Fisheries

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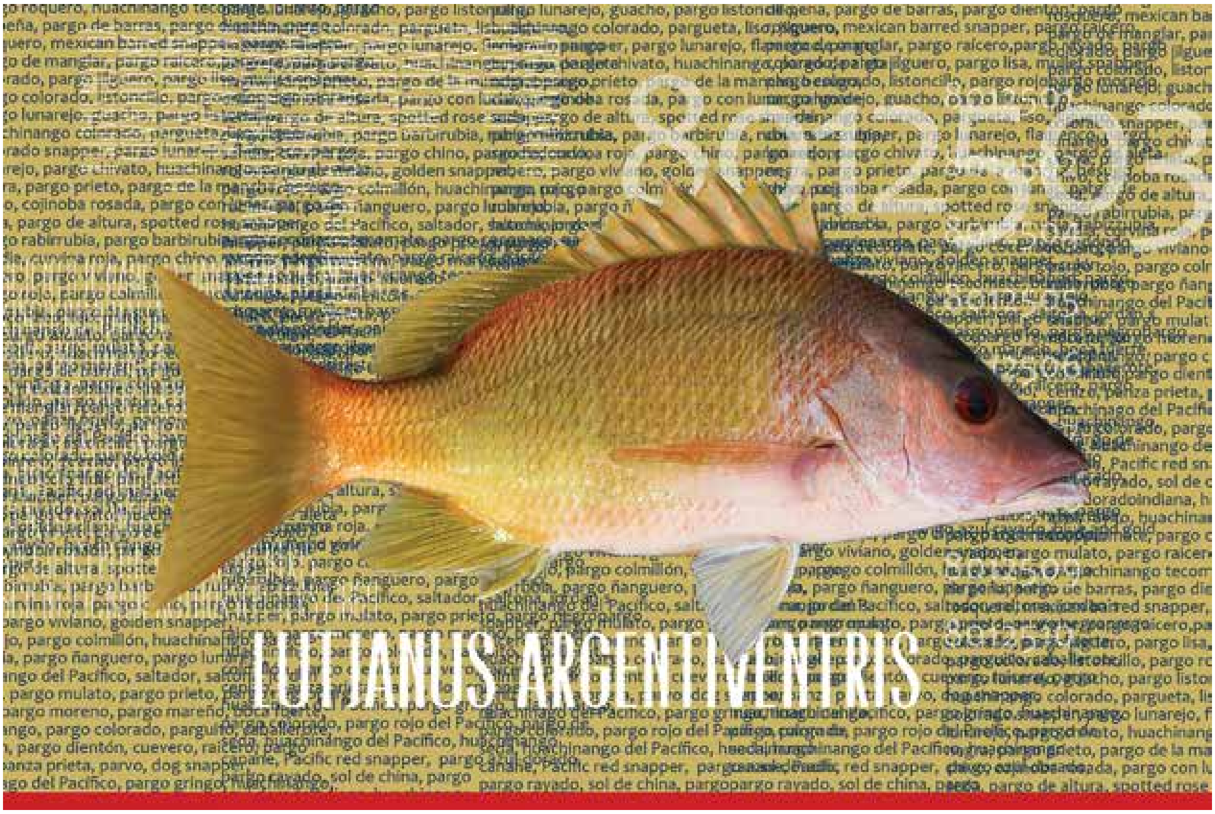

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54 Largetooth Sawfish (*Pristis pristis*) caught in the Grijalva River. Photo credit: Placido Santana.

84 Blue-Barred Parrotfish (*Scarus ghobban*) in Thailand. Photo credit: Johan Lind.

92 Yelloweye Rockfish, *Sebastes ruberrimus*. Photo credit: Victoria O'Connell.

Fisheries

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The American Fisheries Society (AFS), founded in 1870, is the oldest and largest professional society representing fisheries scientists. The AFS promotes scientific research and enlightened management of aquatic resources for optimum use and enjoyment by the public. It also encourages comprehensive education of fisheries scientists and continuing on-the-job training.

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Yellow Snapper (*Lutjanus argentiventris*). Photo credit: S. Gilbert.

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AFS Policy Director
Thomas E. Bigford
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Roles for Everyone

Thomas E. Bigford, AFS Policy Director

I dedicated my June 2014 column to how we and our Society can wield greater influence through partnerships. Fish-centric opportunities abound, but bonus points await those who reach beyond fish and toward aquatic systems on larger geographic scales, toward other natural resources such as wildlife, toward cross-cutting efforts based on topical themes such as resource economics, and toward select social interchanges like listservs and Twitter. A groundswell of recent opportunities has prompted me to revisit the topic with increasing interest. The members of AFS have much to offer as individuals and through their institutions. We also have much to gain from experts in other arenas.

Let's make certain we collectively don't drop the proverbial ball as the second assessment is released in very late 2015.

Some of these occasions are rare or monumental, while others are simply timely. Each occasion offers the chance to sharpen scientific needs, share new insights, inform resource managers, compare results, distill trends, identify best practices, improve training and education, support decisions, impress siblings, and much more. To make this even more enticing, opportunities are unfolding on geographic scales ranging from small regions to national and on temporal scales that can yield immediate benefits. There truly are openings for each specialty across our membership. Let's take advantage of the opportunities!

Perhaps the most interesting effort is the new Blue Ribbon Panel on Sustaining America's Diverse Fish and Wildlife Resources. Led by Bass Pro Shops founder John L. Morris and former Wyoming governor Dave Freudenthal, the panel of 22 experts seeks to create a new conservation funding model that better addresses needs for all fish and wildlife, nationwide and across political aisles. This timely effort was announced at the Association of Fish and Wildlife Agencies (AFWA) meeting in September 2014 and organized this past autumn, with the intention to meet in early 2015. The Panel's singular goal is to create a 21st century model to provide sufficient funds to meet societal needs related to fish and wildlife diversity. The members of AFS can track progress at the AFWA (2014) website and provide input via that site, public scoping meetings such as the one at the AFWA annual meeting last fall, and through Panel members. Our creative input could contribute to a more secure future for all fish programs. This has to be a top priority for 2015.

Another national opportunity is provided by landscape approaches to conservation. The U.S. Department of the Interior (DOI) Fish and Wildlife Service (FWS; 2014a) has led the Landscape Conservation Cooperatives (LCC) program since its creation in 2010 and now has 22 units in the FWS Strategic Habitat Conservation Vision. The LCC concept was the focus of a special National Workshop on Large Landscape Conservation convened by AFS and the Chesapeake Conservancy last October. That event sought to showcase conservation innovation at the landscape scale. The Society was prominent as an organizer; now we can lead as lessons are exported, policy is written, and conservation proceeds. And simultaneous with the national workshop, DOI released a five-year strategic plan that reflects the LCC's vision and mission to conserve and maintain landscapes and seascapes capable of sustaining natural and cultural resources for current and future generations. The coming months will be prime time for AFS members to contribute to an LCC near them on regional conservation strategies, collaborative conservation, science, communications, and more.

A slightly more established effort is the National Fish Habitat Partnership (NFHP), around since 2006 and now represented by 19 regional fish habitat partnerships that bring habitat protection and restoration to priority fish habitats near every AFS member in the United States and parts of Ontario. One great opportunity now is the second national assessment of fish habitat, due in late 2015. The NFHP Science and Data Committee has been assembling information to support the second assessment, offering great opportunities for AFS members to share knowledge and insights. We also could be ideal partners to translate the national assessment into priorities for habitat protection and restoration. That was the NFHP design for the initial report, but those extrapolations didn't materialize. The 2010 report evaluated the status of fish habitat health, established a national basis for regional fish habitat partnerships to set priorities, and provided a nice tool for partners as they render regulatory, research, and management decisions. Let's make certain we collectively don't drop the proverbial ball as the second assessment is released in very late 2015.

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Candidate Statement: AFS Second Vice President

Dale P. Burkett

BACKGROUND

Burkett received his Ecology, Ethology, and Evolution BS (1978) and Environmental Biology MS (1981). Beginning with the Illinois Natural History Survey, and then the Illinois Department of Natural Resources, the US Fish and Wildlife Service (USFWS), the US Department of Agriculture Forest Service, and now the Great Lakes Fishery Commission, Burkett pursued an active fisheries career. As Sea Lamprey Program Director for the commission, Burkett directs a highly successful bi-national aquatic nuisance species control program.

Over 36 career years, many experiences have shaped Burkett. As co-founder of the Illinois Conservation Congress and co-chair of the Strategic Planning Committee, he sharpened his skills in strategic and tactical planning, conflict resolution, negotiation, team-based management, partnering, and multi-agency issue management, all used when he implemented the Great Lakes Fish and Wildlife Restoration Act for USFWS. For the commission, Burkett directs expenditures of about $20 million annually to protect a bi-national fishery worth more than $7 billion.

AFS INVOLVEMENT

A member since 1979, Burkett belongs to the Illinois, Michigan, and Wisconsin chapters, the North Central Division, and the Canadian Aquatic Resources and Fisheries Administration sections. His activities include: Illinois Chapter President (1990-1991 – Division Most Active Chapter Award 1990); Constitutional Consultant (1991-1994); Fisheries Action Network Implementation Committee Chair (1992-1997); Leadership Training Program Developer and Instructor (1992-1999); Division President (1997-1998); International Steering Committee member of the 4th World Fisheries Congress (2000-2004); Conservation Foundation Advisory Committee Co-Chair (2002-2004); Michigan Chapter Membership Committee Chair (2003-2004); North American Agenda for Aquatic Resources Chair (2002-2010); keynote speaker – Institute of Fisheries Management meeting (2007); Nominating Committee Chair (2009-2010); Division Strategic Plan Revision Committee member (2010-2011); and beginning in 2011, Past Constitutional Consultant's Advisory Committee member. He recently facilitated the Governing Board's Reimagining AFS (2012) and AFS Governance Structure–Finding the Way Forward (2013). Burkett received the North Central Division's Meritorious Service Award (1991), the Society's Distinguished Service Award (1995), and was recently honored with the Society's Meritorious Service Award (2014).

VISION

I believe the Society is rich in its collective wisdom, strong in its diversity, forward thinking, and remains resilient in its capacity to continually adapt to change. I strongly support our forums to exchange high-quality science and management information and will strive to improve and expand communication capacity. I will encourage Unit leadership to mentor future fishery professionals, enrich diversity, train future leaders, maintain professional integrity, and inject sound, science-based recommendations to improve the sustainability of aquatic ecosystems into public decision making processes.

Connectivity, both in terms of aquatic habitat and a rapidly evolving global economy, presents tremendous challenges and opportunities. Instantaneous availability of information via the Internet and social media, ranging from research findings to mere opinion, rapidly morphs public opinion and shapes program directions and funding levels. Aquaculture, sport and commercial fishery management, research, and invasive species control are examples that I believe require an implicit social license of trust to be successful. I will work to expand our relevance beyond the fisheries community, build upon traditional communications tools, increase the flow of information and knowledge through continually emerging pathways, and establish better connectivity with the public. Together, we will engage and educate Congressional leaders on critical issues facing aquatic resources and habitats and also find ways to meaningfully engage with the Canadian Parliament. Only then will we move towards greater relevance in the evolving global economy.

Together, we improve natural resources and their associated economies; nevertheless, support for membership in and travel to Society functions is increasingly jeopardized. Member participation is crucial to sustain the creativity, ingenuity, and quest for knowledge that enables our success. I pledge to better engage with the Association of Fish and Wildlife Agencies and industry partners to engender understanding of our work and its value to increase support for membership and participation.

Decades of active involvement with the Society have enriched my professional development, honed leadership skills, and shaped my continually evolving vision of the future of aquatic resources and our Society. I am committed to continue to invest in an organization that has so inspired me and that I truly love. If elected AFS Second Vice President, I will strive to fulfill the Society's vision, increase professional connectivity, and expand the Society's relevance and impact. AFS

Candidate Statement: AFS Second Vice President

Jesse Trushenski

BACKGROUND

Growing up in Washington, I spent many afternoons catching trout in the "crick" that bordered my family's property. If I caught a big one—at least by my 6 or 7 year-old standards—it took a trip in my trusty red pail up to the house where my mom could give it an approving glance. Pride bolstered, I then hustled back, water and fish sloshing as I hurried to release my catch so that I might hook it again the next day. The time came when I had to leave the crick behind, but I stuck with fish and became part of a research team at Southern Illinois University Carbondale, where I earned a Ph.D. and joined the faculty as a fish nutritionist/physiologist. My red pail is long gone, but a tug at the end of the line still feels the same and my childhood enthusiasm has matured into a "fire in the belly" for fisheries and serving the fisheries profession.

AFS INVOLVEMENT

As a student, I was told that joining AFS is "what we do," but that being an active member meant something more—maybe even the difference between having a good career and a great one. This has proven true for me. I have made varied contributions to AFS, but our Society is fortunate to have many active members with long histories of service. Instead of recounting my service record, I will highlight a couple of undertakings that speak to my initiative and strength as a leader.

My expertise leads me to caucus most often with the Fish Culture and Physiology sections, but through my service, I have become effective in communicating across boundaries. I chaired the Resource Policy Committee for several years and am currently serving my second term as President of the Fish Culture Section. Both roles required the ability to balance divergent perspectives and a commitment to making shared progress. This experience proved essential in chairing the Hatcheries and Management of Aquatic Resources Committee, which involved nearly all of the Society's scientific disciplines and interests. It was a privilege to build and lead this coalition in the development of guidance, grounded in sound science, regarding the use of hatcheries and their products.

I recently guest-edited the first themed issue of *Fisheries*, published last November. It was crafted with the help of many contributors, some "rank and file" AFS members, some not. The result was greater than the sum of its parts: an issue about "all things aquaculture," but one that resonated beyond it. This issue was also about the Society trying something new. Change for the sake of change is foolish, but change that sustains our strengths should be embraced.

VISION

Whether it's a fisherman disposing of live bait or a member of Congress voting on legislation affecting fisheries resources, when people know better, they do better. The AFS is the most comprehensive source of fisheries information in the world—if anyone "knows better," it is us. We are well-positioned to engage with the public, decision makers, and allied organizations to ensure that fisheries resources are understood and valued, and that related policies are effective and scientifically justifiable. My vision includes expanded roles for our Society as an arbiter of fisheries science and a resource for decision makers. My vision also includes greater opportunities for those members who are willing to engage stakeholders in needed conversations about fisheries science and resources.

The fact that the Society would consider a relatively young "Gen Xer" for its highest office makes it clear that ours is an organization that values leadership wherever it finds it. The AFS appreciates and respects its members, and members have an even greater sense of this when they see something of themselves in our leaders. My record involves bringing stakeholders together and into the Society's fold. My vision includes leadership that is representative of and responsive to the membership, and provides motivated members with opportunities to further their careers, our profession, and fisheries conservation.

What I have been a part of, what the Society makes possible for its members is uniquely energizing and fulfilling—much more so than what a single career can offer. I cannot begin to repay my debts to the Society and its members, but I am honored to be considered to serve AFS at the highest level. AFS

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Diet Shifts Detected in Sandbar Sharks Using a Nonlethal Technique

Sarah Harrison
AFS Contributing Editor. E-mail: sharrison@fisheries.org

A Sandbar Shark (*Carcharhinus plumbeus*). Photo credit: Frank Gibson.

Traditionally, dietary studies of sharks have been based on stomach content analysis, which often involves the lethal practice of cutting open a shark. This method, while effective, only provides a snapshot of ingested food in the days prior to death. Furthermore, it is a practice that often requires sacrificing a large number of sharks in order to characterize a species' diet and is not an appropriate choice for heavily exploited species like many sharks (Shiffman et al. 2012). An alternative method, stable isotope analysis, which examines the carbon and nitrogen isotopic signatures in tissues, traces dietary inputs and can provide long-term and temporally integrated diet estimates using techniques that can also be nonlethal and minimally invasive, depending on the type of tissue used (Shiffman et al. 2012). A new study by Shiffman et al. (2014) is among the first to detect a change in the diets of wild sharks using a nonlethal, single tissue stable isotope analysis sample design. In previous diet studies, ontogenetic shifts have been detected using lethal techniques that involved either sacrificing sharks to obtain liver or vertebrae samples or by opportunistically using samples from other studies.

In this study, Shiffman et al. (2014) examined the ratios of carbon (13C/12C) and nitrogen (15N/14N) stable isotopes in the dorsal muscle tissue of Sandbar Sharks (*Carcharhinus plumbeus*), a heavily exploited species, and noted as of particular concern by the National Marine Fisheries Service. Findings showed the presence of an ontogenetic diet shift between age-0 and juvenile Sandbar Sharks, indicated by differences in stable isotope signatures between these two age-classes. This ontogenetic diet shift is consistent with young of year feeding mainly on small benthic crustaceans, while juveniles expand their diets to include additional pelagic species such as Atlantic Menhaden (*Brevoortia tyrannus*). While a change in diet is expected as sharks mature, this diet shift in Sandbar Sharks, from benthic to pelagic, has only previously been described using lethal techniques. This study shows how nonlethal techniques can provide similar results. The authors encourage the continued use of nonlethal stable isotope sampling of sharks to provide basic dietary information to fisheries managers.

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Cast Nets are Useful Sampling Tools, and You Should Try One

Jeff Schaeffer
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Cast nets are commonly used by both sport and commercial anglers in estuarine habitats along the southern U.S. coast, but they are rarely used by fisheries scientists, especially when compared to other gears. This is due to the fact that they require practice and skill to deploy, but also because sampling with them is considered non-repeatable. A new study by Stein et al. (2014) dispels cast net myths and examines them critically as a sampling tool.

Using a creative lawn experiment, the authors found that, although operators varied in skill, replicated throws by individuals were similar, indicating that variation was among operators, and not within individuals. This demonstrates that sampling can be considered repeatable. And in field comparisons, cast nets caught more species, more biomass, and more motile organisms than throw traps. Throw traps caught more benthic-oriented species, but cast nets were faster and easier to deploy, covered more area with less effort, and were effective in a wider range of habitats. Their conclusion was, that in many situations, cast nets were a better sampling tool.

Although a focused gear evaluation and comparison, their approach was creative and the discussion was a good read on the issues of "what should I be thinking about when deciding on a sampling gear?" But more importantly, it raises the possibility that cast nets might deserve reconsideration as a sampling gear, not only in estuarine habitats, but in other habitats where their use is uncommon or non-existent. They have been truly overlooked, but this study suggests that they deserve more than a second glance.

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A Historical Record of Sawfish in the Southern Gulf of Mexico:

Evidence of Diversity Loss Using Old Photos

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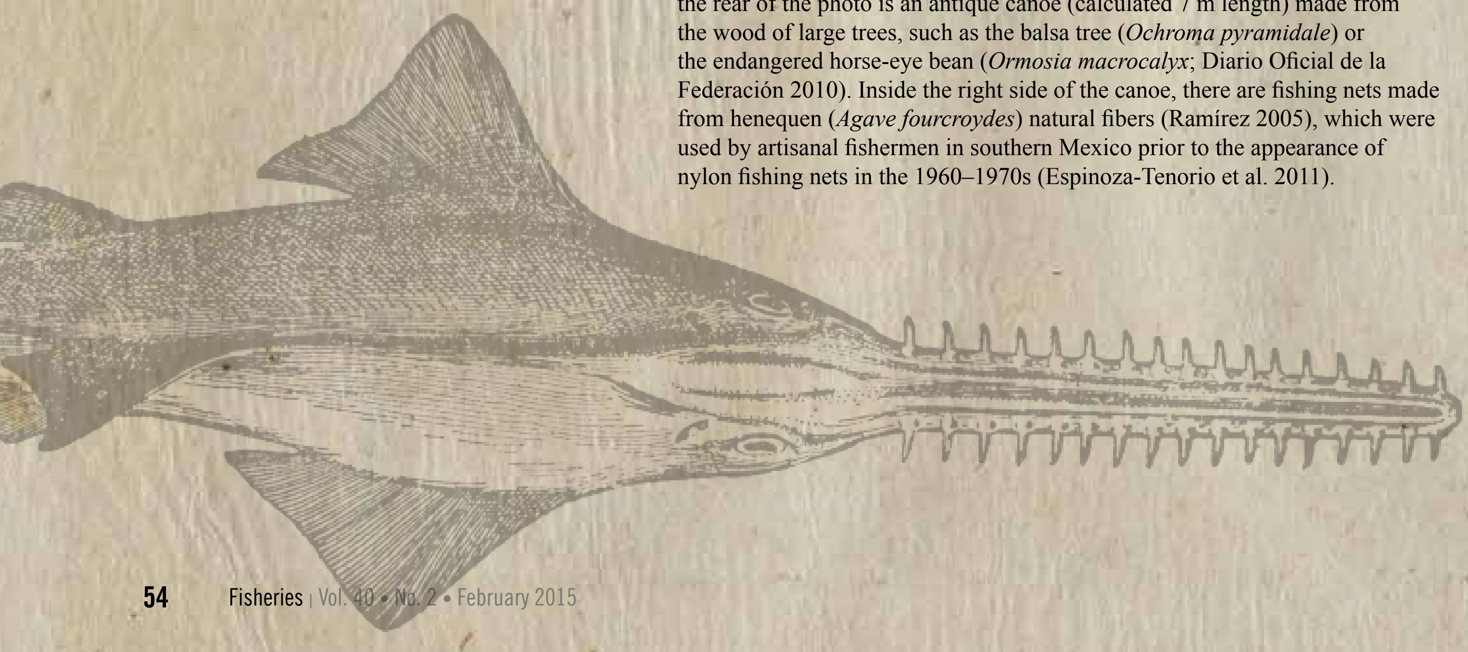
Despite the conspicuous character of sawfish (*Pristis* spp.) in shallow estuarine waters, current records in the southern Gulf of Mexico are so scarce that they have been declared locally extinct from many areas where they formerly occurred (Fernandez-Carvalho et al. 2013). In Mexican waters of the Gulf of Mexico, historical reports for sawfish exist for the upper Usumacinta River (Emiliano Zapata City), Chiltepec Lagoon in Tabasco (Castro-Aguirre et al. 1999), and the Términos Lagoon, Campeche (Zarur 1962) in the 1960s; however, recent but occasional reports are restricted to Mexican Caribbean waters (Schmitter-Soto et al. 2009). Here, we present an anonymous photo (see p. 55) taken in the 1950s in Frontera City, Tabasco, Mexico, found during our fieldwork on reconstructing past fishery conditions based on the traditional ecological knowledge from fishers of the Tabasco coast. This enlightening image is currently part of the electronic historical collection of local chronicler Placido Santana, who donated a copy to support our research. Based on tooth size and first dorsal fin position, this sawfish was likely a 6-m-long Largetooth Sawfish (*Pristis pristis*) caught in the lower Grijalva River; this photo represents the only documented record for the lower Grijalva-Usumacinta River. According to senior fishers interviewed in the Port of Frontera, in the rear of the photo is an antique canoe (calculated 7 m length) made from the wood of large trees, such as the balsa tree (*Ochroma pyramidale*) or the endangered horse-eye bean (*Ormosia macrocalyx*; Diario Oficial de la Federación 2010). Inside the right side of the canoe, there are fishing nets made from henequen (*Agave fourcroydes*) natural fibers (Ramírez 2005), which were used by artisanal fishermen in southern Mexico prior to the appearance of nylon fishing nets in the 1960–1970s (Espinoza-Tenorio et al. 2011).



In the 1950s, southern Mexico, especially Tabasco, was a very isolated area; consequently, documental evidence or data about its diversity are extremely rare. Historical photos are an important source of evidence of the longtime changes in the environment and biodiversity, where historical data are not available, especially for highly vulnerable marine species that have been exploited over long time periods (McClenachan 2009). This photo is evidence of the extremely fast loss of biological and social diversity in tropical coastal ecosystems worldwide, particularly in the southern Gulf of Mexico. Although sawfishes are critically endangered worldwide and under special protection status by Mexican law, their population recovery in southern Mexico waters may be unviable. The difficulty in the recovery of this species is due to low growth and reproductive rates, strong degradation of estuarine ecosystems, and intensive fishery practices. Historical photos help us to understand the high level of degradation of current coastal ecosystems and to elucidate historical baselines for future restoration goals, especially when interpretation is assisted by fishers who possess traditional ecological knowledge.

FUNDING

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FEATURE

Learning to Manage and Managing to Learn: Sustaining Freshwater Recreational Fisheries in a Changing Environment

Freshwaters are being transformed by multiple environmental drivers, creating uncertainty about future conditions. One way of coping with uncertainty is to manage for resilience to unanticipated events while facilitating learning through adaptive management. We outline the application of these strategies to freshwater recreational fisheries management using a case study in Wisconsin, USA, where black bass (*Micropterus* spp.) populations are increasing, while Walleye (*Sander vitreus*) populations are decreasing. Managing for heterogeneity in functional groups (e.g., age classes and prey species of sport fishes), fishery objectives, and regulations can increase resilience, although heterogeneity must be balanced with replication to facilitate learning. Monitoring designed to evaluate management objectives and inform about critical uncertainties, when combined with heterogeneity, creates opportunities for adaptive management, another critical resilience strategy. Although barriers exist to implementing resilience strategies, management designed to accommodate uncertainty and illuminate its consequences is needed to maintain critical fisheries in a rapidly changing world.

Aprendiendo manejo y manejando el aprendizaje: sostenibilidad de pesquerías recreativas de agua dulce en un ambiente cambiante

Los cuerpos de agua dulce están siendo transformados por múltiples factores ambientales, lo que genera incertidumbre sobre lo que sucederá en el futuro. Una forma de enfrentar esta incertidumbre es el manejo de la resiliencia con respeto a eventos no anticipados y, simultáneamente, facilitar el aprendizaje a través del manejo adaptativo. En este trabajo se muestra la aplicación de estas estrategias en el manejo de pesquerías recreativas de agua dulce tomando un caso de estudio en Wisconsin, en el que las poblaciones de la lobina negra (*Micropterus* spp.) están incrementándose, en tanto que las de la lucioperca americana (*Sander vitreus*) están disminuyendo. El manejo enfocado en la heterogeneidad de grupos funcionales (p.e., ciertas clases de edad y presas de peces de pesca deportiva), en los objetivos y en las regulaciones de la pesquería pueden aumentar la resiliencia, no obstante atender la heterogeneidad debe equilibrarse usando réplicas que faciliten el aprendizaje. El monitoreo diseñado para evaluar los objetivos del manejo e informar acerca de imprecisiones importantes que, al combinarse con la heterogeneidad, generan oportunidades para el manejo adaptativo, representa otra estrategia crítica para incrementar la resiliencia. Aunque existen obstáculos para implementar las estrategias enfocadas en la resiliencia, se necesita un manejo que incorpore la incertidumbre y que advierta sobre sus consecuencias, con el fin de mantener vivas importantes pesquerías en un mundo que está en constante cambio.

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INTRODUCTION

Freshwaters are being transformed by climate change, habitat alterations, invasive species, and pollution (Carpenter et al. 2011), creating conditions beyond the scope of past experiences and forecasting capability. For example, the locations and durations of droughts and floods or the identity of new invasive species are difficult or impossible to predict. Although natural resource management decisions have always been made under uncertain conditions, global change is expected to increase the magnitude and influence of uncertainty (Nichols et al. 2011). As a result, local and regional managers may feel that they have little influence over the trajectories of ecosystems they manage. However, freshwater recreational fisheries management (hereafter fisheries management) can and should be designed to be robust and adaptable to unpredictable conditions while promoting learning (Food and Agriculture Organization [FAO] 2012; Pope et al. 2014). In short, we must learn to manage for resilience while managing to learn through adaptive management.

Resilience is the capacity of a system to absorb or recover from disturbance while retaining its essential structure and function (Holling 1973). In this article, managing for resilience means maintaining a system in a desirable state by promoting its resilience; in other cases, resilience management could entail reducing resilience to switch the system to a more desirable state (Allen et al. 2011). Adaptability, or the capacity to thrive in the face of change through learning about and adjusting to changing drivers, is a form of resilience (Folke et al. 2010). Adaptive management (AM; Holling 1978; Walters 1986) provides a framework for increasing adaptability and allowing learning, and in this way AM is a critical component of resilience management (Allen et al. 2011; Pope et al. 2014). In AM, management actions are implemented as experiments in a structured, iterative fashion to meet explicit objectives and allow learning about critical uncertainties. Although fisheries literature contains numerous recommendations to implement AM (e.g., Lester et al. 2003; FAO 2012), the track record of successful implementation has been poor (Gregory et al. 2006; Walters 2007), suggesting that new strategies for applying AM may be warranted.

Managing for resilience can at times involve strategies that play out over decades or centuries and are outside the control of fisheries managers. However, landscape-level management of diverse freshwater recreational fisheries, such as that undertaken by North American state and provincial agencies, provides numerous opportunities to employ resilience management. In fact, fisheries managers working within a state or province (hereafter regional fisheries managers), with extensive knowledge of both the environment and stakeholders, may be in the best position to implement such strategies (Walters 2007). This article focuses on opportunities for regional fisheries managers to increase resilience of managed systems while learning about critical uncertainties and interactions. We describe how strategies frequently used in fisheries management, if implemented thoughtfully, can encompass several critical components of managing for resilience and AM. Our goal is not to conduct an exhaustive review of resilience approaches to management (for a review, see Allen et al. 2011; Biggs et al. 2012), nor to provide a prescriptive approach to managing diverse fisheries in the context of global change. Rather, we outline key strategies for managing fisheries for resilience in a way that is accessible to regional fisheries managers. We use a case study of black bass (*Micropterus* spp.) and Walleye (*Sander vitreus*) management in Wisconsin, USA, to illustrate how these concepts could be applied within the context of constraints and challenges common in natural resource management.

MANAGING FOR RESILIENCE OF FRESHWATER RECREATIONAL FISHERIES

Managing for resilience focuses on maintaining the structures and processes that provide ecosystem services such as recreational fishing (Chapin et al. 2010), in contrast to more traditional management approaches focused on steady-state provision of a single species (Finley 2009). Such single-species approaches can maximize yield in the short term as long as external conditions remain largely the same (Chapin et al. 2010). However, attempts to reduce variability to achieve stable and predictable harvest can have disastrous results in the long term (Holling and Meffe 1996), such as the collapse of fisheries stocks (Post 2012) and ecosystem-level effects (Walters et al. 2005). Managing for resilient recreational fisheries entails managing habitats, functional groups, food webs, policies, and stakeholders to allow the fisheries to sustain themselves in desirable states across a range of conditions (Allen et al. 2011; FAO 2012; Pope et al. 2014).

Multiple strategies for achieving resilience exist (e.g., Folke et al. 2010; Allen et al. 2011; Biggs et al. 2012), including specific recommendations for resilient fisheries management (Hilborn et al. 2003; Carpenter and Brock 2004; FAO 2012; Pope et al. 2014) that span a range of temporal scales of application and relative accessibility for fisheries managers. For example, identification of regime shifts and their drivers (Pope et al. 2014) is virtually impossible given the data available on most recreational fisheries (Andersen et al. 2009) and thus not likely to be implemented on broad scales. In contrast, implementing heterogeneous regulations (Carpenter and Brock 2004) and monitoring are approaches already underway by many regional fisheries management agencies, although their application in a resilience context could be improved with a few strategic changes. In the following sections, we outline the resilience strategies that we believe are most relevant and accessible to regional recreational fisheries management.

Heterogeneity

Managing for heterogeneity, both within and across lakes, can promote resilience (Figure 1). Within a lake, heterogeneity of functional groups means that if one species or group is negatively affected by a disturbance, others can fill the same role (Elmqvist et al. 2003). Managing for heterogeneity in the age structure of sportfish populations, by protecting certain sizes (ages) from harvest, can provide resilience to year-class failures due to unexpected environmental conditions (Gwinn et al. 2013). Similarly, fish in lakes containing multiple (heterogeneous) prey species may be more resilient to species invasions or other unexpected events that reduce the population of one type of prey (Vander Zanden et al. 1999).

Cross-lake heterogeneity also provides insurance against unanticipated events that may influence populations or communities differently in heterogeneous environments, and can apply to fishery management objectives and management tools as well as genetic strains or life history types (Figure 1). Managing for a variety of fishery objectives increases resilience by maintaining recreational fishing opportunities in many lakes, albeit for different species or sizes (Carpenter and Brock 2004). Resilience is also increased by heterogeneity of genetic stocks

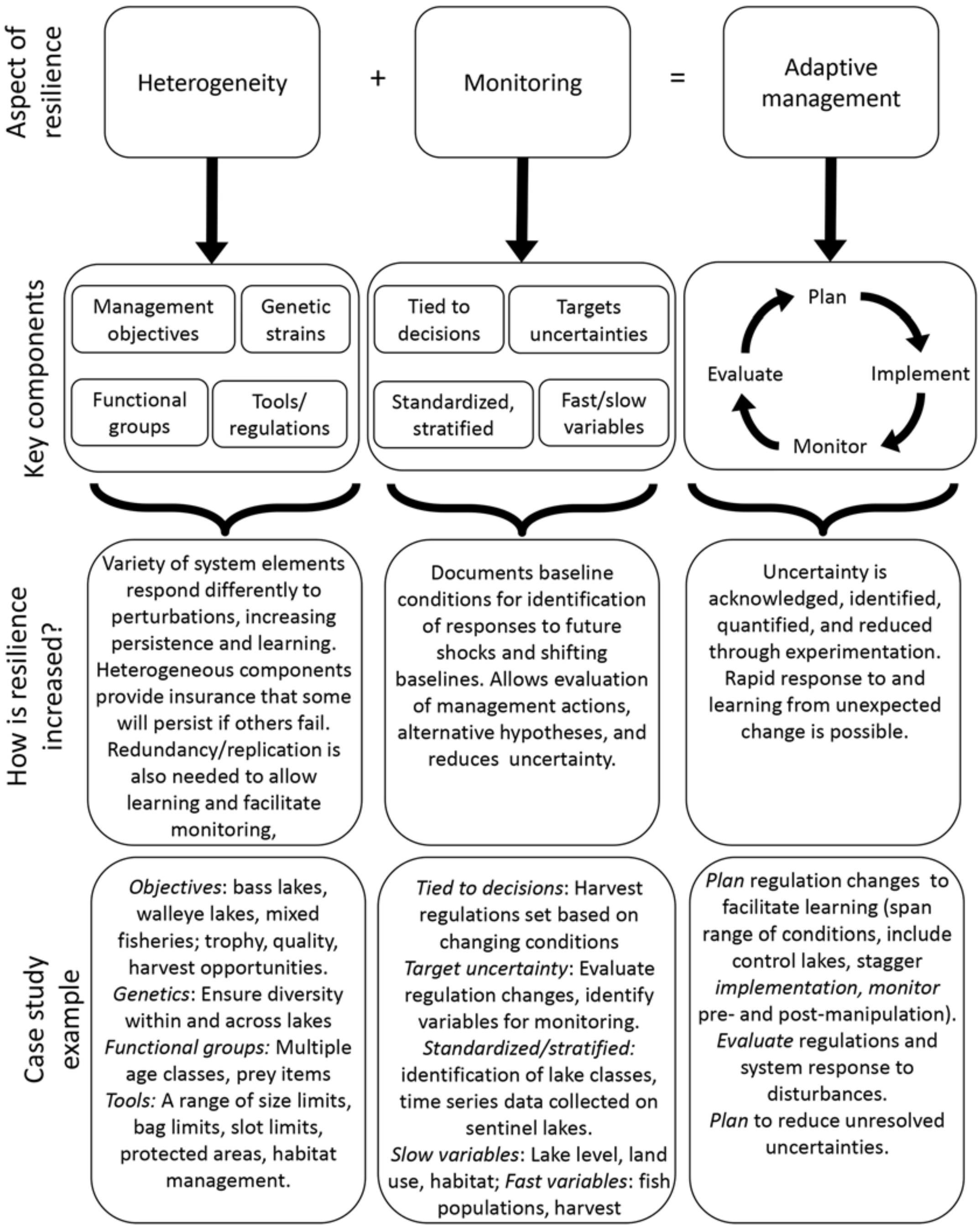

Figure 1. Key components of resilience management that are most relevant for recreational fisheries, and how they apply to the case study example of Walleye and black bass management in Wisconsin, USA.

or life history types across lakes that may respond differently to environmental variation or disease (Hilborn et al. 2003). Heterogeneous management tools can also increase resilience by guarding against failures of a single regulation type to produce desired outcomes due to shifts in angler behavior or dynamics of the resource (Hunt et al. 2011; Post and Parkinson 2012). Although heterogeneity of management tools provides resilience, managing water bodies on an individual basis is not practical given limited resources and to do so creates a complex system of regulations that is neither desirable to anglers nor amenable to evaluation (Lester et al. 2003). Heterogeneity of management tools must therefore be balanced against the need for replication in order to evaluate the effects of management actions on relevant scales (Fayram et al. 2009). Heterogeneity is also a key aspect of AM, but learning is only possible when heterogeneity is combined with strategic monitoring (Figure 1).

Monitoring

Monitoring is a critical component of managing for resilience and AM. In this applied context, monitoring provides information about uncertainties that limit management effectiveness, and monitoring results are explicitly tied to management decisions (Nichols and Williams 2006). Because monitoring each lake in a landscape of tens of thousands is impossible, standardized monitoring stratified across lake classes, watersheds, or some other strata is necessary (Lester et al. 2003; Fayram et al. 2009). In an ideal world, monitoring should include both "fast variables" (i.e., those changing over months to years; e.g., fish populations and harvest rates) and "slow variables" (i.e., those changing over years to centuries; e.g., land use, nutrient loading, and habitat; Walker et al. 2006). Modeling of species–environment interactions can be used to guide which environmental variables must be monitored to distinguish among competing hypotheses (Nichols and Williams 2006); however, at times, such environmental monitoring may not be cost-effective (Walters and Collie 1988). Changes in regulations may affect fish populations, as well as angling effort (Hunt et al. 2011); therefore, the effects of regulation changes should be evaluated based on monitoring both fish population metrics and angler dynamics (Lester et al. 2003). The specifics of where, what, and how to monitor are the subject of much debate and beyond the scope of this article (see Nichols and Williams 2006). Limited resources mean that monitoring costs should be assessed relative to the benefits monitoring provides for decision making (e.g., Hansen and Jones 2008). Increased monitoring of new variables may require scaling back on existing programs, a trade-off that is not to be taken lightly. Monitoring in an AM context can help assess this trade-off by evaluating the outcomes of management decisions made under existing knowledge and illuminating circumstances where information on additional variables may be necessary to achieve objectives.

Adaptive Management

Adaptive management (AM) promotes learning by implementing management actions to test hypotheses, monitoring the objective variables, and adjusting management strategies as new knowledge becomes available. Adaptive management is more than just trial and error; it provides a structure for adjusting management strategies to changing conditions in order to maintain resilience while avoiding responses that would eliminate the possibility of learning. Adaptive management encompasses two broad approaches: active and passive (Walters and Holling 1990). In active AM, interventions are designed and implemented to test hypotheses, with learning as an explicit objective. Although extreme manipulations that push systems to their boundaries result in faster learning, such direct approaches may be socially unacceptable (Gregory et al. 2006). In passive AM, policies are designed to achieve objectives other than learning but are implemented in an experimental design that allows learning to occur. Passive AM is often less costly and controversial than active AM, even if learning occurs more slowly (Murray and Marmorek 2003).

Heterogeneity of management strategies combined with strategic monitoring form the core of passive AM (Figure 1). Heterogeneity provides contrast for evaluating the effects of various strategies and could be as simple as implementing a policy on some lakes (treatments) but not others (references). Replication is also necessary for distinguishing responses due to management actions from those due to other sources of variation. Monitoring allows evaluation of the effects of management and comparison of competing hypotheses and closes the iterative adaptive management loop. We believe that implementing resilience strategies in the management of freshwater recreational fisheries offers high potential for this type of passive AM with relatively little change from existing management practices, and the case study of black bass and Walleye in Wisconsin provides an excellent example of this approach.

CASE STUDY OF RESILIENCE STRATEGIES: MANAGING BLACK BASS AND WALLEYE IN WISCONSIN LAKES

Case Study Background

Our case study involves black bass (hereafter bass) and Walleye in the northern third of Wisconsin, known as the Ceded Territory. This area was ceded by the Lake Superior Chippewa Tribes to the United States through treaties, and tribal rights to spear Walleye were reinstated in 1983 (United States Bureau of Indian Affairs [USBIA] 1991). Seventy-seven percent of Wisconsin's lakes are in the Ceded Territory, including the majority of Walleye lakes (Staggs et al. 1990); these lakes support a joint Walleye fishery composed of tribal spearing and recreational angling (USBIA 1991). Walleye harvest is managed through lake-specific safe harvest limits based on adult population estimates and recruitment status (Hansen 1989), which dictate tribal spearing quotas and angler bag limits (USBIA 1991). Walleye are stocked when natural reproduction and/or adult densities are perceived as too low to optimize fishing opportunities. Both Walleye and bass are managed through angling harvest regulations (length and bag limit restrictions) designed to offer three distinct types of fishing opportunities that account for the trade-off between population density and size structure: sustainable harvest (maximizing density), quality (moderate densities and moderate size), and trophy (maximizing size).

In the past two decades, Walleye recruitment in lakes throughout the Ceded Territory has decreased, whereas bass populations have increased (Hansen et al. in press; Figures 2A, 2B). Maintenance of self-sustaining Walleye densities, of at least three adult Walleye per acre, is a primary management objective (USBIA 1991), and the proportion of lakes at or above this density has also declined (Figure 2C). Managers are anxious to reverse these trends because Walleye are the species preferred by many stakeholders (McClanahan and Hansen 2005). However, the causes of the trends and the appropriate management actions are uncertain. The temporal correlation and inverse relationship of the trajectories of bass and Walleye have resulted in the perception that increases in bass populations are responsible for Walleye declines. However, numerous hypotheses to explain these changes are plausible (Figure 3). For example, statewide temperature increases have occurred in Wisconsin over the past 50 years and are predicted to continue (Kucharik et al. 2010), and growing bass populations could be a result of increased recruitment due to longer growing seasons and more mild winters (Ludsin and DeVries 1997). An increased catch-and-release ethic and more restrictive bass regulations could have bolstered adult bass populations and may affect the ability of managers to control bass harvest (Hansen et al. in press). Walleye population declines could be explained by increased predation by bass (Fayram et al. 2005); alternatively, warmer, clearer water could potentially reduce Walleye production (Lester et al. 2004). Thus, the trends in bass and Walleye could be directly connected, opposite consequences of some hidden variables, or completely independent. Resilience strategies offer one method of coping with these uncertainties.

Case Study Applications of Resilience Concepts

In our case study, Walleye populations within a single lake may be resilient to drought, increased harvest, invasive species,

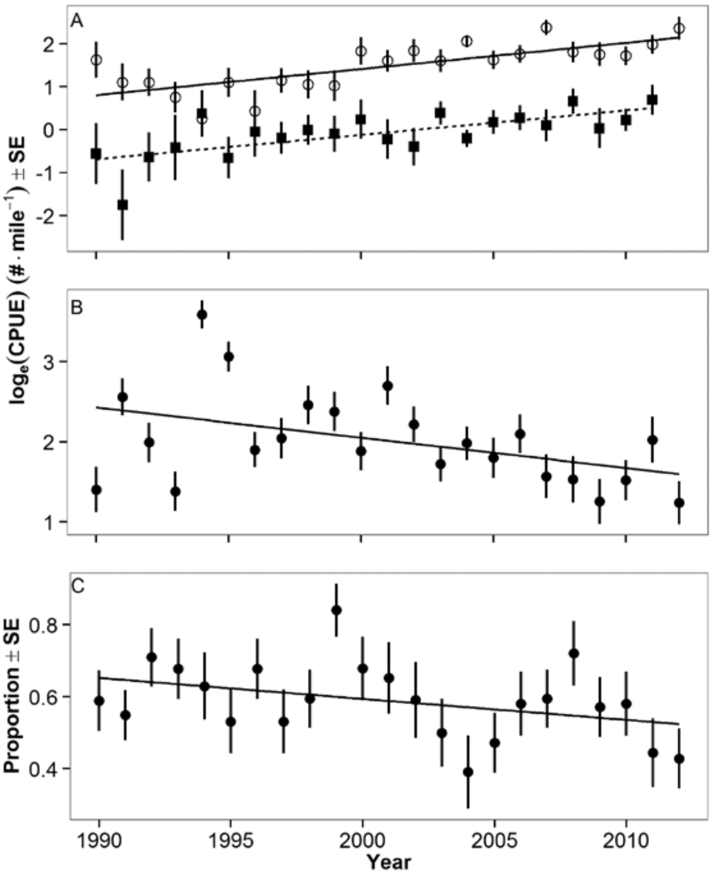

Figure 2. (A) Log$_e$(mean CPUE) (±SE) of black bass abundance (*Micropterus* spp.; catch per electrofishing mile of black bass > 8 inches total length). Both Largemouth Bass (*Micropterus salmoides*; open circles and solid line) and Smallmouth Bass (*Micropterus dolomieu*; filled squares and dashed line) increased over time (Largemouth Bass: $y = 0.061x - 120.43$; adj. $R^2 = 0.53$, $P < 0.001$; Smallmouth Bass: $y = 0.057x - 113.65$; adj. $R^2 = 0.45$, $P < 0.001$). (B) Log$_e$(mean CPUE) (±SE) of Walleye recruitment (catch per electrofishing mile of age-0 Walleye). Walleye recruitment decreased over time ($y = -0.038x + 77.50$; adj. $R^2 = 0.15$, $P = 0.037$). (C) Proportion of surveyed lakes (±SE) in which adult Walleye density met the objective of greater than three per acre from 1990 to 2012. The proportion of lakes meeting this objective decreased over time ($y = -0.006x - 12.25$; adj. $R^2 = 0.10$, $P = 0.075$). All data are from Wisconsin Department of Natural Resources. Data for (A) are from fall surveys throughout Wisconsin in lakes with ≥ 2 years of data. Data for (B) and (C) are from lakes in which natural recruitment of Walleye has been documented in the Ceded Territory of Wisconsin; in (B) data are from lakes with ≥ 5 years of data.

or disease; at the same time, the fisheries of the entire state may be resilient to gradual changes in climate, angler dynamics, or unexpected extreme events. These scales of resilience interact; even the most resilient Walleye population in a single lake could be devastated by disease, but regional resilience could allow replenishment of this population. Although current management focuses primarily on single-species objectives for densities and size, some components of resilience management already exist in the management of bass and Walleye, although the resilience of this system could be improved.

Like most inland fisheries in North America (Post 2012), management of Walleye and bass in Wisconsin relies primarily on harvest-based regulations, such as bag and length limits as well as stocking. As biologists collect more information from Wisconsin lakes and as conditions change, a heterogeneous makeup of fishing regulations is emerging (i.e., lakes differ in their bag limits, length limits, and stocking densities throughout the state) that reflect heterogeneous management objectives (e.g., some lakes are managed to maximize Walleye harvest, others managed for trophy bass, and others managed to maximize bass harvest). Within lakes, diverse harvest regulations are relatively successful in achieving diverse size structures of Walleye (Hansen and Nate 2014). Resilience of these fisheries would be further increased by employing other types of regulations, including habitat management (Carpenter and Brock 2004), nutrient management, and land-use regulations (i.e., ecosystem-based management; Francis et al. 2007), and spatial and temporal protected areas (Bengtsson et al. 2003).

Walleye populations in the Ceded Territory are monitored closely as required by the federally mandated Walleye management system (Staggs et al. 1990), with adult population estimates and recruitment indices measured annually in an average of 43 and 224 lakes, respectively, from 1989 to 2013. Past monitoring establishes a reference, present-day monitoring provides information tied directly to management decisions, and continued monitoring will allow learning about responses to management actions. bass abundance is also monitored regularly; Largemouth Bass (*Micropterus salmoides*) relative abundance was measured in an average of 124 lakes annually from 1989 to 2013. Bass management decisions are also tied to monitoring, although less formally than for Walleye. Bass management goals tend to be lake specific, and managers propose regulation changes when data show that the population is not meeting the goals, although long-term time series of data are rare. Monitoring of ecosystem conditions in Wisconsin lakes is less common, with little data available on habitat, the non-sport-fish community, or lower trophic levels. Due to the high costs of creel surveys, time series data of angler harvest are also lacking. This lack of information on variables other than sportfish populations hinders the ability to evaluate competing hypotheses to explain trends in sportfish populations (Figure 3).

Some regulations have been changed in Wisconsin specifically in response to observed trends in bass and Walleye. Beginning in 2011, regulations were changed in 26 Ceded Territory lakes; bass minimum length limits were removed, Walleye minimum length limits were increased and bag limits decreased, and large fall fingerling Walleye (152–203 mm) are being stocked every other year to increase survival of stocked fish (Kampa and Hatzenbeler 2009). These actions were taken to maximize the probability of increasing Walleye abundance, not necessarily to learn about bass–Walleye interactions. Still, heterogeneity in regulations in response to declining Walleye and increasing bass populations can promote resilience and provide opportunities for learning through passive AM, provided that a few critical steps are taken. First, specific and measurable objectives must be stated, such as to increase naturally reproduced age-0 Walleye catch rates to 10 fish per mile in 50% of lakes within 7 years. Uncertainties must also be identified and framed as questions or hypotheses in an AM framework. Questions that could potentially be answered in this case:

- Are Walleye recruitment failures responsible for Walleye population declines, and can this be remedied with stocking?

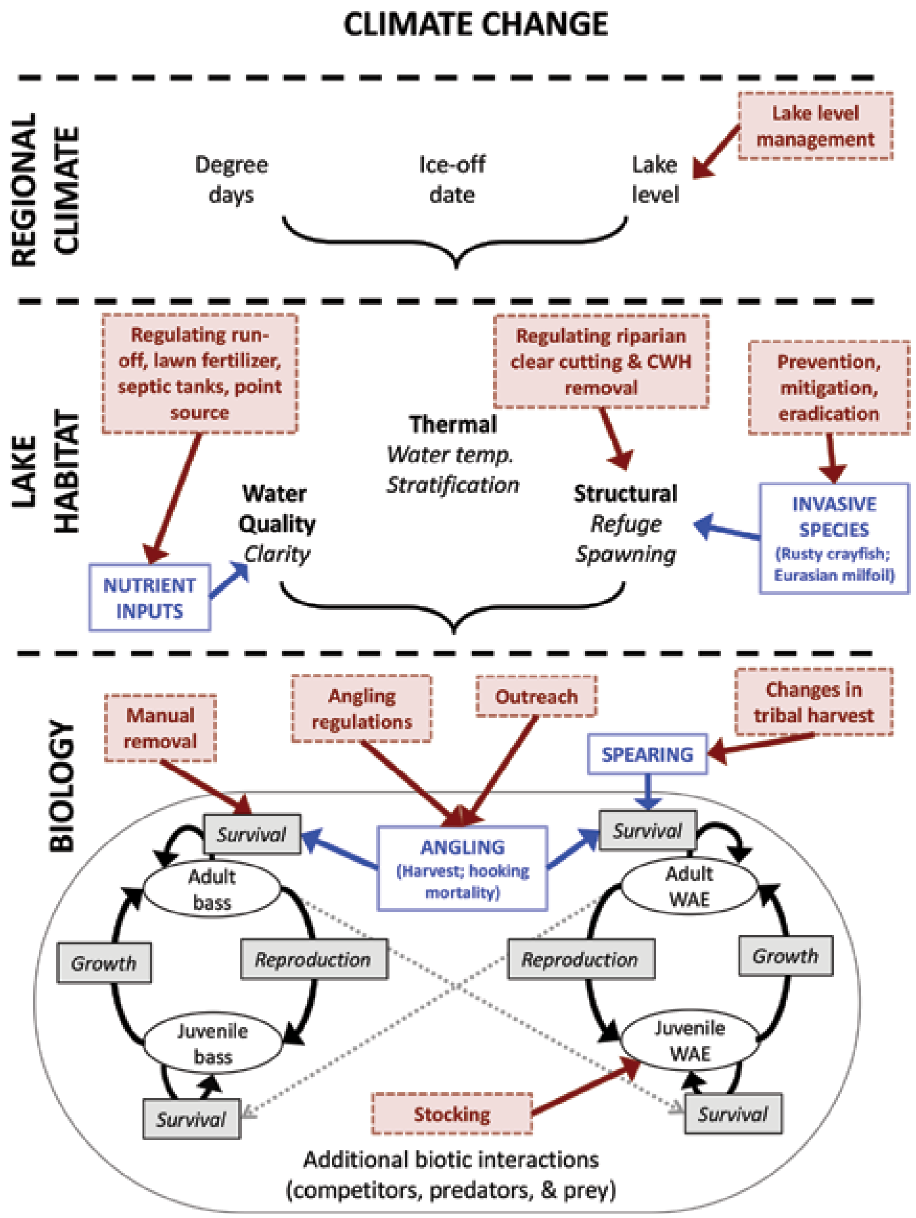

Figure 3. Processes operating on multiple spatial and temporal scales that could potentially influence black bass (*Micropterus* spp.) and Walleye (*Sander vitreus*) populations in Wisconsin. Blue boxes (solid outlines) represent anthropogenic influences, and red boxes (dashed outlines) represent areas of potential influence by managers. Circles represent populations being managed. Dashed arrows connecting adults of one species to the juveniles of another represent predation. CWH = Coarse woody habitat.

- Will liberalized bass regulations reduce bass populations?
- Will reductions in bass populations result in Walleye population increases?

In order to answer such questions, regulations should be implemented following experimental design principles, which will increase resilience through heterogeneity and allow learning through passive AM.

An example of a strong experimental design includes treatments and reference systems replicated across an environmental gradient (e.g., lake size or trophic status; Figure 4A). Treatments should be applied in a time-varied manner to separate regulatory effects from variability due to climate or other factors affecting all lakes in a region simultaneously (Walters et al. 1988). Although multiple interventions can be explored, such as is the case in the 26 experimental bass–Walleye lakes, ideally all combinations of these interventions should be tested independently. In Figure 4A, two interventions are shown, such as increased Walleye size limits and decreased bag limits (A), decreased bag limits and no minimum size limit for bass harvest (B), or both (A and B), with no intervention applied to reference lakes. Adding a third intervention (e.g., C, stocking of extended growth Walleye fingerlings) would increase the number of treatments by four (by adding treatment categories C; A and C; B and C; and A, B, and C), thereby increasing the number of blocks in our idealized experimental design by 24. Thus, evaluating multiple treatments concurrently quickly becomes impossible, as the capacity of an agency to monitor replicated experiments on such a large scale is limited.

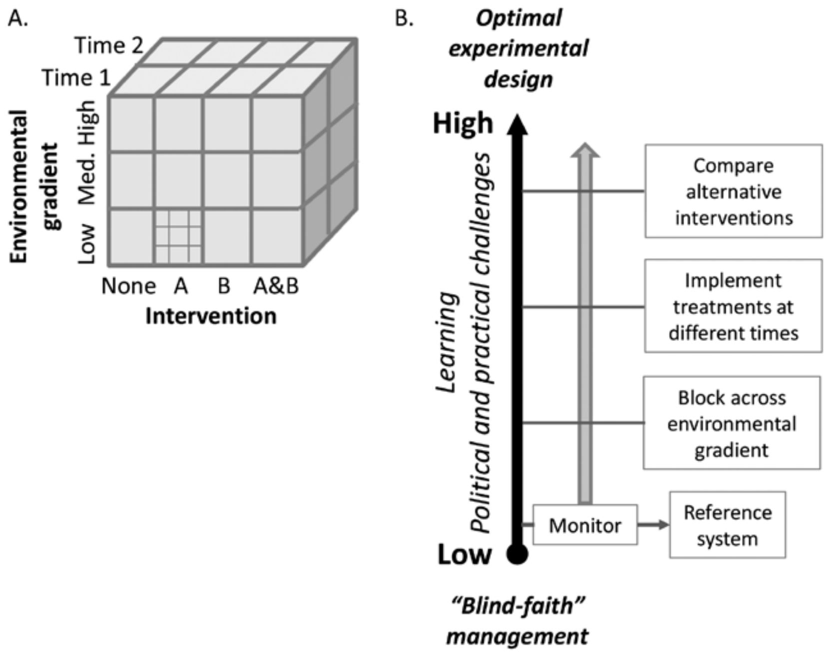

Figure 4. Experimental design for implementing management interventions to allow learning. (A) Hypothetical experimental design, which includes two interventions (A and B) implemented singly and in combination with a reference system (no intervention). Each intervention is implemented across an environmental gradient (e.g., lake trophic status) in two time periods. All treatments are replicated, but for clarity, replication (small boxes) are only shown in one treatment block. (B) The components of the optimal experimental design illustrated in (A) arranged in order of importance for learning.

In reality, all 26 lakes received all three treatments and thus represent a single treatment group receiving the full suite of regulation changes. Finally, the duration of the experiment should be long enough to include multiple generations of response variables (e.g., Walleye populations). Intensive monitoring tied to objectives is needed; in our case, bass adult abundance and Walleye recruitment will be measured annually on the treatment lakes and several reference systems.

Meeting all of these components of optimal experimental design is nearly impossible due to social and fiscal constraints. Nonetheless, even a compromised design can provide useful information for informing future decisions. Figure 4B presents the components of experimental design arranged across a spectrum of learning potential and societal cost. The bottom represents best-guess management actions implemented with no monitoring or evaluation and thus no possibility of learning; this approach has been called a "blind-faith" approach to management (Hilborn 1992). The top of the spectrum represents the optimal design of management interventions, where learning is maximized but so are costs. The steps along the spectrum are arranged in order of importance for learning. Monitoring is the first and most important step and must occur with every subsequent step. Without monitoring, there exists no method of detecting responses to management actions and no baseline for comparison. Additionally, monitoring creates de facto reference systems when conducted in locations where no changes to management occur. Though very few management systems will be able to implement the optimal design illustrated by the upper end of this spectrum, by prioritizing the aspects most important for learning, management can be designed to take advantage of learning opportunities as they arise.

Of course, management experiments focused on changing bag limits, size limits, and stocking rates cannot resolve all uncertainties in the bass–Walleye case study. For example, if increased stocking of large Walleye fingerlings increases adult Walleye abundance, uncertainty will still exist as to the ultimate causes of Walleye recruitment failures (Figure 3). Still, if applied in the framework outlined above, such an approach could increase the resilience of Walleye fisheries (through heterogeneity) and allow learning (through monitoring and passive AM). Even if the ultimate drivers of changes in bass and Walleye populations are outside the realm of fisheries managers' control (e.g., climate change), harvest regulations and stocking may succeed in dampening the effects of outside drivers, maintaining Walleye fisheries for a longer time period than if no action had been taken. If no combination of interventions alters trajectories, alternative strategies will have to be explored, but learning will have occurred and agency credibility increased by demonstrating that certain interventions do not work (Fayram et al. 2009). Going forward, this increase in credibility may increase the social acceptability of potentially more radical strategies that may be required to increase resilience of these fisheries. Such results may also provide a basis for increased monitoring of other variables in order to evaluate alternative hypotheses regarding the cause of Walleye declines.

CHALLENGES TO MANAGING FOR RESILIENCE

Despite the intuitive appeal of resilience concepts in general and AM in particular, numerous challenges exist to implementing these strategies. The first is a failure to understand why such an approach is needed (Walters 2007). This resistance often stems from a belief that the right course of action is known, even though current knowledge in fisheries is frequently based on limited data and little or no replication (Hilborn 1992; Fayram et al. 2009). The costs and risks of resilience strategies are paid in the short term, whereas benefits accrue in the long term, which means a commitment to resilience management must span time periods much longer than typical budgetary and political cycles in order to pay off (Nichols et al. 2011). Admitting uncertainty about the optimal management action may make both managers and stakeholders uncomfortable, because intuitive arguments at times must be abandoned in favor of more complex ones in order to understand uncertainty and need for experiments (Walters 2007). For example, the inverse correlation between bass and Walleye could easily be interpreted as resulting from the negative effects of bass on Walleye as predators and competitors, with calls for intervention to reduce bass. The alternative views are potentially more complex, involving multiple interacting drivers with several plausible hypotheses to explain current trends, each of which suggests a different management response (Figure 3).

Global change may provide the context for overcoming resistance to implementing resilience strategies. In a rapidly changing environment, the old tenet that "the same actions produce the same results" is unlikely to be true (Hilborn 1992). As conditions change, all management actions become experiments, meaning that even if the "optimal" course of action was known in the past, it is impossible to know now and especially in the future. This uncertainty is not a failure on the part of managers but rather a reflection of the fact that we are entering conditions outside the realm of past experience, and managers are forced to make decisions in environments lacking historical analogues. The real failure would be to miss opportunities that increase the likelihood of positive management outcomes given the unprecedented rate and magnitude of change. At the same time, scientists pushing for heterogeneity, replication, increased monitoring, and reference systems must be sensitive to the risks posed by such actions, recognizing that management agencies have multiple priorities (Gregory et al. 2006). Treating management as a learning process and a partnership among scientists, managers, and stakeholders is a way forward that increases the resilience of freshwater recreational fisheries by implementing small changes in management strategies (Chapin et al. 2010).

Another critically important barrier to resilience management is lack of funding for monitoring (Walters 2007). Monitoring is the single most important component of AM and other management strategies designed to understand and reduce uncertainty (Figure 4) and should be a top management priority for freshwater recreational fisheries. However, a lack of adequate funds for monitoring is a near-universal problem in natural resource management, and fisheries are no exception. In some cases, monitoring costs can be reduced through the use of citizen monitoring programs (Silvertown 2009) or via technological advances, such as remote sensing (Kerr and Ostrovsky 2003). However, monitoring at the level required for management of state or provincial inland fisheries will likely always be costly, and tradeoffs between monitoring objectives will perhaps always be debated. No matter what the strategy, monitoring is essential for the resilience of freshwater recreational fisheries.

CONCLUSION

The only constant in ecological systems is change (Botkin 1990). Resilience approaches are needed to ensure that ecosystems are robust to a changing environment and unpredictable events. Resilience strategies can be accessible to fisheries managers if management actions are regarded as provisional ideas to be tested and evaluated by employing principles of experimental design and monitoring strategically before, during, and after implementation. This approach to management will reveal the range of responses of fisheries to the tools available to managers. Likewise, it will frame uncertainties in accurate, transparent ways that allow decision makers the opportunity to choose actions that are most robust to the range of potential outcomes. Barriers to these strategies must be overcome in order to maintain valued freshwater recreational fisheries in a rapidly changing world.

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ESSAY

Turning Class Field Trips into Long-Term Research:

A Great Idea with a Few Pitfalls

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LONG-TERM RESEARCH

As we conduct fieldwork and process samples in the lab afterwards, we often ponder what the real sample size is. We measured hundreds or thousands of fish, shrimp, clams, or whatever it is that we work on. These seem like adequate sample sizes until we remember that they were all collected at a few sites (e.g., five), and so maybe our true sample size is five. Then it dawns on us that the samples were all taken in a single year, and we have to face the reality that our sample size may actually be one. Interannual variation has always been recognized, but the pressing issues of climate change, invasive species, and habitat degradation (and restoration) make it all the more important that we keep tabs on important physical conditions and biotic responses over long periods of time in order to discern patterns in freshwater (Dauwalter et al. 2009; Dodds et al. 2012; Wagner et al. 2013) and marine systems (Millner and Whiting 1996; Rogers et al. 2011). Long-term research projects are difficult for agencies to start because they involve tough decisions, such as where to situate the study and what the study goals are, but once it gets going, the momentum often carries the study for a while. However, inevitably, budget cuts, retirement or reassignment of key staff, changing priorities within the agency, or other processes undermine support for the project, and many end just as they are becoming most valuable. Some faculty members or teams at universities carry out long-term research, and the National Science Foundation supports some Long-Term Ecological Research Network sites, but for many faculty members, it can be very difficult to obtain continued funding for what some deride as "mere monitoring."

UNIVERSITY FIELD TRIPS

Few of us can remember the details of lectures, no matter how much we enjoyed the class, but many remember the field trips. Speaking for myself, I can vividly recall both the experience and the content of field trips and associated labs in which I participated as a student four decades ago. So, those of us who are teachers are challenged to create the kinds of hands-on educational experiences that will anchor our lecture materials and give the students richer and more powerful learning opportunities. Of course, there are lots of reasons not to take classes on field trips. First, field trips are a lot of work, including (1) the logistics of moving students off-campus (vans to reserve or car-pools to organize, certification of drivers to operate university vehicles, etc.), (2) ever-increasing requirements for permits and subsequent reporting of sampling (access to land, state collection permits, Institutional Animal Care and Use Committee permits, Endangered Species Act take permits in some cases, etc.), (3) the actual field time (often occupying precious weekends in conflict with family plans), (4) the management and handling of samples, and (5) the need to maintain long-term data sets in a coherent manner. There are also safety and liability issues, and of course, someone at the college or university has to okay the costs associated with the trips. These costs may be trivial or not, depending on whether a vessel or other pricey aspect of the operation is involved. So, there are lots of reasons to stay in the classroom and lecture, even though we know how much the students learn on the field trips, remember the content, and benefit from the opportunity to obtain skills in sampling. The students also enjoy the time outdoors, the fellowship that comes with shared experiences, and a chance to meet teachers in a less formal setting than classrooms allow. These benefits are not strictly academic, but they are worthy too.

TURNING FIELD TRIPS INTO LONG-TERM STUDIES

Remembering how important field trips were for me as a student, as I started my teaching career, I knew I had to make the effort to give students those kinds of experiences. When I joined the faculty at the University of Washington's School of Aquatic and Fishery Sciences (known then as the School of Fisheries), I tried to design field trips that would reinforce the lectures and benefit students for whom this kind of experiential learning is most effective. I take my classes to sample stream, lake, and marine habitats. The stream sampling is designed to illustrate the relationship between physical habitat and small-scale fish habitat use patterns. We use electrofishing to determine the species composition and size distribution of fishes in riffles and pools, measure the available habitat (depth, velocity, substrate size), and take "microhabitat" data at the point where each fish is found. This trip occupies a full day in the field, including transportation. The lake sampling is designed to evaluate diel shifts in depth distribution and feeding by three planktivorous fish species, and we record water temperature profiles, sample zooplankton, catch fish at different depths from afternoon to night, and process the plankton and diet samples later in the lab. The marine fish sampling reinforces the concept of diel movements and also shows how community composition shifts with depth. We use a small bottom trawl at four different depths, every 5 h for around-the-clock sampling. As with the lake trips, the students each go on one shift and we all share the data. I also teach a class in the fall that includes structured observations of salmon reproductive behavior as well as the stream and lake sites sampled in the spring.

So, we went to stream, lake, and marine habitats, collected data and samples that the students worked on in the lab, and the students wrote papers in scientific format based on the data. The field trips went more or less as I had hoped, and we saw the basic ecological patterns that were expected. For example, in small streams, the depth and velocity where juvenile Cutthroat Trout (*Oncorhynchus clarkii*) are found tend to increase with fish size, and juvenile Coho Salmon (*O. kisutch*) occupy somewhat deeper and slower water than do the trout (Bisson et al. 1988), and our data show these patterns clearly (Table 1). Similarly, sampling from afternoon to evening to night in Lake Washington showed the expected diel vertical migration by juvenile Sockeye Salmon (*O. nerka*; Table 2). However, it soon dawned on me that if I could make the field trips consistent each year, I could gradually accumulate data that might be useful in the years to come. Because each trip was designed to reinforce concepts in lectures and I kept the same syllabus, the seasonal timing of the trips was automatically quite regular (i.e., same week of the academic calendar). At first colleagues and friends at agencies giggled a bit when I mentioned "long-term" studies that at the time spanned all of two years. However, by now, more than two decades have passed and I am still collecting the data, and people are starting to take notice.

When collecting long-term data, it is always hard to know when you have enough of a "story" to report to the scientific community. In some cases, interannual variation is not as important as a large and consistent sample size for some ecological or behavioral phenomenon. For example,

Table 1. Average depth and water velocity where juvenile Coho Salmon and Cutthroat Trout were caught in Rock Creek, Washington, in the spring revealing both species-specific and ontogenetic differences in habitat use. Data from 2004 to 2013 were combined to produce averages.

	Coho Salmon		Cutthroat Trout		
Fish age class	0+	1+	0+	1+	2+
Depth (cm)	21.40	45.10	12.20	28.30	34.30
Velocity (m/s)	0.15	0.30	0.13	0.45	0.53

Table 2. Average catches of juvenile Sockeye Salmon per 15-min tow in mid-April in Lake Washington (1997–2013) in shallow (10–15 m), intermediate (20–30 m), and deep (40–50 m) mid-water tows in the afternoon (15:30–20:20 h), dusk (20:30–21:45 h), and night (21:45–22:45 h) showing diel vertical migration.

	Afternoon	Dusk	Night
Shallow	0.1	4.3	16.3
Intermediate	0.5	7.4	6.3
Deep	2.8	3.4	2.3

data on comparative reproductive behavior of three Pacific salmon species (*Oncorhynchus* spp.) became rich enough to be published (Quinn 1999), but we continue to collect the data because the field trip works well for the class. In this case, we do not anticipate any important long-term trends; each year is more or less self-contained, but having data from many years tends to iron out the vagaries of observer error and unusual but accurate data when looking for overall patterns.

The contrasting diel vertical migrations of three species of planktivores in Lake Washington in spring and fall were also reported in a paper that emphasized the patterns rather than the interannual variation (Quinn et al. 2012). However, the data collection continues, and we are seeing a marked shift in species composition. From 1997 to 2004 the spring sampling yielded 9.7% Three-Spine Sticklebacks (*Gasterosteus aculeatus*), 39.1% juvenile Sockeye Salmon, and 51.2% Longfin Smelt (*Spirinchus thaleichthys*), but from 2005 to 2013 the Three-Spine Sticklebacks increased to 45.8%, the Sockeye Salmon declined to 16.4%, and the Longfin Smelt are still prominent (37.8%). There has also been a dramatic difference in abundance between the odd-year and even-year classes of Longfin Smelt, with an associated density-dependent effect on growth. This pattern was reported four decades ago (Moulton 1974), and we can show that this intriguing phenomenon persists. Our mean of annual mean lengths of yearling Longfin Smelt on even-numbered brood years has been 68.9 mm (SD = 10.1) compared to 95.3 mm (SD = 8.0) for odd-numbered years. In this case, the continuation of the class sampling provides an important, albeit incomplete, contribution to our understanding of this lake, building on Lake Washington's fascinating history of changes associated with nutrient input and climate affecting multiple trophic levels (Edmondson 1994; Hampton et al. 2006; Winder et al. 2009).

The sampling in Rock Creek takes advantage of the fact that it enters the Cedar River upstream of Landsburg Dam, which blocked migration by fishes from its construction in 1901 until 2003, when it was modified for fish passage. So, in the first few years, there were resident Cutthroat and Rainbow (*O. mykiss*) trout and other non-salmonid fishes in Rock

Creek but no salmon. Subsequently, Coho and Chinook (*O. tshawytscha*) salmon have been recolonizing the Cedar River above the dam, and the Coho Salmon in particular have been spawning in Rock Creek. Our class data show this pattern, and it greatly enhances the educational experience of the students when they realize what a rare opportunity they have to help document this recolonization process. However, the field trips are linked to the lecture schedule; consequently, the dates when we sample are not necessarily the ideal dates if one were to conduct a long-term study. For example, our spring sampling in Rock Creek occurs earlier than would be ideal; in some years, the young of the year trout and salmon have not yet emerged from the gravel. Nevertheless, we continue our sampling but have not contributed directly to the peer-reviewed literature documenting the recolonization process (Anderson et al. 2008, 2013). On the other hand, the sampling in Lake Washington takes place at a very interesting point in the annual cycle, as the lake is beginning to stratify and we see great interannual variation in the density of *Daphnia*, the primary prey for many of the planktivorous fishes (range of annual estimates: 0.04 to 3.83 per liter). This allows students to compare the proportion of *Daphnia* in the plankton community and in the diets of the different fish species using electivity and diet overlap indices.

In addition to the stream and lake field trips, our proximity to Puget Sound allows us to sample the marine environment too. One might think that the oceanography and biotic communities in Puget Sound would have been subjected to many intensive, long-term studies given the large programs in oceanography and fisheries at the University of Washington and the many other agencies, academic programs, and groups operating in the region. However, there are surprisingly few such studies, most have been of short duration. Puget Sound has a wide range of habitats from intertidal to hundreds of meters deep, including rock, sand, and mud substrates; a variety of macrophytes, such as eelgrass (*Zostera marina*) and kelp; over 200 fish species (DeLacy et al. 1972); and an exceptionally rich macroinvertebrate community. No sampling can encompass such diverse habitats, and many seasonal processes affect what one might catch at any site, including migrations and breeding cycles. However, we selected Port Madison for our sampling because it affords good protection from winds when we are trawling, and we can tow the net along smooth bottom contours at depths of 10, 25, 50, and 70 m. At this site we have sampled 65 different fish species over the years, and each

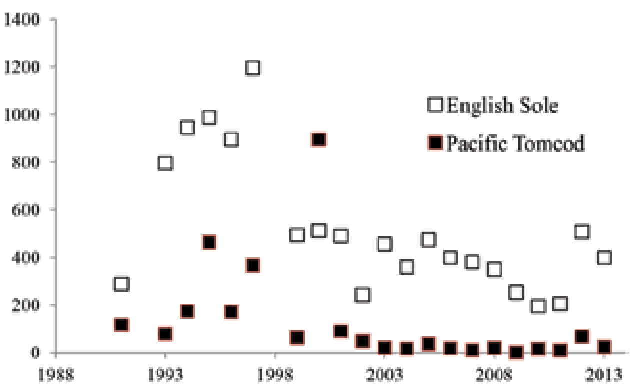

Figure 1. Catches of English Sole (*Parophrys vetulus*) and Pacific Tomcod (*Microgadus proximus*) in standard trawl surveys at 10, 25, 50, and 70 m depth at five time periods covering an entire day in mid-May in Port Madison, Puget Sound, conducted by University of Washington classes from 1991 to 2013.

year we typically catch at least 40 species, as well as many invertebrates representing multiple phyla. Trawling at these depths, sequentially in the afternoon, evening, night, dawn, and mid-day periods in May, allows students to participate in shifts while the instructor and teaching assistants remain on board. Such sampling is tiring but quickly reveals that species and size classes within species segregate by depth, and many species show onshore–offshore diel movements. In some cases, the class data can be linked by collaboration to other kinds of data, such as acoustic telemetry, to provide a clearer picture of the diel activity rhythms and movements of fish than either technique alone could give (Andrews and Quinn 2012). In addition to these patterns, which are more or less obvious in every year to the students collecting the data, we were able to take a longer view and detect significant changes in the fish community, including a rather abrupt decrease in catch rates for many of them (Essington et al. 2013), as shown for two species in Figure 1. The precise cause is not clear but the obvious culprit, overfishing, is not to blame because this area has been closed to bottom-trawling over the entire period. Indeed, our sampling commenced shortly after the closure, and testing the prediction that abundance and diversity would increase was among my goals when starting the sampling.

WHY BOTHER?

I strongly encourage faculty members to establish these kinds of field trips and long-term sampling projects, and there are many reasons to do so. First, many of us got into this business because we love the fieldwork, yet we increasingly stay in the office and look at computer screens. It is fun to get our boots on and get back out where the fishes and other aquatic animals live. Second, the students enjoy and greatly benefit from the trips. They learn not only field techniques (setting nets, identifying fish, etc.) but also the practical aspects of designing fieldwork that are much harder to teach in lectures but obvious outdoors. Third, the students get to interact with each other and with their professor, and this is seldom possible in classroom settings. We can engage with them more deeply with the subject matter, learn about and encourage their career plans, and let them see us as whole people in a manner that is not possible at the lectern. Fourth, we collect data that can be used to test hypotheses about the species and habitats being sampled. The linkage of field sampling with data analysis and preparation of papers in scientific format is essential if students are to progress professionally. Collecting data that mean something is much more engaging than some “cookbook” project in the lab, where the outcome is preordained, and only errors on the part of the students lead to any variation in results. Fifth, students who get especially interested in the class project can often enroll and get independent study credits to continue working on the samples and data, and these can be very important steps toward defining their career goals. Last but not least, if the sampling is conducted in a standardized manner (same net, same time of year, same sites, etc.), the data can accumulate and shed light on important or at least interesting processes as the years go by. In some cases there is an obvious need for a long-term study, such as the planned removal or modification of a dam, change in nutrients in a lake, addition or removal of a predator, etc. Students quickly grasp the value of these studies and greatly appreciate the chance to contribute to the understanding of basic ecological processes and to the documentation of the positive or negative effects of human activity.

SOME CAVEATS

In the spirit of full disclosure, I should point out that there are a number of drawbacks to class field trips and their use in long-term research. The field trips, as noted earlier in this essay, are very time-consuming (preparation, permits, logistics and transportation, gear, the trips themselves, etc.), and those involving vessel charters are costly. Any effort to use the data for long-term work requires organization of the data, and this is much more challenging than one might think. Teaching assistants help with the work but sometimes introduce variation that we must ferret out and fix. Computer programs change, data can get altered, and so forth. There are also important questions of data consistency. Are the students really identifying the zooplankton accurately? In some cases, the faculty member can play a role in the field that assures a high degree of consistency, but inevitably errors creep in, or at least doubts about data quality, from either the sampling itself or the data entry.

In addition to these considerations, there are two other warnings I might issue, and they are related to each other. First, we should recognize the limitations in the field trip data and not overinterpret them. Class field trips are often, of necessity, short in duration and occur only at specific times of the year, typically linked to the academic calendar. These are not always the ideal times of the year to sample if we really wanted to understand the system. So, there are compromises between the study design that we might submit as a proposal and the class field trips. Second and most important, the students are enrolled in the class to get an educational experience and we must make their learning our highest priority. They are not our technicians, and we must allow them the full range of activities, even if this means that they make mistakes. Every year we start over with a new class, and they have to learn to deploy the gear, identify the fish and zooplankton, and all of the other activities involved in the field trips and labs. We should not take advantage of them to do our research for us. Rather, we should regard any research that results from their education as added value.

YOU CAN DO IT—JUST GIVE IT A TRY

I surmise that most fisheries programs in the country are proximate to some body of water (stream, pond, lake, estuary, beach, etc.) that could be safely and efficiently sampled by students in a class. I urge faculty members to consider this way to enhance the education of their students. The chief benefits to us are having fun in the field and seeing students learn and enjoy learning. The time and effort needed to pull off these kinds of field trips are more than balanced by these pleasures. We get the added bonus of generating long-term data that can reveal interesting aspects of the water bodies near where we live and work, and a chance to collaborate with local agency biologists who become interested and involved in the monitoring. I am sure that many faculty members are already doing field sampling like this. I hope they are enjoying the trips as much as I am and that others will give it a try.

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Relating Scientific Names to Common Names for Important Fisheries Species of the Mexican Pacific

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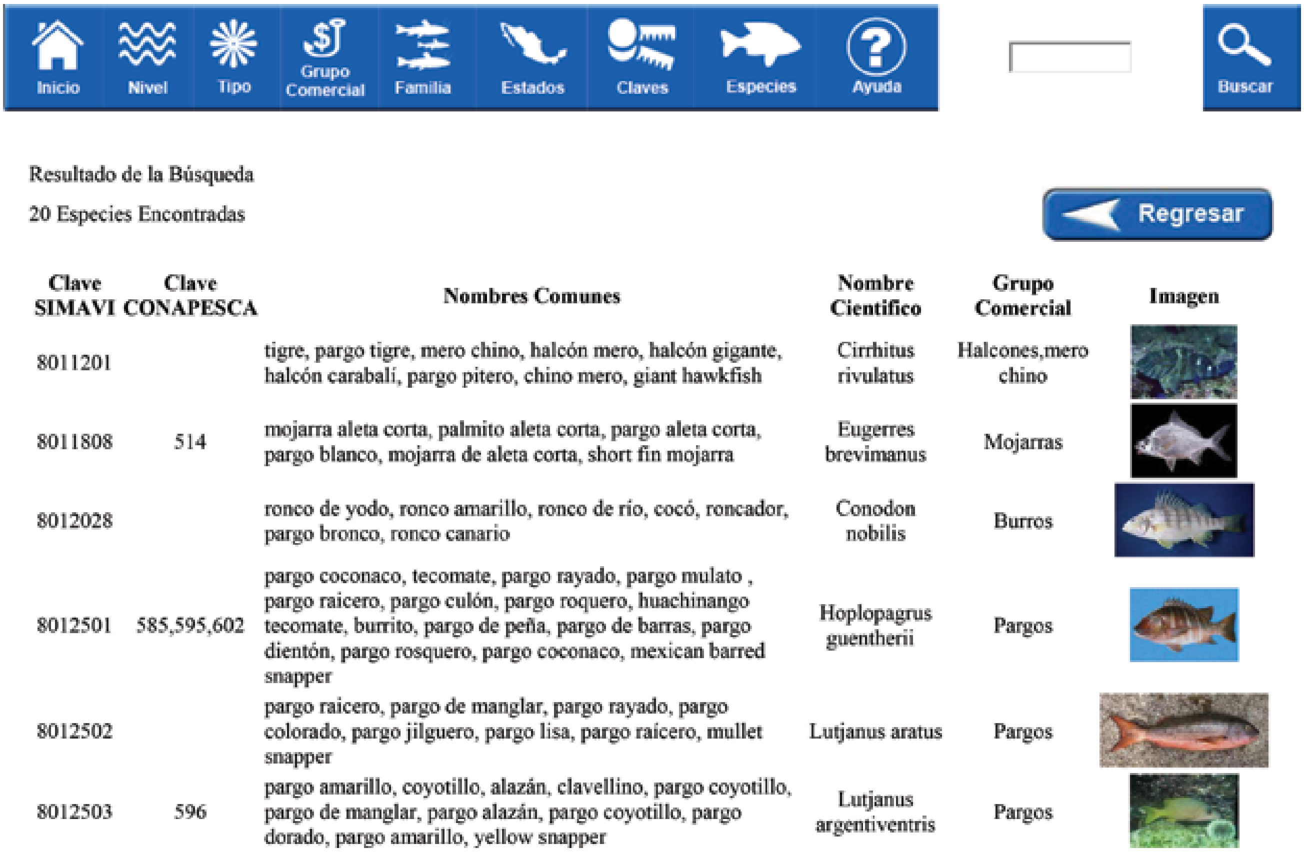
Publications that involve the identification of important fisheries species generally do not relate scientific names to common names in landing records. For this reason, and in order to contribute to improving the quality of fisheries statistics and the works based on them, Mexico's National Commission of Aquaculture and Fisheries (CONAPESCA) and the National Polytechnic Institute convened to compile a list of common names, scientific names, and codes for the recording of commercially important fisheries species in the Mexican Pacific. This list was recently published as an electronic book (Ramírez-Rodríguez 2013) that includes information on 924 species referenced in the literature as important for commercial, recreational, and ornamental (aquarium or craft) uses, or as incidental catch. The book is available online at sistemas.cicimar.ipn.mx/catalogo or from the author.

The objective of the book is to facilitate the identification of species for landing records by associating the scientific name of each species with its common name(s) and defining unique codes that consider different groupings (levels, types, commercial groupings, families, and species; Figure 1). The current proposal is that common names be accepted for data entry, provided that they are associated with a code that corresponds to a single scientific name. For example, *Lutjanus argentiventris* has multiple common names, including Pargo Amarillo, Coyotito, Alazán, Clavellino, Pargo de Manglar, Huachinango del Pacífico, Pargo Dorado, Pargo Cintilla, and Yellow Snapper. Because records are managed by fishers in different fisheries zones, any one of these common names is valid, but the species is represented by a unique code.

The use of official names for species (i.e., one common [official] name for each scientific name) could help improve registers. However, even in the publication of the Mexican fisheries status (Secretary of Agriculture, Livestock, Rural Development, Fisheries, and Food [SAGARPA] 2012), there are several common names related with one scientific name. The electronic book includes the common names from SAGARPA and others in common use in regional fisheries, all related to a scientific name and code. The list of species includes those for which Fischer et al. (1995a, b, c), and other scientific and technical reports, indicated a distribution in the Mexican Pacific and referenced current or potential harvest for food, industry, recreation/sport, and ornamental (aquarium or crafts) uses, or as incidental catch in the harvest of target species. Most scientific names correspond to those used by Fischer et al. (1995a, b, c), though during the process of database construction necessary updates were made. For fishes and elasmobranchs, the works of Nelson et al. (2004) and Froese and Pauly (2012) were used as references. For other taxa, current scientific names were drawn from the World Register of Marine Species (Yasuhara et al. 2015). The list claims no authority on taxonomic issues.

Common names for the species listed in the book include those proposed by the United Nations Food and Agriculture Organization (Chirichigno et al. 1982; Fisher et al. 1995a, 1995b, 1995c; Garibaldi and Busilacchi 2002), and for fishes, by Nelson et al. (2004). Common names recorded in the National Fisheries Chart (SAGARPA 2012) and in the other literature cited were also included. Repetition was avoided by prioritizing publications by date, and the list was complemented using English com-



Clave SIMAVI	Clave CONAPESCA	Nombres Comunes	Nombre Cientifico	Grupo Comercial	Imagen
8011201		tigre, pargo tigre, mero chino, halcón mero, halcón gigante, halcón carabalí, pargo pitero, chino mero, giant hawkfish	Cirrhitus rivulatus	Halcones,mero chino	
8011808	514	mojarra aleta corta, palmito aleta corta, pargo aleta corta, pargo blanco, mojarra de aleta corta, short fin mojarra	Eugerres brevimanus	Mojarras	
8012028		ronco de yodo, ronco amarillo, ronco de río, cocó, roncador, pargo bronco, ronco canario	Conodon nobilis	Burros	
8012501	585,595,602	pargo coconaco, tecomate, pargo rayado, pargo mulato , pargo raicero, pargo culón, pargo roquero, huachinango tecomate, burrito, pargo de peña, pargo de barras, pargo dientón, pargo rosquero, pargo coconaco, mexican barred snapper	Hoplopagrus guentherii	Pargos	
8012502		pargo raicero, pargo de manglar, pargo rayado, pargo colorado, pargo jilguero, pargo lisa, pargo raícero, mullet snapper	Lutjanus aratus	Pargos	
8012503	596	pargo amarillo, coyotillo, alazán, clavellino, pargo coyotillo, pargo de manglar, pargo alazán, pargo coyotillo, pargo dorado, pargo amarillo, yellow snapper	Lutjanus argentiventris	Pargos	

Figure 1. Screenshot of search results from the electronic book (Ramírez-Rodríguez 2013) that contains information on 924 species, including common names, scientific names, and recording codes for commercially important fisheries species in the Mexican Pacific.

mon names accepted by the Food and Agriculture Organization (Fischer et al. 1995a, b, c). The list thus serves as a thesaurus of synonymous common names as well as a dictionary linking common and scientific names.

CODES FOR RECORDING SPECIES

Landings in Mexico are recorded by CONAPESCA using three-digit codes that do not conform to taxonomic criteria and do not allow for the integration of different levels of information (e.g., per family or per commercial group). The sequential numbers do not follow specific rules and do not include all of the actual species of fisheries interest. The codes proposed for the species listed in the book are simple, facilitate the organization and integration of new species, and allow for groupings by levels, species types, commercial categories, families, and species (Ramírez-Rodríguez 2011). These codes come from designed software to facilitate the handling and analysis of official catch statistics registered in fish tickets (Sistema para el Manejo de Avisos de Arribo; Ramírez-Rodríguez and Hernández-Herrera 1999). Each code consists of seven digits: one for higher-level grouping (algae, cnidarians, mollusks, crustaceans, fish, elasmobranchs, turtles, and marine mammals), two for species type (brown algae, red algae, green algae, penaeid shrimp, pandalid shrimp, demersal fish, pelagic fish, etc.), two for family (Arcidae, Haliotidae, Lutjanidae, etc.), and two for genus and species. Names of commercial groups are associated with families (e.g., Arcidae/almeja pata de mula, Haliotidae/abulón, Lutjanidae/pargos) and common names are linked to scientific names. For example, the code 8012501 refers to 8-fishes; 01-demersal fish; 25-Lutjanidae/*pargos* (snappers); 01-*Hoplopargus guentheri*/Pargo Coconaco, Tecomate, Pargo Rayado, Pargo Mulato, Pargo Raicero, Pargo Roquero, Huachinango Tecomate, Pargo de Peña, Pargo de Barras, Pargo Dientón, Pargo Rosquero, Mexican Barred Snapper. The

definition of commercial groups follows, as closely as possible, the categories used by CONAPESCA in its yearbooks of fishery statistics. However, in several cases, no record of a commercial name was found and the group was associated with the name proposed by Fischer et al. (1995a, b, c). The list includes nine levels: algae, cnidarians, mollusks, echinoderms, crustaceans, bony fish, elasmobranchs, turtles, and marine mammals. There are 36 types, 155 commercial groups, 202 families, and 924 species. Most types are crustaceans, though mollusks and fish were the most numerous in terms of commercial groups, families, and species.

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Photo credit: Jeremy Monroe at Freshwaters Illustrated courtesy of U.S. Fish and Wildlife Service

FEATURE

Conserving Pacific Lamprey through Collaborative Efforts

Pacific Lamprey (*Entosphenus tridentatus*) have been an important part of the ecological community and co-evolved with aquatic species of the western rivers of the United States. Scarce information on Pacific Lamprey has hindered conservation and management efforts. To assess and conserve Pacific Lamprey, we developed a conservation initiative composed of three parts: assessment, conservation agreement, and regional implementation plans. We applied a novel ranking system that characterized risk to Pacific Lamprey throughout the U.S. range. We found that the majority of watersheds are at relatively high risk of extirpation, with few secure. The risk assessment results were instrumental in gaining partners' support for a conservation agreement, with the goal of achieving long-term persistence and supporting traditional tribal cultural use of Pacific Lamprey. This extensive support has led to a collaborative effort in developing implementation plans and delivering numerous conservation actions. This approach for assessing Pacific Lamprey status and identifying restoration priorities is easily transferrable to other species.

Conservación de la lamprea del Pacífico mediante esfuerzos de colaboración

La lamprea del Pacífico (*Entosphenus tridentatus*) ha sido parte esencial de la comunidad ecológica y ha co-evolucionado con especies acuáticas de los ríos del oeste de los EE.UU. La falta de información sobre la lamprea del Pacífico ha entorpecido los esfuerzos de manejo y conservación. Con el fin de evaluar y conservar la lamprea del Pacífico, se desarrolló una iniciativa de conservación que se compone de tres partes: evaluación, acuerdos de conservación y planes regionales de implementación. Se aplica un sistema nuevo de ordenación que caracteriza el riesgo de la lamprea del Pacífico a lo largo de los EE.UU. Se encontró que, con algunas excepciones, en la mayor parte de las cuencas hidrológicas, la especie está en riesgo de extirpación. Los resultados de la evaluación del riesgo fueron esenciales para adquirir el apoyo de los participantes en los acuerdos de conservación, con el objetivo de lograr la persistencia de largo plazo y apoyo del uso cultural de la lamprea del Pacífico. Este amplio apoyo ha dado como resultado un esfuerzo de colaboración para desarrollar planes de implementación y la puesta en práctica de numerosas acciones de conservación. Este enfoque para evaluar el estado de la lamprea del Pacífico y para identificar prioridades de restauración se puede transferir fácilmente a otras especies.

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INTRODUCTION

Biology and Ecology

Pacific Lamprey (*Entosphenus tridentatus*) are jawless fishes, considered part of a large, ancient assemblage (Agnatha) that date back to about 500 million years ago (Gess et al. 2006). As such, Pacific Lamprey are among the longest living vertebrates and have persisted through four major extinction events (M. Docker, University of Manitoba, personal communication). Near the end of the Devonian Period (about 350 million years ago), the only Agnathans that remained were the hagfishes and lamprey.

Pacific Lamprey have been an important part of the ecological community that may have influenced the evolution of many aquatic species in the western rivers of the United States. Larval Pacific Lamprey can make up a large portion of the biomass in streams where they are abundant, thus making them an important component along with aquatic insects in processing nutrients, nutrient storage, and nutrient cycling (Close et al. 2002). In addition, adult lampreys die after spawning, leaving marine-derived nutrients in freshwater streams (Beamish 1980). All life stages of Pacific Lamprey appear to be a choice food for both marine and freshwater avian, mammalian, and fish predators, and at times may be preferred over salmonids, acting as a buffer to predation (Roffe and Mate 1984).

Given the dynamic nature of the rivers on the West Coast of the United States and the persistence of Pacific Lamprey, it appears that this species has been successful in pioneering and colonizing emerging habitat across the Pacific Rim from Japan to Mexico. Three genetic studies on the broad-scale population structure of Pacific Lamprey reached a similar conclusion, that there was a high level of historic gene flow for populations separated by large geographic distances (Goodman et al. 2008; Lin et al. 2008; Docker 2010). When interpreted on an evolutionary timescale, these data indicate a shared evolutionary history and a lack of reproductive isolation on small geographic scales. However, components of the available data suggest the possibility of some geographic population structure and adaptive variation: (1) higher number of drainage-specific haplotypes in southern regions, and (2) significant differences in gene frequencies among collection localities. Spice et al. (2012) found that Pacific Lamprey do not exhibit strong site fidelity, but they exhibit limited dispersal, which results in regionally panmictic populations and is supported by the findings of Hess et al. (2013). This would support the concept that the population abundance for a specific watershed may be somewhat dependent on the abundance of neighboring larger watersheds for Pacific Lamprey.

Adult Pacific Lamprey from Cedar Creek, Washington. Photo credit: U.S. Fish and Wildlife Service.

Cultural Importance

Pacific Lamprey have been harvested for many generations by Native American tribes from the West Coast of North America to the interior Columbia and Snake rivers for subsistence, religious, medicinal, and spiritual purposes (Close et al. 2002). Because of the tribes' close connection with Pacific Lamprey, they were the first people to express concern about the precipitous declines in population numbers and constriction of distribution. This decline greatly reduced the tribes' fishing opportunities and impacted the flow of traditional ecological knowledge surrounding Pacific Lamprey (Petersen Lewis 2009). The Native American tribes of the Columbia River convened a Lamprey Summit in 2004 to raise awareness of declines in Pacific Lamprey to the U.S. Fish and Wildlife Service (USFWS) and other state, federal, and local partners in the region. The summit outcome was a commitment by these partners and the USFWS to collaborate on efforts to conserve the species. The USFWS was petitioned to list Pacific Lamprey under the Endangered Species Act (Nawa 2003), but the findings did not warrant listing. The USFWS committed to develop the Pacific Lamprey Conservation Initiative (Initiative) in collaboration with Native American tribes; federal, state, and local agencies; and other entities. The Initiative is a strategy to improve the status of Pacific Lamprey throughout their range in the continental United States, the geographic scope that these entities have management influence for Pacific Lamprey.

Background for Assessing Status

In the Pacific Northwest, research has focused on anadromous salmonids, and this large information base has greatly advanced tools for guiding salmonid conservation and restoration. However, relative to salmonids, lamprey are among the most poorly studied groups of fishes on the U.S. West Coast, despite their diversity and presence in many rivers, including coastal streams (Moyle et al. 2009). Until the current assessment, a systematic evaluation of Pacific Lamprey status in the U.S. has not been conducted (Luzier et al. 2009). Pacific Lamprey have not been important to commercial or recreational fisheries of the West Coast, likely explaining the paucity of information on abundance and distribution collected by state and federal agencies. This lack of information for anadromous lamprey repeats across the globe (Thiel et al. 2009) and has hampered efforts to guide conservation and restoration measures. There have been some geographically limited planning efforts for Pacific Lamprey conservation (USACE 2009; CRITFC 2011); however, a wide-ranging, comprehensive conservation plan has not been developed.

In order to inform a comprehensive conservation plan, our first step was to identify an approach to consistently evaluate the risk of extirpation to Pacific Lamprey in watersheds and then summarize the risk across watersheds (conservation risk) for a larger geographic area. We reviewed assessment approaches applied to anadromous lamprey worldwide that also had limited information. A number of anadromous lamprey species are considered to be in an imperiled status in Europe (Mateus et al. 2012). Assessing threats and demographics guided the selection of special areas to conserve lamprey species (Goodwin et al.

2008). Loss of larval habitat (Kirchhoefer 1995), migration barriers, water quality, and habitat issues (Igoe et al. 2004) have been identified as causes for the decline of lamprey species in Europe and Great Britain. Kelly and King (2001) evaluated three species of lamprey in Ireland, providing a detailed and comparative account of lamprey ecology, particularly regarding those river life stages most likely to be affected by human activity. Areas were identified where more information is needed to form a basis for decision making regarding conservation requirements. In Canada, only half of the lamprey species have been assessed by the Committee on the Status of Endangered Wildlife in Canada, and NatureServe conservation rankings have been applied to a number of lamprey species (excluding Pacific Lamprey) at the national and subnational levels (Renaud et al. 2009). Pacific Lamprey in Canada have not been ranked through NatureServe at the national level, but in British Columbia they have been ranked as secure at the subnational level (Renaud et al. 2009). Moyle et al. (2009) conducted a systematic analysis using available information for lamprey in California. This approach used criteria that included aspects of lamprey biology, vulnerability to environmental change, and limiting factors; they found that all species are either declining, exist in low numbers, or are isolated populations.

Most of these evaluations related to lamprey conservation have been challenged by the scarcity of demographic information and the biology and ecology of anadromous lamprey species. However, a recurring approach for informing lamprey conservation is to pool information on populations and synthesize information on the biology, ecology, and habitat requirements for lamprey species. Most of these systematic analyses also focused on specifically identifying the threats or limiting factors that are impacting the lamprey populations. The USFWS and partner agencies have applied similar systematic assessment approaches to evaluate aquatic species status and guide development of conservation plans (USFWS 2008a). The USFWS has specifically used NatureServe to evaluate the relative conservation status of Bull Trout (*Salvelinus confluentus*) at a core area level (USFWS 2008a). This systematic approach of assessing an aquatic migratory species, with limited information, can be applied at various spatial scales (Faber-Langendoen et al. 2012), is well documented, scientifically supported, and widely used by many USFWS partners.

Andelman et al. (2004) conducted a review of protocols for identifying species at risk in the context of viability assessments for the U.S. Forest Service. They reviewed nine published protocols (including the NatureServe ranking system, USFWS listing factors, International Union for Conservation of Nature classification system, and others) and concluded that all were useful, but NatureServe ranks may be the most suitable for identifying species at risk on national forests because of the flexibility of scale, potential for use of existing information, and ability to integrate threats analyses.

Conservation Initiative

The goal of the Initiative is to collaborate on efforts that reduce or eliminate threats to Pacific Lamprey and to achieve long-term population persistence while supporting traditional tribal cultural use. We applied the Strategic Habitat Conservation (SHC) approach to Pacific Lamprey through an Initiative that is composed of a three part process: The Assessment and Template for Conservation Measures (Assessment; Luzier et al. 2011); a conservation agreement (Agreement; USFWS 2012); and regional implementation plans. The USFWS adopted SHC, which is a landscape (riverscape) approach to conservation that emphasizes planning, science, partnership, and learning from experience (USFWS 2008b). The Assessment uses current knowledge of historic and current distribution, abundance and trends in abundance, and threats to Pacific Lamprey and their habitat to assess relative risk to populations. The Agreement is a voluntary commitment of the USFWS, tribes, and other partnering agencies and organizations to collaborate on efforts to achieve the Initiative goal. The regional implementation plans identify and prioritize conservation actions, research and monitoring needs, as well as potential funding sources for these activities across regions. Lamprey restoration efforts are coordinated with restoration activities for other aquatic species (e.g., salmon, steelhead, and bull trout) that should lead toward healthier riverscapes.

METHODS

The SHC approach (USFWS 2008b) is composed of biological planning, conservation design, conservation delivery, and an adaptive management feedback loop. Biological planning is the systematic application of scientific knowledge about species to guide habitat management actions. We did this in the Assessment by using the demographic information and identified threats to assess the relative risks of extirpation of Pacific Lamprey. By evaluating the results of the risk assessments and ongoing conservation measures, we identified gaps in conservation actions. This constituted our conservation design approach, which shaped the Conservation Agreement and is guiding regional implementation planning. Conservation delivery is guided by the regional implementation plans and adjusted through a feedback loop. This adaptive management approach is informed by all of the regions sharing information on evaluation of conservation action effectiveness and evaluation of population status.

Assessment

To characterize the conservation risk of Pacific Lamprey, we took a novel approach in applying the NatureServe ranking system (Faber-Langendoen et al. 2012). The three factors used in NatureServe are rarity (distribution and abundance), trends in abundance, and threats (Luzier et al. 2011). We made the following changes to the default rank calculator values to better reflect the quality of the information for Pacific Lamprey rarity, trends, and threats: (1) changed the weighting of the historic distribution, current distribution, population size, and ratio of current to historic distribution so all equal 1; (2) added the ratio of current to historic distribution (the addition of this ratio lets us factor in the risk associated with rearing and spawning in less spatially diverse areas) with a weight of 1; (3) changed the relative weights of the three major factors (rarity, trends, and threats) from 0.65, 0.20, and 0.15 to 0.60, 0.10, and 0.30, respectively. This change increases the weight for threats from standard NatureServe ranks, reflecting the fact that we were highly confident in our threat information, and our trend data are either lacking or uncertain (Luzier et al. 2011). The weights used for the ranking factors reflect the relative confidence in the data.

We applied the NatureServe ranks to discrete watersheds (4th code Hydrologic Unit [HUC 4]), a scale that is rarely used for assessing species status with this tool. We used data at the HUC 4 scale because it provided the highest degree of specificity for demographics and threats, assessing patterns of relative risk of extirpation, and to identify any relative strongholds or weak areas for Pacific Lamprey conservation. The findings of risk rank and threats by HUC 4 were summarized for 10 regional management units (RMUs) to assess conservation risk at a scale that promotes collaboration among resource managers on conservation and restoration activities. The RMUs are Northern California, Southern California, coastal Oregon, lower Columbia/Willamette, Mid-Columbia, upper Columbia, Snake, mainstem Columbia and Snake, Puget Sound/coastal Washington, and Alaska (Figure 1). Maps by region were constructed to display the spatial arrangement of risk by watershed (Luzier et al. 2011; Goodman and Reid 2012). Through this novel application of NatureServe, we could provide the range of ranks for the watersheds within RMUs and consider the spatial arrangement of risk levels for these watersheds.

We assessed the conservation risk for all of the RMUs except the mainstem RMU and Alaska. The mainstem RMU represents a migratory corridor that summarizes threats that impact the populations of the other RMUs of the Columbia River Basin. This summary of threats was applied to the RMUs that migrate through this corridor. There is little information about distribution and status for Pacific Lamprey in Alaska, which precluded a NatureServe risk assessment.

We conducted a series of meetings across the RMUs to consistently collect data on rarity, trends, and threats by HUC 4 (Luzier et al. 2011; Goodman and Reid 2012). This

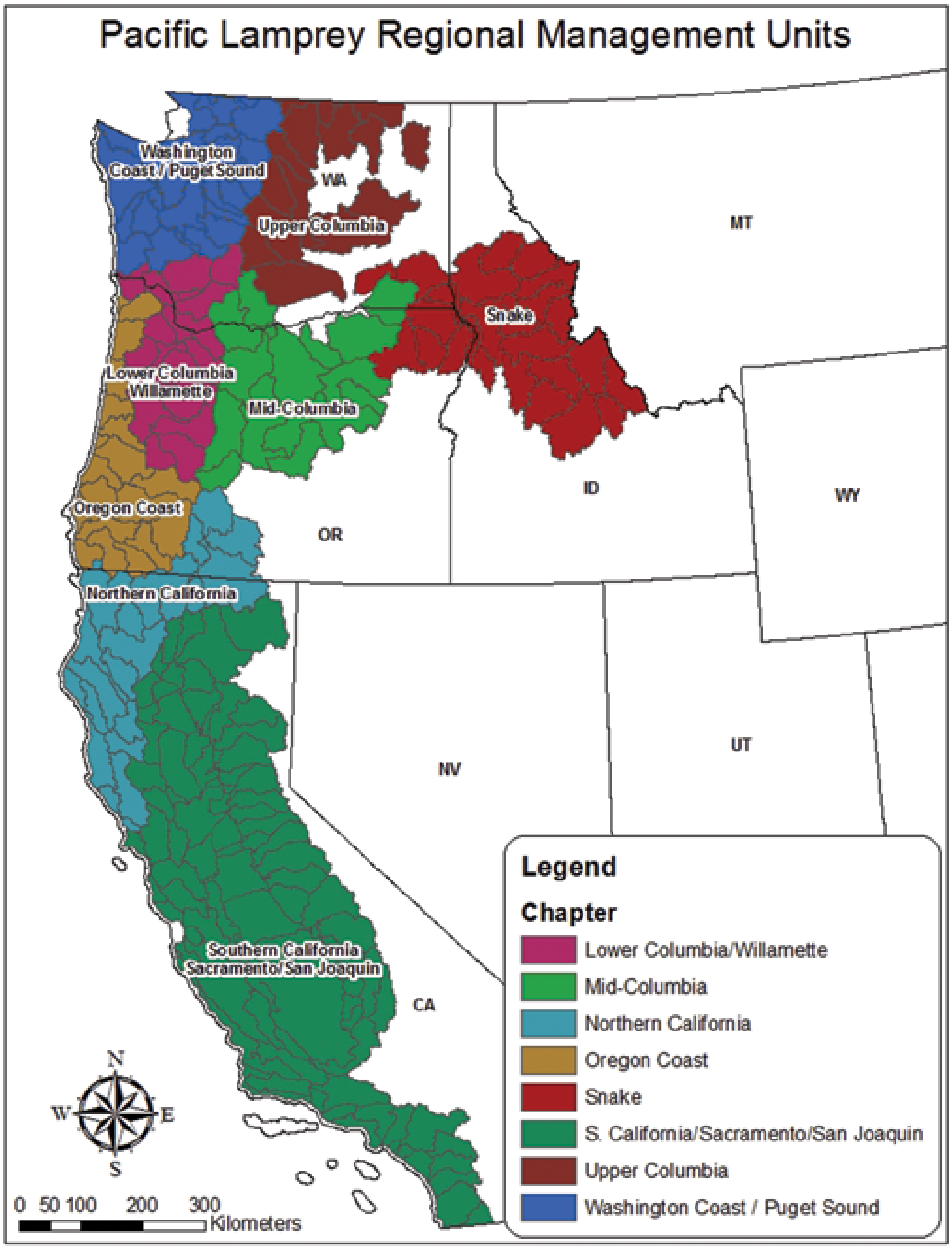

Figure 1. Pacific Lamprey distribution has been divided into 10 regional management units (RMUs): Northern California, Southern California, coastal Oregon, lower Columbia/Willamette, Mid-Columbia, upper Columbia, Snake, mainstem Columbia and Snake, Puget Sound/coastal Washington, and Alaska.

information was organized around the NatureServe categories used in the rank calculator to provide consistency for future status assessments of Pacific Lamprey. The NatureServe technical experts confirmed that our application of the rank calculator (including revised weights) and the spatial scale to Pacific Lamprey was consistent with their principles for conservation assessment (B. Young and M. Ormes, NatureServe, personal communication).

Conservation Agreement

The Agreement provides a mechanism for the involved parties to collaborate and pool available resources to expeditiously and effectively implement conservation actions and to share success of restoration actions and research, monitoring, and evaluation results for Pacific Lamprey. Working through a steering committee of partners, we jointly developed the guiding principles of the Agreement. We worked with these parties to finalize the Agreement language in order to maximize the number of supporters.

Implementation Plans

We are in the process of developing implementation plans for each of the 10 RMUs. For each watershed in a region, the threats identified in the Assessment and by local experts will be summarized. Then the regions will identify ongoing and planned conservation actions and determine the gaps in conservation needs.

RESULTS

Assessment

Abundance and distribution of Pacific Lamprey throughout California, Oregon, Washington, and Idaho has declined and contracted. Threats such as barriers to mainstem and tributary passage, streamflow management, stream and floodplain degradation, and reduced water quality are impacting all freshwater life stages. The majority of watersheds are at relatively high risk, with very few that are relatively secure. The patchy distribution of watersheds at low risk limits the potential for a rescue effect for high-risk watersheds (Figure 2).

In Northern California (north of Point Conception), Pacific Lamprey were extirpated from at least 55% of their historical habitat by 1985. The primary threat responsible for extirpations was large impassible dams, which excluded migrating adults from access to high-quality spawning and rearing habitat in the foothills and higher elevations. In Southern California, results indicate that no viable populations of Pacific Lamprey currently occupy drainages south of the Big Sur River on the central coast, and there is evidence for a general northward range contraction (Goodman and Reid 2012).

The NatureServe rank indicates that Pacific Lamprey for the coastal Oregon RMU are at relatively lower risk than those of other RMUs in the range. The most serious threat in this region is stream and floodplain degradation, which was classified as a moderate threat (Luzier et al. 2011).

The Columbia River Basin is composed of the Snake, Upper Columbia, Mid-Columbia, Lower Columbia, and Willamette RMUs. The NatureServe ranks indicate that Pacific Lamprey are at high risk throughout much of the Columbia River Basin, particularly in the Snake River, the Mid-Columbia, and the Upper Columbia RMUs. Results from the mainstem RMU threat assessment (Luzier et al. 2011) identified that the primary threat affecting these populations is adult and juvenile passage at mainstem dams. Tributary passage, stream and floodplain degradation, and water quality are also affecting Pacific Lamprey in these RMUs. Pacific Lamprey of the Lower Columbia and Willamette rivers are at relatively lower risk; however, the risk levels are still high to moderate.

Because of the lack of information on demographic and threat factors, the watersheds in the Puget Sound/Strait of Juan de Fuca/Coastal Washington geographic area were not assessed with the NatureServe ranking approach. However, several of these watersheds were appraised using expert opinion with the available information on short-term trends and general threats. The abundance of the Pacific Lamprey in these watersheds was characterized as rapidly declining (Luzier et al. 2011).

Conservation Agreement

The Agreement was signed by 12 tribes from California, coastal Oregon, and the Columbia River Basin; four state fish and wildlife agencies; eight federal agencies; non-governmental organizations; and a number of local governments that span the geographic range of Pacific Lamprey in the continental United States. The goal is securing long-term persistence of Pacific Lamprey and supporting traditional tribal cultural use throughout their historic range in the U.S. Through the Agreement, the parties committed to restoring Pacific Lamprey, enhancing watershed conditions, and data sharing in each RMU.

Signatories to Pacific Lamprey Conservation Agreement signed June 20, 2012, in Portland, Oregon. Photo credit: US Fish and Wildlife Service.

DISCUSSION

Partner commitment to the Initiative is the first time that wide-ranging support has been focused on Pacific Lamprey conservation. The Assessment was supported because it was systematic, transparent, repeatable, and relied on data, research, and expert opinion from multidisciplinary scientists, managers, and decision makers. The completion of the Assessment was the key to bringing people to the table to commit to collaborative conservation, through the signing of the Agreement. By including the traditional tribal cultural use of Pacific Lamprey in the goal of the Agreement, numerous Native American tribes from the states of Washington, Oregon, and California supported and signed it. This broad tribal support was instrumental in solidifying support of the four states and the many federal agencies. In addition, the voluntary nature of the Initiative provided an atmosphere where our partners were more willing to explore collaborative conservation strategies. This was likely related to avoiding the regulatory process of the Endangered Species Act, which can sometimes be constraining. This unprecedented interest in Pacific Lamprey has increased the potential for funding conservation actions (USFWS 2012).

The partners adopted a consistent approach for regional implementation planning and it is active through all RMUs. These plans will allow each region to prioritize actions and collaboratively address conservation and restoration needs for Pacific Lamprey. The regions committed to sharing success and failures of restoration actions and research, monitoring, and evaluation results for Pacific Lamprey among the RMUs. Partners are working together to fund activities prioritized in the regional plans.

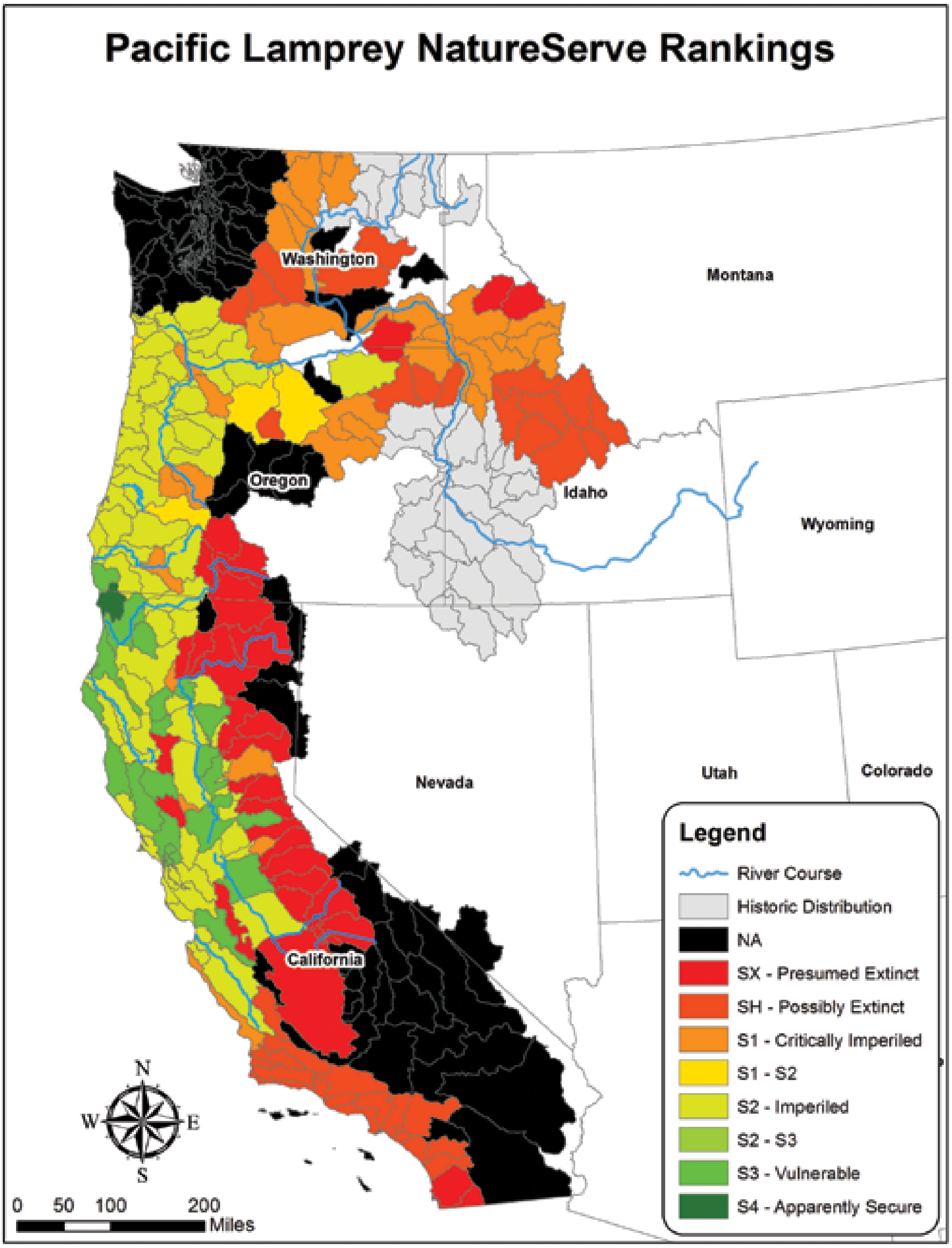

Figure 2. Calculated NatureServe relative risk ranks for Pacific Lamprey (Luzier et al. 2011; see tables 4-1 through 4-6). NA is for HUCs with insufficient data.

The Initiative and the planning process have yielded immediate benefits in addressing the most serious threats and information gaps for Pacific Lamprey. Examples of these include systematic evaluation of adult passage at Columbia River dams (Keefer et al. 2012), juvenile lamprey enumeration and condition sampling at Columbia River dams (McCann and Chockley 2011), artificial propagation research and translocation (Jolley et al. 2013), distribution sampling (Hayes et al. 2013), species identification, development of best lamprey management practices for stream disturbing activity (USFWS 2010), evaluation of lamprey during instream work activities (Jolley et al. 2012), increased funding for restoration activities (Luzier et al. 2011), and funding of lamprey tributary passage structures (Jackson et al. 2011; Luzier et al. 2011).

The Initiative coordinates restoration of habitats that cover close to a million square kilometers in California, Oregon, Washington, and Idaho. These efforts to restore the habitats of Pacific Lamprey and increase their abundance will also benefit many other aquatic species of the western rivers of the United States because of the Pacific Lamprey's key ecological role. The demonstrated support by the signatories of the Agreement and swift implementation of actions has raised the general awareness of the cultural and ecological importance, status, and conservation needs of Pacific Lamprey.

The USWFS's SHC approach proved to be useful in developing and implementing a conservation strategy for Pacific Lamprey, a wide-ranging and highly mobile species with little commercial value and a paucity of information. From this experience, we conclude that the organization of information and the resulting risk assessment were the keys to getting a wide range of partners to the table to explore collaborative conservation strategies for Pacific Lamprey. This relationship allowed us to develop an Agreement that solidified the parties' commitment to developing implementation plans, delivering numerous conservation actions on the ground, and sharing monitoring and evaluation results. Applying the principles of SHC proved helpful in organizing information and jointly developing conservation strategies that the numerous partners committed to monitor and evaluate, closing the loop on adaptive management.

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NEWS

Environmental DNA Clearinghouse: New Tools for Managers

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Recent advances in genetic analysis are transforming the ways in which biologists monitor and manage aquatic organisms. Traditional monitoring techniques for aquatic species are often costly and time-intensive, especially when managers need information about rare, elusive, or newly-colonizing species. Analysis of DNA found in the environment, or eDNA, can provide managers with data about the presence and distribution of aquatic species in a timely and cost-effective manner.

The American Fisheries Society, the U.S. Forest Service, and the Association of Fish and Wildlife Agencies have teamed up to inform the broader aquatic management community about the promises and opportunities associated with the emerging field of eDNA analysis. Accompanying this article and a forthcoming review paper is an online "clearinghouse" which provides contact information for current eDNA researchers, as well as information about each researcher's capabilities, tools, and services. This clearinghouse is intended to facilitate connections between the scientists who are developing eDNA technology and managers seeking to apply this technology to conservation questions. Interested researchers are welcome to join the clearinghouse by registering at: www.surveymonkey.com/s/eDNAclearinghouse. The clearinghouse will be housed on the American Fisheries Society website: edna.fisheries.org.

WHAT IS eDNA ANALYSIS?

eDNA analysis uses polymerase chain reaction (PCR) technology to amplify genetic material from organisms in water or soil samples (Taberlet et al. 2012). eDNA analysis has been widely applied in freshwater and marine systems, with studies that span a range of vertebrate, invertebrate, and plant taxa, and applications to management problems such as invasive species detection, rare species monitoring, and biodiversity monitoring (Schwartz et al. 2006).

RECENT eDNA APPLICATIONS

Invasive Species

eDNA analysis can facilitate detection and monitoring of invasive species, as in the well-known case of Asian carp (Bighead Carp, *Hypophthalmichthys nobilis,* and Grass Carp, *H. molitrix*) in the Chicago Sanitary and Shipping Canal (Darling and Mahon 2011).

Rare or Elusive species

eDNA analysis also lends itself well to the detection of rare or elusive species. In Idaho, Goldberg et al. (2011) used eDNA to assess the presence of the Rocky Mountain tailed frog (*Ascaphus montanus*) and the Idaho giant salamander (*Dicamptodon aterrimus*). Olsen et al. (2012) assessed eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*) populations in Missouri and Indiana rivers using eDNA.

Community Composition and Biodiversity Monitoring

eDNA analysis can also be used to determine species composition and overall diversity of aquatic communities. Thomsen et al. (2012a, b) tested this approach successfully in a controlled mesocosm environment and subsequently applied eDNA analysis to detect aquatic vertebrate and invertebrate species in European ponds, lakes, and streams.

THE FUTURE

eDNA analysis is a rapidly-evolving field which holds considerable promise for managers who need information about aquatic species and communities. The eDNA clearinghouse is intended to help acquaint managers with this new technology, and to provide a point of connection where managers and researchers can work together to develop new applications of eDNA analysis to solve practical problems in the management of aquatic organisms and ecosystems.

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Purpose, History, and Importance of the Student Angle

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AFS Education Section
Student Subsection

The Students' Perspective

1992 Southern Division Fisheries Student Colloquium—Professionally Hip

The Tenth Annual Fisheries Student Colloquium was held 10–12 April 1992 at the Upper Cumberland Biological Station on the shores of Center Hill Reservoir, Tennessee. This year's meeting was cosponsored by the AFS Southern Division, the AFS Tennessee and Auburn Chapters, and the AFS Student Fisheries Association-Tennessee Technological University. This is the fourth colloquium cosponsored by the Southern Division. Approximately 75 students, faculty, and staff representing 11 universities were in attendance, making this year's colloquium one of the largest to date.

This annual event provides an informal atmosphere for students to discuss ongoing and completed projects and to solicit constructive critiques and advice from peers. Twenty-one student presentations were given on a variety of subjects, including biomass estimation of aquatic vegetation, invertebrate ecology, and reservoir fisheries management. Student participation included not only graduate students, but also undergraduates interested in continuing their education.

In addition to student presentations, the coordinators arranged for three guest speakers. Dr. Clyde Voigtlander of the Tennessee Valley Authority and former science editor of *Fisheries* began the colloquium with an informative workshop on improving scientific writing skills. This seminar was of particular value to students as they prepare their research for publication. On Saturday morning Nick Parker, president of the Southern Division, spoke on the importance of aquaculture on a global scale. Dr. Michael Van den Avyle, unit leader of the Georgia Cooperative Wildlife and Fishery Research Unit, began the afternoon session by presenting his research on coastal striped bass in the Savannah River.

The colloquium formally concluded with a student forum. Mike Allen (Auburn University), president of the Student Subsection, and Elise Irwin (North Carolina State University), president-elect, provided a summary of the status of the Subsection after its first year and discussed ideas for its future. Bob Bet-

Students hang out at the recent Southern Division Fisheries Student Colloquium.

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The Student Angle began in 1991 as the Students' Perspective. Since its inception, the student column has facilitated communication among students and fostered professional development of readers and authors. This image was taken at the 1992 Southern Division Fisheries Student Colloquium.

INTRODUCTION

More than 20 years ago, a column in *Fisheries* was launched for dissemination of news and activities relevant to students in the American Fisheries Society (AFS). The birth of the Student Angle coincided with the establishment of the Student Subsection of the Education Section (hereafter Subsection) of AFS in 1991. This forum continues to serve a crucial role for students within AFS, providing information for students by students, and fostering professional development of readers and authors alike. The Student Angle exposes the *Fisheries* readership—including students, biologists, scientists, and educators—to important student perspectives. A communication forum fueling dialogue among students and professionals benefits the Society and the aquatic ecosystems students will inherit. As a venue for information exchange in the flagship AFS journal, the column also helps fulfill the Subsection's mission to "facilitate interactions among our peers and mentors by providing member services consistent with the goals and mission of the parent Society." For authors, the Student Angle is a valuable opportunity to sharpen communication skills (i.e., writing and reviewing), convey information to a wide readership of fisheries professionals, and encourage student involvement in the Subsection.

Despite the significance of the Student Angle, many current aspiring professionals are unacquainted with the forum. Lack of familiarity and indefinite scope may have caused a recent plateau in column submissions below historical levels. To increase awareness of and participation in the Student Angle, we review the history and detail the submission process of this one-of-a-kind resource.

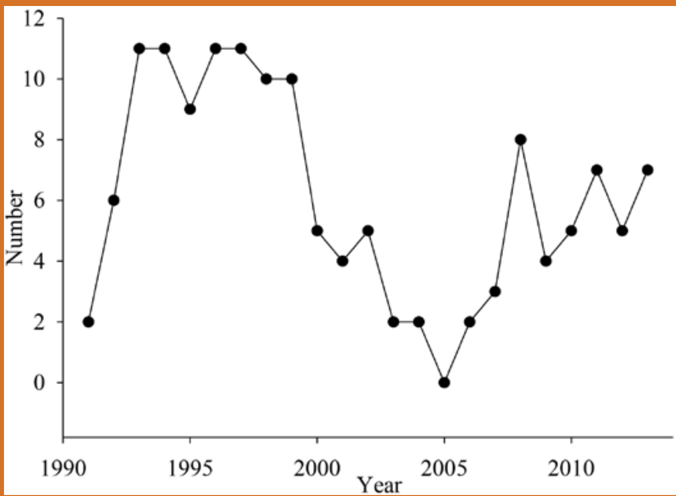

Figure 1. Number of Student Angle articles by year from 1991 to 2013.

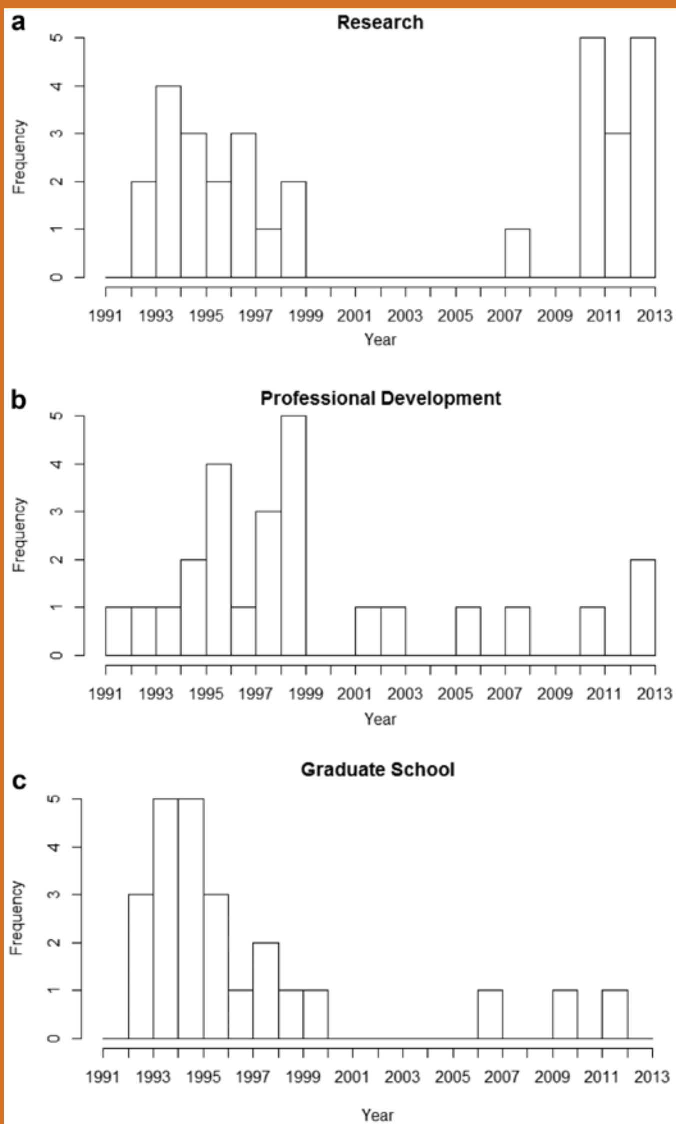

Figure 2. Frequency of Student Angle articles written about (a) research, (b) professional development, and (c) graduate school from 1991–2013.

HISTORY

The *Fisheries* student column began in 1991 as the Students' Perspective, with name changes occurring in 1993 (Students' Corner), 1995 (Students' Angle), and 2011 (Student Angle). A total of 140 articles spanning diverse topics have been published. In our review of past publications, we encountered articles on graduate school selection, manuscript submission, time management, and professional networking. Early column submissions informed readers about the formation of the Subsection, a watershed moment for student involvement in the Society. Articles appeared in nearly every issue of *Fisheries* until 2000, when a downward publication trend began (Figure 1). Submissions have increased since 2005, when no articles were published, but participation still falls short of the 1990s. The scope of the Student Angle is broad and deep, giving authors considerable flexibility in topic selection.

Student Angle articles have emphasized research (Reynolds 1994; Isaak 1998; Chenoweth 2013), professional development (Neumann 1993; Jones 2002; James 2011), and graduate school (Allen 1993; Overton et al. 2000; O'Connor 2012; Table 1) over other topics. Given that more than 60% of articles are authored by M.S. and Ph.D. students (Table 2), this trend is predictable as students may be expected to write about the issues that most concern them and the primary audience—other students. Articles describing student research were written frequently before 2000, but only one submission was published in the next 10 years (Figure 2a). However, a resurgence of research publications has occurred, with 13 articles since 2011. Professional development articles were frequent in the mid-1990s and peaked in 1999 but have since declined (Figure 2b). Student Angle submissions about graduate school have followed a similar decreasing trend, with 21 articles published before 2000 but only three from 2000 to 2014 (Figure 2c). In addition to student research, recent articles have explored student-centered AFS programs including the Janice Fenske Excellence in Fisheries Management Fellowship and the Hutton Junior Fisheries Biology Program.

Authors from 51 universities have published Student Angle articles, but only 21 institutions have had more than two authors (Table 3). More than one-third (34.3 %) of submissions have been authored by students from three universities: South Dakota State, Virginia Tech, and North Carolina State. Along with Kansas State University and Montana State University, students from these institutions have written nearly half (47.1 %) of the Student Angle articles. We encourage submissions from other universities to illustrate the diverse aquatic research occurring throughout the country and abroad. Furthermore, students need not be the only authors. Diversity in authorship, as seen in the past (e.g., a former director of AFS, a *Fisheries* editor, biologists, supervisors, and postdoctoral researchers), provides topical variety and ensures readers are exposed to a rich mosaic of student and professional perspectives.

SUBMISSION PROCESS

The submission process for Student Angle articles is similar to standard peer-reviewed manuscripts. First, authors brainstorm topics, typically those related to their academic and professional experiences. At this stage, we encourage authors to discuss potential publication ideas with the Subsection President and President-Elect, who act as editors of the column and can offer recommendations for innovative article topics. All types of submissions (e.g., research summaries, advice, short stories, opinions, and collaborative efforts) are welcome. After selecting a topic, authors submit a first draft (typically 1,600 words or less and formatted for *Fisheries*) and cover letter to the President, who forwards the manuscript to the President-Elect for review. Comments are generally returned to authors within one month. Authors then submit a revised draft to the President, who convenes with the President-Elect to determine if additional revisions are necessary. When the manuscript is polished and ready for submission, the final draft is sent to *Fisheries* for publication.

FUTURE DIRECTIONS

If you would like to write a Student Angle article, please contact the Subsection President right away! We encourage submissions from all realms of fisheries and would love to hear your ideas. Innovative topics include groundbreaking research, new technologies, emerging fields of study, social media, a student's guide to professional meetings, and collaborations in ecological fields outside fisheries. However, authors (both students and professionals) have the freedom to investigate virtually any aspect of aquatic ecology. The Student Angle is an outstanding forum for information exchange, professional development, and a valuable way to contribute to AFS. Don't pass up this one-of-a-kind resource!

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Table 1. Number of Student Angle articles by subject.

Subject	Articles
Research	31
Professional development	26
Graduate school	25
AFS involvement	17
AFS Subsection news	16
Public outreach	11
AFS Annual Meeting	9
Publishing	9
AFS Student Subunits	9
Student symposium or conference	5
Study and research abroad	5
Teaching	5
Technology	5
Safety	3
Volunteering	3
Janice Fenske Fellowship	3
AFS certification	2
Minorities in fisheries	2
Hutton Junior Fisheries Biology Program	1

Table 2. Number of Student Angle authors by title.

Title	Authors
Ph.D. student	86
M.S. student	51
Unspecified student	31
Unspecified graduate student	24
B.S. student	8
Faculty	8
Postdoctoral researcher	3
Biologist	2
Law school student	2
Not available	2
Other	7

Table 3. Number of Student Angle authors by institution for universities with three or more authors. Institutions with fewer than three authors (N=36) are not listed.

Institution	Authors
South Dakota State University	19
Virginia Tech University	15
North Carolina State University	14
Kansas State University	9
Montana State University	9
Tennessee Technological University	8
University of Wyoming	8
Pennsylvania State University	7
Auburn University	6
University of Georgia	6
North Dakota State University	5
University of Idaho	5
University of Waterloo	5
Carleton University	4
Oklahoma State University	4
University of Connecticut	4
University of Illinois–Urbana-Champaign	4
University of Minnesota	4
Michigan State University	3
University of British Columbia	3
University of Illinois	3
Institutions with <3 authors	36

Blue-Barred Parrotfish (*Scarus ghobban*) in Thailand. Photo credit: Johan Lind.

ESSAY

Underwater Romance: A Valentine's Day Ode to Fishes

Natalie Sopinka
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If Jane Austen were to write a romance novel on fishes, which species would be the main characters?

HISTORICAL ROMANCE

A tale of two lovers trying to find each other in a Scotland loch 385 million years ago would of course feature the ancient fish *Microbrachius dicki*. Unearthed in Scotland, fossils of these fish have claspers on males and genital plates on females (Long et al. 2015). Considered the earliest evidence of copulation, when a male and female are side-by-side, claspers are thought to dock to a female's plate and transfer sperm into the female's cloaca.

ROMANTIC SUSPENSE

The mysterious love affair between a devoted seabed architect and a fastidious female could be inspired by the pufferfish (*Torquigener* spp.). The males of this genus, found in waters south of Japan, wiggle through sand creating a circle of intricate "peaks and valleys" (Kawase et al. 2013). Referred to as the ocean's crop circles, the exquisite structures grab the attention of females. Will the architect's nest be of high enough quality for the lead female to enter and release her eggs?

The thrilling life in the coral reef fast lane is full of both passion and danger for parrotfishes (Family Scaridae). The frenzied spawning of parrotfishes is dramatic; the upward rushes of mating fish are so rapid noise is generated (Lobel 1992). But the overfishing of parrotfish is also dramatic; populations have suffered significant declines in abundance over the last 20 years (Jackson et al. 2014). Can fisheries management ensure coral reefs, and parrotfish romance, survive?

Breeding pair of Oyster Toadfish with eggs in an empty whelk shell. Photo credit: Gregg P. Sakowicz, Jacques Cousteau National Estuarine Research Reserve, Rutgers University.

CONTEMPORARY ROMANCE

The love story of two smitten neighbors among Australia's seagrasses would be best portrayed by the White's Seahorse (*Hippocampus whitei*). Throughout the spawning season, *H. whitei* regularly bid good morning to their mate at a "greeting" location (Vincent and Sadler 1995). Upon arriving at the meeting site, both male and female brighten in color and grasp tails. Connected, the pair begin to spin like an amorous, waltzing couple.

A rock 'n' roll celebrity looking to settle and find love on the Atlantic coast could follow the life of the Oyster Toadfish (*Opsanus tau*). Known for their "boatwhistle" mating call, male Oyster Toadfish emit grunts via contractions of their sonic muscles which vibrate the swim bladder (Fine 1978). The low frequency bellows attract females, and males hunker down for the long haul, caring for eggs until they are free-swimming fry.

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An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico

National Research Council of the National Academies. The National Academies Press, Washington, D.C. 2013. 235 pages. US$59.00 (paperback)

In April 2010, the *Deepwater Horizon* drilling platform in the Gulf of Mexico exploded and sank, triggering a blowout of the Macondo wellhead 1,600 m below the water's surface. By the time the wellhead was capped three months later, 4.9 million barrels of oil had been released, making it the largest marine oil spill in history. Eventually, close to 1,800 km of Gulf Coast shoreline was oiled; fisheries were closed; sea turtles, birds, and marine mammals were killed; and many people's lives were disrupted. The litigation that inevitably follows such a disaster (in the United States, at least) is still ongoing.

This book comes from a committee of the National Research Council convened to evaluate the effects of the spill on the ecosystem services of the Gulf. It is this focus on ecosystem services and the related themes of management of ecosystem processes and enhancement of ecosystem resilience that makes this book unique, important, and a bit frustrating.

The emphasis on ecosystem services—the goods and services that people derive from functioning ecosystems—represents a significant departure from the Natural Resource Damage Assessment (NRDA) process that currently guides assessments of damages from environmental accidents, such as an oil spill. The NRDA directs attention to injuries and recovery of natural resources, usually species, whereas the ecosystem services approach is all about impacts on benefits to people; it is explicitly human-centered rather than nature-centered (although the natural resources considered in a NRDA process are often those with value to people).

The meat of this book is in chapters describing the ecosystem services approach, the concept of ecosystem resilience, the specifics of how ecosystem services to people may have been affected by the oil spill, and some research needs that would bolster the approach (another chapter details several technologies that were employed to contain, disperse, or clean up the spilled oil). Four case studies (wetlands, fisheries, dolphins, and the deep sea) receive detailed attention. The recurrent theme of these chapters is that, in comparison with the traditional NRDA process, the ecosystem services approach provides a more comprehensive consideration of factors that interact to determine how benefits flow to people; it opens more options for restoration or recovery efforts by directing actions where they may produce the greatest benefits; and it highlights the importance of ecosystem resilience as a target for management.

This approach is not without problems, many of which are acknowledged and discussed. Establishing a prespill baseline for evaluating spill effects is difficult when the baseline is shifting (as with sea-level rise or extreme events such as hurricanes). When one adopts an ecosystem-based approach, modeling the welter of interacting factors and dynamics, many of them operating at different scales of time or space, becomes daunting. Adding in the socioeconomic components is difficult enough, because different segments of society may benefit from ecosystem services in quite different ways. There is also the vexing problem of how to value individual ecosystem services, and the tradeoffs among services, in ways that make sense to people and to the environment. And then there is the reality that current laws and regulations are designed for resource-by-resource management; the more integrative approach advocated here, with its emphasis on resilience, tradeoffs, flexibility, and processes, may require a new legal framework.

Book reviewers always have quibbles, and I'm no exception. Overall, this book is very well done—detailed where it needs to be, well referenced, and readable throughout. I would have liked to have seen more attention given to the problem of uncertainty beyond the statement that "it will not be considered here for the sake of simplicity" (p. 122). And the extensive scientific work done in the aftermath of the *Exxon Valdez* oil spill was scarcely mentioned. But my major quibble is the lack of an index, something that apparently is routine in books from The National Academies but that really compromises their usefulness.

The value of this book is in developing a framework for thinking about a new ecosystem services approach to environmental management. Figuring out how to actually do it is a work in progress. But the approach shows promise; anyone with an interest in any aspect of environmental management, not just oil spills, will benefit from reading this book.

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AFS

AFS NEW MEMBERS

Kevin Atkins
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Justin Baker
Brooke Bannerman
Douglas Bateman
Brandon Baumhoer
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Tedra Booker
Spencer Bruce
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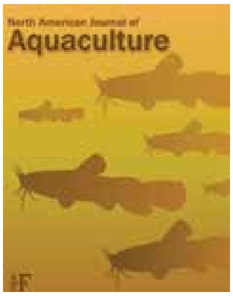

Journal Highlights

NORTH AMERICAN JOURNAL OF AQUACULTURE
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CORRECTION

2015 AFS abstracts are due on March 13th

Abstracts for symposia and contributed sessions for the 2015 AFS meeting are due March 13th at 11:59pm (Pacific Time), NOT February 13th as previously published in the call for papers. The 2015 AFS meeting will BEGIN accepting abstracts on February 13th.

We recommend all contributed session presenters to consult the list of accepted symposia that will be posted on the AFS website by February 13th prior to submitting their abstract. As supported by the AFS, we encourage all contributed session presenters to indicate in their abstract submittal whether their presentation may fit the topic of an accepted symposium. This will facilitate integrating appropriate contributed session abstracts within symposia.

Please note that the 2015 AFS website is the final word for deadlines and other information.

AFS 2015 Program Co-Chairs
Jim Bowker and Nancy Leonard

CALENDAR

To submit upcoming events for inclusion on the AFS website calendar, send event name, dates, city, state/province, web address, and contact information to sgilbertfox@fisheries.org. (If space is available, events will also be printed in *Fisheries* magazine.) More events listed at www.fisheries.org

March 2–4, 2015

AFS Minnesota Chapter Annual Meeting | Brainerd, Minnesota | afs-oc.org

March 4–6, 2015

AFS 2015 Idaho Chapter Meeting | Boise, Idaho | afs-oc.org

March 5–7, 2015

AFS 29th Annual AFS Tidewater Chapter Meeting | Pine Knoll Shores, North Carolina | sdafs.org/tidewater/AFSTidewater/Annual_Meeting.html

April 28–30, 2015

FLOW 2015: Protecting Rivers and Lakes in the Face of Uncertainty | Portland, Oregon | www.instreamflowcouncil.org/flow-2015

May 17–19, 2015

NPAFC International Symposium on Pacific Salmon and Steelhead Production in a Changing Climate: Past, Present, and Future | Kobe, Japan | npafc.org

May 18–22, 2015

AFS AFS 2015 Piscicide Class | USU, Logan, Utah | fisheries.org

May 26–30, 2015

World Aquaculture 2015 | Jeju Island, Korea | was.org

June 22–24, 2015

Fish Passage 2015 | Groningen, Netherlands | fishpassageconference.com

July 12–17, 2015

39th Annual Larval Fish Conference | Vienna, Austria | larvalfishcon.org

July 26–31, 2015

World of Trout | Bozeman, Montana | Facebook > The World of Trout - 1st International Congress

August 16–20, 2015

AFS 145th Annual Meeting of the American Fisheries Society | Portland, Oregon | 2015.fisheries.org

November (TBA), 2015

5th International Symposium on Stock Enhancement and Sea Ranching | Sydney, Australia | www.searanching.org

February 22–26, 2016

Aquaculture 2016 | Las Vegas, Nevada | marevent.com

March 13–15, 2016

Muskie Symposium | Minneapolis, Minnesota | www.muskiesinc.org

September 19–22, 2016

OCEANS 2016 | Monterey, California | oceanicengineering.org

POLICY (continued from p. 47)

The National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries Service's Habitat Blueprint offers a different showcase for AFS talents. Like the LCCs, the Blueprint is driven mostly by internal agency priorities, with the many NOAA bureaus providing their expertise. Once each "habitat focus area" is selected, NOAA works with partners to protect and restore habitats. The AFS can help by providing data that can help shape priorities or assist decisions. Focus areas in the Great Lakes and along our ocean coasts offer opportunities to export tools and concepts to fish habitat anywhere. Check out the U.S. Department of Commerce/NOAA (2014) for a glimpse of the small-scale regional efforts awaiting our contribution.

The last regional effort I'll mention is the coastal and marine spatial planning along all U.S. coasts. The Coastal and Marine Spatial Planning (CMSP) effort was launched by President Obama's "National Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes" in 2010, with nine regional efforts now well underway (National Ocean Council 2014). Each regional partnership is now deciding how best to proceed, from well-organized efforts in some regions to cautious discussions elsewhere. Where the states, federal government, and tribes choose to proceed, regional partnerships are developing a strategic approach to solving their special suite of problems, often including fishing, access, data holdings, and other issues that intersect nicely with AFS interests.

The special advisory committees established by state and federal resource agencies offer opportunities to engage in a more general forum. Most states have an advisory board to support their fisheries agency and other natural resource programs. The four regional interstate fisheries commissions and their fish and habitat committees cover the Atlantic, Gulf, Great Lakes, and Pacific states. The DOI has its Sport Fishing and Boating Partnership Council, which was the impetus behind what is now the National Fish Habitat Partnership (discussed above). The NOAA's Marine Fisheries Advisory Council (MAFAC) addresses several priority topics annually. The NOAA's National Marine Fisheries Service works closely with each of its seven regional fishery management councils, each of which has a Science and Statistical Committee composed of regional fish experts. The Environmental Protection Agency and most other agencies have their own Science Advisory Board. Those are a mere sampling of the groups awaiting fisheries expertise. The AFS works on select issues with some of these groups each year, such as the AFS members who have volunteered to serve on NOAA's MAFAC special task forces on climate and marine resources in 2015. You have the opportunity to contribute as an AFS member or in your work affiliation.

These are exciting times, with ample opportunities to share your knowledge. Go forth and make a difference. The fish will appreciate it, and so will AFS.

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Yelloweye Rockfish, *Sebastes ruberrimus.* Photo credit: Victoria O'Connell.

ROCKFISH

Milton Love
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Did You Know?

Did you know that your cargo of fish is not necessarily lost if your vessel is commandeered by Welsh separatists?

Yes, there you are heading down along the southeastern Alaska coast with 17 tons of nicely iced rockfishes in your hold. And wouldn't you know, just outside of Sitka, nine disaffected members of Plaid Cymru, frustrated with the slow pace of Welsh devolution, take over your vessel. And then, having thrown your fish out on deck, and iced down numerous 9-gallon casks of Plassey's Cwrw Tudno Ale, here they are drinking, chanting *Llaeth i blentyn, cig i wr, cwrw i hen* ("Milk for a child, meat for a man, beer for the old") and defying the Coast Guard, Sid (your lawyer and brother-in-law), and a very junior representative from the British Embassy.

Okay, while all these attempts to end the standoff continue, just how long do you have before your rockfishes go bad? Well, if it is 9°C (48°F) out on deck, you have a total of 72 hours before you can kiss those fishes (assuming fish osculation is your bag) goodbye.

And a tip o' the hat to O. M. Mel'nikov, E. F. Kleie, and the whole gang, at the old Soviet Union Pacific Scientific Research Institute of Marine Fisheries and Oceanography, who way back in the early 1960s did that analysis for us (Kizevetter et al. 1965).

Excerpt from Milton Love's (AFS Member 2012) book: *Certainly More Than You Want to Know About the Fishes of the Pacific Coast*

Yelloweye Rockfish, *Sebastes ruberrimus.* Photo credit: Victoria O'Connell.

REFERENCE

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Sacramento Pike Minnow with Juvenile Salmonids Image Courtesy: FISHBIO