography 34:193–198.

______. 2008. The North Atlantic Ocean: need for proactive management. Fisheries 33(4):180–184.

Brock, V. E. 1952. A history of the introductions of certain aquatic animals to Hawaii. Biennial Report, Board of the Commission on Agriculture and Forests, Territory of Hawaii, June 30, 1952:114–123.

Cheung, W. L., T. J. Pitcher, and **D. Pauly.** 2005. A fuzzy logic expert system to estimate intrinsic extinction vulnerabilities of marine fishes to fishing. Biological Conservation 124:97–111.

Christensen, V., S. Guénette, J. J. Heymans, C. J. Walters, R. Watson, D. Zeller, and **D. Pauly.** 2003. Hundred-year decline of North Atlantic predatory fishes. Fish and Fisheries 4:1–24.

Courtenay, W. R., Jr., J. E. Deacon, D. W. Sada, R. C. Allan, and **G. L. Vinyard.** 1985. Comparative status of fishes along the course of the pluvial White River, Nevada. Southwestern Naturalist 30(4):503–524.

Courtenay, W. R., Jr., and **C. R. Robins.** 1989. Fish introductions: good management, mismanagement or no management? Reviews in Aquatic Sciences 1(1):159–172.

Dierking, J. 2008**.** Effects of the introduced predatory fish *Cephalopholis argus* on native reef fish populations in Hawaii. Cybium 32 (2):172.

Earle, J. L. 2005. Have we created a monster? Hawaii Fishing News 31(1):14.

Eldredge, L. G. 1994. Perspectives in exotic species management in the Pacific islands. Inshore Fisheries Research Project Technical Document 7, vol. 1:1–27.

Hamner, R. M., D. W. Freshwater, and **P. E. Whitfield.** 2007. Mitochondrial cytochrome *b* analysis reveals two invasive lionfish species with strong founder effects in the western Atlantic. Journal of Fish Biology 71, Suppl. B:214–222.

Harmelin-Vivien, M. L., and **C. Bouchon.** 1976. Feeding behavior of some carnivorous fishes (Serranidae and Scorpaenidae) from Tuléar, Madagascar. Marine Biology (Berlin) 37:329–340.

Hansen, J. A., and M. I. Jones. 2008. The value of information in fishery management. Fisheries 33(7):340–348.

Helfirch, P., T. Piyakarnanchana, and **P. S. Miles.** 1968. Ciguatera fish poisoning. I. The ecology of ciguatera reef fishes in the Line Islands. Occasional Papers of the Bernice P. Bishop Museum 23:305–369.

Hemmingsen, W., P. A. Jansen, and **K. MacKenzie.** 2005. Crabs, leeches and trypanosomes: an unholy trinity? Marine Pollution Bulletin 50(3):336–339.

Hilborn, R. 2007. Biodiversity loss in the oceans: how bad is it? Science 316:1281–1282.

Jørgensen, L. L., and **R. Primicerio.** 2007. Impact scenario for the invasive red king crab *Paralithodes camtschaticus* (Tilesius, 1815) (Reptantia, Lithodidae) on Norwegian, native, epibenthic prey. Hydrobiologia 590:47–54.

Kottelat, M., and **J. Freyhoff.** 2007. Handbook of European freshwater fishes. Publications Kottelat, Cornal, Switzerland.

Kuzmin, S., and **J. H. Sundet.** 2000. Joint report for 2000 on the red king crab (*Paralithodes camtschaticus*) investigations in the Barents Sea. Basic requirements for management of the stock. Report to the 29th Session of the Mixed Russian-Norwegian Fisheries Commission. Fiskeriforskning Report 19/2000.

Maciolek, J. A. 1984. Exotic fishes in Hawaii and other islands of Oceania. Pages 131-161 *in* W. R. Courtenay Jr. and J. Stauffer, eds. Distribution, biology and management of exotic fishes. John Hopkins University Press, Baltimore.

Matishov, G., Golubeva, N., Titova, G., Sydnes, A. and **B. Voegele.** 2004. The Barents Sea report, United Nations Environmental Program. Barents Sea, Global International Waters Assessment. Regional assessment 11. University of Kalmar, Kalmar, Sweden.

Minckley, W. L., and **M. E. Douglas.** 1991. Discovery and extinction of western fishes: a blink of the eye in geologic time. Pages 7–17 *in* W. L. Minckley and J. E. Deacon, eds. Battle against extinction. University of Arizona Press, Tucson.

Palumbi, S. R., P. L. Sandifer, J. D. Allan, M. W. Beck, D. G. Fautin, M. J. Fogarty, B. J. Halpern, L. S. Incze, J-A Leong, E. Norse, J. J. Stachowicz, and **D. H. Wall.** 2008. Managing for ocean biodiversity to sustain marine ecosystem services. Frontiers in the Ecology and Environment 7: doi. 10.1890/0700135.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and **F. Torres Jr.** 1998. Fishing down marine food webs. Science 279 (5352):860–863.

Pauly, D., V. Christensen, S. Guénette, T. J. Pitcher, U. R. Sumalla, C. J. Waters, R. Watson, and **D. Zeller.** 2002. Towards sustainability in world fisheries. Nature 418:689–695.

Pauly, D., **and J. Maclean.** 2003. In a perfect ocean. The state of fisheries and ecosystems in the North Atlantic Ocean. Island Press, Washington, DC.

Petryashov, V. V., N. V. Chernova, S. G. Denisenko, and **J. H. Sundet.** 2002. Red king crab (*Paralithodes camtschaticus*) and pink salmon (*Oncorhynchus gorbuscha*) in the Barents Sea. Pages 147–152 *in* E. Leppakoski, E.S. Gollasch, and S. Olenin, eds. Invasive aquatic species of Europe. Distribution, impacts and management. Kluwer Academic Publishers, Dordrecht, Netherlands.

Randall, J. E. 1980. A survey of ciguatera at Enewetak and Bikini, Marshall Islands, with notes on systematics and food habits of ciguatoxic fishes. Fishery Bulletin 78:201–249.

______. 1987. Introductions of marine fishes to the Hawaiian Islands. Bulletin of Marine Science 41 (2):490–502.

______. 2007. Reef and shore fishes of the Hawaiian Islands. Sea Grant College Program, University of Hawaii, Honolulu.

Randall, J. E., and **V. E. Brock.** 1960. Observations on the ecology of epinepheline and lutjanid fishes of the Society Islands, with emphasis on food habits. Transactions of the American Fisheries Society 89(1):9–16.

Rodger, R. 2008. Stocking the North Atlantic. Canadian Marine Publications, summer 2008: 1–2. [Accessed at www.cmppublications.com/na_fisheries.htm, 7 August 2008].

Ruiz-Carus, R., R. E. Matheson, Jr., D. E. Roberts, Jr., and **P. E. Whitfield.** 2006. The western Pacific red lionfish, *Pterois volitans* (Scorpaenidae), in Florida: evidence for reproduction and parasitism in the first exotic marine fish established in state waters. Biological Conservation 138:384–390.

Semmens, B. X., E. R. Buhle, A. K. Salomon, and **C. V. Pattengill-Semmens.** 2004. A hotspot of non-native marine fishes: evidence for the aquarium trade as an invasion pathway. Marine Ecology Progress Series 266:239–244.

Simberloff, D., I. M. Parker, and **P. N. Windle.** 2005. Introduced species policy, management, and future research needs. Frontiers in Ecology and the Environment 3(1):12–20.

Sindermann, C. J. 1992. Role of the International Council for Exploration of the Sea (ICES) concerning introductions of marine organisms. Pages 367–376 *in* A. Rosenfield and R. Mann, eds. Dispersal of living organisms into aquatic ecosystems. Maryland Sea Grant Publication UM-SG-TS-92-04.

Smith-Vaniz, W. F, B. B.Collette, and **B. E. Luckhurst.** 1999. Fishes of Bermuda: history, zoogeography, annotated checklist, and identification keys. American Society of Ichthyologists and Herpetologists Special Publication 4. Allen Press, Lawrence, Kansas.

Streftaris, N., A. Zenetos, and **E. Papathanassiou.** 2005. Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. Pages 419–453 *in* Gibson, R. N., R. J. A. Atkinson, and J. D. M. Gordon, eds. Oceanography and marine biology: an annual review. Taylor and Francis, London.

Whitfield, P. E., T. Gardner, S. V. Vives, M. R. Gilligan., W. R. Courtenay, Jr., G. C Ray, and **J. A. Hare.** 2002. Biological invasion of the Indo-Pacific lionfish *Pterois volitans* along the Atlantic coast of North America. Marine Ecology Progress Series 235:289–297.

Whitfield, P. E, J. A. Hare, A. W. David, S. L. Harter, R. C. Munoz, and **C. M. Addison.** 2007. Abundance estimates of the Indo-Pacific lionfish *Pterois volitans/miles* in the western North Atlantic. Biological Invasions 9:53–64.

Zelenina, D. A., N. S. Mugue, A. A. Volkov, and **V. I. Sokolov.** 2008. Red king crab (*Paralithodes camtschaticus*) in the Barents Sea: a comparative study of introduced and native populations. Russian Journal of Genetics 7:983–991.

COLUMN:
DIRECTOR'S LINE

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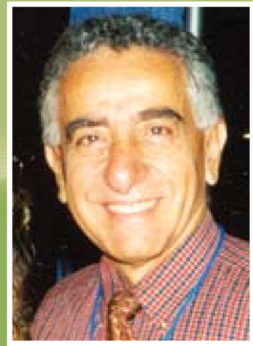


Issues of Concern to AFS

In March, AFS sent the following letter to U.S. federal agencies, Congressional committees, and others who set policy related to fisheries and fisheries professionals:

We welcome the new administration and Congress who have taken their place in the governance of these United States of America. The American Fisheries Society (AFS), a professional scientific society established in 1870 with a membership of over 9,000 scientists and managers worldwide, would like to highlight for you some of the major issues facing fisheries and fisheries professionals in the coming years. Our purpose in this letter is to initiate dialogue with you about these issues and demonstrate how we can work together to bring scientific information to inform debates involving fisheries.

Fisheries are major resources for the United States. These resources contribute to the national economy on many levels: as sources of protein and healthy diets, as providers of jobs, as opportunities for pleasurable outdoor activities, and as contributors to an array of industries from tourism to manufacturing that add billions of dollars annually to the U.S. economy.

Fisheries face multiple challenges and uncertain futures. In the past, lack of proper management, global competition for fish stocks, and inexorable demands placed by increased uses have put major strains on many important fish species, leading to the extirpation of some stocks and an increasingly fragile existence of others. Fishing communities throughout the United States have felt that pressure as well. Some have changed drastically, both economically and socially. Many of these changes affecting both the resource and the communities dependent on that resource are well documented in the scientific literature published by AFS, as well as in research reports presented at Society meetings. This information can be extremely valuable as an aid to setting government policy and initiating legislation.

Clearly, a major goal of U.S. fisheries policy should be to enhance the sustainability of existing fish stocks while rebuilding troubled stocks when feasible.

From that perspective, the following issues are of consequence in the formulation of such a policy:

Commercial and sport harvests—Overharvest of fish and other aquatic animals continues to reduce the overall sustainability of harvests and economic benefits to industries and people dependent on fisheries, as well as impact the quality of sport fishing and associated industries.

Habitat degradation—Widespread degradation of freshwater, estuarine, and marine ecosystems on which fish and other aquatic animals depend continues to occur. Coupled with increasing human populations and subsequent competition for water and land resources, that degradation leads to habitat loss which in turn threatens the sustainability of fisheries and the continued existence of species.

Global climate change—Alterations of aquatic ecosystems due to changes in precipitation patterns and air temperatures associated with global climate change threaten the sustainability of both freshwater and marine fisheries and numerous aquatic species throughout the world.

Invasive species—Nonnative species that establish themselves, proliferate, and cause deleterious changes in aquatic ecosystems are creating serious threats to the sustainability of many commercial and sport fisheries, as well as the continued existence of many species of native fishes and aquatic animals worldwide.

Declines and extinctions of species—Very large numbers of fish and other aquatic species, such as mussels and crustaceans, are experiencing declines and extinctions due to a variety of causes. These organisms provide a warning of the magnitude of alterations being experienced by aquatic systems throughout the world. The biological diversity needed to adapt to worldwide environmental change, as well as for potential human uses (fish farming, medicines, industrial products, etc.), is being lost.

Alterations of ecosystems due to diverse human activities—the effects of overharvest of fisheries, habitat degradation, global climate change, invasive species, and loss of species are having cumulative impacts, contributing to alterations of ecosystems and the services these systems provide to humans throughout the world.

As a professional society, we also have concerns for the future development of fisheries scientists and managers. It is critical that those professionals who work for government agencies are able to express their scientific views freely and to participate fully in professional societies such as AFS.

For AFS, it is especially important that agency staff are:

- Allowed and enabled to participate in the leadership of professional societies;
- Encouraged to publish their research and attend scientific meetings; and
- Rewarded for professional certification.

In addition, AFS, through its publications, scientific meetings, peer-reviewed position papers, and technical reviews, can provide information needed in debates regarding the effects of globalization of trade, economic growth, ecosystem-based management, increasing urbanization (Nature Deficit Syndrome), and "green" approaches to natural resource management.

We would appreciate the opportunity to enter into dialogue with you on ways and means that we can work together for the betterment of U.S. fisheries both today and into the future.

NEWS: AFS UNITS

Tom Gengerke (center) receives the FMS Hall of Excellence Award in Spirit Lake, Iowa, in August 2008. He is congratulated by Joe Larscheid (left) and Iowa Chapter President Mike Hawkins (right).

Fisheries Management Section *Presents 2008 awards*

The AFS Fisheries Management Section (FMS) recognized five outstanding fisheries professionals with awards in 2008. However, only one presentation was actually made at the FMS business meeting in Ottawa, Canada. The other awards were presented at four different venues in three different countries, making 2008 truly a year of international recognition for the FMS.

The highest honor given by the FMS is selection into the Fisheries Management Hall of Excellence (HOE). The hall is located at the AK-SAR-BEN Aquarium in Gretna, Nebraska, where plaques of inductees are prominently displayed. It was established in 1992 with the stated objectives:

1. To recognize fisheries management professionals who have made outstanding contributions to the advancement of fisheries management;
2. To provide a site where the contributions of those honored can be displayed and viewed by the public and other fisheries professionals;
3. To emphasize the accomplishment, dedication, and principles of those honored in the HOE; and
4. To describe the fisheries management profession.

In 2008, there were three inductees into the HOE:

- **Tom Gengerke** was recognized for his leadership in fisheries management both within the state of Iowa and regionally though his 35-year

Howard Tanner (center) receives his FMS Hall of Excellence Award from Kurt Newman (left) and Kelley Smith (right) in Roscommon, Michigan, on 5 November 2008.

career. His work on the Mississippi and Missouri rivers was instrumental in the development of several fisheries and water management plans. In Iowa, he facilitated record high walleye harvests at Clear Lake and Storm Lake, initiated commercial fishing programs for rough fish, and most notably permanently protected three large land tracts with 13,900 feet of shoreline on three natural lakes. Past President Joe Larscheid presented Gengerke with his award at the Department of Natural Resources office at Spirit Lake, Iowa, on 28 August 2008.

- **Howard Tanner** was recognized for his distinguished fisheries accomplishments, most notably for his collaboration with Wayne Tody in conducting the predator-prey research that led to the decision to introduce coho and Chinook salmon into the Great Lakes. These stockings, combined with sea lamprey control, restocking of lake trout, and converting commercial fisheries from gill nets to more selective trapnets, led to the emergence of the Great Lakes as a leading recreational fishing center of North America with an estimated $7.1 billion in economic output annually. Tanner received his award during a Lake Huron Citizens Fisheries Advisory Committee meeting in Roscommon, Michigan, on 5 November 2008.
- **Richard Whitney** was recognized for his exemplary, long-time accomplishments in West Coast fisheries management. He is perhaps best known for his role as technical advisor and chairman of the Fisheries Advisory Board for the U.S. District Court and its "Boldt Decision" on treaty fishing rights for Pacific salmon in Washington State. His contributions toward developing methodologies for in-season run-size updates moved salmon management into a fully quantitative system. Whitney received his award at the 2008 FMS business meeting in Ottawa, Canada, on 17 August 2008.

FMS Hall of Excellence Award winner Richard Whitney (center) displays his award and accepts congratulations from Joe Larscheid (left) and Ron Essig (right) in Ottawa, Ontario, on 17 August 2008.

The Award of Excellence is given for inspirational leadership in the fishery profession and substantial achievements for AFS and the fisheries resource. The recipients must have effectively communicated their work at the national and/or international level. This award is given for cumulative accomplishments rather than a singular effort. The 2008 Award of Excellence was made jointly to **Robert Arlinghaus** and **Ian Cowx.** Arlinghaus and Cowx were recognized for their many accomplishments and leadership in the field of recreational fisheries management at the international scale. Their collaboration on disseminating research and knowledge to the masses through books, articles, short courses, and symposia; thinking globally on such issues as a Global Code of Conduct for recreational fisheries; and crossing boundaries to incorporate human dimensions into the ecosystem approach to fisheries management demonstrate their excellence as fisheries scientists within the world community. Ron Essig presented the award to Arlinghaus at the International Fisheries Section business meeting in Ottawa, Canada, on 19 August 2008, and to Cowx at the Institute of Fisheries Management conference in Leeds, England, on 15 October 2008.

—Ron Essig

Robert Arlinghaus (left) accepts the FMS Award of Excellence from Ron Essig in Ottawa, Ontario, on 19 August 2008.

Ian Cowx (right) accepts the FMS Award of Excellence from Ron Essig in Leeds, England, in October 2008.


2008 John E. Skinner Memorial Travel Award winners

GARRY WISE

Join the Education Section: A Great Way to Become Involved in AFS!

Julianne E. Harris
Harris is a Ph.D. student in Fisheries and Wildlife Sciences at North Carolina State University and can be contacted at jeharris@ncsu.edu.

Student members of the American Fisheries Society (AFS) are involved in their Student Subunits, Chapters, Divisions, and the parent Society. Participation in AFS is a great way to learn about fisheries research, practice professional skills, and socialize with past, present, and future colleagues. By serving as an officer or organizing service events in their Subunits, students can improve leadership and outreach skills and help build networks among students, faculty, and professionals within and near their universities. Just as important as professional development, these interactions give students the opportunity to better integrate themselves into the larger community of scientists and administrators where they plan to play roles throughout their professional careers. Even with attendance and participation in AFS, students may be less aware of the opportunities available in the many diverse AFS Sections and how they might benefit from becoming involved in that capacity. Involvement in an AFS Section is rewarding both professionally and personally, and students can contribute through membership, committee service, or holding office in an AFS Section.

AFS Sections strive to provide services to members of the Society and to improve communication among members and between the scientific community and the public. Each Section has a unique focus and can respond to the specific needs of some or all AFS members. The Education Section was founded in 1979 and is dedicated to improving the quality of education for fisheries students, educators, and the public. The Section is committed to the development of future fisheries professionals, and as such, mentors the Student Subsection of AFS, a group governed by students from a variety of universities and directly concerned with the specific needs and contributions of fisheries students. The Education Section is an asset to student AFS members and is a great place for students to become more involved in the Society.

WHAT DOES THE EDUCATION SECTION DO?

Much additional information about the goals, services, and activities of the Education Section, as well as their bylaws, and lists of present and recent officers and committee chairs, can be found on the Section's website (www.fisheries.org/units/education/). This webpage also provides information about fisheries/marine science programs at universities in North America, as well as requirements for AFS certification. The specific goals of the Education Section as stated in their bylaws are the following:

1. Improve the quality of college and university education for fisheries scientists.
2. Promote exchange of post-secondary education information, techniques, and materials among educators and among educational institutions.
3. Foster improved communication and information exchange among fishery educators, employers, fisheries specialists, students, and the public.

The Education Section serves the fisheries community through a variety of activities. The Section leads the planning aspects of resolutions related to educational issues, such as the recent "Evolution in Education Resolution" regarding the teaching of evolution in public primary and secondary schools. Additionally, the Section financially supports and organizes publication of new books and new editions of common textbooks used by professionals and students, including *Fisheries Techniques* (presently completing the 3rd edition, editors: Zale, Parrish, and Sutton), *2nd edition of Employment in Fisheries Sciences* (editors: Hewitt, Zale, and Pine), and *Analysis and Interpretation of Freshwater Fisheries Data* (editors: Guy and Brown).

To reward excellence in students and educators, the Education Section annually administers a number of Society-level awards. The Excellence in Fisheries Education Award is given to a member of the fisheries community who has shown excellence in teaching and mentoring for at least 10 years. This award is a great honor and serves to recognize a highly dedicated and talented educator. The Education Section also administers two types of awards for students, the John E. Skinner Memorial Travel Award and the AFS/Sea Grant Outstanding Student Presentation Award and Poster Award. The Skinner Award is competitive and enables graduate and undergraduate students (presently about 10 full awards and about 5 honorable mentions) to present their research at the international level by providing funding for travel to the AFS Annual Meeting. The Education Section also regularly augments the Skinner Fund to increase the number of awarded students in future years. The AFS/Sea Grant Outstanding Student Presentation and Poster Awards recognize exceptional research and presentation skills. These awards are given to the best student platform and poster presentations in the Best Student Presentation Symposium at the AFS Annual Meeting. The Education Section has worked extensively with the Student Subsection in the last few years to initiate the Best Student Presentation Symposium and to improve judging protocol.

The Education Section has also benefited student AFS members by mentoring the AFS Student Subsection. As a result of being a subsection of the Education Section, Student Subsection officers actively participate in Section activities. Section leaders initially worked extensively with the Student Subsection on a variety of projects including student/

mentor lunches and colloquiums at AFS Annual Meetings. These projects are now regular activities at the Annual Meeting and are organized and carried out by the Subsection. The student/mentor lunch pairs a student with a professional in their area of interest for a lunch outing. Colloquiums focus on topics of interest to students, such as publishing, presenting research, and career choices.

HOW CAN STUDENTS BECOME INVOLVED IN THE EDUCATION SECTION?

The easiest way to become involved in the Education Section is to join! Students can become members of the Education Section when renewing their memberships in the parent Society simply by checking the box to be an Education Section member (new AFS student members can do the same). Section membership is FREE to student members of AFS. Members receive e-mail updates on activities and are offered opportunities to propose and vote on issues pertinent to the Section such as the use of funds generated partially by the sale of published texts. Some proceeds from sales are directed to support student activities, such as providing additional funding for the Skinner and Equal Opportunities Travel Awards, which both support student travel to Annual Meetings. Recently, the Education Section voted to support the Hutton program, which sponsors high school students considering the fisheries profession through a summer internship project where the student works directly with fisheries biologists and managers.

The Education Section holds a meeting each year at the AFS Annual Meeting and Section members and non-members are encouraged to attend and participate. Education Section meetings are informative and valuable to students by providing opportunities to meet Section members, observe how an AFS Section operates, hear updates on the progress of new books, listen to proposals, contribute comments or suggestions, and learn about opportunities to join committees or help with projects. Also, during these meetings, awards administered by the Education Section are given, which is a great chance to hear about the accomplishments and productivity of fellow students and professionals.

Student members of the Education Section can participate more actively by becoming a committee member or chair. The Education Section has numerous permanent, ad-hoc, and special committees responsible for various projects. Permanent committees with student positions include: Newsletter, Excellence in Fisheries Education Award, Skinner Award, and Student Paper/Poster Award. Newsletter editors are appointed by the president elect and student Education Section members have jointly held the position. The newsletter mainly reports on activities and proposals in the Section, but also includes short articles on mentoring students, teaching, and educating the public, as well as announcements on student colloquiums, special meetings, and spotlights on Student Subunits. These newsletters can be viewed on the Education Section's website. The Excellence in Fisheries Education Award Committee reviews applications and selects the recipient of the award. Similarly, the Skinner Award Committee examines applications and chooses which students will receive travel awards to attend the AFS Annual Meeting. Members of the Student Paper/Poster Awards Committee are responsible for organizing the Best Student Presentation Symposium at the Annual Meeting. More specifically, committee members call for and review applications, organize the symposium, and recruit judges for the presentations. The Membership Committee is in charge of recruiting new members to the Education Section and might benefit from the addition of a student member, since students may be able to contribute alternative ideas and avenues to recruit new student members. Student committee members often serve one annual term, but some serve longer, such as the newsletter editors. To learn more about volunteer service on a committee, contact the chair of the committee that interests you. A list of committee chairs and their e-mail addresses can be found on the Education Section's website.


2008 John E. Skinner Memorial Travel Award runners-up

GARRY WISE

FINAL COMMENTS: WHY SHOULD STUDENTS JOIN THE EDUCATION SECTION?

Participation in the Education Section gives students opportunities for leadership, networking, and professional development which can help them gain the skills needed for future leadership in AFS and the scientific community as a whole. Service in the Education Section can be included on a resume and, along with academic and research excellence, is a consideration for numerous AFS travel awards and scholarships, such as the Skinner Award. Through membership in one of the various committees, students can serve the fisheries community in ways that best suit their individual interests and talents. Fisheries students are highly valuable as members of the Education Section and its committees because they are immersed in education and can contribute unique perspectives on educational needs and fresh ideas on committee projects. However, with time always short and so much to do and learn in classes and through research, it might seem difficult to add more to the plate. The amount of time invested for service to the Education Section depends on individual ambition and can be incredibly rewarding both professionally and personally. Service in the Education Section gives students the opportunity to give back to a community that continues to make education better.

REFERENCES

Guy, C. S. and **M. L. Brown (editors).** 2007. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Hewitt, D. A., W. E. Pine, III, and **A. V. Zale (editors).** 2006. The AFS guide to fisheries employment, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Murphy, B. R. and **D. W. Willis (editors).** 1996. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland. (3rd edition in progress: Zale, Parrish, and Sutton, editors).

ACKNOWLEDGMENTS

I thank Tom Kwak, president of the Education Section, for insights and information on the Education Section, and for reviewing an earlier draft of this article. I would also like to thank Patrick Cooney, Joe Hightower, Steve Midway, and Kristal Schneider for their very helpful comments on earlier drafts of this article.

CALL FOR AWARD NOMINATIONS:
2009 AMERICAN FISHERIES SOCIETY AWARDS

The American Fisheries Society is seeking nominations and applications for several 2009 awards. Award recipients will be honored at the Annual Meeting in Nashville, Tennessee, August 2009. Nominations typically require a candidate's name, full contact information, biographical information, and/or history of service to the Society. Some awards require additional nomination materials. For more information on how to nominate an individual, or organization, see descriptions below or contact the award chair. You may also contact Gail Goldberg, AFS awards coordinator, at ggoldberg@fisheries.org or 301/897-8616 x201 for more information.

Award of Excellence

Presented to an AFS member for original and outstanding contributions to fisheries and aquatic biology.

Nomination deadline: 17 April 2009
Contact: Margaret H Murphy
Quantitative Environmental Analysis, LLC
290 Elwood Davis Rd
Liverpool, NY 13088
Phone: 315/453-9009
Fax: 315/453-9010
E-mail: mmurphy@qeallc.co

Carl R. Sullivan Fishery Conservation Award

Presented to an individual or organization for outstanding contributions to the conservation of fishery resources. Eligibility is not restricted to AFS members, and accomplishments can include political, legal, educational, scientific, and managerial successes. Nominations should include a synopsis of fishery conservation contributions; a description of the influence of those contributions on improved understanding, management, or use of fishery resources; and at least one additional supporting letter.

Nomination deadline: 16 April 2009
Contact: Don Jackson
Mississippi State University Box 6960
Department of Wildlife and Fisheries
Mississippi State, MS 39762
Phone: 662/325-7493
Fax: 662/325-8726
E-mail: djackson@cfr.msstate.edu

Excellence in Public Outreach

Presented to an AFS member who goes the "extra mile" in sharing the value of fisheries science/research with the general public through the popular media and other communication channels. Two or more individuals may act as nominators, but at least one nominator must be an AFS member. Entries must include a biographical sketch of the nominee (not to exceed three pages) and supporting evidence of communicating the value of fisheries issues/research to the general public through the media and other communication channels, plus any evidence of teaching others about communication with the public.

Nomination deadline: 5 May 2009
Contact: Jan Konigsberg
E-mail: jkberg@gci.net

Honorary Membership

Presented to individuals who have achieved outstanding professional accomplishments or have given outstanding service to the Society. Honorary Members must be nominated by at least 100 active members and elected by a 2/3 majority of active members online.

Nomination deadline: 1 May 2009
Contact: Gail Goldberg
American Fisheries Society
5410 Grosvenor Lane, Suite 110
Bethesda, MD 20815
Phone: 301/897-8616 x201
E-mail: ggoldberg@fisheries.org

Meritorious Service Award

Presented to an individual for loyalty, dedication, and meritorious service to the Society throughout the years and for exceptional commitment to AFS's programs, objectives, and goals.

Nomination deadline: 1 May 2009
Contact: Patricia M. Mazik
West Virginia University
WVCFWRU
322 Percival Hall
Morgantown, WV 26506-6125
Phone: 304/293-3794 x2431
Fax: 304/293-4826
E-mail: pmazik@wvu.edu

Outstanding Chapter Award

Recognizes outstanding professionalism, active resource protection, and enhancement programs, as well as a strong commitment to the mission of the Society. Three awards are given, one for small Chapters, one for large Chapters, and one for a Student Subunit of a Chapter. Chapters should submit an application to their Division presidents to be considered. Division presidents must nominate two best Chapters from their Divisions, one with less than 100 members and another with 100 members or more by 1 June 2009 Applications can be obtained from the AFS website (see the main awards page for more information).

Nomination deadline: 1 June 2009
Contact: Desmond Kahn
Delaware Fish and Wildlife
P.O. Box 330
Little Creek, DE 19961-0330
Phone: 302/739-4782
Fax: 302/739-6780
E-mail: Desmond.kahn@state.de.us

The Emmeline Moore Prize: A New AFS Award to Recognize Career Achievement in the Promotion of Diversity in the Society, the Workplace, and in Education

This award recognizes the efforts of an individual AFS member who has demonstrated exemplary service to the cause of equal opportunity of access to higher education in fisheries and/or to professional development in any of the disciplines of fisheries science and/or management. The award is named for Emmeline Moore, the first female president of the American Fisheries Society, elected in 1927–28.

Nominations close on 31 May 2009.

Please forward nominations for this award to:
Larry A. Alade
Chair, AFS Emmeline Moore Prize Committee
NOAA Fisheries
NEFSC / Woods Hole Laboratory
166 Water Street
Woods Hole, MA 02543

Phone: 508/495-2085

Fax: 508/495-2393

E-mail: Larry.alade@noaa.gov

President's Fishery Conservation Award

Presented in two categories: (1) an AFS individual or Unit, or (2) a non-AFS individual or entity, for singular accomplishments or long-term contributions that advance aquatic resource conservation at a regional or local level. The award is administered by the Past President's Advisory Council. A nomination package should include a strong and detailed letter describing the nominee's contribution and the evidence for accomplishment at a regional or local level. If the nomination is for an individual, include a CV if possible. Nominations may be supported by multiple individuals by signing one nomination letter, or by submitting supporting letters in addition to the main nomination letter. Include the nominee's title and full contact information (address, e-mail, phone).

Nomination deadline: 15 May 2009
Contact: Mary C. Fabrizio
Virginia Institute of Marine Science
Department of Fisheries Science
Box 1346, Gloucester Point, VA 23062
Phone: 804/684-7308
Fax: 804/684-7327
E-mail: mfabrizio@vims.edu

William E. Ricker Resource Conservation Award

Presented to any entity (individual, group, agency, or company) for accomplishment or activity that advances aquatic resource conservation that is significant at a national or international level. The award is administered by the Past President's Advisory Council. A nomination package should include a strong and detailed letter describing the nominee's accomplishments and the evidence for being "significant at a national or international level." If the nomination is for an individual, include a CV if possible. Nominations may be supported by multiple individuals by signing one letter, or by submitting supporting letters in addition to the main nomination letter. Include the nominee's title and full contact information (address, e-mail, phone).

Nomination deadline: 15 May 2009
Contact: Mary C. Fabrizio
Virginia Institute of Marine Science
Department of Fisheries Science
Box 1346, Gloucester Point, VA 23062
Phone: 804/684-7308
Fax: 804/684-7327
mfabrizio@vims.edu

Retired Members Travel Award for the AFS Annual Meeting

The American Fisheries Society has established this travel award to encourage and enable members of the Society to attend Annual Meetings, particularly those members who might play a more active role in the meeting. The Society recognizes that some retired members who desire to participate in the Annual Meeting might be inhibited for financial reasons. Retired members may not have funds for travel to meetings that were available to them while employed. Therefore, this award is meant for those members who truly have a need for financial assistance. The Society has neither means nor desire to verify financial need, so that your request for support is based on an honor system. However, you must be a dues-paying retired member of the American Fisheries Society to apply. A maximum of $1,500 may be awarded for reimbursable expenses. See the main awards page on the AFS website for the application form.

Nomination deadline: 9 June 2009
Contact: Mary C. Fabrizio
Virginia Institute of Marine Science
Department of Fisheries Science
Box 1346, Gloucester Point, VA 23062
Phone: 804/684-7308
Fax: 804/684-7327
E-mail: mfabrizio@vims.edu

Student Writing Contest

Recognizes students for excellence in the communication of fisheries research to the general public. Undergraduate and graduate students are asked to submit a 500- to 700-word article explaining their own research or a research project in their lab or school. The article must be written in language understandable to the general public (i.e., journalistic style). The winning article will be published in *Fisheries*. Students may write about research that has been completed, is in progress, or is in the planning stages. The papers will be judged according to their quality and their ability to turn a scientific research topic into a paper for the general public.

Submission deadline: 5 May 2009
Contact: Jan Konigsberg
E-mail: hydro@gci.net

AWARD ADMINISTERED BY EDUCATION SECTION

Excellence in Fisheries Education Award

The Excellence in Fisheries Education Award was established in 1988. The award is administered by the Education Section and is presented to an individual to recognize excellence in organized teaching and advising in some aspect of fisheries education. Nominees may be involved in extension or continuing education, as well as traditional college and university instruction. Nominees must be AFS members, have been actively engaged in fisheries education within the last 5 years, and have had at least 10 years of professional employment experience in fisheries education. Two or more people may act as nominators, but at least one nominator must be an AFS member. The nominator(s) is responsible for compiling supporting material and submitting the application. The suggested format for applications can be found on the Education Section web site. Application materials should be sent to Michael Quist (mcquist@iastate.edu) in digital form.

Nomination deadline: 15 May 2009.

Contact: Michael Quist
Department of Natural Resource Ecology and Management
Iowa State University
339 Science II
Ames, IA 50011
Phone: 515/294-9682
Fax: 515/294-2995
E-mail: mcquist@iastate.edu

AWARD ADMINISTERED BY EDUCATION SECTION

John E. Skinner Memorial Fund Award

The John E. Skinner Memorial Fund was established in memory of John Skinner, former California-Nevada Chapter and Western Division AFS President. The fund provides monetary travel awards for deserving graduate students or exceptional undergraduate students to attend the AFS Annual Meeting. The 2009 meeting will be held in Nashville, Tennessee, 30 August–3 September. Any student who is active in fisheries or related aquatic disciplines is eligible to apply. Awardees are chosen by a committee of the AFS Education Section. Selection is based on academic qualifications, professional service, and reasons for attending the meeting. Travel support (up to $800 per award) will be made available to successful applicants. Award winners will also receive a one-year paid membership to the American Fisheries Society. See the main awards page for Skinner Award Applications —"Part 1 Student" and "Part 2 Faculty."

Nomination deadline: 8 May 2009

Contact: Joseph E. Hightower
U.S. Geological Survey
NC Cooperative Fish and Wildlife Unit
Campus Box 7617 NC State University
Raleigh, NC 27695
Phone: 919/515-8836
Fax: 919/515-4454
E-mail: jhightower@ncsu.edu

CALENDAR: FISHERIES EVENTS

Date	Event	Location	Web
Apr 17-19	**Fisheries and Marine Ecosystems Network Sixth Annual Graduate Student Conference**	Crescent Beach, British Columbia	www.fameconference.org
Apr 17-19	**Sixth Annual Graduate Student Conference**	Cresscent Beach, British Columbia	www.fameconference.org
Apr 26-29	**65th Annual Northeast Fish and Wildlife Conference and AFS Northeastern Division Annual Meeting**	Lancaster, Pennsylvania	www.neafwa.org
May 3-7	**Western Division Annual Meeting—Evolution of the Western Landscape: Balancing Habitat, Land, and Water Management for Fish**	Albuquerque, New Mexico	www.aznmfishsoup.org/wdafs09/index.htm
May 22-26	**Third and Last GLOBEC Open Science Meeting**	Victoria, British Columbia, Canada	www.globec.org
May 25-29	**World Aquaculture 2009**	Veracruz, Mexico	www.was.org
Jun 1-11	**Indo Pacific Fish Conference and Australian Society for Fish Biology**	Fremantle, Western Australia	www.asfb.org.au/events
Jun 14-19	**Seventh International Conference on Molluscan Shellfish Safety**	Nantes, France	www.icmss09.com
Jun 16-17	**World Ocean Council—Sustainable Ocean Summit**	Belfast, Ireland	www.oceancouncil.org
Jun 16-18	**Hydroacoustic Lake Survey Workshop**	Bear Lake, Utah	www Workshop2009@HTIsonar.com
Jun 23-26	**International Paleolimnology Symposium**	Guadalajara, Jalisco, Mexico	www.paleolim.org
Jul 20-24	**Sixth International Fisheries Observer and Monitoring Conference**	Portland, Maine	www.st.nmfs.noaa.gov/iformc209
Jul 22-27	**Early Life History Section's 33rd Annual Larval Fish Conference and American Society of Ichthyologists and Herpetologists Conference**	Portland, Oregon	www.dce.k-state.edu/conf/jointmeeting
Aug 14-17	**Aquaculture Europe 2009**	Trondheim, Norway	www.easonline.org
Aug 24-27	**Sixth International Conference on Marine Bioinvasions**	Portland, Oregon	www.clr.pdx.edu//mbicd
Aug 30-Sep 3	**American Fisheries Society 139th Annual Meeting**	Nashville, Tennessee	www.fisheries.org
Sep 16-19	**World Fishing Exhibition 2009**	Vigo, Spain	www.worldfishingexhibition.com
Sep 21-25	**International Council for the Exploration of the Sea Annual Science Conference**	Berlin, Germany	www.ices.dk
Nov 3-6	**Asian-Pacific Aquaculture 2009**	Malaysia	www.was.org
Dec 9-12	**Fourth Shanghai International Fiseries and Seafood Expo**	Shanghai, China	www.gehuaexpo.com

Continued from page 160

for me to present this award to him personally during the annual banquet.

The remaining 2.5 days of the IFM conference were devoted to topical sessions on current legislation and barriers to fish passage, habitat, understanding, participation, cooperation, and fish health. There was far too much information from these presentations than space here to review, but I'd like to share a few of the main themes that I carried away from the meeting:

- **Water Framework Directive (WFD)—**This major European Union (EU) legislation passed in 2000 with a 15-year target date for European waters to achieve "good ecological status," or for heavily modified waters to achieve "good ecological potential." There is disagreement still on what these terms mean and how to measure them, creating implementation problems. The WFD provides authority for many fisheries management activities like provision of fish passage for all species in inland waters.
- **Fish passage**—Most rivers in Europe are heavily modified, mostly with weirs and associated canals for navigation. For example, there are 2,600 barriers just within the Netherlands. There is increasing government support for small-scale hydropower development as a "green," renewable energy source. So European fisheries biologists are devoting more and more time on the development of fish passes like the award-winning Castleford pass on the River Aire that we visited one afternoon during the conference.
- **European eel declines**—Recruitment of this species has declined over much of Europe since the 1980s to about 10% of former levels. All countries in the EU are required to submit management plans for this species by the end of 2008. Provision of upstream passage of elvers and downstream passage of silver eels is now commonly provided with fish passage projects.
- **Fish diseases**—A new European Aquatic Animal Health Directive has effectively loosened current control practices so that fish can be moved more freely within the EU. There are current outbreaks of red vent syndrome in Atlantic salmon and koi herpes virus. It is thought that climate change will increase fish disease risks.
- **Trout stocking**—England's new policy for recreational trout stocking is to use either triploid trout or brown trout from local broodstock. Annually, private growers raise 800,000 brown trout for streams and 2.6 million rainbow trout for stillwaters. A guide to the production of all female triploid brown trout was published in 2005.
- **Aquatic resource education**—England is moving from a "Trout in Tanks" program in schools to a "Sticklebacks in Schools" program. This is primarily to save the money previously needed to chill aquaria for salmonids. The IFM decided to provide a significant portion of the raffle proceeds from this meeting toward this effort.
- **Angling participation**—England has about 4 million anglers (8% of the age 12+ population) compared to 30 million anglers in the United States (13% of the age 16+ population). Rod license sales have increased in recent years, contrary to the recent U.S. decline in fishing license sales. There are some free fishing areas, primarily in saltwater and along urban rivers, but most anglers either need to be members of angling clubs or pay a daily fee to fish on privately-held waters.
- **Canoeing conflicts**—There is much less boat-based angling in England than in the United States, however canoeing and kayaking are increasing 15% each year. So there are inevitable conflicts when these boaters use rivers where shore anglers have paid to fish. Time and space zoning may be needed.
- **Atlantic salmon**—Contaminant effects on smolt production is a contributor to depressed adult population levels in many rivers. However, in the 2000s salmon returned to and spawned in the Mersey River near Manchester after being gone for over 150 years. Elimination or severe restrictions imposed on commercial salmon fisheries off two rivers in England resulted in increases in recreational catch-per-unit-effort. However, recreational effort has decreased through time as the average age of salmon anglers has increased.
- **Estuarine sampling**—It has only been within the past decade that England has come to fully recognize the importance of estuaries to marine fisheries production. There has been standardized sampling, primarily with fyke nets and seines, in 27 estuaries nationwide during the past 3 years.

International transfer of fisheries information was one of the benefits envisioned by the FAS and FMS when they approved the officer exchange arrangement with IFM in 2004. It was to be on a four-year trial basis with the host organization covering the cost of the meeting registration and accommodations. Since this was the fourth such visit to the IFM conference by AFS representatives, an evaluation was conducted this past winter. Based on overwhelming support by FAS and FMS members, the AFS Governing Board approved the continuance of this exchange program at its March 7, 2009 meeting. So both AFS Sections look forward to welcoming IFM Chairman Ian Dolben to the 2009 AFS meeting in Nashville and participating in the 2009 IFM conference in Stratford-upon-Avon, England (Shakespeare's birthplace and final resting place).

I hope these observations have added to your knowledge of fisheries issues in Europe, particularly England. You can see that in spite of our differences, there are indeed many similarities on both sides of the pond. I anticipate that these thoughts will also be published in Fish, the magazine of the IFM, as an American perspective on the 2008 conference. To the IFM delegates at the Leeds conference who I had the pleasure of meeting and who welcomed me so warmly, I extend my sincere appreciation. My congratulations to all for a superb conference!

AMERICAN FISHERIES SOCIETY
APPLICATION FOR COMMITTEE APPOINTMENT

As a small organization, AFS depends on volunteers for many tasks related to the science and the profession. Committees at all levels of the American Fisheries Society (AFS) provide many ideas that shape the future of the Society, and they are excellent avenues for members to begin or continue volunteer service to AFS. We encourage new members to contact their Chapter, Division, and Section officers to volunteer their services. We encourage experienced members, including students, to apply for AFS Committee appointments. (AFS committee terms are considered by the incoming AFS President for appointment starting in September) By volunteering at one or more of these levels, a member gains experience and leadership skills

Please number, in order of priority, no more than two (2) Committees on which you would like to serve:

____ Associate Editor on a Journal
____ Awards
____Ballot Tally
____Board of Professional Certification
____Continuing Education
____Endangered Species
____Ethics and Professional Conduct
____External Affairs
____Hutton Junior Fisheries Biology
____Investment
____Meetings Overview
____Membership
____Membership Concerns
____Names of Aquatic Invertebrates
____Names of Fishes
____Program
____Publications Award
____Public Policy Guidance
____Publications Overview
____Resolutions
____Resource Policy
____Task Force on Fishery Chemicals
____Time and Place
____Web Advisory
____Other
____

I AM NOW SERVING ON THE FOLLOWING COMMITTEE(S):
(Please indicate level--Chapter, Division, Section, Society)

....

....

I HAVE HAD EXPERIENCE ON THE FOLLOWING COMMITTEE(S):
(Please indicate level--Chapter, Division, Section, Society)

....

....

I CAN CONTRIBUTE TO THE COMMITTEE(S) INDICATED ABOVE BECAUSE (optional):

....

....

(Continue on back if more space is needed)

NAME: .... **DAYTIME PHONE**: ....

ADDRESS: ....

CITY: .... **STATE, ZIP:** ....

COUNTRY:... **FAX**:...............................

AFS MEMBERSHIP #:... **E-MAIL**: ....

CURRENT EMPLOYER: ....

☐ Self-employed, ☐ retired, ☐ undergrad, ☐ M.S, ☐ Ph.D. student, or ☐ postdoc at the following university: ....

SIGNATURE: ....

Please complete and return form for consideration to:
Unit Services Coordinator
American Fisheries Society
5410 Grosvenor Lane, Suite 110
Bethesda, MD 20814-2199
e-mail: ggoldberg@fisheries.org

Clarification regarding the article *Fishery closure "windows" scheduling as a means of changing the Chinook salmon subsistence fishery pattern: Is it an effective management tool?* (*Fisheries* 33[10]: 495-501).

On page 497 it is stated that "The primary objective of the windows was not to reduce total Chinook salmon subsistence harvests (*since there are no harvest limits in subsistence fisheries*), but to reduce the harvest early in the season (Burkey et al. 2002)" [emphasis added]. While it is correct that there are no regulatory harvest limits for the subsistence salmon fishery in the Kuskokwim River system, there are in some other systems in Alaska. Also, in this river system, as elsewhere in Alaska, conservation of the resource is a first principle in both federal and state regulation. Although subsistence is the priority use, it is not at the expense of resource conservation. A statement made earlier on page 497 captures this more accurately in noting that "The subsistence fishery is conducted with fewer restrictions and without harvest limits, unless the number of returning salmon is too low to meet the escapement."

While on the one hand this clarification may seem a fine point, we felt it important to not allow for this well-intentioned article to inadvertently contribute to a misunderstanding of subsistence fisheries management in the broader professional community.

—Toshihide Hamazaki,
Alaska Department of Fish and Game, and
Lawrence S. Buklis,
U.S. Fish and Wildlife Service, Anchorage, Alaska

2009 American Fisheries Society
OFFICER ELECTION

This ballot is only to be used by members who ***did not*** receive an e-mail with online voting privileges.

To be valid, your ballot must be received no later than **Friday, 12 June 2009**.
AFS Officer Election
5410 Grosvenor Ln. Ste 110
Bethesda, MD 20814

Officers: (See March *Fisheries* for candidate biographical information.)

Second Vice President: (Vote for one.)
__________ John Boreman
__________ Margaret H. Murphy
__________ Other

First Vice President:
__________ Bill Fisher (current Second Vice President)

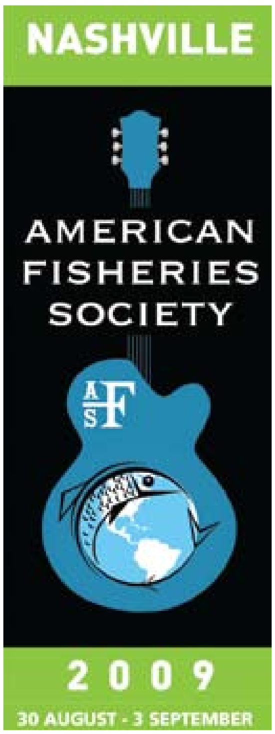
President Elect:
__________ Wayne A. Hubert (current First Vice President)

President:
Donald C. Jackson will be installed as President for 2009–2010 at the Annual Meeting in Nashville, TN.
(Current AFS President William Franzin, will preside at the 2009 Annual Meeting.)

YOUR NAME ____ MEMBER NUMBER ______________________________
ADDRESS ____
E-MAIL ____

SIGNATURE ____

AFS ANNUAL MEETING:
DIVERSITY, THE FOUNDATION OF FISHERIES AND OF AFS



PLENARY SESSION

The theme of the 139th Annual Meeting is "Diversity, the Foundation of Fisheries and of AFS: Are We Gaining Ground?" We will have four plenary speakers to deliver the answer to this question:

Jeff Hutchings of Dalhousie University and chair of COSEWIC (Committee on the Status of Endangered Wildlife in Canada, the Canadian Endangered Species Act organization) will be speaking on marine biodiversity;

Peter Moyle of the University of California Davis will be speaking on freshwater biodiversity in North America and elsewhere;

Doug Austen, executive director of the Pennsylvania Fish and Boat Commission and longtime member of the National Fish Habitat Action Plan will be talking about fish habitat in freshwater and marine systems;, and

Ambrose Jearld of the NOAA's Northeast Fisheries Science Center will be talking about diversity in AFS, the fisheries workplace, and in the populations from which we get our members.

We have not addressed these topics since the late 1990s and it is time to take stock and hear how we are doing at maintaining fisheries sustainability and improving diversity in our profession.

PROGRAM UPDATE

The AFS'09 Planning Committee is pleased to report that our colleagues from around the world stepped up to the plate and submitted plenty of symposium proposals. At the time this issue of *Fisheries* went to press, we are able to report that the following topics will be covered in half-day, full-day, and two-day symposia:

Functional Genomics and Changes in Gene Expression Assays in Aquaculture and Fisheries Research
Conservation of Genetic Diversity in Unexploited Populations
Pacific Cod: Biology, Population Structure, Stock Assessment, and Fisheries
Society's Role in Understanding and Protecting Instream Flows
Carp Biology and Control Across Continents and Hemispheres
Energy Production and Fisheries in the Coastal Zone
Striper 2009: Inland Striped Bass and Hybrid Striped Bass Management
Fisheries Science in the Year of Science
Collaborative Development of a North American Spatial Framework for Rivers Assessment and Classification
Acipenseriformes in North America—Where Do We Stand in 2009?
Incorporating Environmental Factors in Stock Assessment
Mapping the Distributions of the Freshwater Fishes of North America: Data and Tools
Demographic Diversity in Natural Resource Science Professions: Towards an Inclusive Scientific Democracy
Status, Conservation and Management of Endemic Black Bass Species in the Southern United States
Promoting Innovation in Fish Passage and Protection
Reframing the Argument for Sustainable Global Fisheries: Resources, Policy, Governance, Business Strategies, and Management
Monitoring, Characterizing, and Managing Big River Fish Communities
Inland Fisheries—The Hidden Crisis
Bioelectrical Impedance Analysis to Measure Condition, Body Composition, and Energy Content in Fish
Catch Share Management: Experience and Performance
Fisheries Education in the 21st Century: Accommodating Change
Lake Trout: Threats to the Diversity of Native Western Salmonids
Advances in Tagging and Surgical Procedures
Bycatch Reduction Developments
USDA Natural Resources Conservation Service: Linking Private Landowners with the Science for Effective Conservation Management of Aquatic Biodiversity in North America
Headwater Streams III: Linkages, Function, and Diversity
Fisheries in a Changing Climate: Guidance for Decision-Makers and Resource Managers
Enhancing Conservation of Freshwater Fishes through Diverse Partnerships

STUDENT ACTIVITIES

If you are a fisheries student, you need to be at the AFS'09 meeting in Nashville!

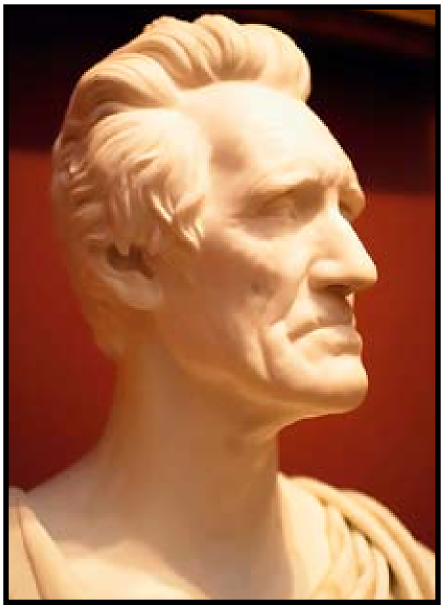
Members of the Nashville Planning Committee and the Education Section are working hard to maintain the same level of commitment to fisheries students established by our predecessors. The cost to register for students who are AFS members ($100) will once again be well below the registration cost for regular AFS members ($330). For the third year in a row, a Student Symposium will be hosted by the Education Section, showcasing some of the best and brightest young talent in our Society, with awards going to the Best Oral Presentation and Best Poster. A student-mentor luncheon is once again being planned; look for details soon on our website and in future issues of *Fisheries*. The tradition of having a Student Colloquium will also be upheld; this year's colloquium (being sponsored by the Student Subsection of the Education Section) will be titled "A Fisheries Science Career: Perspectives from Interview to Retirement." Speakers will discuss landing that first job, future challenges, and career perspectives. An off-site Student Social on Tuesday night (September 1st) will give students an evening to network, interact with each other, and let their hair down at the famous Wild Horse Saloon just down the street. The Student Subsection of the Education Section will once again be working tirelessly to provide students with helpful feedback on presentations given outside of the Student Symposium, but they need your help! Anyone can provide constructive criticism for student papers and posters on forms that will be provided at the meeting. Details on where to pick-up and drop-off evaluation forms will be provided onsite and in future *Fisheries* articles. But wait—there's more! The Education Section (what a bunch of hard-chargers!) will be also be sponsoring a "regular" symposium entitled "Fisheries Education in the 21st Century: Accommodating Change" that will feature 15+ speakers in a day-long gathering of our brightest, most dedicated educators. Most of these student activities occur on Tuesday (September 1st), so mark your calendars now!

THINGS TO DO AND SEE

in Nashville have been described in previous issues of *Fisheries* and are listed on our website (**www.fisheries.org/afs09/tours.html**). The Country Music Hall of Fame, the Frist Fine Arts Museum, and numerous (and colorful) honky-tonk bars and music venues—they're all near the conference hotel, but if you have time and the inclination, consider visiting some of these points-of-interest outside of downtown Music City before or after the conference (for complete charter tour information, please visit our website at **www.fisheries.org/afs09/sight.html).**

CIVIL WAR BATTLEFIELDS

The Stones River National Battlefield is a short march from downtown Nashville, as are historical sites relating to the Battle of Franklin. On 30 November 1864, the Carnton Plantation was engulfed in what was possibly the five bloodiest hours of the Civil War at the Battle of Franklin. Afterwards, the mansion housed hundreds of the more than 6,000 Confederate casualties. The property includes a restored 1847 garden, slave cabin, smokehouse, and springhouse. Adjoining the property is the largest private Confederate cemetery in the nation, a national historic landmark. The Battle of Franklin tour will also include a visit to the Carter House nearby, which Federal troops commandeered as their command post for the battle. Tents were pitched in the dooryard and outbuildings were quickly torn down to provide breastworks against the oncoming Army of Tennessee. The Carter family was soon caught in the middle of one of the bloodiest battles of the War Between the States. A chartered tour is available (you can sign up at our Tours website above) and includes visits to the Carnton Plantation, the Confederate Cemetery, and the Carter House (lunch and shopping will be on your own in historic downtown Franklin); the date is Sunday, 30 August (9:15 a.m.–3:15 p.m.) and the cost is $47 per adult ($43 per child). If folks go on their own, the costs for touring the Carnton Plantation and Carter House are $12 and $10, respectively (please visit **www.carnton.org** and **www.carterhouse1864.com** for more information).



ANDREW "OLD HICKORY" JACKSON

Andrew Jackson, one of Tennessee's most famous "favorite sons" was the seventh President of the United States and one of the most colorful and polarizing figures to ever hold that office. If you take the official tour of The Hermitage, the stately manor of President Jackson, you'll be guided by costumed historical interpreters, weaving tales of Jackson's colorful and controversial life, and stories of his family. The tour is highlighted by the complete restoration of the mansion that appears just as Jackson would have seen it in 1837. Also on tour are a film, museum, church, formal garden, Jackson's tomb, and original log cabins. A bountiful buffet lunch is included afterwards at the Hermitage House Smorgasbord. The cost of the chartered tour (which is scheduled for Thursday, 3 September, 9:30 a.m.–1:30 p.m.) is $48 per adult (less for children). If you prefer to explore the site on your own, The Hermitage is open daily from 8:30 a.m.–5:00 p.m.; admission is $17 per person and there is a senior discount. Complete tour information is at our website, or you can visit **www.thehermitage.com**.

NATCHEZ TRACE PARKWAY

The 444-mile Natchez Trace Parkway south of Nashville is a National Scenic Byway managed by the U.S. Park Service. "The Trace" follows an ancient trail used by Native Americans and early settlers to travel between middle Tennessee and southern portions of the Mississippi River; early explorers used The Trace to return north on foot after voyaging down the Ohio and Mississippi Rivers. In addition to gorgeous scenery and stunning bridges, The Trace is also known for being the final resting place of Meriwether Lewis (yes, that Lewis, of Lewis and Clark fame). Captain Lewis died near Grinder's Stand (about 70 miles from Nashville) under somewhat mysterious circumstances on his way to meet with government officials in Washington, D.C., in 1809. The Natchez Trace was named one of America's top 10 road biking destinations in 2006; visit **Tracebikes.com** for information on how easy it is to rent a bike and strap yourself to it for a day's ride along this scenic and historic parkway. Otherwise, carpool with some friends in a fuel-efficient car and enjoy the country drive! Go to **www.nps.gov/natr/** for more information on visiting The Trace.

JACK DANIEL'S DISTILLERY TOUR AND SHINDIG

You don't have to be a drinker of bourbon or anything else to appreciate this iconic product known around the world. View the quiet vistas of Middle Tennessee as you travel 75 miles from Nashville to the Jack Daniel's Distillery, the oldest and most famous registered distillery in the United States. You can take the tour on your own at no cost. If enough people (50) sign up for the chartered bus tour leaving the conference hotel, the cost will be $70 per person and will include a mouth watering BBQ lunch along with the famous Jack Daniel's Band, to keep your toes tappin'….all in the open-air pavilion which overlooks the "bustling" town of Lynchburg (pop. 361) and Jack Daniel's Hollow.

DUCK RIVER FIELD TRIP

The Duck River is located approximately one hour south of Nashville in central Tennessee. It is the largest tributary to the Tennessee River located entirely within the state. The Duck flows in a westerly direction from the Eastern Highland Rim across the Nashville Basin and the southern portion of the Western Highland Rim for approximately 497 km where it joins the Tennessee River. The Duck River has one of the most extant biologically diverse aquatic faunas in the United States, with 146 species of fish, 53 mussel species, and 22 snail species. Local experts in the identification and natural history of these species will demonstrate collection techniques, species identification, and provide an overview of current threats and opportunities for conserving this extraordinary freshwater ecosystem. Details on this trip are still being worked out as of press time; please check our Tour's website for more information later this spring!

FISHING IN MIDDLE TENNESSEE

Have you ever hooked up with a Tennessee striped bass (or hybrid striped bass)? The reservoirs surrounding Nashville such as Old Hickory, Percy Priest, and Cordell Hull are famous for growing big ones! We recommend hiring a guide to pursue these bruisers (because you'll need a boat—and you won't want to pack the gear you would need to land one of these landlocked monsters). Check out some high-quality guide services such as **www.nashvillefishingcharters.com** or **www.tennesseestriperguide.com/** for more information.

If you are interested in trout fishing, the Caney Fork River below Center Hill Dam (an hour's drive east of the convention site) is where you need to go. Depending on river conditions, you can choose to explore it on your own or hire a guide to bring you up to speed quickly. The river is heavily stocked, but the serious angler can expect to see many brown trout and rainbow trout that holdover from year-to-year and achieve large sizes. Warning to flyfishers: those holdover trout didn't survive and grow big because they were stupid and the fly fishing can be highly technical. Just Google "Caney Fork River trout" for loads of information. Some of our favorite websites on that trout fishery are **www.southeasternoutdoors.com/outdoors/fishing/caney-fork-trout.html** and **http://thetroutaddiction.blogspot.com/2008/05/caney-fork-05-28-08.html.** Check 'em out!

If you are dedicated to pursuing native sport fishes in the Volunteer State, the reservoirs that bracket Nashville provide plenty of opportunities to fish for black bass, crappies, and catfish. Guide services for those warmwater species abound; here's but one example: **www.briancarper.com/services.html.** For a long list of guides who know their way around the many and varied waters of middle Tennessee, please visit our website at **www.fisheries.org/afs09/docs/fishing.pdf.** For online fishing license information, visit **www.tennessee.gov/twra/fishlicense.html**.

ANNOUNCEMENTS: JOB CENTER

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 (150 words or less) for organizations with Associate, Official, and Sustaining memberships, and for Individual members, who are faculty members, hiring graduate assistants. If space is available, jobs may also be printed in *Fisheries* magazine, free of additional charge.

Internship; Kinmundy, Charleston, and Sullivan; Illinois Natural History Survey.
Salary: $1,000.00 per month plus housing and utilities.
Closing: 18 April 2009.
Responsibilities: Work with aquatic ecology and fisheries management at Sam Parr, Ridge Lake, and Kaskaskia Biological Stations and research laboratories. Projects include lake and stream studies dealing with growth, recruitment, population ecology, behavior, reproductive strategies, and management of largemouth bass and muskellunge. Assist with field data collection, sample processing, and laboratory experiments.
Start date: Summer 2009.
Qualifications: Working toward B.S. in fisheries, natural resources, environmental biology, zoology, or closely related field.
Contact: Send cover letter, resume, and contact information for 3 references to Matt Diana; mattd@illinois.edu; Kaskaskia Biological Station, RR 1, Box 157, Sullivan, Illilnois 61951, or Michael Nannini; mnannini@uiuc.edu; Sam Parr Biological Station, 6401 Meacham Road, Kinmundy, Illinois 62854.

Post-doctorial Researcher, Oregon State University, College of Oceanic and Atmospheric Sciences.
Salary: $45,000-47,000 per year.
Closing: 30 April 2009.
Responsibilities: Work with an interdisciplinary team of researchers to study the trophic interactions, distribution, and abundance changes of commercial groundfish populations in the eastern Bering Sea and Gulf of Alaska in relation to changing oceanic and demographic conditions. Perform advanced statistical analyses of groundfish distribution and trophic interactions. Possible opportunities to participate in research cruises.
Qualifications: Ph.D. in biological oceanography, fisheries, ecology, biostatistics, or related disciplines. Interest in population ecology preferred. Experience with or a desire to learn advanced statistical analysis, such as Generalized Additive Models and geostatsistics is required.
Contact: Lorenzo Ciannelli; lciannel@coas.oregonstate.edu; 541/737-3142. See http://bsierp.nprb.org/index.htm. posting 0003756, for the position announcement. See http://oregonstate.edu/jobs for application instructions. AA/EOE.

Group Leader, Marine Sciences, Jacques Whitford, British Columbia, Canada.
Salary: To be determined.
Closing: 1 May 2009.
Responsibilities: Manage 15–20 staff members. Manage workload and resource allocation, and discretionary spending budget. Ensure performance. Set goals and professional development requirements. Ensure QMS and H\S processes are followed. Coordinate business development efforts with other managers. Responsible for price and resource commitment for proposals. Responsible for client satisfaction. Ensure group profitability.
Qualifications: B.S. or M.S. in marine or related discipline plus 8–10 years consulting experience. Excellent client relationship and problem solving skills.
Contact: See www.jacqueswhitford.com/en/home/careers/default.aspx, job 2008-338.

Student Summer Field Assisants (2 positions), Virginia Institute of Marine Science.
Salary: $10–12 per hour depending on experience.
Closing: 15 May 2009.
Start date: Work July–September 2009.
Responsibilities: Work on seine survey and assist with field operations in southeastern Virginia. Help deploy a 100-ft seine through waist- or chest-deep water. Aid in fish identification, measurements, and data recording.
Qualifications: Ability to swim, pull seine, and help to move equipment up to weighing 50 pounds. Ability to resist motion sickness while work is performed rain or shine for 8–12 hours outdoors onboard 18-foot vessels. Experience identifying fish preferred.
Contact: Send cover letter, resume, and three references from previous employment to Leonard Machut, lsmachut@vims.edu. See www.fisheries.vims.edu/trawlseine/sbmain.htm.

Ph.D. Assistantship in Mapping Ecosystem Services, Virginia Polytechnic Institute.
Salary: $22,000–24,000 per year plus tuition.
Closing: 31 July 2009.
Responsibilities: Participate in a multidisciplinary effort to examine where and when biological conservation enhances delivery of aquatic ecosystem services. Participate in conceptual-model development for and spatial analyses of relations among conservation practices, biodiversity, delivery of ecosystem services, and human well being in a U.S. river basin. Perform project data analysis and report writing, while completing Ph.D. coursework.
Qualifications: M.S. in landscape ecology, ecological economics,

conservation biology, geography, or related discipline. Commitment to multidisciplinary research, demonstrated scientific productivity, including peer-reviewed publications, strong statistical skills experience with large geo-spatial datasets, excellent writing skills.
Contact: Send letter of interest, resume, GRE scores, names of three references to Paul Angermeier, biota@vt.edu; Department of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, Virginia 24061-0321; 540/231-4501.

Ph.D. Assistantship in Marine Baitfish Physiology, Aquaculture Research Station, Louisiana State University.
Salary: $1,550 per month plus tuition waiver.
Closing: Untill filled.
Responsibilities: Perform both applied and basic research on project that is part of a larger effort to increase marine baitfish availability to Louisiana and Gulf Coast anglers. Collaborate on work that will ultimately transfer the applied research back to stakeholders. Obtain critical experience in marine baitfish production, physiology, and reproduction through the development and execution of hypothesis-driven research.
Qualifications: M.S. in biological sciences, zoology, wildlife and fisheries, or related field, 1100 on the verbal and quantitative sections of the GRE or equivilant on TOEFL, and 3.0 GPA.
Contact: Christopher Green, Aquaculture Research Station, Louisiana State University Agricultural Center, 2410 Ben Hur Road, Baton Rouge, Lousiana 70820, 225/765-2848, fax 225/765-2877 See www.

rnr.lsu and www.lsuagcenter.com/en/our_offices/research_stations/Aquaculture.

Fisheries Technician (2 positions), Montana State University, Bozeman.
Salary: $10 per hour, housing provided near field site.
Closing: Until filled.
Responsibilities: Assist graduate student in implementing a variety of fisheries field work and a limited amount of office-lab activities. Assisting with the installation and maintenance of PIT—passive integrated transponder antenna equipment. Track fish with portable PIT antennas. Survey stream habitat, electrofish, and handle and tag fish.
Qualifications: Recent B.A./B.S. graduate preferred or current undergraduate with prior field experience. Must be comfortable wading streams of moderate flow while performing detail-oriented field tasks. Must be willing to work odd hours, long days, and have a flexible schedule. Some camping may be required.
Start date: Approximately early June.
End date: Approximately mid October.
Contact: Send a brief cover letter, resume, and any questions to Shane Vatland, svatland@montana.edu.

Fishery Scientist—Habitat Analysis, Columbia River Inter-Tribal Fish Commission, Oregon.
Salary: $55,000–70,000
Closing: Until filled.
Responsibilities: Inventory and evaluate salmonid habitat, with emphasis on substrate analysis, water temperature, streamflow, riparian zone, pools, streambank condition, fish populations at a stream-reach and watershed-scale abundance, size, survival, growth rates literature review and synthesis monitoring methodologies, fish population analyses, carrying capacity, and habitat classification theory.
Qualifications: M.S. plus 3-years relevant experience, or Ph.D. in fisheries or related field. Experience with hydrological analysis or stream geomorphology. Evidence of substantial ability to conduct critical evaluation of scientific methods, scholarly analysis of scientific literature, collection of high quality natural resource data, and quantitative analysis.
Contact: Columbia River Inter-Tribal Fish Commission, Attn: Human Resources, 729 Northeast Oregon Street, 200 Portland, Oregon 97232; hr@critfc.org; fax 503/235-4228. See www.critfc.org.

Aquatic Biologist, Advanced Technical Aquatic Control, Ohio.
Salary: Based on education and experience.
Closing: Until filled.
Responsibilities: Aquatic weed identification and control by applying algaecides and herbicides. Develop biological control techniques including enzyme and bacterial applications for improving nutrient cycling and organic matter degradation. Supervise aquatic applicators that comply with EPA and ODA regulations. Consultwith private pond and lake owners. Collect, analyse, and interpret limnological data including water chemistry, zooplankton identification and quantification, and phytoplankton identification. Perform analysis and report writing. Maintain equipment. Assist other departments as needed and any other assigned duties. Install, maintain, and repair. Possess good communication and people skills.
Qualifications: M.S. in aquaculture, fish management, aquatic biology. Experience in aquatic plant identification and control, nutrient cycles, water chemistry, zooplankton and phytoplankton identification, and ability to identify stressors on lake and pond ecosystems data collection and analysis techniques for fisheries management such as electrofishing.
Contact: President of Advanced Technical Aquatic Control, Richard A. Rogers, rick@atac.cc, P.O. Box 1223, Lebanon, Ohio 45036; 888/998-7663; fax 513/932-9706.

Monitoring the 3D Behavior of Acoustically Tagged Dock Shrimp and Kelp Crab in the Puget Sound

Project Location: Friday Harbor, Washington, USA

FHL image courtesy of Dr. William Calvin, University of Washington.

Puget Sound Dock shrimp and Kelp Crab with micro-acoustic tags.

Roughly 70 miles north of Seattle, in a quiet cove on San Juan Island, is University of Washington's Friday Harbor Laboratories (FHL). This unique center for marine biology research hosts collaborative studies and workshops under the direction of world-class university professors and staff. And in 2007, a talented group of scientists, researchers, and students reconvened at a bioacoustic workshop to study the underwater lives of the Puget Sound.

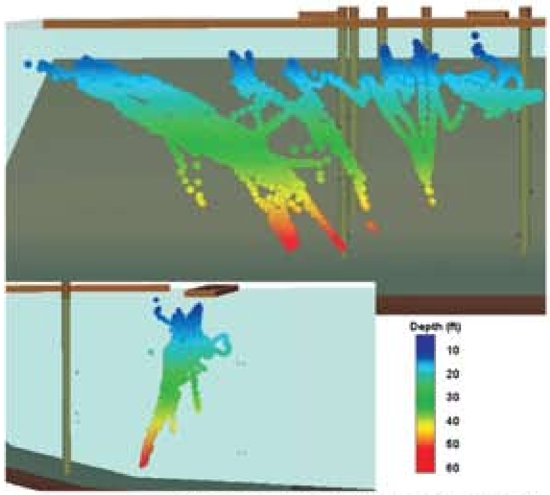
One of the objectives of the workshop was to develop a technique for monitoring the three-dimensional movement in real-time of Puget Sound dock shrimp (*Pandalus danae*) and kelp crab (*Pugettia producta*). To see the behavior of these shrimp and crab in fine scale and in real-time required HTI's *Model 290 Acoustic Tag Tracking System*. It was installed at the FHL dock and breakwater. Dock shrimp and crab were tracked with acoustic tags for a 9 day period. Originally developed and demonstrated in 2005, the technique was later refined in 2007.

The length of the shrimp ranged from 72.5 to 90.0 mm; weight ranged from 5.2 to 8.6 g. *Model 795s Micro Acoustic Tags* weighed in at 0.65 gm each and operated at 307 kHz. Each tag was programmed with an encoded pulse width of 2 milliseconds and a repetition rate of 2.0-2.2 seconds. Hydrophone mounting positions were modeled to ensure sub-meter predicted positional variability. The 3D tracks for the shrimp and crab were monitored in real-time and recorded throughout the study.

Various swimming behaviors were observed, including vertical and horizontal excursions of the tagged shrimp. The 3D positions of the shrimp movements showed that they tended to spend time directly below a floating breakwater. The two tagged crab also spent the majority of their time in front of the breakwater. Three-dimensional animations were used to visualize their behavior over the study period.

There is little existing information regarding the behavior of shrimp and crab. This study provided invaluable information regarding the home range of individuals tagged over the course of a week. HTI is proud to be involved with the bioacoustic workshop at FHL and would like to extend our appreciation for the many efforts of John Horne at University of Washington and Chuck Greene at Cornell University. To learn more about the equipment or the techniques applied, visit HTIsonar.com or call us at 206-633-3383.

A kelp crab tagged with a micro-acoustic tag.



Shrimp behavior tracked in 3D over a 24 hour period.

> “It was very exciting to release the first tagged shrimp and seconds later see its movement throughout the water column.”
>
> – Tracey Steig, HTI Senior Scientist