

Fisheries

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**Invasive Species Policy at the Regional Level:
A Multiple Weak Links Problem**

**On the Boots of Fishermen:
The History of Didymo Blooms on Vancouver Island, BC**

**Are We Doing All We Can to Stem the Tide of
Illegal Fish Stocking?**



Standard Methods for Sampling North American Freshwater Fishes

Scott A. Bonar, Wayne A. Hubert, and
David W. Willis, editors

This important reference book provides standard sampling methods recommended by the American Fisheries Society for assessing and monitoring freshwater fish populations in North America. Methods apply to ponds, reservoirs, natural lakes, and streams and rivers containing cold and warmwater fishes. Range-wide and eco-regional averages for indices of abundance, population structure, and condition for individual species are supplied to facilitate comparisons of standard data among populations. Provides information on converting nonstandard to standard data, statistical and database procedures for analyzing and storing standard data, and methods to prevent transfer of invasive species while sampling.

284 biologists and managers from 107 agencies, universities, and businesses contributed to the book as authors, reviewers, or sponsors.

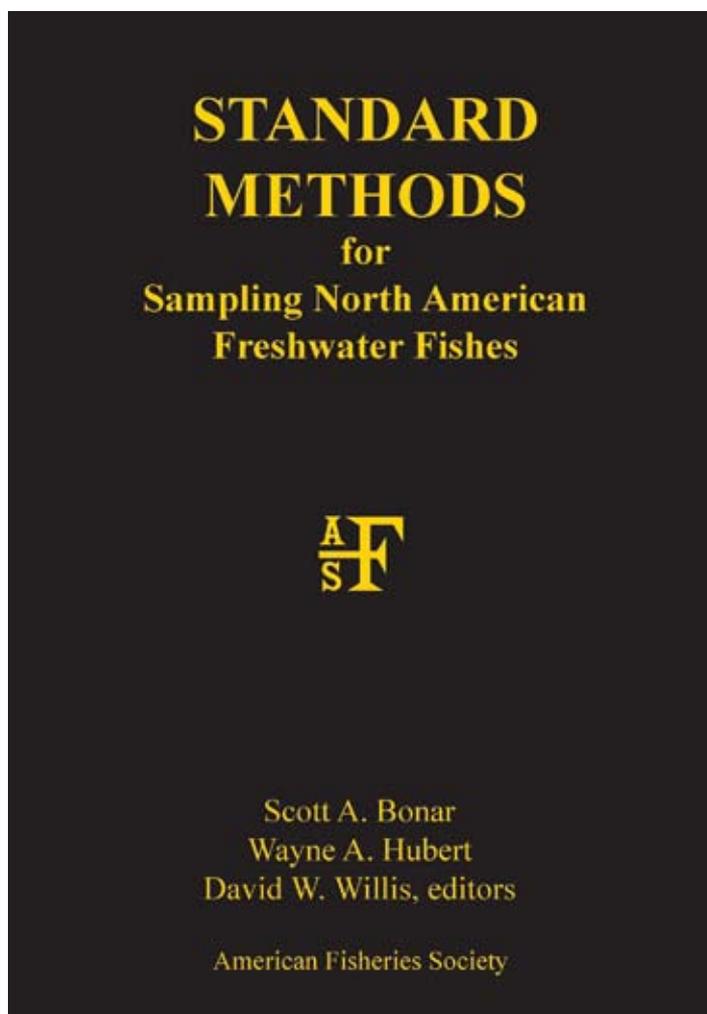


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*Brett M. Johnson, Robert Arlinghaus, and Patrick
J. Martinez*

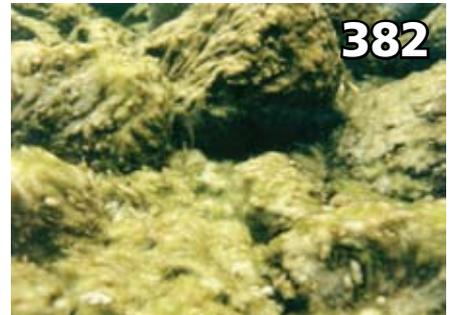
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COVER: Red swamp crayfish (*Procambarus clarkii*) being moved through trade.
CREDIT: C. Kelly



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COLUMN: PRESIDENT'S HOOK

Thanks to Our Skilled and Talented Members for a Great Year!

William G. Franzin
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franzin@shaw.ca.



Members make a society great and in this, my last Hook, I want to recognize some AFS members who have contributed significantly to what for me was a successful year. I can mention only a few below because it isn't physically possible for me to thank personally everyone who helped me during this year. I am grateful to all of the many committee chairs and members, all members of the Governing Board, members of the AFS staff, and the many individual members who provided assistance and encouragement to me during the year; thank you all.

The skilled and talented members of AFS facilitate the job of president. This year, I set out to complete new initiatives that were begun by my two predecessors, **Jennifer Nielsen** and **Mary Fabrizio**. Early last fall, the Society had to focus efforts on restraining costs as the ongoing recession unfolded and the potential of moving our offices evaporated. In spite of a year in which the economic downturn shrunk our reserves and cut into attendance at several Unit meetings, it has not been without accomplishments.

Thanks to the concerted efforts of the **Strategic Plan Revision Committee** under the guidance of **Eric Knudsen** and with the special assistance and skills of **Margaret Murphy**, we have a completely

I am grateful to all of the many committee chairs and members, all members of the Governing Board, members of the AFS staff, and the many individual members who provided assistance and encouragement to me.

new Strategic Plan ready for implementation in the coming year. I have heard quite a lot of positive feedback, so if you haven't read it please have a look.

Gwen White, our tireless constitutional consultant (CC), has been updating our Constitution, Rules, and Procedures continuously during her term as CC, completing work begun earlier by **Dirk Miller** and **Joe Margraf**. Former AFS President **Ira Adelman** will relieve Gwen in 2009 following her completion of two terms as CC. I especially thank Gwen for assisting me to streamline the president's committee appointment workload. Gwen and Equal Opportunity Section President **Larry Alade** helped as we forged our new Emmeline Moore Prize (EMP), recognizing members who have helped under-represented groups with access to the fisheries

profession. The EMP will be awarded for the first time this year in Nashville.

Also beginning in Nashville, members of AFS who have maintained their memberships for more than 25 years will be recognized with commemorative pins. Outgoing members of the Governing Board also will receive special GB pins acknowledging their service on the prime decision-making body of AFS. We cannot thank our members too often, especially those

that step up and take office to carry on the business of the Society. These pins are small but visible tokens of gratitude.

Our new online-only, open-access journal, *Marine and Coastal Fisheries*, has been published with 11 papers in the first volume, thanks to tremendous efforts by the Publications Oversight Committee chaired by **Steven Cooke**, the editorial group led by **Don Noakes**, and staff members **Aaron Lerner** and **Donna Davis**. Steve also will be facilitating the Governing Board retreat at Nashville as we explore options for the AFS journal publishing program to meet the needs of changing times.

I want to thank all of the other committees for diligently carrying

Continued on page 411



Calls for CITES to ban trade in Atlantic bluefin tuna

President Nicolas Sarkozy of France has announced his country's support for a ban of international trade in Atlantic and Mediterranean bluefin tuna, joining a growing call to list the overexploited fish under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Sarkozy's announcement was quickly followed by support for the proposal by fisheries and environmental ministers from the United Kingdom, Germany, and the Netherlands. The Mediterranean bluefin tuna industry has often exceeded its yearly quota, and illegal and under-reported fishing is thought to be an ongoing problem as well.

The Principality of Monaco was first to communicate its willingness to sponsor

a proposal to ban international trade in Atlantic bluefin tuna, and has launched a formal CITES consultation process to seek the support of other range states—countries through whose waters the species swims. CITES contracting parties next confer in Doha, Qatar, in March 2010, but proposals need to be submitted by 17 October to be eligible for consideration. A two-thirds majority of the 175 signatory countries is needed to ban trade in the species.

Marine recreational fishing down slightly

As part of its annual "Fisheries of the United States" report to Congress, NOAA released U.S. marine recreational fishing figures for 2008. Saltwater recreational anglers took an estimated 85 million fishing trips

in 2008, down slightly from the 93 million trips estimated in 2007. Saltwater anglers caught an estimated 464 million fish in 2008, also down slightly from the 475 million caught in 2007. Spotted seatrout was the most popular catch among marine recreational anglers in 2008. The species is caught in the Gulf of Mexico and the south Atlantic regions, which have the highest combined concentration of saltwater anglers in the nation. The top catches in other regions were grouper (Caribbean), striped bass (North Atlantic), summer flounder (Mid-Atlantic), chub mackerel (Pacific), black rockfish (Pacific Northwest), skipjack tuna (Western Pacific). The full report is available online at <http://www.st.nmfs.noaa.gov/>.

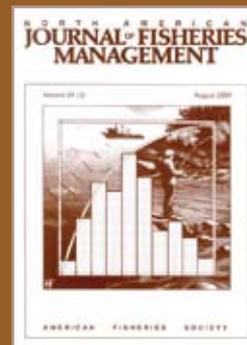


CATFISH 2010: First Call for Papers and Posters The Second International Catfish Symposium 20–22 June 2010, St. Louis, Missouri

You are invited to attend and participate in the 2nd International Catfish Symposium to be held 20–22 June 2010 in St. Louis, Missouri, along the banks of the mighty Mississippi. This is our first call for oral platform and poster presentations at the symposium, including those to be considered for publication within the resulting peer-reviewed proceedings. This meeting will provide a forum for the exchange of information about the biology, ecology, management and conservation of worldwide populations of both game and nongame catfish species. The publication from the First International Catfish Symposium, *Catfish 2000*, continues to sell and has been a solid reference source for managers and researchers alike.

The theme for the 2nd International Symposium is the conservation, ecology and management of worldwide catfish populations and their habitats. Presentations on all aspects of catfish biology and ecology are welcome, and those focusing on conservation and management challenges are actively being sought. We encourage you to submit your research on the following topics: Evaluating sampling methods and their effectiveness; Population dynamics and community interactions; Life history investigations providing information on predation, competition, prey utilization, age and growth; Conservation efforts including species status and restoration efforts; Management strategies to enhance recreational fisheries including regulations, human dimensions and production. Individuals interested in developing topical review papers are encouraged to contact the Program Committee Co-Chairs to assist with topic coordination.

To submit a presentation and for the most up to date information on the symposium, visit the web site at www.catfish2010.org. Bookmark it now and return often for updates! Presentation abstracts and manuscript submission deadline is January 29, 2010. Don't miss being a part of this important gathering of scientists, educators, administrators, and the public interested in what the next decade will bring for catfish science.



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[Management Brief] **An Evaluation of Visible Implant Elastomer for Marking the Federally Listed Fountain Darter and the San Marcos Salamander.** Catherine T. Phillips and Joe N. Fries, pages 529-532.

Potential Consequences of Climate Change to Persistence of Cutthroat Trout Populations. Jack E. Williams, Amy L. Haak, Helen M. Neville, and Warren T. Colyer, pages 533-548.

The Response of Salmon Populations to Geomorphic Measurements at Three Scales. M. D. Bryant and R. D. Woodsmith, pages 549-559.

[Management Brief] **The Use of Stable Oxygen Isotope ($\delta^{18}\text{O}$) Composition in Sockeye Salmon Body Fluid to Determine whether a Fish Has Been Caught in Freshwater.** R. W. Macdonald, V. Forsland, R. E. Withler, D. A. Patterson, and A. Demsky, pages 560-569.

Evaluating the Power Output of the Smith-Root GPP 5.0 Electrofisher to Promote Electrofishing Fleet Standardization. Patrick J. Martinez and A. Lawrence Kolz, pages 570-575.

Amount and Disposition of Striped Bass Discarded in Delaware's Spring Striped Bass Gill-Net Fishery during 2002 and 2003: Effects of Regulations and Fishing Strategies. John H. Clark and Desmond M. Kahn, pages 576-585.

The Effect of Forestry Roads on Access to Remote Fishing Lakes in Northern Ontario, Canada. Len M. Hunt and Nigel Lester, pages 586-597.

[Management Brief] **Organochlorine Fingerprinting to Determine Foraging Areas of Sea-Ranched Atlantic Salmon: A Case Study from Denmark.** Tore C. Svendsen, Katrin Vorkamp, Jon C. Svendsen, Kim Aarestrup, and Jens-Ole Frier, pages 598-603.

Habitat Use, Home Range, and Movement of Shoal Bass in Alabama. David G. Stormer and Michael J. Maceina, pages 604-613.

Evaluation of Largemouth Bass Length Limits and Catch-and-Release Regulations, with Emphasis on the Incorporation of Biologists' Perceptions of Largemouth Bass Length Frequency Distributions. Paul Radomski, Charles S. Anderson, and Kevin S. Page, pages 614-625.

[Feature Article] **A Synthesis of Cisco Recovery in Lake Superior: Implications for Native Fish Rehabilitation in the Laurentian Great Lakes.** Jason D. Stockwell, Mark P. Ebener, Jeff A. Black, Owen T. Gorman, Thomas R. Hrabik, Ronald E. Kinnunen, William P. Mattes, Jason K. Oyadomari, Stephen T. Schram, Donald R. Schreiner, Michael J. Seider, Shawn P. Sitar, and Daniel L. Yule, pages 626-652.

[Management Brief] **Passive Integrated Transponder Tag Retention Rates in Headwater Populations of Coastal Cutthroat Trout.** Douglas S. Bateman, Robert E. Gresswell, and Aaron M. Berger, pages 653-657.

Effects of Passive Integrated Transponder Tags on Smolt-to-Adult Recruit Survival, Growth, and Behavior of Hatchery Spring Chinook Salmon. Curtis M. Knudsen, Mark V. Johnston, Steven L. Schroder, William J. Bosch, David E. Fast, and Charles R. Strom, pages 658-669.

A Multiple-Release Model to Estimate Route-Specific and Dam Passage Survival at a Hydroelectric Project. John R. Skalski, Rebecca

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Steelhead Genetic Diversity at Multiple Spatial Scales in a Managed Basin: Snake River, Idaho. Jennifer L. Nielsen, Alan Byrne, Sara L. Graziano, and Christine C. Kozfkay, pages 680-701.

Salmon Carcass Movements in Forest Streams. Burke Strobel, Daniel R. Shively, and Brett B. Roper, pages 702-714.

[Management Brief] **Observations of American Eels Using an Upland Passage Facility and Effects of Passage on the Population Structure.** Robert E. Schmidt, Catherine M. O'Reilly, and Daniel Miller, pages 715-720.

Capture Probability and Behavioral Response of the Robust Redhorse, a Cryptic Riverine Fish, to Electrofishing. Timothy B. Grabowski, Tyler D. Ferguson, James T. Peterson, and Cecil A. Jennings, pages 721-729.

[Management Brief] **Maturation and Reproduction of Shovelnose Sturgeon in the Middle Mississippi River.** Sara J. Tripp, Quinton E. Phelps, Robert E. Colombo, James E. Garvey, Brooks M. Burr, David P. Herzog, and Robert A. Hrabik, pages 730-738.

Assessment of Trout Passage through Culverts in a Large Montana Drainage during Summer Low Flow. D. Drake Burford, Thomas E. McMahon, Joel E. Cahoon, and Matthew Blank, pages 739-752.

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Rehabilitation Needs for Burbot in the Kootenai River, Idaho, USA, and British Columbia, Canada. Vaughn L. Paragamian and Michael J. Hansen, pages 768-777.

Abundance and Distribution of Precociously Mature Male Spring Chinook Salmon of Hatchery and Natural Origin in the Yakima River. Todd N. Pearsons, Christopher L. Johnson, Brenda Ben James, and Gabriel M. Temple, pages 778-790.

Walleye and Muskellunge Movement in the Manitowish Chain of Lakes, Vilas County, Wisconsin. Jordan G. Weeks and Michael J. Hansen, pages 791-804.

Evaluating the Power to Detect Temporal Trends in Fishery-Independent Surveys: A Case Study Based on Gill Nets Set in the Ohio Waters of Lake Erie for Walleyes. Tyler Wagner, Christopher S. Vandergoot, and Jeff Tyson, pages 805-816.

Conditional Capture Probability of *Scaphirhynchus* spp. in Drifting Trammel Nets. Christopher S. Guy, Eric W. Oldenburg, and Paul C. Gerrity, pages 817-822.

Use of Ice-Water and Salt Treatments to Eliminate an Exotic Snail, the Red-Rim Melania, from Small Immersible Fisheries Equipment. Andrew J. Mitchell and Thomas M. Brandt, pages 823-828.

Effects of Increasing Chinook Salmon Bag Limits on Alewife Abundance: Implications for Lake Michigan Management Goals. Randall M. Claramunt, Tracy L. Kolb, David F. Clapp, Daniel B. Hayes, James L. Dexter Jr., and David M. Warner, pages 829-842.

UPDATE: LEGISLATION AND POLICY

Elden Hawkes, Jr.

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Chesapeake Bay hearing

On 8 July 2009, the House Committee on Natural Resources' Subcommittee for Insular Affairs, Oceans and Wildlife held a hearing to discuss the Chesapeake Bay Science, Education, and Ecosystem Enhancement Act (H.R. 1771) and the Chesapeake Bay Accountability and Recovery Act (H.R. 1053).

Many witnesses felt that H.R. 1771 would assist greatly with current efforts to restore finfish and shellfish populations through technical assistance to watermen to develop aquaculture programs. It will also enhance the National Oceanic and Atmospheric Administration's (NOAA) ability to collect and supply information necessary for habitat and resource management to assist policy makers, resource managers, scientists, and the public. The panel also viewed the reauthorization of the act as strengthening current critical habitat protection and restoration efforts. This would be accomplished by establishing a Chesapeake Bay coastal living resources management and habitat program to support the coordinated management, protection, characterization, and restoration of priority Chesapeake Bay habitats and living resources, including oysters, blue crabs, and submerged aquatic vegetation.

H.R. 1053 calls for the administrator of Environmental Protection Agency to develop an adaptive management plan with specific and measurable objectives to improve water quality, habitat, and fisheries.

More stocks of Atlantic salmon listed

NOAA Fisheries Service and the U.S. Fish and Wildlife Service have extended Endangered Species Act (ESA) protection to more Atlantic salmon as part of an ongoing effort to recover the imperiled fish. The extended protection area now includes fish in the Penobscot, Kennebec, and Androscoggin rivers and their tributaries, to the endangered Gulf of Maine population first listed in 2000. Listed species receive full protection of the Endangered Species Act, including a prohibition against take. Landlocked salmon and salmon raised in hatcheries for aquaculture are not included in the listed population.

Endangered status under the ESA will now apply to all anadromous Atlantic salmon whose freshwater range covers the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River,

an area which includes the Penobscot and Kennebec rivers. It also applies wherever these fish occur in these rivers' estuaries and marine environment. Hatchery fish used to supplement these natural populations are also included under this rule.

NOAA Catch Share Task Force

NOAA has created a new Catch Share Task Force in order to develop a strategy that will move forward on making catch share management more available to fisheries in the United States. The task force will be operating to achieve the following objectives:

1. To develop a new NOAA policy on catch shares that ensures that catch shares are fully considered when councils take up fishery management plan amendments.
2. To make sure that councils that want to move forward with catch shares have the technical and administrative support to move quickly to design a catch share system while empowering local fishermen to be part of the process.
3. To make sure that catch share designs achieve the best possible environmental and economic performance by supporting healthy ecosystems, reducing bycatch and habitat damage, and helping to meet annual catch limits.
4. To consider whether any organizational changes are needed within NOAA to provide the best possible communication and support.
5. To provide advice to the under secretary on how to allocate resources to the councils to support this work, and how to create milestones so that progress can be evaluated.

This task force is designed with NOAA's commitment to moving forward to implement more catch share programs based on scientific results. Catch shares that are well-designed and thoughtfully prepared are felt to be the best way to have healthy, profitable fisheries that are sustainable.

THE RETURN OF THE CISCO AND THE FUTURE OF GREAT LAKES MANAGEMENT

Perhaps once the most numerous fish in the Great Lakes, cisco, or lake herring, began to plummet in population in the 1970s. Commercial fisheries that had captured 26.5 million lbs. (12 million kg) per year from 1910-1955 only yielded .77 million lbs. (.35 million kg) by 1992. However, in recent years cisco numbers in Lake Superior have rebounded, thanks perhaps to an unlikely ally—the predatory lake trout. In a recent synthesis in the *North American Journal of Fisheries Management*, scientists from across the Great Lakes region explore the dynamic balancing act of managing today's Great Lakes fisheries communities and the complex interactions of their native and nonnative species. An examination of decades of literature and data reveals that ciscoes probably collapsed due to over-fishing, but their recovery was hindered by the introduction of rainbow smelt, which prey on larval ciscoes. Efforts to increase the numbers of native lake trout in Lake Superior benefited ciscoes as well by increasing predation on rainbow smelt, especially since lake trout had largely

switched away from a diet of ciscoes to a diet of rainbow smelt and alewives in the 1960s. The authors note that this raises an interesting question for Great Lakes fisheries management: should agencies continue to manage for nonnative alewives and their likewise nonnative Pacific salmon predators, or could lake trout recovery be possible if alewives and rainbow smelt were reduced, allowing ciscoes and other native prey fish to come back? **A Synthesis of Cisco Recovery in Lake Superior: Implications for Native Fish Rehabilitation in the Laurentian Great Lakes**, by Jason D. Stockwell, Mark P. Ebener, Jeff A. Black, Owen T. Gorman, Thomas R. Hrabik, Ronald E. Kinnunen, William P. Mattes, Jason K. Oyadomari, Stephen T. Schram, Donald R. Schreiner, Michael J. Seider, Shawn P. Sitar, and Daniel L. Yule. *North American Journal of Fisheries Management* 29:626-652. Stockner may be contacted at jstockwell@gmri.org.

BETTER TO LEAVE HOOKS IN?

Catch-and-release anglers face a dilemma when releasing their catch—whether to leave the hook in or take it out. Although studies conducted by

professional biologists have shown that deeply-hooked fish fare better if the hooks are left in, what about fish that are handled and released by ordinary anglers? In a recent article in the *Transactions of the American Fisheries Society*, scientists from Texas and Australia examined 248,010 records of anglers catching, tagging, and releasing 27 species of Australian fish and calculated the relative risk or probability of fish surviving and being recaptured after either having their hooks removed or left in place. The hooks were not removed in only 1.1% of the released fish. Although there were differences among species, overall the researchers found that across all species, leaving the hooks in fish increased their recapture rate by 18%. The authors support earlier recommendations that anglers be encouraged to leave hooks in deeply-hooked fish, although more study is needed.

Effect of Hook Removal on Recapture Rates of 27 Species of Angler-Caught Fish in Australia, by Gene R. Wilde and William Sawynok. *Transactions of the American Fisheries Society* 138:692-697. Wilde may be contacted at gene.wilde@ttu.edu.



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Invasive Species Policy at the Regional Level: A Multiple Weak Links Problem

Jody A. Peters and
David M. Lodge

Peters is a graduate student at the University of Notre Dame in Indiana. She can be contacted at jmurray7@nd.edu. Lodge is the director of the Center for Aquatic Conservation and professor of biological sciences in the Department of Biological Sciences, University of Notre Dame.



Rosie the pet crayfish (*Procambarus clarkii*) with her owner.

ABSTRACT: Policy is used to prevent the introduction and spread of invasive species. For aquatic invasive species that can easily cross political boundaries, regional policies are needed. A weak link problem occurs when regulations of individual jurisdictions increase the region-wide risk of species introductions, especially in adjacent jurisdictions. Such cross-jurisdictional weak links may be compounded by another sort of weak link within jurisdictions: inconsistent regulation among multiple vectors that may introduce the same species. We used crayfish as a model system to study regulations for anglers, bait dealers, the pet trade, and aquaculture across the Great Lakes region. We identified a continuum of regulations ranging from no regulations to those that prohibit all use of crayfish. Furthermore, regulations differed depending on state and vector. Many states had regulations that specifically targeted the invasive rusty crayfish (*Orconectes rusticus*). However, these regulations were enacted reactively only after rusty crayfish had become established in the state. The lack of regulatory consistency among the Great Lakes jurisdictions is creating a multiple weak links problem and making success unlikely in efforts to slow the spread of crayfishes and other invasive species throughout the region.

INTRODUCTION

Policy is often used at the federal and state (United States) or provincial (Canada) levels to combat the introduction and impact of invasive species (Benson 2000; Fowler et al. 2007). Federal regulations focus on preventing the introduction of species from other countries, with the majority of species targeted being those harmful to human health and agriculture (Environmental Law Institute 2002; Fowler et al. 2007). State/provincial regulations generally address the use of invasive species within the state or province, and often address private recreational activities or commercial uses not addressed extensively at the federal level (Reeves 1999). Such recreational or commercial vectors for the introduction and movement of aquatic species include the bait trade, pet trade, and aquaculture. For example, state/provincial jurisdictions can develop policies for species that are native to one area of a country but may be invasive in another area. In addition, federal laws and regulations often have inconsistencies and gaps regarding invasive species because they tend to tackle the problem reactively, species by species or habitat by habitat, rather than proactively addressing vectors or pathways of spread (Environmental Law Institute 2002). For comprehensive policymaking, state/provincial level policies are needed to address invasive species at smaller jurisdictional scales.

In North America, state/provincial policy is essential for the many species that are native to one area of the conti-

Política regional sobre especies invasivas: un problema con múltiples eslabones débiles

RESUMEN: Las políticas de manejo se utilizan para prevenir la introducción y dispersión de especies invasivas. En el caso de las especies invasivas acuáticas, que pueden fácilmente atravesar las fronteras geopolíticas, se requieren políticas a nivel regional. Un problema de eslabón débil se da cuando las regulaciones o jurisdicciones individuales incrementan el riesgo de introducción de especies a nivel regional, sobre todo en jurisdicciones adyacentes. Tales eslabones débiles trans-jurisdiccionales pueden confundirse con otro tipo de eslabones débiles que se dan dentro al interior de éstas: regulaciones inconsistentes entre múltiples vectores a los que se les puede atribuir la introducción de una misma especie. Se utilizó el langostino como sistema modelo para estudiar las regulaciones aplicadas a los capitanes de barco, vendedores de carnada, al tratado de mascotas y a la acuicultura a lo largo de toda la región de los grandes lagos. Se identificó un gradiente de regulaciones que va desde la falta de regulación hasta aquellas que prohíben todo uso del langostino. Más aún, las regulaciones difieren dependiendo del estado y el vector. Muchos estados tuvieron regulaciones aplicables específicamente al langostino (*Orconectes rusticus*). Estas medidas, sin embargo, fueron aceptadas después de que el animal se estableciera en el estado. La falta de consistencia en las regulaciones entre las diferentes jurisdicciones de la región de los grandes lagos está creando un problema de múltiples eslabones débiles, haciendo poco probable el éxito de los esfuerzos para frenar la diseminación del langostino y otras especies invasivas a través de la región.

ment, but invasive elsewhere on the continent. At least 50% of the aquatic taxa that are nonindigenous in some regions of the United States, for example, are native to one or more areas of the continent (Perry et al. 2002). High proportions of nonindigenous fish (> 65%), mussel (20%), and crustacean (50%) species originate within the United States (Perry et al. 2002). While state/provincial policies are needed for these species, cooperation among states to create regional policies is also essential because invasive species do not respect political boundaries (Cambray 2003; Shine et al. 2005; Bossenbroek et al. 2007). Such a cooperative regional approach was suggested almost 10 years ago by Reeves (1999) to effectively control invasions through the aquaculture, bait, and pet trades in the Great Lakes region where eight U.S. states and Ontario share a continuous aquatic ecosystem.

If only some states/provinces have effective policies for invasive species and the vectors through which they are spread, invasive species will spread from adjacent states and provinces that have less effective policies. Such a weakest link problem means that a contiguous region is protected only as well as is the constituent jurisdiction with the weakest policies (Perrings et al. 2002). Especially in the case of aquatic invasive species, such regional policies are needed because species can easily disperse naturally within and between connected water bodies. The probability of dispersal is increased further because humans, who transport species, can easily move across multiple jurisdictional boundaries (Bossenbroek et al. 2007).

Anthropogenic vectors moving aquatic invasive species include ballast water, bait buckets and live wells of boats, boat trailers and hulls, and shipments of fishes, invertebrates, and aquatic plants sold to aquarium hobbyists, aquaculturalists, and for water gardens (Lodge et al. 2006). Species spread especially quickly in aquatic ecosystems compared to terrestrial ecosystems (Kinlan and Hastings 2005) and similarly, once an invasive species has established in freshwater, their dispersal through highly-connected lake and river ecosystems may occur rapidly compared to the dispersal of terrestrial invasive species (e.g., Bobeldyk et al. 2005). In addition, introductions and rapid dispersal are often exacerbated by a range of human-mediated drivers of global change, all of which are increasing in frequency (Kolar and Lodge 2000). Examples of these drivers include globalization of commerce, engineering of waterways, land-use changes, climatic changes, and fisheries management (Kolar and Lodge 2000).

National and state governments of the Great Lakes region have declared that reducing the spread and impact of invasive species is a priority policy goal (e.g., GLRC 2008). We suggest here that one important approach in achieving that goal would be the development of cooperative multi-jurisdictional policies. Below we examine the current regulations to reduce the introduction and spread of nonindigenous crayfish species in the Great Lakes region. We use the rusty crayfish (*Orconectes rusticus*), in particular, as an exemplar of a species native to North America

that has spread widely throughout the Great Lakes region (and many other regions; Hobbs and Lodge 2009).

MODEL SYSTEM USED TO ASSESS REGULATIONS

As one of the largest freshwater invertebrates, nonindigenous crayfishes often have large impacts on fish and wildlife populations including negative direct and indirect effects on aquatic vegetation, other invertebrates, and fish populations in many lakes and rivers (Nystrom 2002). Crayfishes can carry diseases or parasites that lead to the extirpation of native crayfish (Hobbs and Lodge 2009). Omnivory by crayfishes directly reduces the abundance of insect larvae, other invertebrates, and aquatic plants, which indirectly impacts other organisms, such as fish and waterfowl, through competition for food and loss of important habitat (e.g., aquatic plants; Lodge et al. 1994, 1998). Nonindigenous crayfishes decrease aquatic plant biomass and species diversity by consuming or physically destroying plants (Lodge and Lorman 1987; Nystrom 2002; Rodriguez et al. 2005), and this inevitably destroys fish nurseries. Slow-moving invertebrates, which are often preferred food of sportfishes (Blumenshine et al. 2000), are most vulnerable to crayfish predation (Lodge et al. 1994; Nystrom 2002). Finally, crayfish are directly injurious to fish and amphibian populations by consuming eggs and larvae (Dorn and Wojdak 2004).

Nonindigenous crayfishes, some which have become invasive, within the Great

Lakes region include the rusty crayfish, the Allegheny crayfish (*O. obscurus*), the calico crayfish (*O. immunis*), the ringed crayfish (*O. neglectus*), the virile crayfish (*O. virilis*), the red swamp crawfish (*Procambarus clarkii*), and the white river crayfish (*P. acutus*; Benson et al. 2004; Crocker and Barr 1968; Thoma and Jezerinac 2000; USGS 2008). Anglers and the bait trade (Capelli and Magnuson 1983; Taylor and Redmer 1996; Benson et al. 2004), the biological supply trade (Lodge et al. 2000; Keller and Lodge 2007), aquaculture for food and bait (Lodge et al. 2000; Benson et al. 2004), and the pet trade (Lodge et al. 2000) have been implicated in the spread of many of these crayfishes. Of the nonindigenous crayfishes found in the Great Lakes region, the rusty crayfish has spread most extensively. Rusty crayfish are native to the Ohio River Basin and its tributaries in Ohio, northern Kentucky, and Indiana (Taylor and Redmer 1996). Currently in the Great Lakes region its range has expanded to all five of the Great Lakes, the states surrounding the Great Lakes, and Ontario (Crocker and Barr 1968; USGS 2008).

ASSESSING CRAYFISH REGULATIONS

We assessed the policies regulating crayfish use in four vectors of spread (anglers, the bait trade, aquaculture, and the pet trade) for the eight states (Michigan, Wisconsin, Minnesota, Illinois, Indiana, Ohio, Pennsylvania, and New York) and one province (Ontario) bordering the Great Lakes. We did not



Until recently, rusty crayfish (*Orconectes rusticus*) were commonly sold to anglers as live bait, which is the most likely vector by which the species spread throughout the Great Lakes region. In some jurisdictions, sale of live crayfish, including rusty crayfish, continues to be legal.

assess enforcement of these regulations, although we recognize that enforcement is also very important to the efficacy of regulations (Environmental Law Institute 2002). Regulations for crayfish pertaining to anglers and the bait trade, aquaculture, and the pet trade were examined by searching state and provincial agency websites. Regulations that could not be found online were obtained through personal communication with agency or trade personnel. (See Appendix A for details about the source of regulations for individual jurisdictions).

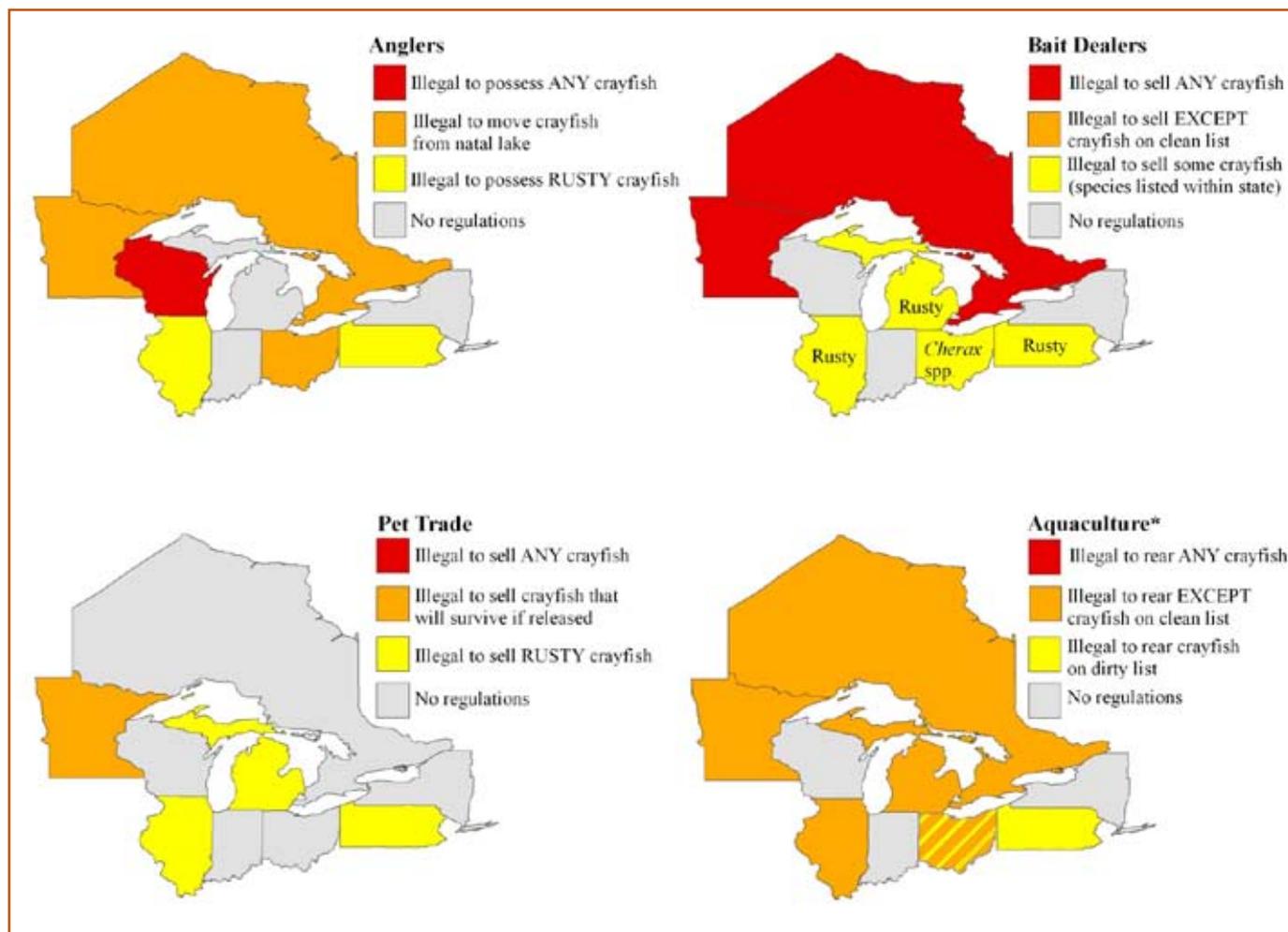
Although a majority of Great Lakes jurisdictions regulate some aspect of crayfish use, there is a continuum of regulations for the four vectors ranging from no regulations to complete prohibition (Figure 1). For each vector there are states that do not regulate crayfish use (anglers: Michigan, Indiana, New York; bait dealers: Wisconsin, Indiana, New York; pet trade: Ontario, Wisconsin, Indiana, Ohio, New York; aquaculture: Wisconsin, Indiana, New York). The least restrictive regulations (other than no regulation) are those that make it illegal to use, sell, or culture species on a “dirty” list. Such an approach therefore allows the use, sale, and culture of all species not included on the dirty list. For anglers (Ontario, Minnesota, and Illinois), bait dealers (Illinois, Michigan, and Pennsylvania), and the pet trade

(Illinois, Michigan, and Pennsylvania), the dirty list only prohibits the use or sale of rusty crayfish. In Ohio, the dirty list for bait dealers, where rusty crayfish are native, prohibits the sale of all *Cherax* species, while for aquaculture only two *Cherax* species (*C. tenuimarus* and *C. destructor*) are prohibited. The dirty list for aquaculture in Pennsylvania prohibits rusty crayfish and the red swamp crayfish (Appendix B).

The next level of regulation restrictiveness are those that allow crayfish species to be used, but only specific species or under certain conditions. Regulations for anglers include those that allow the use of crayfish but only in water bodies where they were caught by the angler (Ontario, Minnesota, and Ohio). There are no jurisdictions that have such a regulation for bait dealers. Regulations for the pet trade allow suppliers to sell crayfish, but only if they will not survive if released (Minnesota), while regulations that govern aquaculture facilities (Ontario, Minnesota, Illinois, Michigan, and Ohio) allow crayfish to be reared, but only those on a “clean” list (Appendix B).

The clean list approach identifies species allowed for use, sale, or culture, and thereby prohibits the use of species not included on the list (Environmental Law Institute 2002). Species on a clean list are usually native to the area or are presumed to be unable to repro-

Figure 1. Summary of regulations for crayfish use, possession or sale for anglers, bait dealers, the pet trade, and aquaculture (*see Appendix B for list of crayfish on clean and dirty list) in the Great Lakes region. Although details differ among vectors (see legends), colors represent a general gradient of regulations where red prohibits all crayfish use, orange allows for the use of specific species under certain conditions, yellow prohibits the use of specific crayfishes, and gray represents no regulations.



duce if they escape (i.e., they are believed to require warmer waters than are available in the Great Lakes region). The clean list for Illinois, however, includes crayfish species native only to the southern portion of the state (*Cambarellus puer*, *C. shufeldtii*, *P. clarkii*, *P. viaeviridis*, *O. illinoensis*, and *Fallicambarus fodiens*) as well as species native throughout the state (*P. acutus*, *P. gracilis*, *O. immunis*, *O. propinquus*, and *Cambarus diogenes*; Page 1985). Similarly, Ontario allows species with more restricted native ranges (*O. immunis* and *Cambarus robustus*) and others that are more widespread (*O. virilis*, *O. propinquus*, and *Cambarus bartonii*; Crocker and Barr 1968) to be reared. Most of the species on Michigan's clean list are native throughout the state (*O. propinquus*, *O. immunis*, and *O. virilis*), except *C. robustus*, which was only found in the lower peninsula in 1931 (Creaser 1931) and *C. bartonii* whose known distribution does not include Michigan (Creaser 1931; Taylor et al. 2007). Ohio has two types of clean lists: a Class A permit provides a list of species that can be used in aquaculture and does not require containment measures to be in place; a more restrictive Class B permit is granted on a case-by-case basis for species reared outside their native watershed, if the facility has two escape prevention measures in place. The three crayfish species (*P. acutus*, *O. immunis*, and *O. rusticus*) listed under Ohio's Class A permit are native to some watersheds in the state, while those listed for the Class B permit include species both native to some watershed and those not native to the state (i.e., *P. clarkii* and *Cherax quadricarinatus*; Thoma and Jezerinac 2000). (See Appendix B for full list of species allowed under class B permit.) In the Great Lakes region many crayfish species on a clean list are able to thrive in areas where they do not naturally occur.

The most restrictive laws prohibit the use, sale, or culture of any crayfish under any circumstances. Of the vectors examined, this type of regulation was only found for anglers (Wisconsin) and bait dealers (Minnesota and Ontario). In discussions with agency personnel, it is clear that one motivation for this sort of policy is that most people, including anglers, agency personnel, and biologists, have difficulty taxonomically distinguishing among crayfish species. Under this policy, crayfish need not be identified to species, and enforcement is easier.

Minnesota has the most consistently restrictive regulations for crayfish (Figure 1). Ontario is the next most restrictive with regulations for anglers, bait dealers, and the aquaculture trade, but does not specifically address the pet trade. Illinois, Michigan, Ohio, and Pennsylvania have less restrictive regulations but they address many vectors consistently. Wisconsin, conversely, has restrictive regulations that target only angler use of crayfish, while New York and Indiana have no regulations for any of the vectors, making these two states the weakest links with respect to the escape of nonindigenous crayfishes for all the vectors examined. However, throughout the region there are multiple weak links given that there are multiple vectors with multiple regulatory approaches among the Great Lakes jurisdictions.

In addition to examining the types of regulations for the four vectors in the Great Lakes jurisdictions, we also examined whether regulations pertaining to rusty

crayfish were reactive or proactive. In all six jurisdictions that regulate rusty crayfish use, sale, or culture, the regulations were all reactively enacted between 15 and 40 years after rusty crayfish had been found in the state (Table 1).

Table 1. The year rusty crayfish were first recorded in the jurisdictions that have regulations for rusty crayfish and the year those regulations were enacted.

Jurisdiction	Year Crayfish Recorded	Year Regulation Enacted
Michigan	*	1990
Wisconsin	1965	1982
Minnesota	1967	1992
Illinois	1973	1988
Pennsylvania	1976	2005
Ontario	1968	2007

* Rusty crayfish may be native to southeastern Michigan. In 1931 an extensive survey reported rusty crayfish had a very limited range only being found in a single small stream in southeastern Michigan (Creaser 1931). By the late 1980s rusty crayfish were reported from surveys in the upper peninsula of Michigan (1987 Lake Ottawa, 1989 Smoky Lake; B. Ziegler, Michigan DNR, pers.comm.). See Appendix C for list of sources for year crayfish were recorded and year regulations were enacted.

DISCUSSION

Our review of crayfish regulations demonstrated inconsistency among the jurisdictions bordering the Great Lakes, and inconsistency across vectors within jurisdictions. According to Shine et al. (2005), such fragmentation is similar to other legal approaches to invasive species elsewhere, which are also falling short of meeting the policy goal of reducing the introduction of harmful species. As Meronek et al. (1995) showed in their review of bait regulations, inconsistencies among states and vectors likely confuse consumers, hinder the vector industries, and reduce the credibility of management agencies. The most effective policies are those targeting economic production sectors (Ruiz and Carlton 2003), such as the vectors we reviewed above, but as we discovered, the focus of many regulations are on species rather than on industries.



Many recent studies suggest that managing vectors rather than specific species is a more effective approach to controlling the spread of invasive species (Ruiz and Carlton 2003; Leung et al. 2006; Lodge et al. 2006). In the Great Lakes region many of the regulations enacted for crayfishes were in response to invasions by the rusty crayfish; in some cases the regulations specifically target only the rusty crayfish. For example, in Illinois it is illegal to possess, transport, or sell the rusty crayfish. This type of regulation targets all the vectors distributing rusty crayfish, but fails to address other potentially harmful species in the

same vector industries. In addition, the lag time between widespread invasion by rusty crayfish and the enactment of regulations for the species (15–40 years) illustrates the inherent limitations of a reactive approach to invasive species policy. While existing regulations may slow the spread of rusty crayfish, the invasion in most jurisdictions was already progressing and likely to proceed apace regardless of regulations.

Many crayfish species exist in North America (and on other continents) that pose potential harm to the Great Lakes region. One example is the red swamp crawfish (*P. clarkii*), which is native to the south-central United States from Texas to Florida and north to Tennessee and Illinois (but not in the Great Lakes basin). This species is used as fish bait and sold extensively by biological supply houses for use in schools and universities (Huner 2002). It has been introduced to the Great Lakes region, but has a limited known range in New York, Illinois, Indiana, and Ohio (Thoma and Jezerinac 2000; Benson et al. 2004). Thus an important opportunity exists to prevent its spread to other jurisdictions in the region. Experience from other regions where the species has been introduced suggests that potential for damage is high (Hobbs et al. 1989; Huner 2002). The impacts of the red swamp crawfish are very similar to those of the rusty crayfish in that they displace native crayfish (Gil-Sanchez and Alba-Tercedor 2002), and reduce macrophyte, gastropod, other macroinvertebrate, and amphibian populations in areas where they become established (Correia et al. 2005; Cruz and Rebelo 2007).

Currently, only Pennsylvania prohibits the aquaculture of the red swamp crawfish. Conversely, Illinois allows red swamp crawfish to be cultured throughout the state, even though the species is native to only the very southern part of the state and is considered invasive in the northern part of the state (Page 1985; Simon and Thoma 2006). Proactive regulation in other Great Lakes jurisdictions of red swamp crawfish and other potentially invasive crayfish might better accomplish the established policy goal of preventing damages from invasive species. Clean lists would also be more effective if the permitted species were native throughout the jurisdiction, rather than allowing the use of species native to only part of the state.



Dirty and clean lists can be effective means of preventing the spread of species if they proactively consider species prior to allowing them in commerce. Without a change from the reactive approach used for rusty crayfish, the current dirty list management for many vectors in many states makes it unlikely that the dangers posed by other crayfish species in those states will be recognized until after the species has been introduced. However, the proactive listing of two *Cherax* species and the red swamp crawfish in Ohio and Pennsylvania aquaculture, respectively, provide examples where the introduction and spread of these species by this vector will be limited in these two states.

Our analyses are consistent with earlier recommendations made for Michigan (Reeves 1999) but we expand them to the regional scale. First, Reeves (1999) recommended that state departments of natural resources (DNR or other relevant agencies) should have clear authority over all aquatic organisms and pathogens such that industries could have greater consistency in regulation. There are currently multiple agencies in all jurisdictions that regulate different vectors of crayfish use. In the Great Lakes region, the DNRs regulate anglers, bait dealers, and the pet trade in many states, whereas it is typical for departments of agriculture to regulate aquaculture.

Second, Reeves (1999) recommended that any person or company proposing to introduce a species be held responsible for demonstrating that the species will not cause economic or ecological harm. This method of developing clean lists would place the burden of proof on the commercial interest rather than on the regulatory agency (Environmental Law Institute 2002). At the very least, industries that would be affected by regulations should be included in the development of clean and dirty lists that represent reasonable policies developed through sound science. If not, there will be less incentive for these industries to support such regulations. Regardless of where the burden of risk assessment falls, better protection of the environment and wildlife health would result from risk assessment conducted before introduction rather than after a species is widespread.

Third, Reeves (1999) and others (Environmental Law Institute 2002; Padilla and Williams 2004) recommend that funding mechanisms be established with emergency authority to clean up any biological “spill” of invasive species. Potential funding mechanisms for such a clean-up authority include: (1) taxing the public via general tax revenues or species-specific sales tax or (2) requiring businesses selling species to purchase bonds or liability insurance (Padilla and Williams 2004). An effort of this magnitude would require the coordination and cooperation of national and international agencies within the Great Lakes region to respond to the initial introduction and spread of invasive species. The U.S. Department of Agriculture (USDA) currently has analogous authority and

funding sources to respond to plant pests (e.g., PPA 2000), and a fund and authority exists to clean up oil spills (e.g., OPA 2000). Because no such authority and funding usually exists for aquatic invasive species, society is left to bear the costs and adapt (Lodge et al. 2006).

Our analyses demonstrate that there are multiple weak link problems with every jurisdiction lacking regulations for one or more vectors addressing the introduction and spread of invasive species, especially freshwater species in the Great Lakes region. Given that the current, un-coordinated multiple-policy approach has not been successful, solutions will require a coordinated regional effort (Environmental Law Institute 2002; Perrings et al. 2002). Because invasive species are a regional issue, a regional Great Lakes invasive species council, including representatives from all affected states/provinces, other parties, and industry stakeholders, could help accomplish the recommendations described above. Possible models or vehicles for such inter-jurisdictional and international cooperation already exist in the Great Lakes region, including the Great Lakes Fishery Commission, the International Joint Commission, the Great Lakes Commission, the Great Lakes Water Quality Agreement, the Great Lakes Regional Panel of the Aquatic Nuisance Species Task Force, and the recently passed Great Lakes Water Compact.

These challenges and possible solutions apply not only to crayfish and not only to the Great Lakes region, but to invasive species in general and indeed to many environmental problems (Stoett 2007). Water and air pollution also do not respect political boundaries and are increasingly addressed regionally (e.g., Regional Greenhouse Gas Initiative 2008). Although the majority of nonindigenous species moved through commerce do not become invasive, a large number of species can result in economic and ecological harm (Lodge et al. 2006; Keller and Lodge 2007). We suggest that one way to accomplish the policy goal of minimizing harm from invasive species is to shift policy focus from individual species to vectors. A regional council could guide proactive regulations that could be applied consistently among jurisdictions and across vectors.

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Appendix A. Sources of regulations found for each state and province.

Jurisdiction	Regulation Source
IL	Illinois Injurious Species Code
IL	Illinois 2007 Fishing Regulations
IL	Aquaculture Code: 17 Ill. Admin. Code 870 (http://dnr.state.il.us/legal/adopted/870.pdf) Illinois Aquatic Life Approved Species List , (www.agecon.purdue.edu/aquabusiness/files/Illinois_Approved_Species_List.pdf)
IN	Permit Guidelines (www.in.gov/dnr/files/PermitGuidelines.pdf)
IN	Randy Lang, Indiana DNR Aquaculture Permits
IN	2008 Guidelines for Fish Hauler and Supplier, Importation and Aquaculture Permit Applications (www.in.gov/dnr/files/PermitGuidelines.pdf)
IN	Indiana Aquaculture Application (www.in.gov/dnr/files/AquacultureApplication.pdf)
IN	Aquaculture Permit Regulations (www.in.gov/dnr/files/aquaculture_permit.pdf)
IN	Purdue Extension (www.agecon.purdue.edu/aquabusiness and www.in.gov/dnr/fishwild/3719.htm)
MI	Michigan 2007 Fishing Regulations
MI	Michigan Aquaculture Application (www.michigan.gov/documents/MDA_Aquaculture_Registration_Application_38588_7.pdf)
MI	Michigan Aquaculture Development Act: Act 199 of 1996 (www.legislature.mi.gov/(S(vfrgtb55ih0jydwz2wuzj545))/documents/mcl/pdf/mcl-act-199-of-1996.pdf)
MI	Michigan Fisheries Order 227 (www.michigan.gov/documents/dnr/FO-227-04A_182421_7.pdf - obtained 18 June 2008)
MN	Minnesota Rules, Chapter 6259 (from Roy Johannes, MN DNR)
MN	Minnesota Fishing 2007 Regulations
NY	Ted Universal, president of New York State Aquaculture Association; John Naylor, Naylor Trout Hatchery
NY	New York 2007 Fishing Regulations
NY	Department of Environmental Conservation Regulations Chapter 1 Part 4 Subchapters C, D,E (www.dec.ny.gov/regs/2494.html)
OH	Ohio 2007 Fishing Regulations
OH	Ohio Aquaculture Law Digest (www.ohiodnr.com/Portals/9/pdf/pub%2061,%20aquaculture%20law.pdf)
OH	Ohio Commercial Fishing Law Digest (www.ohiodnr.com/Portals/9/pdf/pub002.pdf)
ON	Stop the Invasion document from the Ontario Ministry of Natural Resources about use of crayfish as bait (www.ontla.on.ca/library/repository/mon/7000/10317038.pdf)
ON	Ontario Fishing 2007 Regulations
ON	Moccia, R.D., and D.J. Bevan. 2000. Aquaculture Legislation in Ontario. University of Guelph (www.ontarioaquaculture.com/files/aquaculture_Legislation_June_2000.pdf)
ON	Dave Maraldo, Fisheries Section Manager of the Fish and Wildlife Branch of the OMNR, Letter to Bait Dealers
PA	Approved Aquaculture Species: (www.agriculture.state.pa.us/agriculture/lib/agriculture/animalhealthfiles/Approved_Species_List_Open_System_Aquaculture_for_Dep_of_Ag_2008.pdf)
PA	Pennsylvania 2007 Fishing Regulations
WI	Wisconsin 2007-08 Spearing and Netting Regulations
WI	Wisconsin 2007 Fishing Regulations
WI	Will Hughes, Wisconsin Aquaculture Coordinator, Wisconsin Dept. of Agriculture, Trade and Consumer Protection Division of Agriculture Development.
WI	Mike Staggs, Wisconsin DNR
WI	Ron Johnson, UW Extension Aquaculture Specialist
WI	SAG Fish and Aquatic Invertebrates Recommended Classification (http://dnr.wi.gov/invasives/classification/pdfs/aquatic_inverts_summary.pdf)
WI	Wisconsin Bait Dealer Regulations, sent by Shirley Zwolanek (WI DNR)

Appendix B. Clean and dirty lists of crayfish species used in aquaculture.

*** Approved Species for Aquaculture—Clean List**

Ontario: *Cambarus robustus*, *C. bartonii*, *Orconectes immunitis*, *O. virilis*, *O. propinquus*
 Illinois: *Cambarellus puer*, *C. shufeldtii*, *Procambarus acutus*, *P. clarkii*, *P. gracilis*, *P. viaeviridis*, *Orconectes illinoiensis*, *O. immunitis*, *O. propinquus*, *O. virilis*, *Fallicambarus fodiens*, *Cambarus diogenes*
 Michigan: *O. immunitis*, *O. propinquus*, *O. virilis*, *C. bartonii*, *C. robustus*
 Minnesota: *O. immunitis*, *O. virilis*
 Ohio: Class A Permit (no escape prevention required)—*P. acutus*, *O. immunitis*, *O. rusticus*
 Class B Permit (permitted on case-by-case basis and requires two levels of escape prevention if cultured outside their naturally occurring watershed)—*P. clarkii*, *Cherax quadricarinatus* (Australian red claw crayfish), *O. obscurus*, *O. sanbornii*, *O. propinquus*, *O. virilis*, *O. spinosus*, *O. sloanii*, *Cambarus carinirostris*, *C. ortmanni*, *C. sciotensis*, *Cambarus sp.* (Ohio crawfish), *C. robustus*, *Cambarus sp.* (Great Plains mudbug), *Cambarus sp.*, (paintedhand mudbug), *F. fodiens*

*** Prohibited Species for Aquaculture—Dirty List**

Ohio: *Cherax tenuimarum*, *C. destructor*
 Pennsylvania: *O. rusticus*, *P. clarkii*

Appendix C. Sources for year rusty crayfish were recorded in a state or province and the year regulations were enacted.

Jurisdiction	Crayfish Source	Regulation Source
Michigan	Creaser 1931; Pearse 1910 MI DNR, Bill Ziegler	Todd Grischke MI DNR
Wisconsin	Olden et al. 2006	Olden et al. 2006
Minnesota	Gunderson 1999	Roy Johannes MN DNR
Illinois	Taylor and Redmer 1996	Lynnette Mick IL DNR
Pennsylvania	PA News Release October 2005	PA News Release October 2005
Ontario	Crocker and Barr 1968	Letter from Dave Maraldo Fisheries Section Manager of the Fish and Wildlife Brand of the Ontario Ministry of Natural Resources to bait dealers, October 2006

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FEATURE: INTRODUCED SPECIES

On the Boots of Fishermen: The History of Didymo Blooms on Vancouver Island, British Columbia



Didymo covers rocks on the bottom of the Heber River, September 1989. Algal biomass greatly exceeded guidelines for protecting aquatic life in streams.

ABSTRACT: In 1989 blooms of the river benthic diatom *Didymosphenia geminata* (didymo) first appeared and rapidly spread among rivers on central Vancouver Island, covering the bottoms with thick, woolly-looking mats. Although didymo is native to North America, extensive field surveys of rivers on Vancouver Island and other data indicate that didymo blooms are new. No known environmental changes were associated with the onset of didymo blooms. However the pattern of didymo spread among rivers on Vancouver Island correlates with the activity of fishermen and the commercial introduction and widespread use of felt-soled waders in the late 1980s. Since 1994 nuisance blooms of didymo have appeared in numerous other places in the Northern Hemisphere and South Island, New Zealand, all areas frequented by fishermen. Actions by government agencies to educate the public and restrict the use of felt-soled waders have been undertaken in some jurisdictions and at least one commercial manufacturer of waders will discontinue production of felt-soled models in the near future.

Max L. Bothwell,
Donovan R. Lynch,
Harlan Wright, and
John Deniseger

En los Zapatos de los Pescadores: La Historia de los Afloramientos del Alga Didymo en la Isla de Vancouver, Columbia Británica

RESUMEN: En 1989 aparecieron por primera vez los afloramientos de la diatomea bentónica *Didymosphenia geminata* (didymo) y se extendieron rápidamente entre los ríos de la isla de Vancouver, cubriendo los fondos con manto grueso y difuso. Si bien didymo es un alga nativa de Norte de América, muestreos extensivos en los ríos de la isla de Vancouver y otros datos indican que los afloramientos de didymo son un fenómeno nuevo. Ningún cambio ambiental conocido se relaciona con el inicio de estos afloramientos. Sin embargo, el patrón de dispersión entre los ríos de la isla de Vancouver se correlaciona con la actividad pesquera y el uso extensivo de sobretodos con botas incluidas al final de la década de 1980. Desde 1994, los afloramientos nocivos de didymo han aparecido en muchos otros puntos del hemisferio norte, Isla del Sur y Nueva Zelanda, todas áreas frecuentadas por pescadores. Las agencias de gobierno han tomado acciones para educar al público y restringir el uso de sobretodos con botas en algunas jurisdicciones y en el futuro cercano, al menos una fábrica comercial de este tipo de vestimenta para la pesca discontinuará su producción.

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INTRODUCTION

Didymosphenia geminata (Lyngbye) M. Schmidt (didymo) is a freshwater benthic diatom historically described as inhabiting cold, nutrient-poor, clear water in montane and boreal streams and rivers. It grows attached to solid surfaces with polysaccharide stalks extruded from individual cells. The bifurcating division pattern of cells and associated stalks results in hemispherical colonies attached to stones. When growth conditions are favorable, colony expansion allows stalks to coalesce, forming thick, gelatinous masses that can smother pristine, rocky-bottomed rivers. These massive accumula-

tions have caught the attention of biologists and alarmed fishermen by their noxious appearance and potential to degrade water quality and alter riverine food webs (Kilroy et al. 2006; Larned et al. 2007). Didymo has been dubbed “rock snot” in mass media coverage worldwide.

Early diatomists documented the distribution of *D. geminata* in circumboreal regions of Europe, Asia, and North America, leading to the assumption that it was native to cooler, pristine waters in many parts of the Northern Hemisphere (Blanco and Ector 2009). While much of the early scientific literature describing didymo is floristic, accounts of massive blooms of didymo cover-

ing Scandinavian river bottoms date back over a hundred years (Schmidt-Nielsen and Printz 1915; Skulberg 1984; Lindstrom and Skulberg 2008). In North America, documented didymo blooms only began within the last 20 years (Bothwell and Spaulding 2008). The spread of didymo blooms between river systems in western and eastern regions of Canada and the United States, Iceland, Poland, Italy, Spain, and New Zealand has been alarming (Spaulding and Elwell 2007; Bothwell and Spaulding 2008; Blanco and Ector 2009). Didymo appears to be extending its range and is being found in climatic zones thought by ecologists to be outside its normal preferences, taking on the characteristics of an invasive species (Spaulding and Elwell 2007; Kumar et al. in press).

The first nuisance blooms of didymo documented in North American rivers occurred in British Columbia on Vancouver Island in the early 1990s (Sherbot and Bothwell 1993). All known contemporaneous (the past 20 years) didymo blooms in North America and elsewhere in the world followed the Vancouver Island episode, suggesting they might be causally related. We examined hydrological and water quality databases for possible factors that might have initiated didymo blooms on Vancouver Island. Several commonalities of didymo-infested rivers in British Columbia were identified, among which access by the recreational public was prominent. Using British Columbia freshwater fishing license and steelhead tag data, we quantified public use of rivers by fishermen (angler days) and determined angler origin for major steelhead (*Oncorhynchus mykiss*) fishing streams on Vancouver Island. We compare the spread of didymo on Vancouver Island to outbreaks in other parts of the world and outline the efforts of government agencies and conservation organizations to inform aquatic recreational enthusiasts and professional river biologists about their probable role in the inadvertent spread of didymo both regionally and globally.

DIDYMO ON VANCOUVER ISLAND, BRITISH COLUMBIA

Historical: pre-bloom era

Two of the earliest documentations of *Didymosphenia geminata* in North America are from British Columbia (Lord 1866; Cleve 1894-1896). In these early monographs, *D. geminata* is named by its synonym at the time, *Gomphonema geminatum*. Lord's samples came from the Columbia and Kootenay rivers in southern British Columbia while Cleve's sample was collected on Vancouver Island. Although the source of Cleve's specimen on Vancouver Island is not identified, we speculate that it might have been from the Cowichan River because it was a popular fly fishing river for Europeans in the late 1800s and *D. geminata* is common there today.

Although *D. geminata* is native to British Columbia/Vancouver Island, there are cogent reasons to believe that didymo blooms in rivers on the island in the early 1990s were a new phenomenon. Expert witnesses of rivers on Vancouver Island in the years preceding 1989 reported no unsightly algal blooms. Fisheries biologists working for the British Columbia Ministry of Environment (BC MoE) bear witness to the absence of didymo blooms in Vancouver Island rivers before 1989. Beginning in 1976, annual counts of steelhead escapement were made by the BC Fish and Wildlife Branch Steelhead Snorkel Survey Team (SSST), who wrote standardized reports following each survey. For 13 years, surveys were made without notable incident. However, in 1989 the SSST reported the



The lower Gold River is typical habitat for didymo blooms on Vancouver Island in the early 1990s—broad, shallow, clear, rocky-bottomed river channels passing through forest corridors in remote areas popular with anglers.

bottom of the lower Heber River was completely covered in a blanket of didymo several centimeters thick. Having not seen it before, they did not know what it was (SSST members: L. Carswell, M. Lirette, F. Axford, and S. Rimmer, C. Wightman and R. Hooton, BC Fish and Wildlife Branch, Nanaimo, BC., pers. comms.). BC MoE biologists quickly identified didymo as the culprit.

Similarly, commencing in the early 1980s BC MoE environmental impact biologists conducted routine water quality assessments, which included algal biomass and community taxonomic measures, upstream and down-

stream of wastewater discharges into numerous Vancouver Island streams. Prior to 1988, *D. geminata* was not a significant contributor to the benthic algal community in any of the streams assessed, but in that year small patches of *D. geminata* first appeared and were identified in the Heber River near the confluence with the Gold River. By 1989, didymo mats covered 4 km of the lower Heber River.

The expert testimony that didymo blooms in rivers on Vancouver Island were a new phenomenon in the 1990s is also corroborated by data in a Canadian Department of Fisheries and Oceans scientific report published in 1985. Munro et al. (1985) quantified diatom species and abundance at multiple sites in the Puntledge River on Vancouver Island year round from 1978–1980. *D. geminata* was never sufficiently abundant to make the list of quantifiable diatom taxa, although it was occasionally present (Munro et al. 1985). Beginning in 1991 and continuing to present day, didymo blooms persist to varying degrees in the Puntledge River, where in some reaches it is often the dominant algal taxon. In sum, these reports provide objective evidence that didymo abundance in Vancouver Island's rivers prior to 1989 was low (i.e., non-bloom forming).

Bloom era: 1989–1994

Between 1989 and 1994, British Columbia Ministry of Environment biologists documented massive didymo blooms in 2 to 4 additional rivers each successive year, so that by 1994 persis-

tent didymo blooms had been identified in 13 Vancouver Island watersheds (Figure 1). The BC MoE established the first website describing problematic blooms of didymo (www.env.gov.bc.ca/wat/wq/didy_bctrms.html).

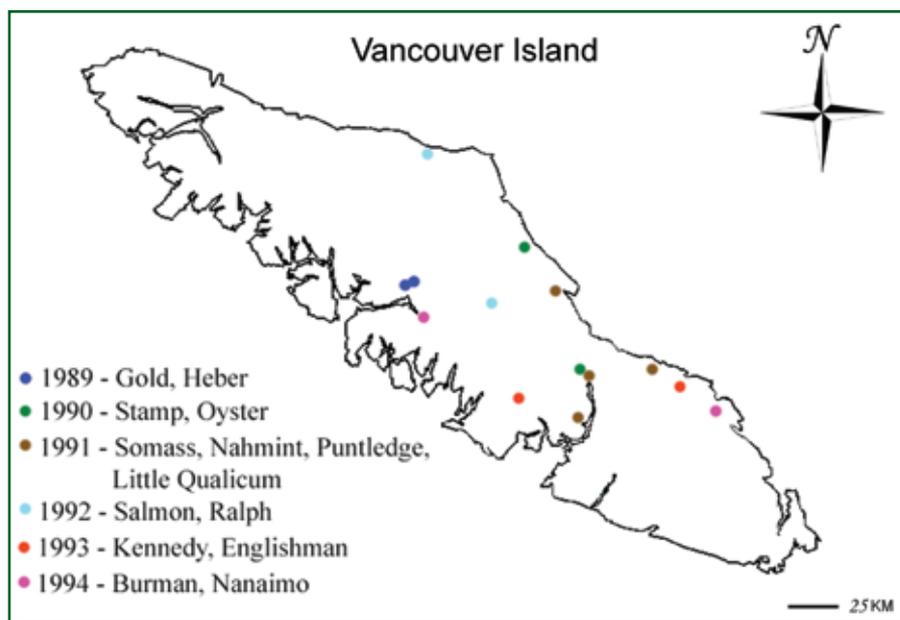
River reaches infested with didymo on Vancouver Island in the early 1990s shared several characteristics. Blooms invariably appeared in the main stems of broad rocky-bottom river channels passing through forest corridors in unpopulated watersheds. The rivers were all clear, shallow, nutrient-poor streams with good exposure to sunlight (Sherbot and Bothwell 1993). While rivers with didymo often had headwater lakes or flow control structures, several did not (Table 1).

Post-bloom era: 1998–2008

After 1995, the spread of didymo blooms to new rivers on central Vancouver Island slowed. By 1998 the only major fishing river added by the BC MoE to the list of didymo-affected rivers was the Cowichan River. More importantly, in the late 1990s didymo abundance began to wane in several of the rivers in which it had first bloomed 6 to 8 years previously. Didymo blooms in the Heber and Oyster rivers declined by 1998 and although didymo can be found in these rivers today, blooms have not been observed since circa 2000.

Notwithstanding the above, substantial mats of didymo still persist in limited reaches of Vancouver Island rivers downstream of flow control structures (e.g., the Puntledge, Little Qualicum, and Nanaimo rivers) and are especially prevalent along bedrock-bottom reaches. These observations corroborate that stabilized flows associated with lake outlets are preferred habitats for didymo and that stable substrata contribute to didymo persistence (Kawecka and Sanecki 2003; Kirkwood et al. 2007; Kirkwood et al. in press).

Figure 1. The rivers on Vancouver Island, British Columbia, Canada in 1989–1994 that were infested with didymo. The reaches of rivers impacted by didymo were all heavily accessed by the fishing and recreational public.



Although didymo is native to Vancouver Island, all evidence suggests that blooms starting in the 1990s were new events. The magnitude of blooms has substantially subsided in recent years, but the persistence of didymo in select habitats indicates that a lasting shift in algal communities on Vancouver Island has occurred.

WHAT CAUSED DIDYMO BLOOMS ON VANCOUVER ISLAND?

The usual suspects

The causes of diatom blooms in rivers have been widely researched and are known to usually reflect changes in the chemical or physical characteristics of their habitat. Eutrophication (elevated nutrient levels) is the most frequently cited reason for excessive algal accumulations in rivers (Biggs 2000; Dodds et al. 2002). Diatom abundance in streams is also strongly affected by scouring events (Biggs and Close 1989). Selective shifts in diatom species composition, diversity, and abundance also reflect chemical and physical characteristics of their habitat (Stevenson and Pan 1999). We examined water chemistry and hydrological databases for rivers on Vancouver Island for possible clues as to what might have triggered the initial didymo blooms.

The levels of soluble reactive phosphorus (SRP) in all didymo-affected rivers on Vancouver Island are extremely low, with mean values ranging from 2.2 to 4.4 ppb (Table 1), and have remained unchanged from the earliest samples in the 1970s to present day. These levels of SRP are typical for Vancouver Island streams and are in the low end of the expected range of North

Table 1. The chronology of the first didymo blooms and the primary characteristics of didymo-affected rivers on Vancouver Island between 1989–1994.

River	Year of first bloom	SRP ^a (µg/L)	Active steelhead fishery	Reservoir/Headwater Lake
Heber River	1989	2.2	Y	N
lower Gold River	1989	2.2	Y	Y
Stamp River	1990	3.6	Y	Y
Oyster River	1990	3.1	Y	N
Somass River	1991	3.2	Y	Y
Nahmint River	1991	NA	Y	Y
Puntledge River	1991	2.7	Y	Y
Little Qualicum River	1991	4.4	Y	Y
Salmon River	1992	NA	Y	N
Ralph River	1992	NA	N	Y
Kennedy River	1993	NA	N	Y
Englishman River	1993	2.3	Y	Y
Burman River	1994	NA	Y	N
Nanaimo River	1994	3.2	Y	Y

^a Soluble reactive phosphorus; data from www.env.gov.bc.ca/emswr, values are the means. NA = data not available

American rivers with forested catchments (Omernik 1977; Binkley et al. 2004). The presence of didymo blooms in nutrient-poor rivers corroborates the conclusion that didymo is an indicator of pristine water quality (Kirkwood et al. 2007). Although didymo responds positively to small amounts of enrichment, blooms of didymo are not initiated by eutrophication events (Kawecka and Sanecki 2003; Noga 2003; Bowman 2008).

In the years leading up to the didymo bloom era on Vancouver Island (1975-1988), the annual discharge of gauged rivers on central Vancouver Island varied widely but the temporal patterns were similar among rivers (Sherbot and Bothwell 1993). The years with lowest annual discharge and reduced winter scour events did not correspond with didymo blooms and there was no evidence that the outbreak of didymo on Vancouver Island was associated with a period of benign hydrological conditions (Sherbot and Bothwell 1993). In the absence of evidence that didymo blooms on Vancouver Island were a response to either changes in their chemical environment or physical forcing functions, we looked elsewhere.

The probable role of fishermen

In addition to the physical and chemical commonalities of rivers supporting didymo blooms in the early 1990s on Vancouver Island, all but two were popular steelhead fishing sites (Table 1). The two exceptions were river sections immediately adjacent to either a popular campground (the Ralph River) or a highway rest stop (the Kennedy River), both heavily accessed by the public during summer months. Reaches of the Kennedy River just 3 km upstream of the public access point remained devoid of didymo in 1993. Furthermore, reaches of three rivers, the upper Gold River, the upper Salmon, and the upper Heber, that were prime didymo habitat did not support blooms in the 1990s. Records show that the upper Gold River and the upper Salmon were closed to fishing starting in 1982 and 1980, respectively. The upper Heber is not regularly fished because of a barrier to anadromous migration.

However, not all popular steelhead rivers on Vancouver Island or elsewhere in British Columbia succumbed to didymo blooms in the 1990s. Notable exceptions on the central part of the island were the Quinsam, Big Qualicum, and Campbell rivers that either had deep channels, heavy riparian shading, or mobile substrata. On northern Vancouver Island, the popular Keogh and Quatse rivers, both heavily stained with humate, did not support didymo blooms. The Dean River on the British Columbia mainland is a highly turbid river subjected to frequent spates of glacial flour. In spite of fishing pressure, the Dean also remained didymo-free. Reduced sunlight exposure from riparian shading and dissolved organic matter attenuation,

bed-smothering sediments, and substrata instability all seemed to play strong roles in determining those rivers that avoided didymo blooms.

The British Columbia Steelhead Harvest Questionnaire database allowed us to quantify public use of many fishing streams on Vancouver Island and to evaluate the potential connection to the initiation and spread of didymo infestations. The total number of steelhead angler days each year fluctuated 4-fold between 1968 and 2003 with changes in steelhead returns and fishing regulations (Figure 2). Very low angler activity in 1980-1982 reflected the implementation of a catch-and-release fishery in response to declining steelhead stocks. However, beginning in 1983 and continuing for a decade, angler activity on Vancouver Island rivers rebounded dramatically following ramping up of the steelhead hatchery release program and a coincidental period of high ocean survival. Increased angler activity from 1983 into the 1990s was also seen on the Stamp River, where strong returns of hatchery-released steelhead allowed a greater catch-and-keep fishery (Figure 3). During this period of escalating fishing pressure, felt-

Figure 2. The total number of angler days for 12 steelhead rivers on Vancouver Island between 1968 and 2003. Data for the Heber, lower Gold, Stamp, Oyster, Somass, Nahmint, Puntledge, Little Qualicum, Salmon, Englishman, Burman, and Nanaimo rivers are summed. All of these rivers became didymo-affected in the early 1990s. The angler activity reflects changes in fishing regulations, size of the catch-and-keep hatchery stocks, and ocean survival. Data are from the British Columbia Provincial Fisheries Branch Steelhead Harvest Questionnaire database.

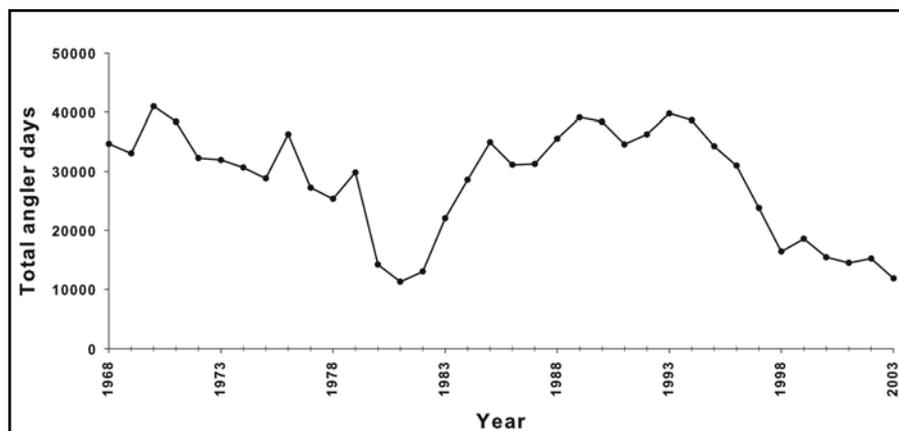
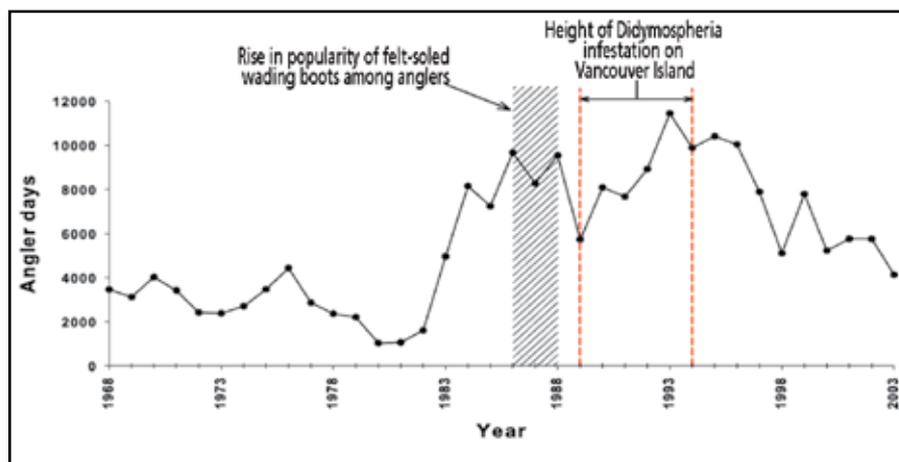


Figure 3. The number of angler days each year on the Stamp River from 1968 to 2003. Increased angler activity beginning in 1983 followed a ramping up of the hatchery release program and increased ocean survival of steelhead. Felt-soled waders and boots were commercially introduced in 1980s and were in wide use by 1988. Didymo blooms began on Vancouver Island in 1989. Angler data are from the British Columbia Provincial Fisheries Branch Steelhead Harvest Questionnaire database.



soled waders were commercially introduced and became widely popular in British Columbia by 1988 (Figure 3). Didymo blooms on Vancouver Island commenced shortly thereafter.

Studies in New Zealand have shown that retention of moisture in wader felts allows didymo cells to remain viable for many hours, even days, after leaving a river (Kilroy et al. 2007). As a vector for transport of didymo, wader felts may be the most problematic piece of fishing gear in wide use (Kilroy et al. 2007; Kilroy 2008). They have also recently been implicated in the spread of whirling disease (Gates et al. 2008) and New Zealand mudsnails (ANSTF 2007). Gates et al. demonstrated that the 30+µm pore size of lightweight felts effectively retained mycospores of the parasite *Myxobolus cerebralis*, making wader felts a probable transmission vector for the disease.

AN INVASIVE FORM OF GLOBALLY CIRCULATING DIDYMO?

The pattern and timing of didymo infestations among watersheds on Vancouver Island implicates fishermen in its regional movement, but it does not address the question of whether a bloom-forming variant of didymo might have been introduced to Vancouver Island. Angler-origin data from the British Columbia steelhead tag program provides some insight. Coincidental with recovering steelhead fishing on Vancouver Island in the 1980s was the expansion of a commercial guided fishing industry. An apparent consequence of that development was an increase in the number of visitors from other parts of the world fishing rivers on the island. Between 1984 and 1990 the percentage of non-Canadians who fished for steelhead on Vancouver Island increased 3-fold from just 1% to more than 3%, a trend that continued to grow (Figure 4). The percentage of non-Canadians fishing for steelhead on mainland British Columbia rivers was even greater and steadily increased from 4-5% in the 1970s to 14% by 2000 (Figure 5). Such shifts in demography of fishermen could significantly elevate the risk of trans-national movement of nuisance aquatic microorganisms and the increased global mobility of fishermen may be the basis for the rapid-fire spread of didymo internationally.

Closely following the infestations on Vancouver Island, nuisance blooms of didymo began to be reported in other parts of the world. They first appeared in Iceland in 1994 (Jonsson et al. 2000). Didymo had not been recorded in Iceland previously and blooms spread rapidly to other rivers on the island nation by 1997. No apparent relationship was found among those rivers with didymo except that all were popular Atlantic salmon (*Salmo salar*) fishing rivers. In a nearly identical scenario to the Vancouver Island experience, didymo

blooms have since waned in many Icelandic rivers while persisting in others (Jonsson et al. 2008). The pattern of didymo blooms suddenly appearing where none existed previously, followed by an equally sudden collapse a few years later, is classic behavior for populations of invasive species (Simberloff and Gibbons 2004). This supports the suggestion that although didymo is native to broad geographic regions, one or more variants of didymo may be being transported globally (Bothwell and Spaulding 2008; Blanco and Ector 2009; Spaulding et al. in press).

Other infestations of didymo within the past 10 to 15 years also highlight the likely connection to globally-mobile fishermen. Best known of these is the appearance of didymo in the lower Waiiau River, Southland, New Zealand, in October 2004 (Kilroy 2004). In this instance didymo was almost certainly introduced by humans and in the past four years has spread to 26 catchments on South Island (Kilroy 2008; Spaulding et al. in press). Although all forms of recreational river use are potential vectors for transport of didymo, the river sites of most early infestations on New Zealand's South Island are highly accessed by trout fishermen (Kilroy 2008).

In North America several regional instances of didymo blooms have been associated with well-known salmonid fishing streams since the Vancouver Island episode of the early 1990s. Didymo

Figure 4. The percent of steelhead anglers fishing rivers on Vancouver Island between 1984 and 2000 that were not Canadian residents. The guided fishing tour industry expanded on Vancouver Island in the 1980s resulting in a greater percentage of non-Canadian fishermen. Data are from the British Columbia Provincial Fisheries Branch Steelhead Harvest Questionnaire database.

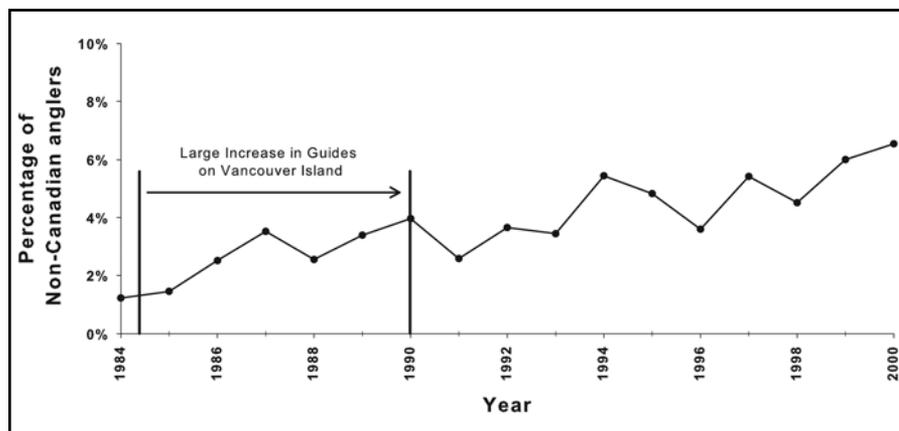
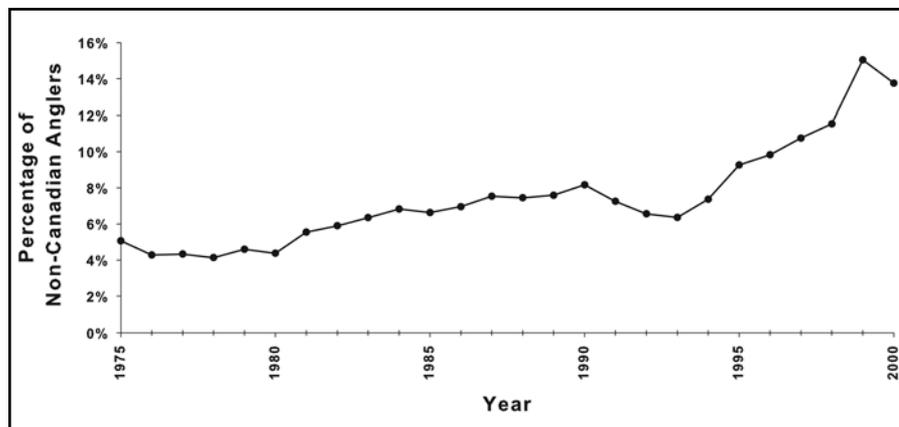


Figure 5. The percent of steelhead anglers fishing all rivers in British Columbia between 1975 and 2000 that were not Canadian residents. Data are from the British Columbia Provincial Fisheries Branch Steelhead Harvest Questionnaire database.



blooms appeared in Rapid Creek, South Dakota, downstream of the Pactola Reservoir in 2002. Ten kilometers of river were heavily impacted, coinciding with a dramatic decline in the blue-ribbon brown trout (*Salmo trutta*) fishery (Shearer and Erickson 2006; Larson and Carriero 2008). In 2006 didymo blooms were first reported in the Atlantic salmon fishing reaches of the Matapédia River in Quebec and have since spread to other rivers in the lower St. Lawrence region, the Gaspé Peninsula, and adjacent New England states (Simard and Simoneau 2008).

WHAT IS BEING DONE?

All of the evidence suggesting that recreational fishermen have played a role in the movement of didymo regionally and globally is circumstantial. However, there are now multiple lines of such evidence from around the world supporting this view, building a compelling case for action. Government agencies have been involved in public awareness campaigns. Biosecurity New Zealand provided the leadership in developing and publishing protocols for cleaning river fishing gear of didymo (www.biosecurity.govt.nz/pests/didymo/cleaning-specific#felt). These precautions have been widely publicized in North America (www.epa.gov/region8/water/didymosphenia/). Two Canadian provinces (New Brunswick and Quebec) have didymo awareness programs (www.gnb.ca/0254/FAQDidymo-e.asp; www.mddep.gouv.qc.ca/biodiversite/eae/didymo.htm) and Parks Canada will begin issuing didymo-alerts to purchasers of freshwater fishing licenses in 2009 (G. Scrimgeour, Parks Canada, Calgary, Alberta, pers. comm.). Workshops sponsored by the Federation of Fly Fishers and the U.S. Environmental Protection Agency in Bozeman, Montana, in 2006 and by the Atlantic Salmon Federation and Environment Canada in Montreal in 2007, have helped inform academics and governmental and non-governmental agencies about didymo (Spaulding and Elwell 2007; Bothwell and Spaulding 2008). In combination with coverage in the popular press, this publicity has resulted in didymo being added to the global invasive species list by the United Nations Global Invasive Species Programme and the Northeast Aquatic Nuisance Species Panel. The combined concerns of biologists and conservation and fisheries agencies have led industry to search for alternatives to felt-soled boots and one manufacturer has announced that they will discontinue felt-soled models in 2010.

As of October 2008, New Zealand has banned the use of footwear with felt soles by fishing licence holders, but fishermen are not the only ones using rivers. Academic and government scientists, aquatic biologists, and water quality and hydrometric monitoring personnel wade rivers frequently in the conduct of their jobs. In North America, few of these agencies take the systematic precautions needed to prevent the spread of aquatic invasive microorganisms such as didymo. However, the U.S. Fish and Wildlife Service recently adopted a new policy (www/fws.gov/policy/750fw1.html) to help prevent the spread of invasive species in its Fisheries Program operations through the use of Hazard Analysis and Critical Control Points planning. The Canadian Rivers Institute has also adopted protocols for field parties requiring the decontamination of footwear when moving between rivers (J. Culp, University of New Brunswick, Fredericton, New Brunswick, pers. comm.) We hope these proactive measures will be followed by other government agencies.

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ESSAY: INTRODUCED SPECIES

A person wearing a red jacket, a blue beanie, and grey waders is standing in a shallow stream. They are holding a white bucket and pouring several fish into the water. The background consists of bare, tangled branches and a clear stream.

Are We Doing All We Can to Stem the Tide of Illegal Fish Stocking?

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OVERVIEW

They've been called "bucket biologists" or "midnight managers" but these nicknames belie the ignorance and selfishness of individuals who engage in illegal stocking. Their actions are defeating multi-million dollar native fish recovery projects, damaging sustainable recreational fisheries worth billions of dollars, threatening native species with extinction, and diverting dwindling agency resources away from programs that benefit fishing and aquatic resources into expensive and often perpetual remediation programs. Illegal stocking is creating a growing burden on agencies and on society, and its impacts can be irreversible. The problem is global and yet there appears to be little collaboration across jurisdictions to seek solutions. We contend that the fisheries profession can and must do a better job of preventing illegal fish stocking through more strategic education programs, proactive regulatory policy, universally severe penalties, an international reward pool, and inter-jurisdictional collaboration.

HOW BIG IS THIS PROBLEM?

The unauthorized, intentional release of aquatic animals to facilitate a fishery, which we refer to as "illegal stocking," is a global problem (e.g., Elvira and Almodovár 2001; Hickley and Chare 2004; Hardie et al. 2006). Within North America it appears to be more prominent in regions with fewer native gamefish species: west of the continental divide, and in the northern and northeastern regions of the continent. In Wyoming, 50% of the unauthorized introductions during the last three decades were deliberate, illegal introductions (Rahel 2004). Montana has documented more than 500 illegal introductions in almost 300 waters (Tipton 2007). Rapid range expansions of smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), rock bass (*Ambloplites rupestris*), and northern pike (*Esox lucius*) in Ontario (Jackson 2002; Vander Zanden et al. 2004); northern pike, yellow perch (*Perca flavescens*), and smallmouth bass in British Columbia (Runciman and Leaf 2008); and northern pike in southcentral Alaska (AFG 2009) are being facilitated by illegal stocking over regions with

thousands of rivers and lakes. In Maine, illegal introductions have established northern pike, largemouth bass, smallmouth bass, black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), and green sunfish (*L. cyanellus*) in more than 150 lakes (Boucher 2007).

Many illicitly introduced populations have generated benefits from recreational fishing. However, in bypassing the regulatory process, each of these introductions has subjected the entire fishery and ecosystem to a degree of unnecessary risk from diseases, parasites, and invasive species that could have been accidentally introduced with the stocked fishes (Stewart 1991; Kerr et al. 2005). Further, some angler introductions have turned into tremendously expensive cleanup projects, as the following cases demonstrate.

LAKE DAVIS, CALIFORNIA

Lake Davis is a 1,629 ha reservoir in northeastern California. Illegally introduced northern pike were discovered in 1994 and were deemed a serious threat to a variety of native species downstream, including many state- and federally-listed species (CFG 2007). The reservoir was treated with rotenone to eradicate northern pike in 1997 at a cost of \$16 million (CFG 2007). Northern pike reappeared in 1999, either due to an unsuccessful treatment or another illegal introduction. Attempts to control and contain the population were unsuccessful and live northern pike were intercepted in possession of anglers stopped at check stations as they were leaving the reservoir. In fall 2007, the reservoir was treated with rotenone again, at a cost of more than \$17 million (Keith 2007). It remains to be seen if this second attempt at eradicating northern pike was successful, and if anglers will reintroduce the species in the future.

YELLOWSTONE LAKE, WYOMING

Yellowstone Lake, in Yellowstone National Park, is one of the largest and most pristine inland lakes in the United States, and it was home to 90% of the remaining Yellowstone cutthroat trout

(*Oncorhynchus clarki bowieri*; Gresswell 1995). Illegally introduced lake trout (*Salvelinus namaycush*) were discovered in the lake in 1994 (Kaeding et al. 1996). Studies predicted that left unchecked, predation by lake trout could result in a severe decline in the cutthroat population (Ruzycki et al. 2003) with a 30-year economic impact on park fisheries of about \$900 million (Varley and Schullery 1995; adjusted for inflation). Consequently, the National Park Service (NPS) implemented a vigorous lake trout suppression program at a cost of about \$300,000 per year (P. Bigelow, NPS, pers. comm.).

The preceding examples illustrate the enormous biological and economic impacts that can result from an isolated illegal stocking event that is confined to a single body of water. More frightening by far is illegal stocking occurring at the landscape scale, where anglers are introducing nonnative fish throughout an entire river basin. These actions are frustrating agencies' best efforts to balance sustainable recreational fisheries and native fish conservation, and jeopardizing countless evolutionarily significant units of endangered, threatened, and special concern species.

UPPER COLORADO RIVER BASIN

The Upper Colorado River Basin covers a 284,000 km² area of Arizona, Colorado, New Mexico, Utah, and Wyoming above Glen Canyon Dam. Only 14 species of fish are native to this region, 57% are endemic, and 5 are federally listed as endangered (Valdez and Muth 2005). Managed fisheries typically emphasize nonnative salmonids because of their limited impact on native species. Anglers unsatisfied with these have illegally established more than 46 populations of cool- and warmwater species in at least 22 reservoirs and the endangered fish recovery program is spending \$1million/y controlling these species in critical habitat. These illegal introductions also threaten the relatively innocuous nonnative fish populations in reservoirs that have sustained valuable recreational fisheries. Further, illegal stocking is diminishing the recovery potential of recent fish passageways constructed for native fish (Figure 1). Water diversion structures constructed in the early

Figure 1. The Price-Stubb Diversion Dam fish passage on the Colorado River near Grand Junction, Colorado, was completed in 2008. Removal of this barrier to fish migration provided endangered fish access to an additional 84 km (52 miles) of critical habitat that had been blocked since 1911.



U.S. FISH AND WILDLIFE SERVICE.

1900s created barriers to fish migration that prevented both native and nonnative fish from accessing large reaches of critical habitat of the Colorado and Gunnison rivers. The endangered fish recovery program has built selective fish passageways (total cost \$30 million, Chuck McAda, U.S. Fish and Wildlife Service, pers. comm.) to restore native fish access to this habitat. Unfortunately, illegally stocked northern pike, smallmouth bass, walleye (*Sander vitreus*), and other species in reservoirs above the barriers have the potential to invade the upstream reaches and defeat the purposes and multimillion dollar expenditures of these fish ladders.

Evaluating the full scope of illegal stocking is difficult due its cryptic and diffuse nature and the impracticality of routine monitoring of spatially dispersed ecosystems. What is clear is that this simple act can have catastrophic ecological impacts and generate enormous economic losses and remediation costs that may continue in perpetuity. While the initial release that establishes a species in a new water body can be an isolated event, the new population can become a chronic source of dispersants that subsequently invade other locations across the landscape by natural or facilitated dispersal (Havel et al. 2005; Rahel 2007).

HOW DID WE GET HERE?

Regrettably, we see illegal stocking as a problem born out of our own profession's historical behavior, and perpetuated by ineffective or conflicting messages to the public regarding authorized and unauthorized fish stocking policy.

1. *Do as we say, not as we do.*

Unauthorized stocking may be partly a legacy of our profession's promiscuous fish stocking past (Li and Moyle 1999) and our present conduct. Many popular recreational fisheries in North America and elsewhere are directed at introduced fishes, some sustained by authorized stocking. Agency transfers of fishes outside their native range and mixing of locally adapted genetic stocks continue today in spite of growing evidence that these practices can have detrimental ecological and genetic impacts (Cross 2000; Goldberg et al. 2005). Agencies continue to promote fish culture and stocking (e.g., hatchery tours, stocking tallies in the media) because it is an expedient way to demonstrate apparent benefits flowing from the license dollar. However, in doing so, we may have instilled the notion among anglers that fisheries can be created or remedied just by stocking fish (Meffe 1992; Arlinghaus and Mehner 2005; Arlinghaus 2006). Cooperative agency-angling club fish rearing and stocking programs further reinforce this perspective and break down the traditional barrier that rested stocking authority in the hands of agencies alone. As professionals, we should recognize that we may have contributed to the problem by unintentionally indoctrinating anglers with potentially unrealistic and ecologically unsustainable attitudes about stocking (Arlinghaus and Mehner 2005).

2. *Ineffective information and education programs.*

Noncompliance with stocking regulations may be partly due to information and education programs that are not reaching the audiences or are not convincing and persuasive. Some anglers may be unaware that transporting and releasing fish in another body of water is illegal, or they may simply not appreciate the severity of potential impacts. Management organizations appear to be acting independently, using variations on the same basic strategy: prohibit unauthorized stocking

and attempt to inform anglers and other stakeholders about the harm it can do. However, the seriousness with which agencies appear to be dealing with the issue differs greatly among jurisdictions. Effort devoted to information and education programs ranges from simple statements that transplanting fish is illegal to elaborate web sites with videos and other resources to download (e.g., AFG 2009). If agencies do a poor job of communicating the negative consequences of illegal stocking angler attitudes will change slowly, particularly when there can be obvious fishery benefits associated with a successful introduction.

Some anglers are aware of the ecological issues and the rationale for stocking regulations but choose to violate the rules in spite of that knowledge. Information and education programs have not failed to reach these individuals, but we have failed to compel appropriate behavior in them by other means, for example by deterrents such as penalties.

3. *Inadequate deterrents.*

Nearly every U.S. state and Canadian province/territory has had laws regulating the release of non-native fishes since at least 1974 (Courtenay and Robins 1975; Courtenay 1995). Is lack of enforcement the paramount problem? We do not think so. Enforcement clearly has a role but should not be viewed as a practical and sufficient solution in the future. We believe we must find other ways of discouraging people from engaging in illegal stocking and stiff penalties for the act are one way to do that. Based on a survey of agency fisheries and law enforcement personnel, penalties for unauthorized stocking, vary greatly. Canada had the most severe penalties: illegal fish stocking can fall under the jurisdiction of the federal Fisheries Act which can impose fines of up to \$100,000 and a year in jail for a first offense. Among the 12 U.S. states with some territory west of the Continental Divide, Colorado had the most lenient penalty: a \$68 fine with no jail time and no loss of fishing privileges, and Alaska had the harshest maximum penalties with a \$10,000 fine and a year in jail with loss of fishing privileges. The average maximum fine across all 12 states was \$2,756. It is likely that the minor penalties in place for illegally stocking fish in some jurisdictions are contributing to misperceptions of the seriousness of the problem among anglers but also within agencies and the legal system.

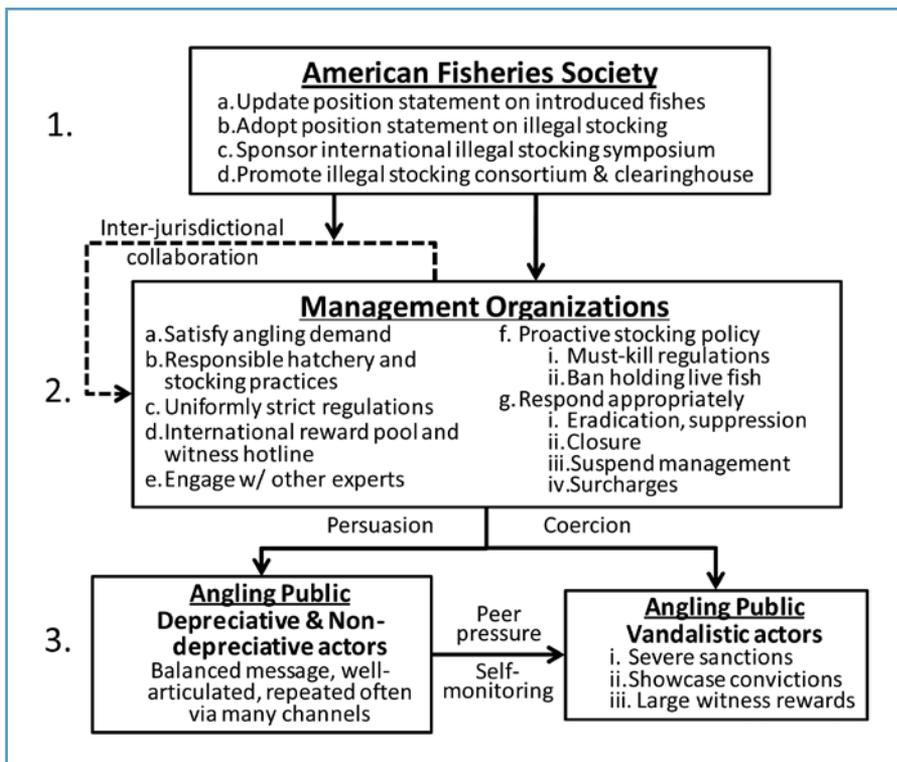
4. *Inappropriate responses.*

The way in which an agency responds to an illegal stocking event is an important signal to the public that may shape their attitudes about the practice. In the past, unauthorized introductions probably met with little concern and may even have been ultimately welcomed by managers if the species contributed to a net increase in fishing quality. Even today, exasperated management agencies may simply throw up their hands and concede when anglers introduce nonnative fishes. In Colorado, anglers illegally established northern pike fisheries in several reservoirs west of the Continental Divide, where stocking non-salmonid sport fish is restricted due to concerns about endangered fish. By failing to respond vigorously to these illegal introductions, and in one case even implementing a special size limit for the illegal pike, the agency tacitly condoned and rewarded the behavior, generated an angling clientele and a demand for the prohibited species elsewhere in the region, and made future efforts to contain the spread of northern pike and other illegally stocked species much more challenging.

SOME SUGGESTIONS FOR PROGRESS

We believe there are many things that can be done to help stem the tide of illegal fish introductions, focusing attention at three levels (Figure 2): (1) the fisheries profession, (2) management agency policy and actions, and (3) the angling public.

Figure 2. A framework for progress on the problem of illegal stocking focusing changes at three levels: (1) the fisheries profession, (2) management organizations, and (3) the angling public. The fisheries profession can facilitate collaboration among management organizations (dashed feedback arrow).



1. Changes within the fisheries profession.

Adopt position statements. Professional organizations' position statements help society by defining the current state of the science and expert opinion on an issue. Policymakers should be able to turn to the AFS for such insights when getting tough on illegal stocking requires agencies to adopt regulations that may be unpopular with some anglers (e.g., prohibitions on live fish as bait, or holding live fish). As professionals, we should support the AFS Introduced Fishes Section in updating the Society's "Policy Statement on Introduced Aquatic Species." The Society also has the opportunity to consider a resolution specifically addressing illegal stocking, put forth by Colorado-Wyoming Chapter for adoption by the parent Society.

Inter-jurisdictional collaboration. Agencies could all do a better job of combating illegal stocking if they could learn from each others' experience. Further, by pooling resources the group could acquire educational materials of a caliber unattainable by any individual jurisdiction. We invite you to contribute to our new website <http://stopstocking.cowyafs.org/>, which can serve as a virtual clearinghouse for gathering illegal stocking information, educating the public, soliciting witness information, showcasing convictions, and sharing policy documents and education materials among agencies. As a professional organization, AFS is in a position to facilitate

collaboration that individual states and provinces cannot, by appealing to national or international bodies for resources to help jurisdictions work together.

Symposium and workshop. The AFS could facilitate inter-jurisdictional collaboration by sponsoring an international symposium and workshop to bring representatives from management institutions, law enforcement, and other groups together to share experience and ideas and to establish the means for states and provinces to continue to work together on the illegal stocking issue. Illegal stocking of sport fish is recognized as a problem throughout the developed world (Elvira and Almodovar 2001; Hickley and Chare 2004; Hardie et al. 2006) and fish stocking experts from other continents (e.g., Cowx 1998) have tremendous experience and knowledge that could be shared in such a venue.

International reward pool and witness hotline. Among the 15 western states and provinces the typical maximum reward being offered was about \$2,000, which doesn't convey the seriousness of the crime and may not motivate an individual to turn in a fellow angler. There would be many benefits of states, provinces, and territories pooling reward resources, possibly administered by a non-profit fishing organization, including international exposure for the issue, endorsement and promotion of the cause by a non-regulatory body, superior fund raising capabilities, and combined resources that could easily increase rewards offered to \$50,000 per conviction. Further, centralization would enable the creation of a toll-free witness hotline (e.g., 1-800-FISH-COP), so a single telephone number could be displayed all over North America to report illegal fish stocking.

2. Changes in management organizations.

Agencies can do a number of things to eliminate the motivation and rewards particular people receive from illegal stocking, and to convey the message that illegal stocking will not be tolerated.

Satisfy angling demand responsibly. When possible, illegal stocking may be minimized by understanding angler desires and satisfying the demand for alternative angling opportunities with more sustainable options. These might include improving existing fisheries through habitat management, more effective harvest regulations, or improved stocking protocols for existing species. In some cases, use of sterile fish might satisfy the desire for a fish that is not common locally, if compatible with widely accepted stocking policies. However, we need to send the message that stocking is only appropriate when scientifically justified and ecologically sound, and management authorities should hold themselves to this standard. Keeping our own house in order by demonstrating good stewardship is prerequisite to requiring responsible behavior from anglers.

Uniformly strict regulations. Highly developed Internet-based social networks allow anglers to exchange information about fishing

and fishing regulations anywhere. Inconsistency among jurisdictions in regulations and penalties pertaining to unauthorized stocking creates the impression that the practice is not universally contemptible, may give stakeholders a pointless bone of contention, and creates unequal and inequitable control of risks of introductions among bordering jurisdictions. As Courtenay and Robins (1975) suggested, a model law with consistent format, rationale, and penalties could be developed, and then tailored as necessary for implementation in each jurisdiction.

Proactive policies: “must kill,” live fish bans. Enacting “must kill” regulations in advance for prohibited species demonstrates agency resolve, and can reduce the motivation to stock illegally. Although enacted after the fact, mandatory kill regulations were established for northern pike at Lake Davis (CFG 2007), lake trout at Yellowstone Lake (Koel et al. 2005), and illegally stocked burbot (*Lota lota*) in Utah (UDWR 2009). Banning the possession of live fish, either as bait or in the creel, or simply banning the transport of water, might be considered draconian measures by some, but there are many benefits. Such bans make it much less likely for anglers to move fish from one water body to another, they make law enforcement much simpler, and there would be a reduced likelihood of transmission of invasive aquatic organisms or potentially devastating diseases.

Respond appropriately: closures and surcharges. Agencies can communicate the message that illegal stocking is intolerable by closing illegally stocked waters to fishing. Such an action denies benefits for the perpetrator and may result in peer pressure against future violations. A recent example of such forthright actions occurred in British Columbia where officials closed eight lakes to fishing in June 2007 after discovering that the lakes had been illegally stocked with yellow perch (Maricle 2007). In addition to clearly demonstrating to anglers the seriousness of the issue, this action may be required to “quarantine” invasive species and give agencies time to attempt to eradicate them before anglers have the opportunity to move them to other waters. Economic measures may also be helpful. For example, a surcharge for fishing on illegally stocked waters would raise funds to offset mitigation costs but more importantly may generate ill will in the local angling community toward the perpetrator that could dissuade that person and others from engaging in illegal stocking in the future.

3. Changes within the angling public.

We believe there are fundamentally two types of people engaged in illegal stocking, requiring different management approaches. The first type, “depreciative” actors (Knopf and Dustin 1992), are probably ignorant of the law and the detrimental effects of unauthorized stocking. They should respond to well-grounded and balanced arguments about the negative effects of illegal stocking. Involving highly respected professional anglers in communication campaigns could enhance credibility and message delivery. The message should be repeated over as many channels as possible, e.g., face-to-face, seminars, angling clubs, magazine articles, newspaper, radio, TV, and Internet. The message must be based on sound knowledge, convincing reasoning, and avoid appeals strictly on moral grounds. A balanced message including impacts to ecosystems, recreational fisheries, economies, and the image of recreational fishing as a pastime is most likely to be most convincing.

The second type, “vandalistic” actors (Knopf and Dustin 1992), stock fish illegally despite knowledge of the law and potential negative effects. Harsh and highly visible sanctions, witness rewards, peer pressure, and enforcement are strategies to coerce vandalistic actors (Ajzen 1992). Sanctions for illegal stocking should be severe, commensurate

with the severity of potential ecological and socioeconomic impacts (Ostrom 2005). Illegal stocking can have vastly greater ecological impacts than harvesting a big game animal illegally, and yet in some jurisdictions the fine for the latter is orders of magnitude higher than the fine for stocking fish without a permit. Why shouldn't all jurisdictions follow Canada's example and increase the maximum penalty for illegal stocking to \$100,000? Can anyone deny that the introduction of a nuisance aquatic species would cause at least this amount of damage? Revocation of fishing privileges denies perpetrators the ability the reap benefits from their actions; the maximum ought to be permanent revocation, and it should be recognized by all jurisdictions continent-wide. For harsh penalties to be fair and effective as deterrents the public must be aware of them so agencies must couple rule changes with effective outreach.

CONCLUSIONS AND OUTLOOK

It would be easy for the fisheries profession to shirk responsibility for this problem by simply declaring a need for more education and enforcement. We believe it will take more than posters and check points to make progress with this issue, and we think we have offered some substantive suggestions. We also see the need to broaden the search for solutions, both conceptually and geographically. As fisheries professionals most of us have limited training in the “human dimensions” of our field (Fulton and Adelman 2003). We are thus ill-prepared to understand the varied values and motivations of our clientele, effectively educate and motivate policy makers, and grasp the realities of law enforcement and criminal justice. To be more effective in preventing illegal stocking now and in the future, we will need to engage with experts from other fields including sociology, psychology, law, environmental education, political sciences, marketing and communication, and reach out to our colleagues worldwide with the common goal of closing a major and preventable pathway of aquatic invasions. The task is clear, the responsibility rests with us and the time to start is now.

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Sportfish Restoration and Boating Trust Fund: User Pays, User Benefits

The 2009 Transportation Bill has been working its way through the Congressional enactment process. It has been "read" twice and referred to the Committee on Environment and Public Works. The following is a statement by the Angling and Boating Alliance about the part of the bill that helps pay for the conservation of aquatic resources in the United States. The Angling and Boating Alliance is an ad hoc coalition of national recreational boating, angling, outdoor recreation organizations, conservation groups, and state boating safety and natural resources agencies committed to the sustainable future of the Sportfish Restoration and Boating Trust Fund. Back in April, the alliance reached consensus agreement on reauthorization priorities and statutory changes to ensure the trust fund's continued vitality and success as a "user pays, user benefits" program.

ABOUT THE TRUST FUND

The Sportfish Restoration and Boating Trust Fund serves as the backbone for conservation funding in the United States—a uniquely American system of conservation funding—and is a critical funding pool for a diverse set of important state and national recreational fishing and boating programs, including recreational boating safety, fisheries management, habitat conservation, vessel pump-out stations, water and boating access infrastructure programs, aquatic resource education programs, and angler and boater outreach, among others.

Funding for the trust fund is attained through a "user tax" system, in which excise taxes on fishing tackle and equipment, motorboat fuel, and import duties on recreational boats and fishing equipment are collected for the various Sportfish Restoration programs operat-

ing under the Dingell-Johnson Sportfish Restoration Act (16 U.S.C. 777). These combined excise taxes and duties on the boating and fishing communities generate nearly \$700 million annually.

The Trust Fund was most recently reauthorized in 2005 as part of the "Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users" or SAFETEA-LU (Public Law 109-59, title XI, subtitle B, part 2, section 11115, approved 10 August 2005) as amended by the Sportfishing and Recreational Boating Safety Amendments Act of 2005 (Public Law 109-74, approved 29 September 2005). The trust fund is up for reauthorization as part of the 2009 Highway Bill.

ALLIANCE AGREEMENT ON STATUTORY AMENDMENTS TO THE TRUST FUND

- To ensure equity among all aspects of the Trust Fund, all administrative costs for both the U.S. Fish and Wildlife Service (USFWS) and U.S. Coast Guard (USCG) will be taken before any percentage distributions to the remaining accounts. Because administrative functions of both federal agencies benefit all stakeholders, the alliance agrees that these costs should be shared equally among all trust fund beneficiaries.
- In recognition of both the current economic climate and the likelihood that revenues for the trust fund will decline to some extent in immediate future years, the alliance agrees that the current administrative cost baselines for both USFWS and USCG should remain at FY2009 actual levels as a hard figure—rather than a percentage of the trust fund—and be adjusted annually by the Consumer Price Index.
- To ensure equity among all aspects of the trust fund, the alliance agrees that all set-aside costs, such as those for commissions, councils, and grant programs, will be absorbed by the appropriate account (e.g., State Boating Safety, Sport Fish Restoration).
- To partially restore original legislative intent with respect to the Coastal Wetlands program, the alliance agrees that the percentage allocation for Coastal Wetlands should be reduced from 18.5% to 18.3%. Coastal Wetlands, which was intended to receive the funds raised from the small engine excise tax, currently receives significantly more dollars than this excise tax generates.
- The alliance agrees that in order to offset the impact of anticipated revenue declines for the crucial Clean Vessel Act (CVA) and Boating Infrastructure Grant (BIG) programs, and to take advantage of current lower real estate market values, the percentage allocation for each of these programs should be increased by .1% from 2.0% to 2.1%.
- The alliance believes that Outreach & Participation is a critical component of the trust fund, particularly given the current economic climate. Therefore, the alliance agrees to support an increase to the Outreach and Participation percentage allocation from 2.0% to 2.2%.
- The alliance agrees to support an adjustment of the Sport Fish Restoration (SFR) percentage allocation from 57% to 56.8%.
- The alliance, in recognition of the importance of recreational boating safety and the need for equity in the funding of federal advisory committees, agrees to add a line item of \$200,000 within the State

Boating Safety Grant account for the National Boating Safety Advisory Council (NBSAC).

- The alliance agrees that the federal/state match requirement for Recreational Boating Safety (RBS) grants should be 75% federal funds and 25% state funds.
- The alliance agrees there should be a statutory Maintenance of Effort clause in the Recreational Boating Safety Program.
- In recognition of the importance of ensuring recreational access to waterways and of the need to have a coordinated approach to water access, the alliance agrees that the statute should be amended to make available up to \$300,000 from the 15% allocation for water access under the Sport Fish Restoration account, subject to a competitive bidding process, for non-profit entities to address specific access concerns.
- The alliance, in recognition of the importance of the USCG Manufacturing Compliance Program and anticipated increased future needs as a result of the current economic climate, supports modifying the statutory minimum

funding for the program from \$2 million to \$2.25 million.

- In recognition of anticipated future needs with respect to the USCG National Recreational Boating Survey, and in recognition of the importance of the data to be provided by this survey, the alliance agrees to commit, in future reauthorization efforts, to discussions to identify a direct funding stream for this survey.
- In order to increase transparency, reporting, and accountability, the alliance agrees that the current statute should be amended to require program administrators for each program under the trust fund to submit reports twice yearly to all relevant stakeholders on expenditures, accomplishments, and other crucial information with respect to the implementation of each program's mission. Additionally, the alliance agrees current law should be amended to require such reporting to the relevant councils to update stakeholders of the trust fund.
- In recognition of new challenges and opportunities associated with access to recreational water bodies

and in awareness of new environmental requirements in states across the nation, the alliance agrees to allow (but not require) a certain portion of Clean Vessel Act program dollars to be spent on a specific set of capital improvement and infrastructure projects to support clean marine programs, such as power wash-down stations at inlets to water bodies, including marinas; containment and treatment stations at marinas; and other such infrastructure projects. The alliance agrees to a maximum allowance of not more than 25% of state-apportioned CVA program dollars to be used for such purposes.

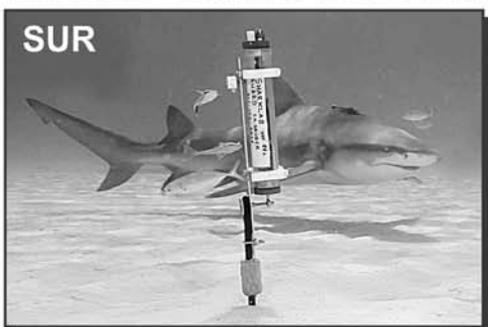
- In recognition of the trend for recreational water bodies and fisheries being closed to recreational angling and boating access in a manner not consistent with scientific evidence, sound policy, or any available data to justify such closures and restrictions, the alliance agrees to amend current law, or the Code of Federal Regulations, to make ineligible the use of any trust fund dollars for such closures.

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COMMITTEE REPORT: SURVEY RESULTS

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2008



Membership Survey Results

EXECUTIVE SUMMARY: The Human Dimensions Research Unit at Cornell University conducted a membership survey for the American Fisheries Society (AFS) in 2008 to ascertain members' level of satisfaction with current AFS services and aid in the strategic planning process. A random sample of 1,500 AFS members was selected for a web-based survey, with a total of 747 surveys completed online. Based on survey results, the profile of AFS membership has changed little since the first membership survey in 1997, except that female membership increased from 16% in 1997 to 24% in 2008. A few highlights from the survey: (1) respondents felt that the reputation of AFS journals was quite high; (2) most respondents (86%) thought that if they were an author of an AFS publication, they would be willing to have their work published in an online journal rather than a print journal (with electronic copy); (3) most respondents (88%) support the development of web-based broadcasts of symposia from the Annual Meeting; and (4) among nine options for future priorities for AFS, enhancing public outreach was the most popular.

INTRODUCTION

The American Fisheries Society (AFS) has found it important as part of its strategic planning process to periodically survey its membership to ascertain the level of satisfaction with current services and to determine future priorities. Previous membership surveys were conducted in 1997 (Brown 1998) and 2004 (Brown and Cooke 2005). In

conjunction with its strategic planning cycle, AFS staff, officers, and the Membership Concerns and Publications Overview Committees indicated the need for an updated survey in 2008.

METHODS

The Human Dimensions Research Unit (HDRU) at Cornell University, which conducted the previous surveys, was chosen to conduct the 2008 survey. The survey collected basic data on the membership and the level of participation in AFS activities. It then focused on eight areas of AFS life: (1) publications, (2) meetings, (3) education/mentoring, (4) professional certification, (5) AFS governance, (6) recruitment and retention, (7) outreach and advocacy, and (8) future priorities for AFS.

A random sample of 1,500 AFS members with e-mail addresses was selected from the membership database for this web-based survey. (Ninety-four percent of AFS members have an e-mail address.) The complete membership list, including students, retired people, and international members, was used. Invitation e-mails were sent out on 19 February 2008. Up to four reminder e-mails were sent to non-respondents over the course of the following month. Data collection ended on 24 March 2008.

RESULTS

Of the 1,500 e-mail invitations sent out, 158 were undeliverable (10.5% of the sample). A total of 747 surveys were completed online, for an adjusted response rate of 55.7%. This compares to a 63.5% response rate for the 2004 survey and 76.6% response rate for the 1997 survey (both of which were sent out by mail).

1997–2008

AFS MEMBERSHIP TRENDS

- Based on the survey results, the profile of the AFS membership has changed little in the past 11 years, but these small changes may suggest some longer-term trends:
- The biggest change has been a consistent increase in female members from 16% in 1997 to 24% in 2008 (Table 1).
- The mean age of members, length of membership, and years as a fisheries professional increased between 1997 and 2004 but decreased between 2004 and 2008 (Table 1). Thus, while fluctuating somewhat from survey to survey, these characteristics are remaining relatively constant over time.
- Although "state/provincial/tribal" remains the largest single employer of AFS members, the proportional size of this group declined between 1997 and 2004,

Table 1. Comparative profile of AFS members, 1997, 2004, and 2008.

Characteristics	1997	2004	2008
Percent female	15.7%	19.2%	24.2%
Mean age	43	45	44
Mean years AFS member	13.5	15.2	13.2
Mean years a fisheries professional	16.1	18.3	15.4

and in 2008 remains near the 2004 level. The percentage of members who are students has increased in recent years.

- The majority of AFS members consider themselves to be fisheries biologists/scientists. Another 25% consider themselves fishery researchers, followed by managers, administrators, and educators.
- Most respondents work in freshwater fisheries as compared with marine/estuarine. About half of respondents worked in research, while 40% were involved in management.
- Half (50%) of the respondents had participated in at least one of the parent Society activities in the past 3 years, most likely attending the Annual Meeting. There appears to be some growth in the proportion of members who attend the Annual Meeting. In the 2008 survey, 42% indicated they had attended an Annual Meeting within the past three years, whereas 38% in 2004 and 32% in 1997 indicated they had attended an Annual Meeting within the past five years. Chapter activities were also popular among respondents—more so than Division or Section activities (Table 2).

MEMBER VIEWS ON ELECTRONIC MEDIA AND AFS PUBLICATIONS

Most respondents (93%) thought agency reports and grey literature should be made accessible electronically (e.g., through Infobase or other

electronic products). Most (86%) also thought that if they were an author of an AFS publication, they would be willing to have their work published in an online journal rather than a print journal (with electronic copy).

Concerning publication costs, regardless of their willingness to publish in an online journal, only 30% would be willing to pay \$250 or more to have their manuscript available in an open-access format (where authors pay a fee in lieu of page charges to defray the cost to readers of accessing the paper online). Of the 23% who had published in an AFS journal within the last 5 years, 83% would be willing to publish in an online journal and 43% would be willing to pay \$250 or more for an open-access format.

The reputation of AFS journals among respondents was generally quite high. The majority of respondents felt *Transactions of the American Fisheries Society* and the *North American Journal of Fisheries Management* had a high reputation compared with other publication outlets for fisheries science and management. The majority of respondents did not know about the reputation of the *North American Journal of Aquaculture* and the *Journal of Aquatic Animal Health*.

MEMBER VIEWS ON AFS MEETINGS

Survey respondents were generally split between medium (41%) and high (54%) interest levels in science-

based meetings that are focused on particular topics and sponsored by AFS and other fisheries or scientific organizations. Respondents also were split in their support for occasionally holding AFS meetings outside of the United States and Canada, with 53% supporting the idea and 47% opposing it. Most respondents (79%) felt that AFS should pursue joint meetings with other professional societies that have overlapping missions, such as the International Council for Exploration of the Sea or the World Aquaculture Society.

Looking to the future, most respondents (88%) support the development of web-based broadcasts of symposia from the Annual Meeting, thus allowing members to view the symposia without having to travel to the meeting. The preferred methods of electronic communication are webcast of symposia (77%) and online continuing education courses (72%). Only 30% favored podcasts of technical sessions from the Annual Meeting.

MEMBER VIEWS ON EDUCATION, MENTORING, AND CERTIFICATION

Respondents were generally supportive of AFS education and mentoring opportunities. Over half (64%) thought the Hutton Junior Fisheries Biology program was important. Most respondents (96%) supported the development of a mentoring program connecting young professionals entering the field of fisheries with established professionals. Most (95%) also favored developing a

program to support undergraduate and graduate fellowships in fisheries, similar to the J. Frances Allen Scholarship fund.

Interest in the certified fisheries scientist program may be declining. In 2004,

Table 2. Percent of 2008 respondents who participated in parent Society or Subunit activities during the past 3 years.

AFS activity in past 3 years	Parent Society	Division	Chapter	Section
	Percent			
Served as an officer	1.1	1.3	10.0	6.7
Chaired a committee	2.5	2.5	7.4	3.1
Served on a committee	8.0	6.6	14.5	5.8
Organized a meeting or symposium	8.2	4.8	7.2	4.1
Presented a paper at an Annual Meeting	26.1	14.9	26.0	4.7
Attended an Annual Meeting	42.4	24.2	43.9	11.5
Attended a meeting	19.1	15.9	32.3	13.4
Participated in a continuing education course	5.9	5.1	16.3	2.7

13% of respondents were certified compared to 9% in 2008. Among those who had some type of certification, 63% thought the program was of some value to them. Of those who were not certified, one-quarter (22%) thought the program still had value to them. Possibly counteracting the slight declining participation in the program, students were most likely to say the program had value to them (51%), and therefore might pursue certification in the future.

MEMBER VIEWS ON AFS GOVERNANCE

The survey asked a series of questions on governance issues, with the results highlighted below.

- 44% of respondents said AFS should continue to play a leadership role in the World Council of Fisheries Societies, 22% thought AFS should continue to build formal international relations, < 1% thought AFS should play a less significant role, and 34% did not know what role AFS should play.
- 32% of respondents said they were aware of the procedures used to govern AFS and how members can raise aquatic resource or membership issues for consideration.
- 37% of respondents said they understood the role of AFS Sections in regards to the governance of the AFS.
- 77% of respondents said that the AFS Sections were meeting their needs.
- 54% of respondents felt that the current practice of permitting non-AFS members to be Chapter members was appropriate.
- 28% of respondents said that as an AFS Chapter member, they felt the Division leadership was representing their interests well on the AFS Governing Board; 4% did not feel well represented;

the remaining 68% did not know—perhaps because they were not Chapter members.

MEMBER VIEWS ON RECRUITMENT AND RETENTION

The majority of respondents felt AFS is doing enough to recruit and maintain students and young professionals as members. However, about 30 to 40% of respondents thought AFS could do more. The most popular suggestions for retaining students after they cease being students and young professionals were providing mentorship opportunities, reducing membership fees, and reducing meeting registration fees. Travel awards and leadership opportunities were also seen as good suggestions by roughly half of the respondents who thought AFS was not doing enough.

A majority of respondents thought AFS should look to the fields of conservation biology (62%) and environmental sciences (56%) to recruit new members to AFS. Oceanography/marine sciences was suggested by about one-third of respondents.

Three-quarters of respondents (78%) thought AFS should be doing more to encourage participation by new members. The survey did not ask what specifically they thought AFS should be doing.

Since only about one-third of North American fisheries profession-

als are AFS members, respondents were asked what they thought limited other professionals from joining AFS. The most commonly mentioned limiting factors were costs, support by employer, and time invested in other activities.

MEMBER VIEWS ON OUTREACH AND ADVOCACY

The results of a series of questions on outreach and advocacy are highlighted below.

- Seventy-one percent of respondents thought AFS should put more emphasis on public outreach, such as developing products for public education; 3% thought AFS should do less, with the remaining 26% indicating no change is needed. No differences were found based on respondents' type of employer.
- Sixty-four percent of respondents thought AFS should put more emphasis on political advocacy for fisheries and aquatic resources by increasing interactions with government policy makers; 6% thought AFS should do less, with the remaining 30% indicating no change is needed. No differences were found based on respondents' type of employer.
- Most respondents (92%) thought AFS should coordinate with the Fisheries Conservation Foundation, Sea Grant, or other

Table 3. Respondents' opinions on AFS priorities for the future.

Future priorities	Percent checking*
Enhance public outreach	58.9
Provide a mechanism to connect professionals among different scientific societies	51.7
Support local social gatherings to connect students with professionals	49.1
Increase national and world leadership in conserving marine and aquatic resources	46.1
Increase the number of mentoring programs	44.4
Pursue a greater role in political advocacy	40.7
Increase the diversity of AFS publications by publishing selected gray literature	39.0
Expand international membership	20.3
Increase the number of books published by AFS	13.0
Other	3.3

*Percentages add to more than 100% because respondents could check as many priorities as they wanted to.

groups such as anglers and teachers to increase public outreach and advocacy.

- About half of the respondents (52%) felt that AFS effectively communicates goals for aquatic stewardship. This percentage was significantly higher among student members (70%).

FUTURE PRIORITIES FOR AFS

Of the nine options respondents were given for future priorities, enhancing public outreach was the most popular (Table 3). Half of the respondents also indicated that providing a mechanism to connect professionals among different scientific societies and supporting local social gatherings to connect students with professionals were things AFS should make a priority in the future. Of lesser interest were increasing the number of books published by AFS and expanding international membership.

In a related question, just under half of the respondents (46%) thought AFS should place more emphasis on marine fisheries issues. Those currently working in the marine/estuarine area were much

more likely (71%) to think AFS should place more emphasis on these issues. Respondents who thought more emphasis should be placed on marine fisheries issues were then asked to write in what products or services they would recommend to improve the current situation at AFS. Only half of the applicable respondents wrote in a suggestion. The most frequently mentioned items were outreach activities and research on marine issues. Increasing the number of journal articles on marine issues or supporting the new marine journal were also common suggestions, as was partnering with other organizations and having more marine-focused meetings.

CONCLUSIONS

Results from this survey show a potentially diversifying membership that is generally satisfied with current efforts of AFS. There are a number of issues that the AFS leadership has asked for feedback from the membership on via this survey. Now the task for AFS leaders is to use this information to inform the strategic plan, which is already

underway, and communicate back to the membership.

ACKNOWLEDGMENTS

Funding for this study was provided by the American Fisheries Society. AFS leadership for the study and questionnaire development was provided by Mary Fabrizio. Other AFS members and staff who assisted, especially with questionnaire development, were Jill Hardiman and the Membership Concerns Committee of 2007, Steven Cooke and the Publications Overview Committee of 2007, Eric Knudsen, AFS officers (Wayne Hubert, Don Jackson, Bill Franzin, and Jennifer Nielsen), Elden Hawkes, and Gus Rassam.

The Cornell University Survey Research Institute implemented the web-based survey and provided HDRU with the final data set.

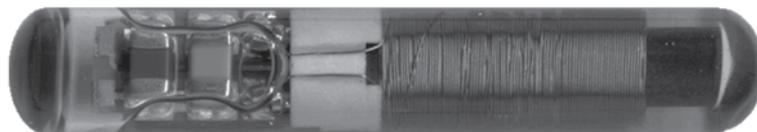
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- Brown, T. L., and S. J. Cooke.** 2005. AFS membership study. New York State College of Agriculture and Life Sciences, Cornell University, Department of Natural Resources, HDRU Series 05-04, Ithaca.



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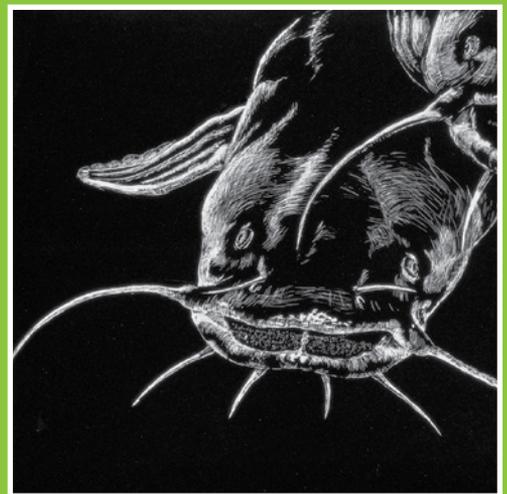
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The Foundation of Fisheries and
of The American Fisheries Society
Are We Gaining Ground?



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The theme of the 2008–2009 year and of course the Annual Meeting in Nashville later this month is **“Diversity, the Foundation of Fisheries and of AFS,”** followed by the question **“Are we gaining ground?”** This question arose for a number of reasons—it has been over 10 years since AFS considered the status of the diversity of fisheries and their supporting habitats and even longer since we considered the diversity of our Society. The Annual Meeting addresses all of these topics, with the Plenary Session providing the kick-off: Jeff Hutchings of Dalhousie University speaking on marine biodiversity, Peter Moyle of University of California Davis talking about freshwater fish diversity, Doug Austen of the Pennsylvania Fish and Boat Commission telling us about the status and trends in fish habitat, and finally Ambrose Jearld of NOAA bringing us up to speed on the human diversity trends in our profession and the Society. Several symposia address various aspects of the theme, from “Mapping Distributions of North American Fishes” to “Sustainable Global Fisheries” to “Diversity in Natural Resource Professions.” Our Annual Meeting is just one of our yearly accomplishments. Below are a few others.

A NEW STRATEGIC PLAN

A strategic plan revision committee was appointed by President Mary Fabrizio in 2008. The committee completed a new Strategic Plan for the period 2009–2014 this past summer and it will be before the Governing Board for approval in Nashville. This plan addresses the major challenges facing AFS in the next few years and will be accompanied each year by the integrated plans of the president and the executive director as their joint operational plan of work.

NEW WAYS TO RECOGNIZE THE VALUES OF MEMBERSHIP

For the first time in many years, we have created a new Society-wide award, the Emmeline Moore Prize, named for our first woman president who held office in 1927–1928. The prize is to be awarded for the first time in Nashville to a deserving member in recognition of dedication to the cause of achieving greater access to the fisheries profession and education by under-represented groups. In addition, starting at this year's Annual Meeting, AFS will award Governing Board members a special service pin. We also will award pins to recognize loyal members who have belonged to AFS more than 50 years and more than 25 years as a token of their support of the Society for those many years.

A NEW JOURNAL IN A NEW FORMAT

The year 2009 marked the first publication of our new online, open-access journal, *Marine and Coastal Fisheries*. This is a new concept journal for AFS and offers multiple possibilities such as color photos, video clips, and interactive maps in a totally electronic format. Eleven papers have been produced in the first volume so far.

WE REMAIN IN OUR BUILDING AFTER ALL

Last year at this time we were seriously contemplating the possibility of leaving our long-standing premises at 5410 Grosvenor Lane in Bethesda for a new building elsewhere due to the pending sale of the property by the major owners. That is all behind us now as the deal with the potential purchaser fell through when the present recession began to develop.

THE RECESSION AND ITS IMPACT ON AFS

The global economic recession has had other impacts on AFS as well. Declining donations and advertising revenue are two of the symptoms. In response, AFS is looking at many avenues for cost cutting without changing the already low dues and individual subscription prices.

CONTINUING LEADERSHIP AT THE WORLD COUNCIL OF FISHERIES SOCIETIES

In October 2008, AFS participated in the 5th World Fisheries Congress hosted by the Japanese Society of Fisheries Science. At that meeting the presidency passed to Felicity Huntingford of the Fisheries Society of the British Isles (FSBI). A new vice president was elected as well, Doug Beard of AFS, replacing Barbara Knuth. The latest meeting of the Council at the FSBI meeting in Leicester, England, was attended by President Franzin and Doug Beard. AFS Executive Director Gus Rassam remains the secretariat of the WCFS as we move forward to inter-congress meetings such as one on Climate Change and Fisheries in Belfast in 2010, as well as the 6th World Fisheries Congress in Edinburgh in 2012.

Bill Franzin
President

Gus Rassam
Executive Director

2008 ANNUAL REPORT

SPECIAL PROJECTS



NATIONAL FISH HABITAT ACTION PLAN

Momentum for the National Fish Habitat Action Plan has grown with the introduction of House bill H.R. 2565, the National Fish Habitat Conservation Act. If passed, the National Fish Habitat Board will be formally established and given authority over funding of up to \$75 million annually to directly support fish habitat work. This legislation recognizes the success and growth of NFHAP, with nine regional partnerships being currently recognized and several candidate partnerships waiting to be recognized.



In the second annual NFHAP awards ceremony, several partners were recognized for their active support of fish habitat efforts. The Outreach and Education Award was presented to the Lake Leaders Institute in Wisconsin while Yvon Chouinard of Patagonia received the Jim Range Conservation Vision Award. Steve Jordan, Lisa Smith, and Janet Nestlerode of the Environmental Protection Agency Office of Research and Development were recognized with the Scientific Achievement Award and Project SHARE (Salmon Habitat and River Enhancement) was given the Extraordinary Action Award.

NFHAP currently supports dozens of local, grassroots-driven projects, as well as U.S. national efforts to identify the root causes of aquatic habitat declines, identify and implement corrective actions, and measure and communicate its progress. For more information, see www.fishhabitat.org.

IMPERILED FRESHWATER ORGANISMS OF NORTH AMERICA

The AFS Endangered Species Committee updated the North American crayfish species conservation status list in 2007 and the freshwater and diadromous fish species list in 2008. Both lists are now available online in an interactive format at <http://fisc.er.usgs.gov/afs/>. The fish species status list includes 700 species, subspecies, and populations, a 92% increase over the 364 listed in 1989. The increase reflects the addition of distinct populations, previously non-imperiled fishes, and recently described or discovered taxa. Approximately 39% of described fish species of the North American continent are imperiled. Of those that were imperiled in 1989, most (89%) are the same or worse in conservation status; only 6% have improved in status, and 5% were delisted for various reasons. Habitat degradation and nonindigenous species are the main threats to at-risk fishes, many of which are restricted to small ranges. North America is considered to have the greatest temperate freshwater biodiversity on Earth for both fish and crayfish and documenting the diversity and status of rare species is a critical step in identifying and implementing appropriate actions necessary for their protection and management.

FIFTH WORLD FISHERIES CONGRESS

The spectacular modern waterfront of Yokohama, Japan, welcomed more than 1,600 scientists from 56 countries for the Fifth World Fisheries Congress (WFC) from 20-24 October 2008. More than 500 of the attendees were students and the meeting was even attended by the Emperor and Empress of Japan. The goal of WFC meetings is to convene fisheries scientists from around the world to discuss and bring attention to the primary issues facing global fisheries. The 5th WFC was organized by the Japanese Society of Fisheries Science (JSFS), and AFS was heavily involved in the program planning. One highlight of the meeting was the presentation of the first-ever International Fisheries Prize to Kurt Fausch of Colorado State University for his record of international cooperation in salmonid research.



Nine topical sessions included fisheries and fish biology; aquaculture; biotechnology; post-harvest science and technology; material cycling in aquatic ecosystems—linking climate change and fisheries; freshwater, coastal, and marine environments; biodiversity and management; fisheries economics and social science; and education and international cooperation. The next World Fisheries Congress will be held in Edinburgh, Scotland, in May 2012.

HUTTON UPDATE

The Hutton Junior Fisheries Biology Program is a summer mentoring program for high school students. The principal goal of the Hutton Program is to stimulate interest in careers in fisheries science and management among groups underrepresented in the profession, including minorities and women. Hutton provides students with a summer-long hands-on experience in fisheries research with a mentor who is working in some aspect of the field. A \$3,000 scholarship and an AFS student membership are provided to each student accepted into the program. The Class of 2009 includes 35 outstanding students who are currently working with mentors in 21 states (Alabama, California, Colorado, Connecticut, Idaho, Massachusetts, Michigan, Minnesota, Missouri, Montana, New Jersey, New Mexico, New York, Oklahoma, Oregon, South Dakota, Tennessee, Utah, Virginia, Washington, and Wisconsin). Of the exceptional students chosen for the Hutton Program this summer, nearly two-thirds are minorities, and more than one-quarter are non-minority females.



The program is evaluated annually through a survey of all previous alumni. The ultimate success of the program is determined by the number of students that enter the fisheries profession. According to the 2008 survey, 64% of Hutton alumni are studying or considering studying fisheries, biology, or environmental science; 10% have received undergraduate degrees in fisheries science; and of those students, 47% are pursuing advanced degrees in fisheries science.



AFS WEB SITE: WWW.FISHERIES.ORG

Visit www.fisheries.org for the latest on fisheries science and the profession. Subscribe to the free Contents Alert e-mail service or search for your colleagues by using the membership directory online.

The Fisheries InfoBase now includes all AFS journals back to 1870, including all issues of *The Progressive Fish Culturist*.

AFS MAGAZINE: FISHERIES

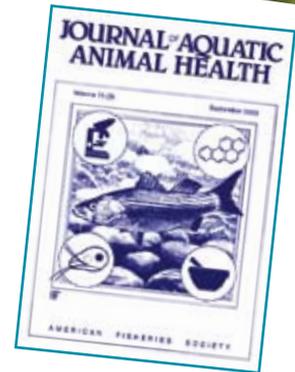
The AFS membership magazine, *Fisheries*, offers up-to-date information on fisheries science, management, and research, as well as AFS and professional activities. Featuring peer-reviewed scientific articles, analysis of national and international policy, commentary, chapter news, and job listings, *Fisheries* gives AFS members the professional edge in their careers as researchers, regulators, and managers of local, national, and world fisheries. *Fisheries* is available to members online at www.fisheries.org.



AFS JOURNALS

- **TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY**, bimonthly, Volume 138
- **NORTH AMERICAN JOURNAL OF AQUACULTURE**, quarterly, Volume 71
- **NORTH AMERICAN JOURNAL OF FISHERIES MANAGEMENT**, bimonthly, Volume 29
- **JOURNAL OF AQUATIC ANIMAL HEALTH**, quarterly, Volume 20

Journals are also available to subscribing members online at <http://afs.allenpress.com>.



• NEW MARINE AND COASTAL FISHERIES JOURNAL



Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, is an international venue for studies of marine, coastal, and estuarine fisheries. Edited by a distinguished and international panel of scientists headed by Dr. Donald Noakes (Thompson Rivers University, British Columbia, Canada), this journal promotes the wide dissemination of scientific research through its open access, online format. The journal encourages contributors to identify and address challenges in population dynamics, assessment techniques and management approaches, fish and shellfish biology, human dimensions and socioeconomics, and ecosystem metrics to improve fisheries science in general and make informed predictions and decisions. The journal is now accepting submissions. For more information, please visit www.fisheries.org/mcf or contact the Editor-in-Chief, Dr. Donald Noakes (dnoakes@tru.ca).

RECENT AND UPCOMING TITLES

AFS BOOKS



- Standard Methods for Sampling North American Freshwater Fishes*
- Challenges for Diadromous Fishes in a Dynamic Global Environment*
- Biology and Management of Dogfish Sharks*
- Pacific Salmon Environmental and Life History Models*
- Enclosing the Fisheries: People, Places and Power*
- Balancing Fisheries Management and Water Uses for Impounded River Systems*
- Urban and Community Fisheries Programs: Development, Management, and Evaluation*
- Pacific Salmon: Ecology and Management of Western Alaska's Populations*



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Midway, Travis Neebling, Ryan Utz
J. Frances Allen Scholarship Melissa
Wuellner
Allen Scholarship Runners-Up Karen
Murchie, Michelle Staudinger
Student Writing Contest First Place Karen
Murchie
Student Writing Contest Second Place
Connie O'Connor

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Robert L. Kendall Best Paper in *Transactions
of the American Fisheries Society*.
Thomas R. Whittier, Robert M. Hughes,
Gregg A. Lomnicky and David V. Peck
Best Paper in the *Journal of Aquatic Animal
Health*. K. Choi, D.W. Lehmann, C.A.
Harms, and J. M. Law

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Education Section 2007 AFS Best Student
Poster Award Melissa Wuellner
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Outstanding Student Paper Award Kiza
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Education Section Outstanding Student
Paper Honorable Mentions Carrie Holt,
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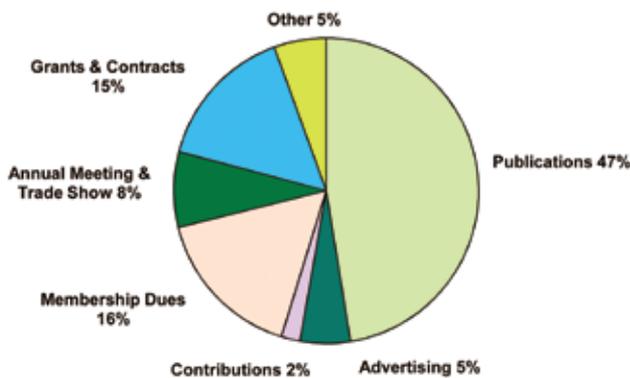
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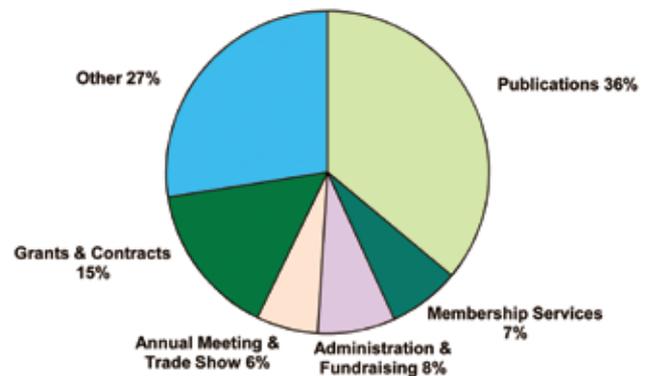
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AMERICAN FISHERIES SOCIETY	
STATEMENT OF FINANCIAL POSITION	
AS OF DECEMBER 31, 2008	
(AUDITED)	
ASSETS	
CASH AND CASH EQUIVALENT	\$1,195,471
ACCOUNTS RECEIVABLE	431,950
INVESTMENT	2,503,578
INVENTORY	341,644
PREPAID EXPENSES	11,940
PROPERTY, PLANT & EQUIPMENT (NET)	625,558
TOTAL ASSETS	\$5,110,141
LIABILITIES AND NET ASSETS	
ACCOUNTS PAYABLE	\$67,486
ACCRUED EXPENSES	503,061
SUBUNITS PAYABLE	58,169
DEFERRED REVENUES	1,005,453
NET ASSETS	3,475,973
TOTAL LIABILITIES AND NET ASSETS	\$5,110,141

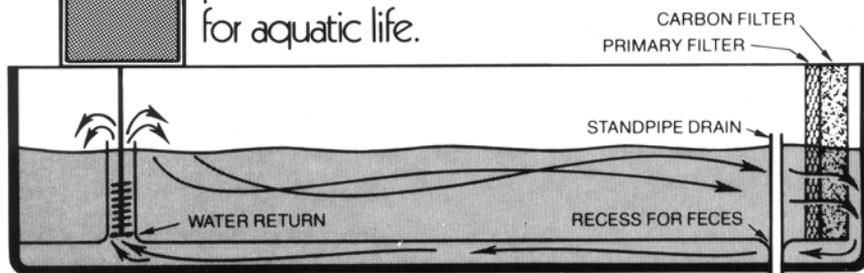
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CALENDAR: FISHERIES EVENTS

To submit upcoming events for inclusion on the AFS Web site Calendar, send event name, dates, city/state/province, web address, and contact information to cworth@fisheries.org.

(If space is available, events will also be printed in *Fisheries* magazine.)

More events listed at www.fisheries.org, click "Who We Are," click "Calendar"

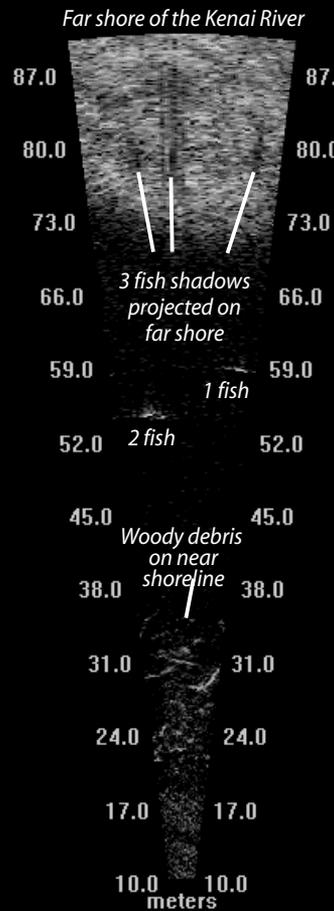
Aug 24-28	4th International Otolith Symposium Monterey, California	Otolith2009@noaa.gov
Aug 30-Sep 3	AFS American Fisheries Society 139th Annual Meeting Nashville, Tennessee	www.fisheries.org/afs09
Sep 16-19	World Fishing Exhibition 2009 Vigo, Spain	www.worldfishingexhibition.com
Sep 21-25	International Council for the Exploration of the Sea Annual Science Conference Berlin, Germany	www.ices.dk
Sep 25-28	Combined Australian Entomological Society's 40th AGM & Scientific Conference / Society of Australian Systematic Biologists / 9th Invertebrate Biodiversity and Conservation / Australian Coral Reef Society Conference Darwin, Australia	www.evolutionbiodiversity2009.org
Sep 28-Oct 2	Australian Society for Limnology Congress: Water in a Dry Land: Sustaining Arid Zone Rivers and Wetlands Alice Springs, Northern Territory	www.asl.org.au
Oct 15-16	2009 Virginia Water Research Conference: Water Resources in Changing Climates Richmond, Virginia	www.vwrrc.vt.edu/2009conference.html
Oct 15-16	Using Acoustic Tags to Track Fish Seattle Washington	www.htisonar.com/at_short_course.htm
Oct 15-17	CANSEE Eighth Biennial Conference—Ecological Economics: Prosperity for a Sustainable Society Vancouver, British Columbia, Canada	www.cansee.org
Oct 22-24	AFS Western Division of the AFS 2nd Annual Student Colloquium Fort Collins, Colorado	Nate Cathcart: cncathca@rams.colostate.edu or http://welcome.warnercnr.colostate.edu/afs-home/index.php
Oct 24-25	Using Acoustic Tags to Track Fish Lyone, France	www.htisonar.com/at_short_course_lyon.htm
Oct 25-30	Sixth International Symposium on Sturgeon Wuhan, Hubei Province, China	www.iss6.org
Nov 2-4	International Symposium on Integrating Offshore Renewable Energy System and Aquaculture Newport, Rhode Island	http://seaagrants.gso.uri.edu/baird/2009
Nov 3-6	Asian Pacific Aquaculture and Malaysian International Seafood Exposition Kuala Lumpur, Malaysia	www.was.org
Dec 9-12	Fourth Shanghai International Fisheries and Seafood Expo Shanghai, China	www.gehuaexpo.com

on the work of AFS. For example, thanks to all those who diligently tried to find common ground on economic growth and fisheries: **Bonnie McCay** and the Resource Policy Committee (RPC) members, **Don Jackson, Bob Hughes, Karin Limberg**, and the AFS officers. The RPC Climate Change Subcommittee under Chairperson **Colleen Caldwell** is working hard to draft a "Climate Change and Fisheries" policy statement that should be available for review in a few months. This is an important issue for AFS since the U.S. government finally has accepted that climate change is a reality that has to be dealt with and AFS will be there to help.

I traveled to as many Division and Chapter meetings as I could. I appreciate the hospitality provided to me by Southern Division Presidents **Mike McMullin** and **Cecil Jennings** and Western Division President **Scott Bonar**. I missed the North Central Division (NCD) meeting chaired by **Jessica Mistak** due to weather but I did catch up with NCD President Elect **Mark Porath** at the Dakota Chapter meeting where I also was welcomed by President **Scott Gangl**. Second Vice President **Bill Fisher**, a new member of the Northeastern Division, attended that Division meeting in my stead. I was able to attend the huge joint Chapter meeting of Minnesota, Ontario, and Wisconsin thanks to Presidents **Tim Cross, Jon Clayton, and John Kubisiak Jr.**, respectively. The Chapter meetings made me realize what I am missing living in an area without an active Chapter.

The Annual Meeting is coming soon in Nashville and I want to acknowledge the prodigious efforts by the Tennesseans to provide us with a great meeting highlighting biodiversity in marine and freshwater fisheries and habitats as well as the diversity of our profession and Society. **Bobby Wilson, David Rizzuto**, and the **local arrangements team** backed by program co-chairs **Phil Bettoli, Mark Bevelhimer**, and **Frank Fiss** have prepared a great meeting. Our Annual Meetings are like an annual homecoming that moves all over the continent providing a celebration of both our science and our camaraderie in the Society. I cannot think of a better place to finish my year as AFS president. Thanks to all of you, it has been a memorable year.

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ANNOUNCEMENTS: JOB CENTER

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

Assistant Leader Human Dimensions, U.S.

Geological Survey, Pennsylvania Cooperative Fish and Wildlife Research Unit, School of Forest Resources, Pennsylvania State University.

Salary: \$66,613–87,893.

Closing: 14 August 2009.

Responsibilities: Conduct human dimensions-related research, mentor graduate students at the M.S. and Ph.D. level, teach one graduate level course in the applicant's area of expertise, and provide technical assistance to cooperators.

Qualifications: Ph.D. and U.S. citizenship required. Additional minimum requirements listed in the job announcement as posted on USAJobs. Knowledge of the ecological, economic, social, political, and cultural processes influencing natural resource policy and management decision-making. Skills to conduct interdisciplinary quantitative and qualitative research that integrates human dimensions into natural resource management, policy, planning, operations, and evaluation. Refer to vacancy announcement ER-2009-0342, Research Ecologist.

Contact: Duane Diefenbach, ddiefenbach@psu.edu, or Tyler Wagner, txw19@psu.edu. See <http://jobview.usajobs.gov/GetJob.aspx?JobID=81974712>.

Research Scientist—Quantitative Population Modeler, Gulf of Maine Research Institute.

Salary: commensurate with experience.

Closing: 15 August 2009 or until filled.

Responsibilities: Be involved in a team-oriented research program with eight other research scientists on the key fish and invertebrate species in the Gulf of Maine region, focusing on fishery ecosystem research.

Qualifications: Doctoral degree and an established research record with a wide interest and experience in fisheries and marine ecosystems. Knowledge of modern stock assessment techniques and of management strategy evaluation is desirable.

Contact: Send letter of interest, curriculum vitae, and five references to Chief Scientific Officer John Annala, Gulf of Maine Research Institute, 350 Commercial Street, Portland, Maine 04101; www.gmri.org; scientistjobs@gmri.org

Assistant Leader—Fisheries, U.S. Geological Survey, Cooperative Fish and Wildlife Research Unit, University of Wyoming.

Salary: \$66,613–87,893

Closing: 25 August 2009.

Responsibilities: Conduct research on applied fisheries management and aquatic conservation issues in the Great Plains and Rocky Mountains that addresses the needs of state and federal resource management agencies, mentor graduate students at both the M.S. and Ph.D. levels. Provide technical services to cooperators, particularly the Wyoming Game and Fish Department. Participate as a faculty member in the Department of Zoology and Physiology at the University of Wyoming. Teach up to one graduate-level course per year.

Qualifications: Education: PhD in fisheries science, ecology, zoology, conservation biology, or related field. Experience: Postdoctoral, agency, or faculty research experience in applied fisheries management, fisheries science, fish ecology, and/or aquatic ecology and conservation. Other: Publication and grant record corresponding with experience demonstrated ability to develop a productive research program involving academic and agency collaborations and interest in application of adaptive management and informed decision-making principles in research and education.

Contact: : Wayne Hubert, whubert@uwyo.edu, or Matthew Kauffman, mkauffm1@uwyo.edu See www.usajobs.gov, Announcement CR-2009-0404.

Ph.D. Research Assistantship, Department of Ecology, Montana State University.

Salary: Stipend of \$18,000 per year with substantial tuition waiver.

Closing: 1 August 2009.

Responsibilities: Investigate the role of biodiversity in infectious disease risk using salmonid whirling disease of western streams as the model system. Collaborate with engineering and molecular population genetics faculty. Direct involvement in both field surveys and laboratory experiments relating the tubificid community to disease risk in salmonids.

Qualifications: B.S. or M.S. degree in ecology, zoology, biology, or a related field. Strong quantitative and

writing skills. Prior experience with field methods used in stream ecology and benthic macroinvertebrate collection and identification and/or disease ecology preferred.

Contact: Submit cover letter, resume, copies of transcripts and GRE scores, and names and telephone numbers of 3 references by either e-mail or regular mail to Billie L. Kerans, bkerans@montana.edu, 406/994-3725, www.montana.edu/wwwbi/staff/kerans/kerans.html.

Postdoctoral Scientist, Department of Fish Wildlife, Colorado State University, Fort Collins.

Salary: Commensurate with qualifications and experience.

Closing: 24 August 2009.

Responsibilities: Study climate change effects on native cutthroat trout. Model persistence of native cutthroat trout given impending changes to interacting aquatic and terrestrial factors caused by climate change. Work involves climate modeling, data analysis, and developing a Bayesian Belief Network decision-support tool.

Qualifications: Earned Ph.D. in aquatic or fisheries ecology, experience in research on ecology of stream fishes, substantial experience with modeling, ability to create and manage large databases, skill in using statistics and computers, strong record of publishing papers in high-quality refereed journals. Desired experience with climate models and fish conservation.

Contact: E-mail cover letter, resume with four references, transcript copies, and publications to Kurt Fausch, kurtf@warnercnr.colostate.edu. Department of Fish, Wildlife, and Conservation Biology, CSU, Fort Collins, CO 80523.

Ph.D. Research Assistantship, Fisheries and Illinois Aquaculture Center, Department of Zoology, Southern Illinois University, Carbondale.

Salary: \$1,426 per month plus full tuition waiver.

Closing: 1 July 2009.

Responsibilities: Conduct research evaluating the dynamics of fatty acid profile change and accumulation of persistent organic pollutants in hybrid striped bass, with the goal of identifying nutritional strategies to minimize risk and maximize value of cultured seafood. Address the controversial use of marine-derived feedstuffs i.e., fish oil and fish meal, as vectors for environmental contaminants that can accumulate in fish tissues along with nutritionally beneficial long-chain polyunsaturated fatty acids. See <http://fisheries.siu.edu>.

Start date: Fall 2009.

Qualifications: M.S. in aquaculture, aquatic toxicology, or related field. Must meet admission requirements for the graduate school and Department of Zoology at SIUC at www.science.siu.edu/zoology/programsgraduate.html.

Contact: Submit a letter of interest, resume and CV, contact information for three references, copies of transcripts and GRE scores to: Jesse Trushenski, Southern Illinois University Fisheries Illinois Aquaculture Center, 1125 Lincoln Drive, Room 173 Carbondale, Illinois 62901-6511; saluski@siu.edu; 618/536-7761.

Ph.D. Assistantship in Mapping Ecosystem Services, Virginia Polytechnic Institute.

Salary: \$22,000–24,000 per year plus tuition.

Closing: 31 July 2009.

Responsibilities: Participate in a multidisciplinary effort to examine where/when biological conservation enhances delivery of aquatic ecosystem services. Participate in conceptual-model development for and spatial analyses of relations among conservation practices, biodiversity, delivery of ecosystem services, and human well being in a U.S. river basin. Perform project data analysis and report writing, while completing Ph.D. coursework.

Qualifications: M.S. in landscape ecology, ecological economics, conservation biology, geography, or related discipline. Commitment to multidisciplinary research, demonstrated scientific productivity, including peer-reviewed publications, strong statistical skills experience with large geo-spatial datasets, excellent writing skills.

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Contact: Send letter of interest, resume, GRE scores, names of three references to Paul Angermeier, Department of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, Virginia 24061-0321; 540/231-4501; biota@vt.edu.

M.S. Graduate Research Assistantship, Aquaculture and Fisheries Center, University of Arkansas.

Salary: First year—\$17,800. Second year—\$18,800. Closing: 1 August 2009 or until filled.

Responsibilities: Use store scanner data to analyze market trends and retail pricing issues for catfish, crawfish, clam, and shrimp, and use household-based scanned data to analyze consumer behavior.

Qualifications: Admission requires a B.S. degree in aquaculture, fisheries, agricultural economics, or a related field, a minimum GPA last 2 years of 3.0 and GRE score of 1,000 verbal quantitative. Minimum TOEFL score of 550 paper based or equivalent for international students. Strong quantitative statistics, mathematics skills, and computer proficiency required. Maintenance of large data set is desired.

Contact: Complete forms at below link and mail hardcopy to Dey Aqua and Fish Center, UAPB 1200 North University Drive, Mail Slot 4912, Pine Bluff, Arkansas 71601. For questions see www.uaex.edu/afqi, mdey@uaex.edu.



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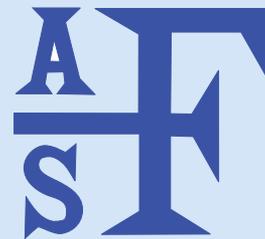
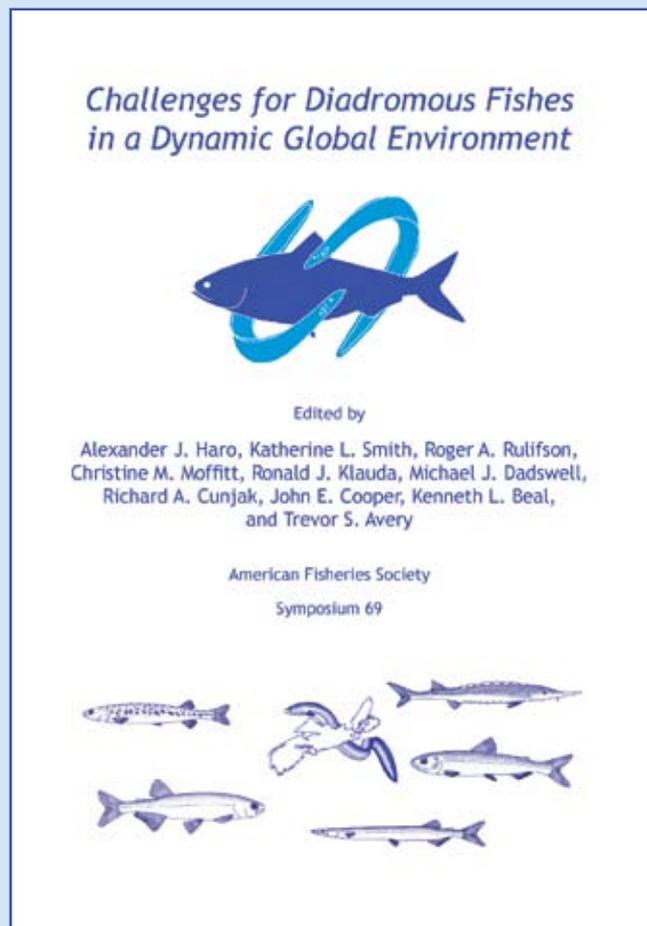
FISHERIES, VOL 34, NO 8, AUG. 2009

Challenges for Diadromous Fishes in a Dynamic Global Environment

Alex Haro, Katherine L. Smith, Roger A. Rulifson, Christine M. Moffitt, Ronald J. Klauda, Michael J. Dadswell, Richard A. Cunjak, John E. Cooper, Kenneth L. Beal, and Trevor S. Avery, editors

Based on a 2007 international symposium, this book reviews the biology, ecology, human importance, and management and conservation of diadromous fishes with the goal of providing innovative interpretations and opportunities for sustainability. Because diadromous fishes use different environments and migration corridors to complete their life history in ocean and freshwater environments, they are particularly vulnerable to direct and indirect consequences of human development and global climate change.

Also presents new ecological and evolutionary concepts and experimental and modeling tools that advance understanding of the significance and the resilience of the diadromy life history strategies within ecosystems. Considers creative approaches for habitat protection and restoration to sustain stocks in the future.



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Using Acoustic Tags to Illustrate Salmon's Real-Time Response to New Non-Physical Barrier

Divergence of Old River and San Joaquin River, Lathrop, California USA



Barrier testing at San Joaquin River (right) and Old River (left).
Image: California Department of Water Resources



Juvenile Chinook salmon
Image: Jon Butau, USGS

Nestled in an area of agriculture near the city of Lathrop, California, researchers from the California Department of Water Resources (DWR) have been busy testing a new fish barrier at the divergence of Old River from the San Joaquin River. This is a non-physical barrier designed to keep juvenile Chinook salmon and steelhead on course as they migrate to the Pacific Ocean.

as state and federal water pumping plants.

Preliminary results show that the barrier is working. The researchers know the juvenile salmon are being successfully diverted because they have observed fish behavior using fish tagged and tracked with HTI's *Model 795 Acoustic Tags*. Each tagged fish's response to the barrier was revealed in real-time, fine-scale 3D tracks. Results from releases of the acoustically tagged salmon indicate that the barrier has increased the number of fish staying in the San Joaquin River to continue their out-migration to San Francisco Bay and the ocean.

HTI is proud to provide the advanced fisheries tools needed for California DWR and the researchers on this project, making a positive difference by helping salmon stay the course. If you'd like to learn more about acoustic tag technology or this study, visit us at HTIsonar.com.

Typically, a rock barrier would be installed in Old River, however, recent biological opinion on delta smelt states rock barriers can have adverse hydrodynamic impacts on delta smelt. With that, the Vernalis Adaptive Management Plan (VAMP), a federal and State multi-agency experimental program, decided to test an alternative non-physical barrier.

The new barrier combines sound and a strobe-lit curtain of bubbles to create an underwater wall of light and different sound frequencies. Its objective is to steer fish to a more direct path to the ocean and away from agriculture diversions, as well

Location of Non-physical Barrier

Example of HTI's *AcousticTag* software tracking acoustically tagged juvenile Chinook salmon.



California DWR Engineer, Katherine Maher, viewing real-time data.
Image: California Department of Water Resources



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