Fisheries

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OCT 2012

Volunteers Needed!

Didymo Control

Fishing in Google

Jawtagged Mississippi River Paddlefish

Parkinson's Disease and Effects of Rotenone Exposure

And The Winners Are—the Sirajo Goby and the Bluehead Chub

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Fisheries

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462 First fish of the day. Photo credit: Cliff Wilson.

Cover: Paddlefish – *Polyodon spathula* (Credit: Eric Fowler—Nebraska Game and Parks Commission)

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

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Where Do I Sign Up?

John Boreman, President

AFS President Boreman may be contacted at: John.Boreman@ncsu.edu

My first true volunteer assignment for the American Fisheries Society (AFS) was as chair of the Newsletter Committee for the Northeastern Division. It was in the spring of 1985 when Fred Serchuk, the newly installed president of the division, popped his head into my office (his office was down the hall) and asked me if I would be willing to chair the committee. Up until that time the only volunteer activity I undertook for AFS was judging posters and presentations at annual meetings, and I never gave much thought to actually donating time to AFS outside of the meetings. I was flattered that Fred asked me to chair the committee and thought that it might be a good diversion from my work assignments, as well as an opportunity to help Fred and the division. Also, I was editor of my college newspaper, so I thought I could put that experience to good use. Since then I have served on a number of AFS standing and special committees, as an officer of the Northeastern Division, Marine Fisheries Section, and now AFS as a whole. My volunteer work for AFS has been, and continues to be, a rewarding experience and one that I can look back upon with a certain degree of pride.

The American Fisheries Society has a relatively small staff, given the size of its budget and membership—only about 20 people are paid to support over 9,000 members. Even though the AFS staff is dedicated and competent, the AFS cannot survive without the help of volunteers who serve at the society-wide, division, chapter, and section levels. At the society level, besides the elected officers, the AFS has over 40 standing committees, subcommittees, and special committees and 10 volunteers who serve as liaisons with other professional societies, councils, and foundations. Each division, chapter, and section also has its slate of elected officers and committee members. This amounts to hundreds of AFS members who take time away from their day jobs or personal lives to work for AFS.

What's in it for you? Besides the reward of being able to give something back to the profession, volunteers gain experience in leadership and team participation. Committee chairs and elected officers learn how to motivate people without authority to do so and how to assemble a diverse group of individuals from across North America (and sometimes around the globe) to achieve specific goals and objectives. Committee members gain from the experiences, expertise, and points of view of fellow committee members; they get to function in a supportive environment where their opinions matter. Many committee members use the expertise and talents they have gained from their jobs to help AFS function, and some members use participation on an AFS committee as a means of stepping out of their comfort zone in order to try something new and different. For students and young professionals, serving on committees is a great way to network with leaders in the fisheries profession and develop lifelong friendships that extend beyond the work environment. For retirees, volunteering is an excellent means of staying connected.

Each year, the incoming president of AFS is tasked with selecting chairs and developing charges for each of the standing and special committees and subcommittees, and working with the chairs to fill out committee rosters. Liaisons who serve as AFS representatives or contact points for other societies and organizations also need to be identified or reaffirmed. As was the case with my predecessors, I continue to be impressed (to put it mildly) by the willingness of AFS members to step forward and donate time to the society, many without giving it a second thought. This spirit of commitment to support and improve the fisheries profession is the lifeblood of AFS.

The range of opportunities for serving as a volunteer for AFS is vast, from overseeing the society's finance, publication, membership, and meeting activities to assisting in the development of policies, resolutions, and electronic services. Guidance from volunteers, especially students and young professionals, is being sought as the AFS expends its use of social media for communications among AFS members. Volunteers are also needed to review applications for professional certification and monitor ethics and professional conduct. In the coming year I would like to re-institute our Capitol Hill briefings, which will require volunteers to assist in the selection of topics and panel speakers.

If you are interested in volunteering to serve as a member of a society-wide committee or subcommittee, please contact Gail Goldberg at AFS headquarters (ggoldberg@fisheries.org), who can assist you. You can also access the volunteer enrollment form on the home page of the AFS website. There are also volunteer opportunities at the division, chapter, and section levels of AFS. Most committees and subcommittees begin their work after the beginning of the calendar year, so please sign up now. And Fred—thanks for asking!

AFS Policy Statement on Fish Sedatives Kick-starts Dialogue with Regulators; Immediate-release Sedative Becomes Available for Field Use Under National INAD Program

J. Bowker and J. Trushenski

Fisheries professionals have long needed legal access to a drug that would allow fish to be sedated and immediately returned to the environment, but there are currently no legal options for such uses. This dilemma prompted the American Fisheries Society to adopt a new policy statement on the need for an immediate-release anesthetic/sedative for use in the fisheries disciplines, calling attention to the need for better options for sedating fish during handling. As part of a strategic plan to more effectively utilize policies statements to better inform others of AFS's position on specific topics, Dr. Gus Rassam (AFS Executive Director) provided the approved policy to Drs. Bernadette Dunham (Director, U.S. Food and Drug Administration Center for Veterinary Medicine [FDA CVM]) and Steven Vaughn (Director, FDA CVM Office of New Animal Drug Evaluation [ONADE]). In addition, a meeting was requested of the AFS and FDA CVM 'top brass' to discuss the content of the policy statement in greater detail. On April 25, 2012, leading representatives of AFS, FDA CVM, and the fish drug research and development community met for an unprecedented meeting at the FDA CVM offices in Rockville, Maryland. The leaders of virtually every FDA CVM office and team involved in fish drug approvals, including Drs. Dunham and Vaughn, came to the table for a frank discussion of fish drug issues, including:

Brown trout being measured for total length following sedation to handleable with AQUI-S20E (25 mg eugenol/L water). Fish were being sedated as part of a collaborative effort to support FDA approval of AQUI-S20E as a fish sedative. Photo credit: USFWS.

Why are compounds considered "Generally Recognized As Safe" in human food considered risky if used to sedate fish that people will consume?

If quality control and manufacturing standards are tailored to the intended use in some areas of food and drug production, why are human drug manufacturing standards applied to fish drugs?

Given these purity, safety, and efficacy concerns regarding fish drugs, why are so many illegal products allowed to be directly marketed to fishermen and fisheries professionals?

In a future issue of Fisheries, you'll see FDA CVM's response to these and other "Frequently Asked Questions" regarding fish sedatives and other drugs—some of the answers may surprise you. But there is one exciting announcement that can not wait:

Authorization has been granted for the use of AQUI-S®20E as an immediate-release sedative for field use under USFWS INAD!

The FDA recently granted amended authorization for the use of AQUI-S®20E (10% eugenol), a sedative drug, to allow for the immediate release of freshwater finfish sedated as part of field-based fisheries management activities. The amended authorization allows use of this product as an immediate-release fish sedative for the above-described use when used under the U.S. Fish and Wildlife Service's Aquatic Animal Drug Approval Partnership (USFWS-AADAP) Investigational New Animal Drug (INAD) 11-741. Although eugenol is also the active ingredient in clove oil (clove oil is 85-95% eugenol), AQUI-S®20E is the only product which can be used under the amended INAD authorization; it is not legal to use clove oil as a fish sedative.

Access to an immediate-release fish sedative represents a significant landmark for the Association of Fish and Wildlife Agencies (AFWA), its Fisheries and Water Resources Policy Committee's Drug Approval Working Group (DAWG), USFWS-AADAP, U.S. Geological Survey Upper Midwest Environmental Sciences Center (UMESC), and the drug sponsor AQUI-S New Zealand, Ltd.

"The collaborative efforts of federal natural resource and science agencies, state fish and wildlife agencies, and drug sponsors are critical to increasing the number of approved drugs available to protect fish health and thereby enhance our nation's fishery resources," said Virgil Moore, Idaho Department of Fish and Game Director and chair of AFWA's Fisheries and Water Resources Policy Committee. "The immediate-release authorization for AQUI-S® 20E represents one step in the entire approval process for

the sedative, but it is an extremely positive step forward," said Steve Sharon, Fish Culture Supervisor from the Wyoming Game and Fish Department and DAWG chair. "Not only will it have an immediate, positive impact on field-based fisheries management activities throughout the country, but it is a clear indication that we are indeed on the track to full approval."

Fisheries professionals may access AQUI-S® 20E by signing up to participate in USFWS-AADAP INAD 11-741. For more information, please see the full AFWA press release (http://www.fishwildlife.org/index.php?section=afwa_press_releases&prrid=180), or visit the USFWS-AADAP website (http://www.fws.gov/fisheries/aadap/AQUIS-E.HTM).

The U.S. Fish and Wildlife Service Aquatic Animal Drug Approval Partnership (USFWS-AADAP) Program is a nationwide, partnership-based program located in Bozeman, Montana. The mission of the USFWS-AADAP Program is "Working with our partners to conserve, protect, and enhance the Nation's fishery resources by coordinating activities to obtain FDA approval for drugs, chemicals, and therapeutants needed in aquaculture and fisheries management programs." Aquaculture in the United States has struggled because of a shortage of FDA-approved drugs for use in aquatic species. This situation jeopardizes the health and fitness of aquatic species held in captivity, many of which are key to conservation and restoration efforts of the USFWS and its many partners. To address this problem, the USFWS-AADAP Program actively pursues safe and effective new aquatic animal drug approvals and administers the National INAD Program. In fulfilling its mission, the USFWS-AADAP Program supports hundreds of federal, state, tribal, and private fish culture and management operations. For more information about the USFWS-AADAP Program and its many services, visit http://www.fws.gov/fisheries/aadap/home.htm.

AFS POLICY STATEMENT

Availability of safe and effective fish sedatives or anesthetics is crucial to fisheries research, management, and culture activities. Unlike most terrestrial vertebrates which may be handled without causing mechanical damage, fishes are particularly vulnerable to external and internal injury during physical restraint. Fish that are handled without proper sedation may also be negatively affected by the physiological consequences of the generalized stress response.—AFS Policy Statement #34f: The Need for an Immediate-Release Anesthetic/Sedative for Use in the Fisheries Disciplines: http://fisheries.org/docs/policy_statements/policy_34f.pdf

North American Fish Extinctions May Double by 2050

From 1900 to 2010, freshwater fish species in North America went extinct at a rate 877 times faster than the rate found in the fossil record, and estimates indicate the rate may double between now and 2050. This new information comes from a U.S. Geological Survey (USGS) study published in the September issue of the journal *BioScience*.

In the fossil record, one freshwater fish species goes extinct every 3 million years, but North America lost 39 species and 18 subspecies between 1898 and 2006. Based on current trends in threatened and endangered fish species, researchers estimate that an additional 53–86 species of freshwater fish may be extinct by the year 2050. Since the first assessment of extinct North American freshwater fishes in 1989, the number of extinct fishes increased by 25%.

***Diplomystus dentatus* fossil with *Knightia* in its mouth. Photo Credit: Arvid Aase of Fossil Country Museum specimen.**

"This study illustrates the value of placing current events into the context of deep geologic time, as rocks preserve an unbiased record of natural rates of processes before human activities began to alter the landscape, the atmosphere, the rivers, and oceans," said USGS Director Marcia McNutt. "Freshwater fish are a good choice for analysis as their bones make clear fossil impressions, and their lake and river environments produce excellent stratigraphic sequences."

The study's author, Noel Burkhead, used an established method to compare the rate of extinction found in the fossil record with modern rates. "Estimates of freshwater fish extinctions during the twentieth century are conservative, because it can take 20–50 years to confirm extinction," said Burkhead, a research fish biologist for the USGS.

Extinction is a natural process, Burkhead explained, so examining its rate over a long geological timescale provides biologists with a benchmark for comparing current extinctions to background rate. The accelerated pace of extinction observed since the beginning of the 20th century suggests human causes.

In North America, assessments of extinctions are conducted by the American Fisheries Society's Endangered Species Committee, using categories to factor in a lag time since the last observation of the species. The study used the categories "extinct" (species not seen for 50 years or more), "possibly extinct" (not seen for 20 years or more), and "extinct in nature." All of these categories require that searches for the missing fishes must have been made by knowledgeable biologists.

"It is extremely rare that the death of the last individual is documented by biologists," said Burkhead, "although it can happen when a fish only is found in a specific spring or caldera, and it dries up. That's what happened with five species of desert pupfishes and the Alberca silverside—the last known fish to go extinct in North America."

The Alberca silverside was found only in the Alberca Caldera, Guanajuato, Mexico; it went extinct when the caldera temporarily dried up in August 2006.

Surprisingly, Burkhead reported that 90–96% of fish extinctions in the fossil record were not linked to the five well-known mass extinctions. Natural causes of fish extinction are linked to transitions in landforms and continental watercourses over time, but many 20th-century extinctions were caused by dams, channelization of rivers, water pollution, and other human-induced factors.

The background rate of extinction is based on the fossil record, which includes information on when ancient fishes lived and how long species survived in the geological past. Burkhead used data on fish extinctions from well-known paleontologist Steven M. Stanley at the University of Hawaii.

"Another cause of extinction can be a change in a fish's food chain, which is what may have happened to the harelip sucker, a really cool fish that used to live in seven states throughout the Ohio River basin," said Burkhead.

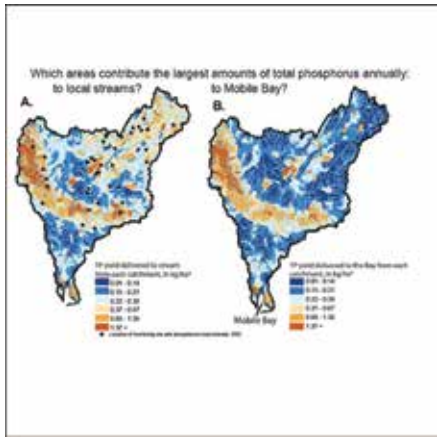
The hairlip sucker was a snail-eating specialist with cleft lips that used to pluck snails off river bottoms and manipulate the snail in its mouth in order to suck out the snail's soft parts, perhaps making little popping sounds. Sadly, snails are highly sensitive to excessive sedimentation and in the late nineteenth century, large amounts of topsoil were washing into rivers along with sewage and industrial effluents from cities. This likely caused snails to decline, which may have been what drove the fish to extinction.

Declines in freshwater fishes are only the "tip of the iceberg" for freshwater ecosystems, with mussels and snails experiencing declines greater than that of freshwater fishes.

AFS POLICY STATEMENT
Recent status assessments conducted by the AFS and its subunits clearly indicate systematic declines in native fish distribution and abundance throughout North America. About one-third of the freshwater fish taxa in North America are endangered, threatened, or of special concern, with membership in each category exhibiting substantial increases during the last decade. At least 106 Pacific coast stocks of anadromous salmon and trout are extinct, and 214 more are at risk of extinction or of special concern status. These trends indicate that the current high rates of freshwater fish extinction will persist into the 21st century.—AFS Policy Statement #27: Conservation of Imperiled Species and Reauthorization of the Endangered Species Act of 1973: http://fisheries.org/docs/policy_statements/policy_27f.pdf

New Maps Show Nutrient Delivery to Gulf of Mexico

For those in need of information on estimates of yields and information on sources of nutrients transported to 21 estuaries, bays, and sounds in the Gulf of Mexico, the U.S. Geological Survey (USGS) Spatially Referenced Regression on Watershed Attributes (SPARROW) system has maps posted here: http://water.usgs.gov/nawqa/sparrow/mrb/ gov. These estimates are based on the SPARROW models developed for the southeastern and south-central United States and integrate federal, state, and local agency monitoring data at over 700 stations. These maps show where estimated nutrient yields are elevated locally and which areas have the highest yields to downstream estuaries, bays, and sounds in the Gulf of Mexico. SPARROW's online, interactive decision support system—http://cida.usgs.gov/sparrow—provides easy access to these regional models, describing how rivers receive and transport nutrients from natural and human sources



*Map *kg/ha, kilograms per hectare. Total nitrogen or phosphorus yields. Photo Credit: http://water.usgs.gov.*

to sensitive waters throughout the Gulf of Mexico. Users can evaluate source reduction scenarios that target one or more nutrient sources to evaluate changes in the amount of nutrients transported downstream.

AFS POLICY STATEMENT
A critical question is: what quantitative criteria related to population decline best reflect risk of extinction for marine fishes?—AFS Policy Statement #31af: Protection of Marine Fish Stocks at Risk of Extinction: http://www.fisheries.org/docs/policy_statements/policy_31af.pdf

New Coin and AFS Books!

The newly minted $3 Tyee coin.

Attention all you over-30-pound-chinook fans (yeah, you Tyee lovers)—the Royal Canadian Mint has devoted a pure $3 silver coin, plated in two tones of gold, to the likes of your favorite fish. Why? Because this fish been an essential food source for the folks living along the Northwest Coast for centuries; hence, it was time to honor these anadromous swimmers. Journalist Dennis Rainey recently broke the news of the newly minted coin in an article for World Coin News, adding some interesting facts about the Tyee, including:

> *The record weight for a sport-caught chinook is 97.25 pounds (44 kg) from the Kenai River in Alaska in 1985. The record commercial chinook is 126 pounds (57 kg) taken in British Columbia, Canada, in the late 1970s.*

and

> *The Tyee Fishing Club of British Columbia was formed in 1924 by three men discussing tuna sport fishing in a hotel who agreed that fishing for large chinooks was fully as exciting as catching a large tuna. They formed the Tyee Fishing Club in 1925 to create interest in Canada's chinook salmon, emphasizing sportsmanship and encouraging young people into the business of guiding and sportsmanship.*

At the end of the article, he went on to give the American Fisheries Society some deserved recognition, "The following publication is highly recommended: Quinn, Thomas P., *The Behavior and Ecology of Pacific Salmon and Trout*. 2005. American Fisheries Society and The University of Washington Press, 378 pp."

Dr. Richard "Rick" Shaw.
Photo Credit: Louisiana State University.

Dr. Richard "Rick" Shaw, Appointed

Dr. Richard "Rick" Shaw (American Fisheries Society '75), the Associate Dean of the School of the Coast and Environment and a professor in the Department of Oceanography and Coastal Sciences at Louisiana State University (LSU), was nominated by the state of Louisiana—then appointed—to serve on the Gulf of Mexico Research Initiative (GoMRI) Research Board. The GoMRI Research Board is an independent board that oversees and administers BP's $500 million research fund that supports investigations for the next 10 years into the impacts of the oil spills and dispersants used to clean them up and the environmental and health complications that arise from such spills. These funds are also used to research prevention and detection techniques for possible future oil spills, in the hope to restore and improve the environmental health of the Gulf of Mexico. The board is unique in that half of the members are selected by the Gulf of Mexico Alliance (GOMA), which then partners with the states of Alabama, Florida, Louisiana, Mississippi, and Texas to appoint the other half in the hope of securing sound ecological collaboration for the region. Shaw was one of four members of LSU's Oil Spill Steering Committee, which oversaw the disbursement of $10 million in BP research funds awarded to LSU shortly after the *Deepwater Horizon* oil spill. His research has focused on ichthyoplankton taxonomy and ecology and the growth, mortality, habitat requirements, and transport and recruitment mechanisms of larval and young fish on the continental shelf and within estuaries. http://gulfresearchinitiative.org

Didymo Control: Increasing the Effectiveness of Decontamination Strategies and Reducing Spread

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ABSTRACT: *Nuisance algal blooms formed by the benthic diatom* Didymosphenia geminata *(didymo) have been spreading rapidly, with negative ecological and economic effects. This microscopic alga is transported on fishing equipment, and controlling the spread of didymo involves proper cleaning of gear. Our study experimentally tested several common decontamination treatments and determined the response of state agencies and fishermen to decontamination procedures. In testing decontamination products, we found that dish liquid detergent was the most effective, followed by bleach, Virkon, and salt. Decontaminants were more effective on cells that were not still attached to their stalks. From the fishermen's perspective, didymo was the aquatic invasive species of highest concern, but there was a wide range of approaches to didymo control. Our final recommendations concentrate on the importance of comprehensive information sources and standards for didymo decontamination and education, specifically, and for invasive/nuisance species more generally.*

Control de didymo: incremento en la efectividad de estrategias descontaminantes y para reducir la expansión

RESUMEN: Los afloramientos nocivos generados por la diatomea *Didymosphenia geminata* (didymo) se han expandido rápidamente, provocando efectos ecológicos y económicos negativos. Esta alga microscópica es transportada en equipos de pesca y su control implica una limpieza adecuada de los artes. En este estudio experimental se prueban varios tratamientos descontaminantes y se estudia la respuesta de las agencias estatales y de los pescadores ante los procedimientos de descontaminación. Al probar los productos descontaminantes, se encontró que el líquido detergente para trastes fue el más efectivo, seguido por los blanqueadores, el Virkon y la sal. Los descontaminantes probaron ser más efectivos en las células que aun no se encontraban fijas a su tallo. Desde la perspectiva de los pescadores, didymo fue la especie acuática invasiva de mayor cuidado, pero hubo una enorme variedad de enfoques para el control del alga. Las recomendaciones finales se concentran, de manera general, en la importancia de fuentes de información comprensibles, estándares para la descontaminación por didymo y educación, y de manera particular en el control de especies invasivas/nocivas.

INTRODUCTION

Nonnative and nuisance species represent one of the largest threats to biodiversity in aquatic systems (Dudgeon et al. 2006). Didymosphenia geminata, commonly known as "didymo" or "rock snot," is a species of diatom that is currently associated with nuisance blooms in streams. The diatom was historically widespread (Blanco and Ector 2009; Whitton et al. 2009), but the nuisance blooms appear to be a more recent phenomenon (Blanco and Ector 2009; Bothwell et al. 2009; Segura 2011), the causes of which remain poorly understood. In the northeastern United States, didymo blooms were officially confirmed in 2007 in New York, Vermont, and New Hampshire. Since then, didymo blooms have been found in five additional streams just within New York—one of which was confirmed right after ice melt in March 2011. The number of affected rivers and streams is likely to continue to rise across the United States in the future (Kumar et al. 2009).

Like many nuisance species, didymo presents both ecological and economic threats (Branson 2006; Spaulding and Elwell 2007; Kumar et al. 2009). When large mats are present, didymo may impact plant, invertebrate, and fish communities (Larned et al. 2007; Bergey et al. 2009; Blanco and Ector 2009; Kilroy et al. 2009; Gillis and Chalifour 2010; James et al. 2010). Impacts to aesthetics are common, with reports of unsightly masses that appear like strands of toilet paper, generating mistaken public concerns about sanitation and sewer malfunctions (Kilroy 2004). The heavy, slippery brownish mats degrade swimming areas, although direct human impacts may be limited to swimmers complaining of eye irritation after swimming in affected areas (Kilroy 2004). Economic impacts include fouling of water intakes that can affect water supply (Kawecka and Sanecki 2003) and, in heavily infested areas, didymo may be linked to a decline in tourism and freshwater angling, particularly fly fishing. In the United States, fly fishing is a $0.9 billion dollar industry that involves 5.6 million people (The Outdoor Foundation 2010). Fly fishermen spend an average of 15.6 days fishing each year and about half of all excursions are overnight trips, which provide additional benefits to local economies (Outdoor Industry Association 2006).

The appearance of didymo blooms in new streams has generally been linked to fly fishing activity and the use of felt-soled waders (Bothwell et al. 2009). When didymo appear in new

locations, the spread is usually related to the fishing industry—either because the site is known to be used by fly fishermen (Kilroy et al. 2008; Bothwell et al. 2009) or through fish stocking introductions (Bhatt et al. 2008). Individual didymo cells are microscopic and hard to detect on gear. Thus, they can easily be transported between streams, and the felt sole common on most waders acts like a sponge that is able to hold enough water to keep didymo cells alive and viable for up to 40 days (Kilroy 2005, cited by Spaulding and Elwell 2007). Even cleaning or soaking felt soles with disinfectant products is not enough to ensure that all didymo cells are dead, because the disinfectant products may not thoroughly reach the innermost parts of the soles (Kilroy et al. 2007).

Our work on didymo in New York streams indicated that there were large discrepancies in how fishermen were being alerted to the presence of didymo and how they were being advised to treat their gear for didymo. Though there were signs warning fishermen about didymo on the Ausable River (didymo-free), the Esopus Creek, where didymo was first reported in 2007, did not have signage at all fishing access points. On the Battenkill River in Vermont, signs advised fishermen to clean gear in "HOT tap water and lots of soap … for 30 minutes," whereas on the same stream across the border in New York they were told to "soak all equipment for 10 minutes with a household cleanser/disinfectant containing alkyl dimethyl benzyl ammonium chloride." In general, the U.S. Environmental Protection Agency recommendations are to "check–clean–dry" using 2% bleach, 5% salt water, or dishwashing detergent (Spaulding and Elwell 2007).

In actuality, very little work has been done to evaluate the effectiveness of decontamination methods. A broad survey of more than two dozen decontamination methods was carried out for Biosecurity New Zealand in 2006–2007 (Kilroy et al. 2007). This study included a wide range of decontamination techniques, such as heating/freezing, drying, submerging in seawater, and applying a cleaning product or detergent, over a time range from 1 min to 48 h. Some of the most commonly used decontaminants (detergent, 2% household bleach, 10% salt water, and 1% Virkon Aqua [an aquatic disinfectant]) were all said to be 100% effective at killing didymo cells after a 1-min submersion. However, as Kilroy et al. (2007) pointed out, this study did not resolve all of the important questions. This study was done only one time, and similar experiments have not been repeated for other regions or at different stages during didymo blooms.

In order to maintain the quality of the mountain streams around the United States, a universal method for controlling didymo must be established with effective outreach and education. To address this, our study examined two components that are critical to decontamination. First, we experimentally evaluated the effectiveness of four commonly used and recommended products (detergent, bleach, salt water, and Virkon Aqua) twice during the summer season using didymo in New York. Second, because didymo control is dependent in part on how informed people are and whether they take action, we also surveyed how

Image 1. There are several information signs posted at fishing access sites on the Battenkill River in New York State. Photo credit: Samantha Root.

Image 2. Didymo information signs posted at the Battenkill River and other streams in New York recommend drying fishing gear or cleaning with household cleanser/disinfectant. Photo credit: Samantha Root.

fishermen were responding to didymo and then compiled the information provided by different state agencies in the northeastern United States. Finally, we synthesized our information to present some general recommendations regarding control of didymo, with broader implications for the management of other invasive/nuisance species.

METHODS

Our study examined two different aspects of didymo control through decontamination experiments and by surveying fishermen and state agencies.

Didymo Decontamination Experiment

We investigated the effectiveness of commonly recommended decontamination products. To do this, we conducted experimental laboratory studies that compared treated and untreated didymo samples. In 2010, we chose three of the most popular decontamination treatments used by environmental agencies and households in New York State: 10% salt water, 2% Clorox® bleach, and 1% Virkon® Aqua (an aquatic disinfectant). In 2011, in an effort to find products that had a less degrading impact on the environment and on fishing gear, we chose three additional decontamination treatments: 10% Green Works® chlorine-free bleach, 5% Dawn® dish detergent, and 5% Green Works® dish detergent. Recognized by the Environmental Protection Agency's Design for the Environment Program, Green Works® products are made with plant- and mineral-based ingredients, are biodegradable, and are available in most grocery stores. Each decontamination product was diluted with tap water and stored in a 1-L Nalgene bottle. We tested the effectiveness of the decontamination products by measuring percentage mortality compared to a control of tap water using fresh didymo samples from local blooms. Didymo-covered rocks were collected from the Esopus Creek, New York, in 2010 and the Rondout Creek, New York, in 2011 and then placed in plastic containers filled with stream water. The containers were kept in an ice-filled cooler for transport to the laboratory, where they remained at 10°C in a cold room. All tests were run within 4 days of didymo sample collection. We tested cell mortality in tap water periodically throughout July to see whether there were natural changes over time and tested every potential treatment product two different times 2 weeks apart during July.

The effectiveness of the decontaminant products was determined using a cell viability assessment. For each test, a 2 × 2 × 2 cm piece of didymo was removed from the rocks and split into two equal pieces. One piece was placed in control (tap) water and the other piece was placed in a decontaminant treatment. The samples were left in the solutions for either 1- or 5-min intervals. There were five such paired replicates for each treatment and time interval. The samples were then transferred to a 0.5% neutral red solution to stain the cells for 30 min. After the neutral red stain, subsamples of the didymo pieces were observed at 400× total magnification. Live cells have dark red spots inside the cell walls, whereas dead cells do not have any spots (Kilroy et al. 2007; Lagerstedt 2007), making it straightforward to assess percentage mortality. In 2010, for each didymo sample we assessed 200 cells: 100 cells that were attached to stalk material and 100 cells that were not attached to stalks. Because unattached cells had consistently higher mortality rates and were thus unlikely to be a major source of contamination, we simplified our live–dead analysis in 2011 to focus on counting 100 attached cells only. We used paired t-tests to examine differences in mortality between the treatment and the control and to examine the difference in mortality between attached and unattached cells for salt, Virkon, and bleach in 2010. We used a two-way analysis of variance to compare 1- and 5-min submersion times for each treatment, taking cell attachment into account. We used Bonferroni corrections in all cases where there were multiple comparisons. We used regression analyses to look for changes in mortality of tap water–treated controls over the summer. To be conservative, we used alpha = 0.01. Data were log-transformed as necessary.

TABLE 1. Questions that were used in the online survey for this study.

Question	Response options
1. How did you connect to this survey?	One selection from list, with "other" option
2. In which state or province do you do most of your coldwater stream fishing?	One selection from list
3. How many years have you been fishing?	One selection from list
4. On a typical day fishing, how many sites do you fish? No. of rivers? No. of sites in each river?	 One selection from list One selection from list
5. Which aquatic invasive species is of the single greatest concern in the coldwater streams you fish in?	One selection from list, with "other" option
6. How did you first learn about [your species of greatest concern]?	One selection from list, with "other" option
7. Do the sites where you fish most of the time have signs posted about [your species of greatest concern]?	Yes/no
8. Has [your species of greatest concern] changed where you fish? How often you fish?	Yes/no
9. How often do you clean your gear?	At the end of a trip/between every site/never
10. If you do clean, what parts of your gear do you clean?	Waders/all gear
11. If you do clean any gear, what do you do?	Comment box
12. What makes it difficult for you to clean your gear?	Multiple selections from list
13. Do you use felt-bottomed waders?	Yes/no

Didymo Survey

Because fly-fishing is a key vector for the transport of didymo (and is highly affected by its presence) we conducted a survey of fly fishermen. The goals of the survey were to collect information about what fishers thought regarding the

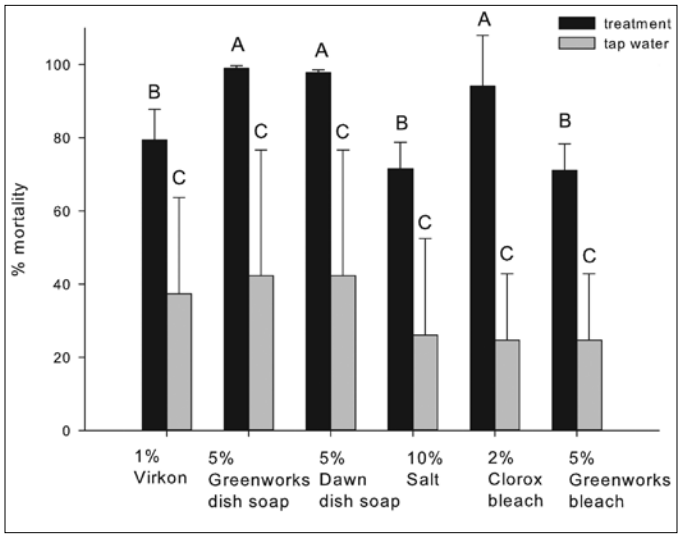

Figure 1. Effectiveness of decontamination treatments compared to a control of tap water. Treatments were significantly more effective than tap water. Letters show significant differences among the treatments. Data are means (n = 10) with standard error.

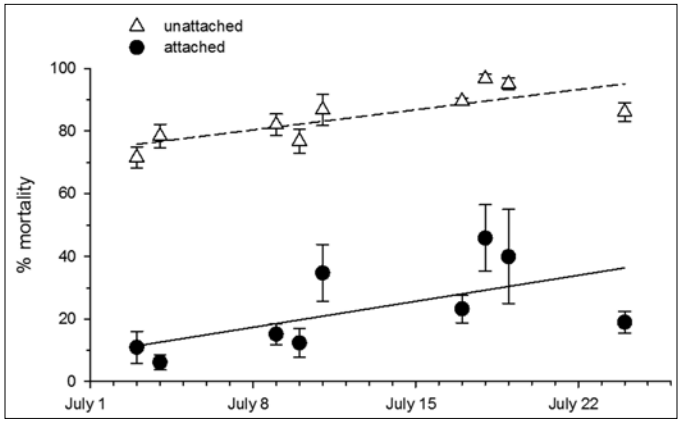

Figure 2. Mortality rates of the tap water–treated didymo samples over the course of July 2010 showed that cells attached to their stalk had significantly lower mortality than unattached cells. Additionally, didymo mortality increased significantly over the summer. Data points are means (n = 5) with standard error; lines are linear regressions.

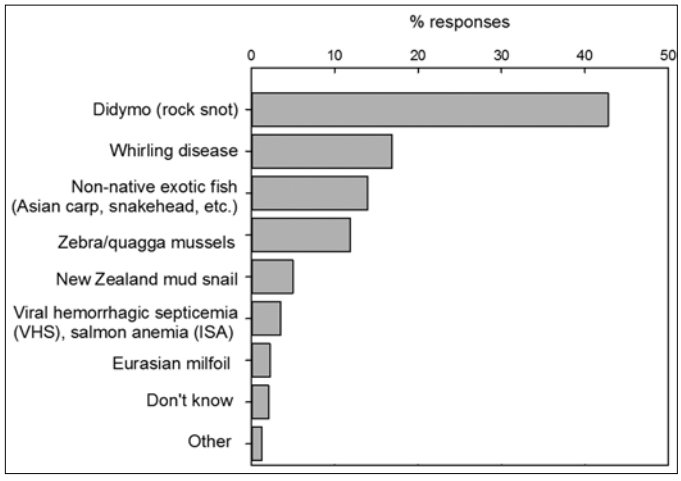

Figure 3. Fishermen's responses to the question "Which aquatic invasive species is of the single greatest concern in the coldwater streams you fish in?" (n = 623). Crayfish was the most consistent response to "other."

threat of didymo compared to other invasive species and what they did for didymo decontamination. The survey was conducted online over 8 weeks in early 2012 in collaboration with Trout Unlimited (TU), with links posted on TU's home page, blog, and Facebook and on Orvis's online newsletter, Twitter, and Facebook, and several other personal web pages. Questions used in this study are presented in Table 1. State agencies are often considered to be a primary source for regulatory and preventative information regarding invasive/nuisance species. To assess the type of information provided by state agencies regarding didymo, we focused on the northeastern United States during the summer of 2010, when didymo blooms first became a widespread emerging threat throughout that region (Maine, Massachusetts, Rhode Island, Connecticut, New York, New Hampshire, Pennsylvania, and Vermont). We determined current regulations and guidelines regarding didymo control by contacting staff at these state agencies and looking at their websites. We were interested in the following: (1) the extent to which state agencies provided information about didymo through signage and/or websites and (2) what methods the state agencies recommended for cleaning fishing gear/boats.

RESULTS AND DISCUSSION

Didymo Decontamination Experiment

We found that none of these decontamination products were 100% effective, contrary to previous work. The decontamination products were always more effective at killing didymo cells than tap water (Figure 1, paired t-test, $P < 0.0001$); the effectiveness was higher for Green Works® dish detergent, Dawn® dish detergent, and Clorox® bleach than for the other products (Figure 1; Tukey's honestly significantly different test, $P > 0.01$). Longer submersion time did not lead to significantly greater mortality for any treatment (analysis of variance, $P > 0.01$), suggesting that a 1-min submersion time is sufficiently effective for these decontamination products. However, mortality was significantly less effective on didymo cells that were still attached to stalk material compared to free-floating cells that were unattached to stalk material for both treatments and tap water (Figure 2; paired t-test, $P < 0.001$). Based on our tap water control samples, there was a significant increase in mortality for both unattached and attached cells over the course of the summer season (Figure 2; linear regression, $P < 0.001$). This increase in mortality over the summer emphasizes the importance of early season decontamination and may misleadingly cause decontamination products tested during the later weeks of the didymo bloom to appear more effective than they would be during the early weeks of the bloom. The persistent resistance of attached cells to treatment suggests that stalks may play an important role in maintaining the viability of the cell and underscores the importance of removing clumps of material from gear, where cells are likely to remain attached to their stalks.

Based on our results, both dish detergent and bleach were the most effective methods of killing attached didymo cells (Figure 1). Bleach solutions are commonly used as disinfectants

and are effective at killing other potential aquatic invaders, but bleach is toxic to both humans and the environment and slowly discolors and degrades fishing waders and gear. The dish detergent solutions offer a much less harmful alternative to humans that is also less toxic to the environment. The Green Works® dish detergent that we used is an environmentally friendly solution that is 97% naturally derived. This suggests that Green Works® or other similar dish detergents might be the best option for decontamination.

Didymo Survey—Fishermen

Six hundred and thirty-nine people responded to the survey, and the average question response rate was 76%. About half of these people initially accessed the online survey via Trout Unlimited and half via Orvis. There was wide representation from across the United States (as well as the Canadian provinces Alberta, British Columbia, Newfoundland, Nova Scotia, Ontario, and Quebec), with every state except Alabama, Delaware, Florida, Hawaii, Indiana, Kansas, Louisiana, Mississippi, Nebraska, and North Dakota represented. The responses were dominated by people who did most of their coldwater fishing in Pennsylvania (9%), New York (8%), Wisconsin (8%), Colorado (7%), California (5%), Utah (5%), Montana (4%), Michigan (4%), and Virginia (4%). Most people had been fly-fishing for more than 20 years (58%), followed by those who had fished up for up to 5 years (13%), 5–10 years (9%), 10–15 years (8%), and 15–20 years (12%).

Didymo was overwhelmingly the aquatic invasive species of most concern in the waters that people fished. Of the seven different categories of invasive species listed, didymo rated the "single greatest concern" for 43% of the responses (Figure 3). Surprisingly, 3% of respondents did not know whether there were any species of concern, and comments indicated that some fishermen had never thought about invasive species before. Fishermen's concerns regarding invasive species came from news stories (26%) and conservation organizations (23%), as well as from conversations with friends, family, or colleagues (13%) and posted signs (9%). Relatively few fishermen first learned about the invasive species from state agency web sites (7%), fishing stores (4%), guides or outfitters (3%), or when they got a fishing license (2%). Other reported sources of information were magazines (2%), online forums (2%), and coursework (2%). This suggests that potentially valuable contact points such as fishing stores and licensing procedures are not being effectively used to disseminate information. There was a wide range of approaches to and challenges for decontamination (Table 2). Most people conducted some sort of decontamination (81%), which was typically done at the end of a fishing trip (62%) but was only rarely done between every site (18%). Most fishermen rinsed (using hose or tap water) and then dried their gear; other typical methods were a diluted bleach or soap/detergent. A few fishermen had multiple sets of waders that they used exclusively on separate rivers. The most frequently identified challenge for decontamination was not knowing what to do or use (37%), and many comments expressed frustration regarding not knowing what treatment was most effective. Additionally, people said that they did not have the time (18%), especially with respect to letting gear dry, or have a good place to decontaminate (14%). Several fishermen used local decontamination stations (Maryland, Idaho) or mentioned that such stations should be established.

On a typical fishing day, the majority of people fish one river (60%) or two rivers (35%) and stop at multiple sites along a river. The number of sites fished was predominantly four or more (32%), followed by two to three (28%). Fishermen rarely fished at only one river site (5%). Given that decontamination while on a fishing trip is not common, the pattern of fishing multiple sites on a single river increases the likelihood of spreading didymo. Fishermen said that didymo had not affected how often they fish (95%) but has somewhat affected where they fish (20%). Fishermen's comments indicated that they stopped fishing in infected streams either altogether or at least temporarily when the bloom was obvious. Instead, they seem to either reduce their fishing during bad blooms or switch to fishing on other streams. If fishermen are more mobile because of didymo presence, the spread to new noninfected streams is likely to be exacerbated. Sixty percent of the fishermen said that they were using felt waders at the time of the survey, and of the fishermen who were not using felt waders, most had only recently switched due to didymo, indicating that fishermen are responsive and willing to take some actions to protect stream environments.

TABLE 2. Responses to "How often do you clean your gear?" (n = 590), "If you do clean, what parts of your gear do you clean" (n = 502), and "If you do clean any gear, what do you do?" (n = 437) were sorted and categorized to show the proportion of fishermen who decontaminated their gear and the method they used.

Decontamination?	Method	%
Yes—waders 45% Yes—all gear 36%	Bleach Other chemical Salt Dry Freeze Soap/detergent Rinse Have separate gear	21 7 3 8 3 14 42 3
No 19%		

Didymo Survey—State Agencies

Recommendations from state agencies in the northeastern United States varied widely. Some state agencies only suggested one decontamination method, whereas others offered as many as six different techniques. In New York State, identifying a proper decontamination method can be especially confusing because the signs posted at fishing access sites offer decontamination instructions that differ from the state's Department of Environmental Conservation website. In all states, the signs and websites generally provide contact information, but this was not always considered helpful because it often resulted in unanswered phone calls, bounced e-mails, or websites that did not directly address didymo or aquatic invasive species.

Image 3. Didymo information signs posted at the Battenkill River and other streams in Vermont recommend removing visible algae clumps from all gear and cleaning with hot water and lots of soap. Photo credit: Vermont Department of Environmental Conservation.

Image 4. Didymo information signs posted on the Farmington River in Connecticut have the most cleaning recommendations of all states in the Northeast. Photo credit: Connecticut Department of Environmental Protection.

Sign-posting by state agencies seemed to occur primarily at locations where didymo was already present, rather than at highly frequented fishing sites. In fact, fishermen indicated that sites where they fished most of the time did not have signs posted about invasive species (68%). Across the northeastern United States, posting generally seems to happen only after didymo is confirmed at that site. One exception to this was the Ausable River in the Adirondack Mountains, where signs were posted as early as 2007 but where didymo had not yet been detected as of August 2010 (at the time we conducted this survey). We suspect that our survey, though focused on northeastern states, is generally representative of the wide variety of means used to provide information to fishermen and the public across the country.

RECOMMENDATIONS

In summary, our findings lead to several broader outcomes. Our recommendations focus on two different management approaches: to (1) create more targeted and consistent outreach and education strategies and (2) facilitate and develop consistent recommendations for decontamination. Both of these goals are most efficiently accomplished by a more coordinated regional or federal effort, including collaboration between scientists and government agencies (Chapin et al. 2000). For didymo, the best management strategies will concentrate on preventing didymo cells from being transferred to new streams (Floder and Kilroy 2009) because blooms are difficult to manage (Clearwater et al. 2011).

As for didymo treatment, we recommend that states consider and encourage the installation of decontamination stations at easily accessible locations, as has been done throughout New Zealand. New Zealand has created a wide range of decontamination station types that are dependent on location and type of user. For example, some locations are self-serve to facilitate an individual's use of detergent packets by providing barrels and water; some locations provide multiple barrels with choices of products (salt, detergent) and include freshwater for rinsing afterwards; and some locations are set up to allow kayakers to wipe down their boats. In addition to location-specific stations, New Zealand has also set up some general-access stations at gas stations, state agency offices, and sporting goods stores. In high-priority regions, they have also incorporated cleaning regulations into certain angling licenses that require the witnessing of their fishing gear being decontaminated at supervised stations. Spray bottles (detergent or disinfectant) and detergent packets are also made available to the general public for hiking, mountain biking, etc.

Although there are challenges, there are many possible ways to facilitate decontamination. Currently, there are a few stations in the Atlantic region. Starting in the summer of 2012, fly-fishing in Maine is supporting three stations in the state, which will be maintained by volunteers and with funding support from L.L. Bean. In Maryland, where felt waders were banned in March 2011, there are several stations located at

Image 5. Found on rocks in the streambed, didymo is easily identified by its light brown color and hairy texture that feels like wet cotton. Photo credit: Samantha Root.

Image 6. Didymo is able to form nuisance blooms that cover up to 100% of the streambed and stretch for miles downstream. This is an example of part of the didymo bloom on the Esopus Creek in New York. Photo credit: Samantha Root.

popular locations, and volunteers are involved in maintenance. Both states use a 5% salt solution in their stations, but based on our work we would recommend using a 5% dish detergent solution. Dipping gear into the solutions for 1 min would be effective at killing didymo cells, although we recognize that these solutions may become less effective over time through dilution and degradation. Additionally, we strongly recommend banning felt-soled waders, which would facilitate decontamination and reduce spread.

We recommend a reconsideration of the phrase "check–clean–dry" for several reasons. From comments in our survey, it appears that many fishermen are interpreting "clean" to mean rinsing with tap water, which, from our controls, we know is not effective at killing didymo. In the survey, 28% of the responses including the comment that they dried their gear after treating it—a common response was "rinse and dry." Additionally, 8% of fishermen used drying as their main method for decontamination, and we know that this is likely only effective for non-felt gear, because didymo can survive for over a month in felt (Kilroy 2005, cited by Spaulding and Elwell 2007). Using the word "dry" implies that it is a viable decontamination method, but the reality is that it will not be effective with felt waders, so this phrase should not be used unless felt waders are banned, which was the case in New Zealand when this phrase was first coined. A more appropriate phrase might use the word "treat," which is more specific, and not include "dry," which is not necessarily an option given that most fishermen fish at multiple sites in a typical day.

Didymo signage and online information should be universal across all state agencies and should include a standard set of information. Important items include the following: (1) basic information about the impacts of didymo, (2) pictures of didymo from U.S. streams and identification criteria, (3) decontamination procedures, (4) information as to why felt-soled waders should be banned or at least an encouragement of alternatives, and (5) accurate contact information for general questions and where/how to report/identify didymo sitings. Many current signs make it difficult for people to identify didymo because they use photos from major blooms in New Zealand, which local blooms do not resemble, and they do not include any descriptive characteristics. In addition, many people do not know the environmental consequences or why they should be concerned about the presence of didymo in their streams. Signs should be posted at all frequently used fishing access locations, rather than only at sites where didymo has been confirmed, and could be made available for fishing stores, guides, etc.

Signage is only one aspect of educating people about didymo control. One recommendation in response to the imminent spread of didymo is to provide more effective educational outreach—a common suggestion by fishermen in our survey. Targeted didymo education programs are essential for getting the word out, and state agencies could make direct contact with fly-fishing organizations, such as Trout Unlimited, and environmental agencies that frequent the rivers and streams. These programs should cover species' information, species' spread, the significance of felt-soled waders, identification facts, how to report sightings, and decontamination methods.

A sustainable management plan integrates environmental, social, and economic components of invasive species (Larson et al. 2011). Effective management includes engaging with stakeholders to increase education and involvement, because the stakeholders are often also responsible for the spread (Epanchin-Niell et al. 2010; Rothlisberger et al. 2010). Our study suggests that agency outreach regarding didymo was mostly ineffective, because fishermen were learning primarily through other sources. Agencies could work more closely with related national nonprofit organizations (e.g., Trout Unlimited), with local economic venues (e.g., fly fishing stores), or through existing regulatory mechanisms (e.g., licensing, signage) to directly provide information.

Potential pathways for the spread of aquatic invasive species can be identified through spatially explicit models that

incorporate human activities (Hulme 2009). Predictive models could be developed based on behaviors and preferences of fishermen and used to identify hotspot sites where nuisance/invasive species might be likely to appear as well as for targeting key locations for decontamination stations (Rothlisberger et al. 2010). In the context of didymo, these models would be particularly useful for states where the species has not yet been detected but its arrival is imminent (i.e., Oregon) and could be coupled to other relevant invasive species (e.g., whirling disease, New Zealand mudsnail). This landscape-level approach is useful for within regions and across state boundaries, scales that are becoming increasingly important for invasive species management (Peters and Lodge 2009; Epanchin-Niell et al. 2010; Paini et al. 2010).

Finally, our recommendations are broadly applicable to other species, and our study adds more support to recent calls to create a more comprehensive national approach to invasive species management that would allow for better coordinated responses (Lodge et al. 2006; Peters and Lodge 2009; Paini et al. 2010). Having a national-level task force or center that could make immediate recommendations would be more efficient and effective than having individual states reinvent the wheel, which in the case of didymo seems to lead to inconsistencies and confusion. Ultimately, a nationally coordinated response would create a more rapid and consistent regulatory approach that would facilitate proactive measures, assess spatial and temporal dynamics at relevant scales, and allow for appropriate flexibility in management strategies over time.

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Swimways: Protecting Paddlefish through Movement-centered Management

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ABSTRACT: *Attempts to mitigate lack of formal interjurisdictional paddlefish management have been made in the United States through the Mississippi River Interstate Cooperative Resource Association (MICRA). We used 1988–2009 data from the MICRA paddlefish (*Polyodon spathula*) stock assessment database—a database containing mark–recapture and biometric information on more than 30,000 individually marked wild paddlefish and more than 2 million hatchery-origin paddlefish—to estimate survival and movement across large and potentially biologically relevant spatial scales. Paddlefish frequently moved between political jurisdictions with differing conservation strategies and harvest regulations and showed differences in survival parameter estimates throughout their range. We argue that the degree of interjursidictional movements, spatially variant survival rates, and conservation concerns associated with paddlefish necessitate more cohesive interjurisdictional management. Based on criteria used to establish flyways for migratory bird management, we offer swimways as a potential spatial configuration for biologically relevant management units.*

Corredores de nado: protección del pez espátula mediante manejo centrado en su movimiento

RESUMEN: La Asociación Interestatal de Recursos Cooperativos del Río Mississippi (AIRCRM) ha hecho intentos para mitigar la falta de manejo inter-jurisdiccional del pez espátula en los EEUU. Se utilizó información sobre evaluación de los stocks de pez espátula (*Polyodon spathula*) contenida en la base de datos de AIRCRM para el periodo 1995-2009, la cual contiene información biométrica y de marca-recaptura de >30,000 peces espátula marcados individualmente y de >2 milliones de especímenes provenientes de cultivo, con el fin de estimar la supervivencia y movimiento a escalas espaciales amplias y con potencial biológico relevante. El pez espátula frecuentemente se mueve entre jurisdicciones políticas que difieren en cuanto a sus estrategias de conservación y regulaciones de captura, y muestra diferencias en sus parámetros de supervivencia a lo largo de su ámbito geográfico. Se argumenta que el grado de movimiento inter-jurisdiccional, el cambio espacial en las tasas de supervivencia y las preocupaciones de conservación asociadas a esta especie, demandan de un manejo inter-jurisdiccional con mayor cohesión. Sobre la base de criterios usados para establecer corredores de vuelo para el manejo de aves migratorias, aquí se muestra un corredor de nado como una potencial configuración espacial para unidades de manejo biológicamente-relevantes.

INTRODUCTION

Habitat alteration, overexploitation, and climate change have led to declines in terrestrial and aquatic migratory animals at a global scale (Dudgeon et al. 2006; Wilcove and Wikelski 2008). Mitigating biodiversity losses of migratory species poses challenges for conservation scientists and managers because migrations often exist at spatial scales exceeding that of data collection programs and jurisdictions of management entities. The result of data-scale limitations is a potentially incorrect understanding of population trajectories due to a limited understanding of the contribution of migratory movements to life histories or population dynamics (Wilcove and Wikelski 2008). Effective conservation for migratory animals will thus require increased knowledge of migratory movements at biologically relevant spatial scales to protect biota from current and future threats (Wilcove and Wikelski 2008).

Global declines of freshwater migratory fishes have been paralleled by the American paddlefish (Polyodon spathula), which has experienced declines as a result of habitat loss, blocked migrations, and alteration of natural flow regimes (Jennings and Zigler 2009). Paddlefish are also a highly valued commercial fish due to their popular caviar and thus have faced growing threats from overharvest as global sturgeon stocks have collapsed. However, consensus on how to most effectively manage this species in a way that offsets threats has not been reached due in part to a near complete absence of basic knowledge about the frequency, scale, or life history significance of their long-distance movements.

Perhaps more important, consensus on how to best manage paddlefish to protect them from threats has not occurred

The result of data-scale limitations is a potentially incorrect understanding of population trajectories due to a limited understanding of the contribution of migratory movements to life histories or population dynamics

because fisheries management of inland waters of the United States, even that of migratory fishes reported to make interjurisdictional movements, is accomplished on a state-by-state basis. For instance, one marked paddlefish was reported to move in excess of 1,600 river kilometers (rkm) from South Dakota to Kentucky (Stancill et al. 2002). This paddlefish moved through no less than seven management jurisdictions, each with different conservation objectives and harvest regulations during its 1,600-rkm movement. Moreover, because paddlefish are able to traverse political boundaries, management decisions from one state may impact management outcomes unpredictably in other states because there is currently no understanding of interactions between interjurisdictional movements and population dynamics.

Some attempts have been made to implement interjurisdictional paddlefish conservation and management measures through voluntary state agreements that any state can opt out of at any point. The Mississippi River Interstate Cooperative Resource Association (MICRA) is one such cooperative entity seeking to provide coordinated sampling, management, and conservation of acipenserid fishes of the Mississippi River Basin among its member states through its Paddlefish and Sturgeon Committee. The MICRA relies on voluntary cooperation among member states from within the basin, the United States Fish and Wildlife Service, Tennessee Valley Authority, U.S. Bureau of Reclamation, U.S. Geological Survey, Chickasaw Indian Nation, and the Chippewa-Cree Indian Tribe. The MICRA Paddlefish and Sturgeon Committee began a voluntary, basin-wide paddlefish stock assessment in 1995 consisting of a nearly species range-wide, mark–recapture study. Data from this massive state-funded sampling effort has been deposited in a centralized database (hereafter, MICRA database) that also contains hatchery release and recapture information since 1988. We used the MICRA database to provide the first-ever description of basic vital rates (i.e., survival and movement) for paddlefish—or for any freshwater migratory fish—at this scale. We also used this database to gain a better understanding of the extent and frequency of interjurisdictional paddlefish movements. Our specific objectives were to (1) describe intrajurisdictional and interjurisdictional movements of wild and stocked paddlefish at a nearly species extent scale; (2) quantify survival (S), movement (ψ), and recapture (ρ) probabilities across major river basins (e.g., Missouri, Mississippi, Ohio, Gulf) for wild and stocked paddlefish; and (3) use large-scale biological data to provide an example of how movement-based management units for paddlefish could be constructed.

MATERIALS AND METHODS

Data Set

The MICRA paddlefish stock assessment project encompasses the 22 states that represent the current distribution of paddlefish. Within this area, harvest regulations and conservation status of paddlefish vary and range from being a protected species to one that is harvested both recreationally and commercially (Figure 1). The MICRA database is a compilation of data collected by cooperating states from 1995 to present and contains morphometric information such as length and weight, as well as habitat information such as flow velocity and water quality where paddlefish were captured. This database additionally contains information from 1988 to the present on dates and stocking locations of all hatchery-reared, stocked paddlefish from the MICRA project area. All encountered paddlefish (hatchery- and wild-origin) were marked with an individually numbered coded wire tag (CWT; Northwest Marine Technologies, Shaw Island, WA) inserted in their rostrum at the time of capture from 1995 through 2006. Coded wire tags were located with a CWT detecting wand (Northwest Marine Technologies), cut out of the rostrum and replaced with a new individually numbered CWT upon recapture. Coded wire tags were removed from the rostrum because the tag can only be decoded by reading a series of physical marks on the tag under a microscope. The years 2007 through 2009 were treated as a recapture-only

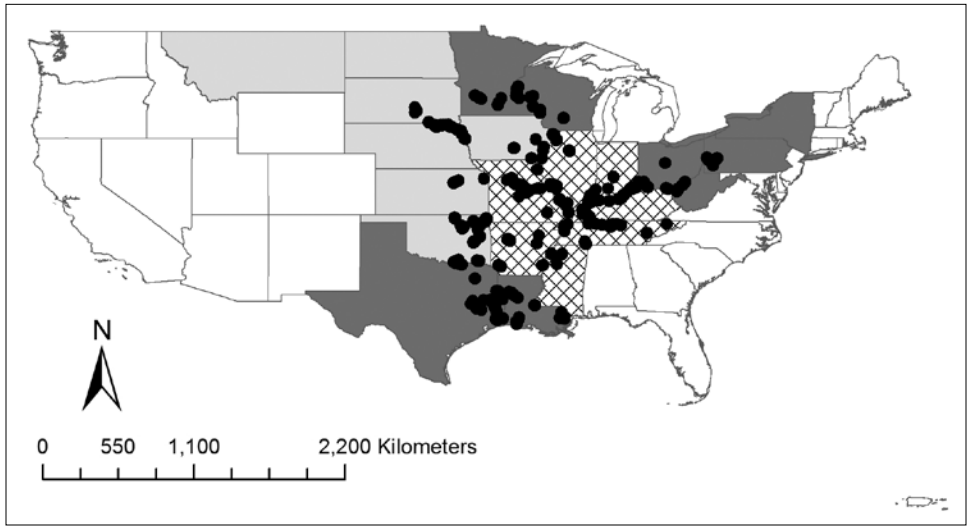


Figure 1. Map of collection sites as included in the Mississippi Interstate Cooperative Resource Association paddlefish stock assessment database from 1995 to 2009 (black dots). Type of harvest allowed in each state is indicated by shading: no harvest (dark gray); sport harvest (light gray); sport and commercial harvest (cross-hatch). Harvest status obtained from Bettoli et al. (2009).

period, where no new fish entered into the study because the use of CWTs for wild fish was discontinued by MICRA, although stocked paddlefish continue to be marked with CWTs to the present. The CWTs were replaced with individually numbered metal jaw tags during the recapture-only period to differentiate previously marked from unmarked paddlefish. More than 40 different gear types were used by biologists over the course of the MICRA study period; thus, standard effort calculations by gear type were cumbersome. We quantified hours of biologist sampling effort by basin by summing the hours of sampling effort across all gear types. We used the number of CWT recaptures from commercial and sport harvest as a proxy for harvest effort because the MICRA database does not contain harvest effort information. Unknown numbers of unreported CWTed paddlefish are recaptured by sport and commercial anglers. Coded wire tags are inconspicuous and cannot be detected without a CWT detector wand; thus, anglers do not know when they have recaptured a CWTed paddlefish. Discussion of recaptured paddlefish refers only to reported recaptures and we acknowledge that the actual numbers of recaptures are likely higher than those reported in the MICRA database.

Data Analysis

We quantified intrajurisdictional (within a state) and interjurisdictional (between states) movements of paddlefish at multiple spatial scales by enumerating movements of wild and stocked paddlefish from one state to another. The large number of sampling gears used to collect fish in the MICRA database prohibited many standard fishery population analyses that require gear-specific catches to account for size selective gear bias. Therefore, we used multistate mark–recapture (MSMR) analyses (Hestbeck et al. 1991; Brownie et al. 1993) in Program MARK (multistate recaptures only model; White and Burnham 1999) to compute maximum-likelihood estimates of survival (S), recapture (ρ), and movement (ψ) probabilities. A benefit of this approach is that ρ can account for unequal effort (Steffensen et al. 2010), allowing us to capitalize on the large spatial and temporal scale of data in this database despite the lack of gear consistency.

We determined whether individual paddlefish were of hatchery- or wild-origin from tagging information found within the database and then assigned those origins to each fish for initial capture and all recaptures throughout its life. States are the current management unit for migratory fishes; however, the data in the MICRA database were too sparse to allow for informative state-specific analyses of S, ρ, and ψ. Instead, we pooled states within river basins to estimate S, ρ, and ψ. We used river basins as designated in the MICRA database (Figure 2): Gulf Basin (*G*: rivers that drain directly into the Gulf of Mexico), Missouri Basin (*Mo*: Missouri River and its tributaries), Mississippi Basin (*Ms*: Mississippi River and its tributaries, excluding the Missouri and Ohio rivers), and Ohio Basin (*O*: Ohio River and its tributaries). We conducted MSMR analyses using only wild-origin paddlefish collected from 1995 to 2009 (the duration of the MICRA project) to provide estimates of population vital rates (S, ρ, and ψ) at the scale of river basins. Like the state-level mark–recapture data, mark–recapture data for hatchery-origin paddlefish from 1988 to 2009 were also too sparse to yield parameter estimates and were not included.

We considered three competing models to evaluate hypotheses regarding temporal variation in survival and movement estimates. Capture and recapture periods were designated as a calendar year running from January 1 to December 31. All models included basin-specific (indicated by subscript B) estimates. Our models included a null model with time constant S and ψ (S_B, ρ_B, *and* ψ_B). Four more complex models were considered: time- and basin specific $S(S_{B*t}$, ρ_B, *and* $\psi_B)$; time- and basin-specific $\rho(S_B$, ρ_{B*t}, and $\psi_B)$; time- and basin-specific $\psi(S_B$, ρ_B, and $\psi_{B*t})$; and time- and basin-specific S, ρ, and $\psi(S_{B*t}$, ρ_{B*t}, and $\psi_{B*t})$. Each basin-specific estimate of S, ρ, and/or ψ and/or time-specific estimate of S and/or ψ represented one parameter in the estimation models. Estimates of basin-specific rates of emigration, ψ, resulted in estimates of ψ_{rs}, the annual probability of moving from a basin of origin, r, to all potential destinations, s (e.g., with the Gulf as the source basin: ψ_{GO}, ψ_{GMo}, ψ_{GMs}). The annual probability of not emigrating, ψ_{rr}, can be estimated as the complement of the sum of all ψ_{rs} (e.g., $\psi_{GG} = 1 - [\psi_{GO} - \psi_{GMo} - \psi_{GMs}]$; Brownie et al. 1993). The probability of not emigrating from a basin over a period of years (y) is calculated as: ψ_{rry}.

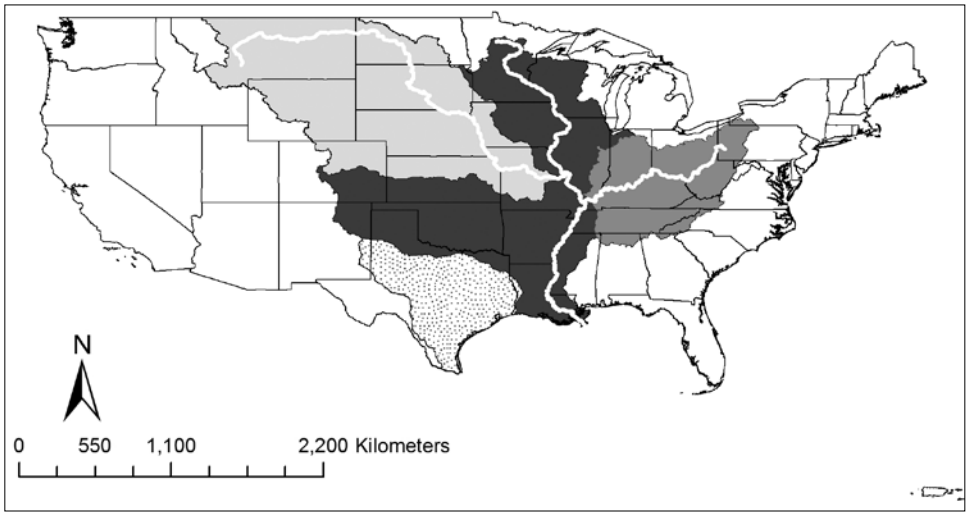


Figure 2. River basin designation as listed in the Mississippi Interstate Cooperative Resource Association paddlefish stock assessment database. River basins are designated as follows: light gray, Missouri Basin; dark gray, Mississippi Basin; medium gray, Ohio Basin; stipple, Gulf Basin.

Movement parameters, ψ_{rs} (e.g., ψ_{MoMs}: Missouri Basin to Mississippi Basin; ψ_{OMs}: Ohio Basin to Mississippi Basin; etc.), were fixed to zero when movement between basins was not recorded in the MICRA database. Movement parameters that were fixed to zero in the MSMR analysis

included the Gulf Basin to all basins and the Missouri Basin to the Ohio Basin (although not the reciprocal). There was one movement from the Ohio Basin to the Missouri Basin in the MICRA database, but we were unable to include this in the MSMR analysis because it was not associated with a recapture year. However, we did include this movement in state-specific movement tallies. We selected the best model among the three considered with Akaike's information criterion (AIC); the model with the lowest AIC was considered the best model, and model weights were used to assess the strength of the top model, relative to the other models. We used 95% confidence intervals to compare parameter estimates between river basins.

RESULTS

Data Analysis

A total of 22,231 wild paddlefish was marked from 1995 to 2006 (Table 1). Biologist and sport harvest accounted for the most common source of recaptures in the MICRA database, with commercial harvest accounting for less than 10% of all recaptures (Table 2). The Ohio Basin had the largest amount of biologist effort (Figure 3) and issued the most marks, although the largest number of recaptures occurred in the Missouri Basin (Table 1). Most movements of wild paddlefish (as determined by state of initial capture and state of recapture) occurred within a single state (61%; 1,011 of 1,655; Table 3). However, 39% of movements of wild paddlefish occurred across state boundaries (644 of 1,655) with movements out of river basins accounting for 2% of interjurisdictional movements (14 of 644) and 1% of total movements (14 of 1,655).

TABLE 1. Numbers of wild- and hatchery-origin paddlefish marked and recaptured in the MICRA paddlefish stock assessment study.

		Gulf	Mississippi	Missouri	Ohio
Wild	Marked	701	6,111	6,797	8,622
	Recaptured	29	565	1,759	933
Hatchery	Marked	1,059,375	262,270	1,092,724	121,418
	Recaptured	339	582	1,797	29

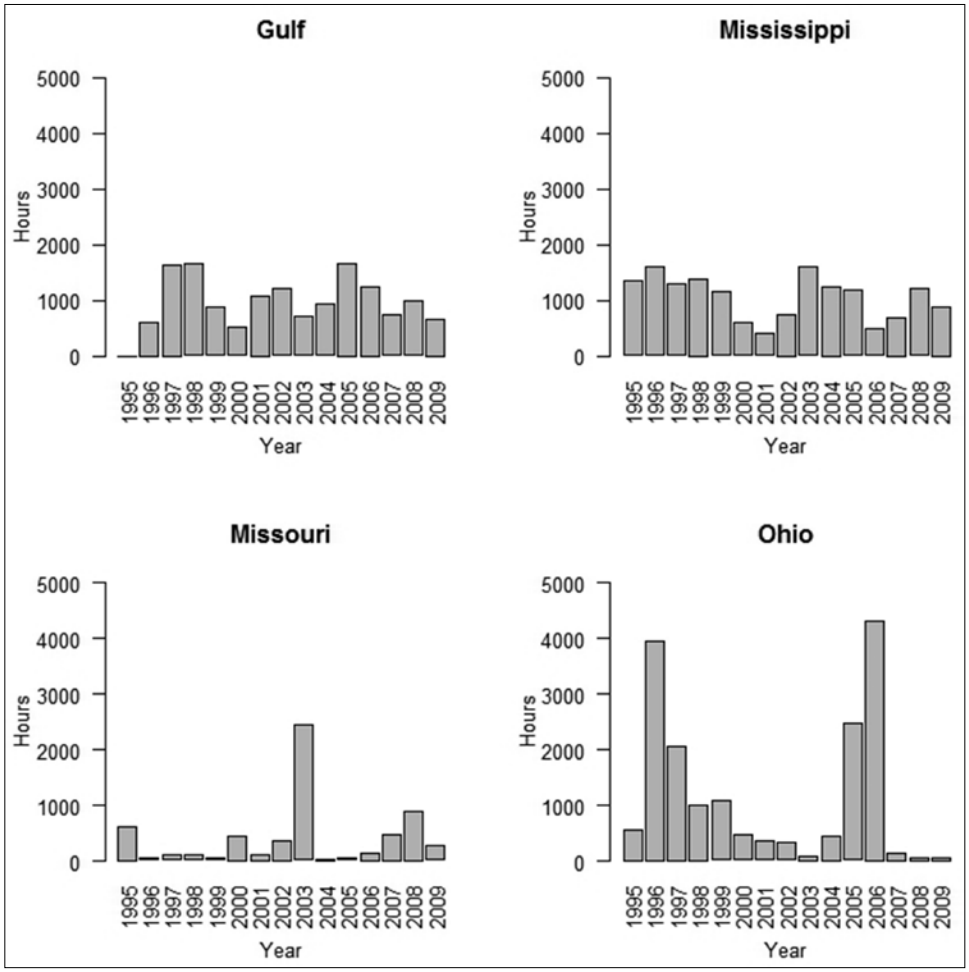


Figure 3. Biologist sampling effort (hours of effort) by year summed across all gear types for each river basin in the Mississippi Interstate Cooperative Resource Association paddlefish stock assessment database from 1995 to 2009.

A total of 2,535,787 marked paddlefish was stocked from 1988 to 2009 (Table 1). Similar to wild paddlefish, most movements of hatchery-origin paddlefish occurred within the state that originated the stocking (71%; 1,616 of 2,261; Table 4). Interjurisdictional movements did take place: 29% of recaptures indicated movements outside the state of original stocking (645 of 2,261), with movements out of river basins accounting for less than 1% of interjurisdictional movements (1 of 645). Most interjurisdictional movements of hatchery-origin paddlefish originated from two states: Kansas, where 93% (183 of 196) of recaptures indicated movement outside of Kansas, and South Dakota, where 36% (448 of 1,244) of recaptures indicated movement outside of South Dakota.

The simplest (time constant) model (S_B, ρ_B, and ψ_B) for wild paddlefish had a lower AIC value than the two time-specific models, and we selected it as the best model because it received 100% of the model weight (Table 5). The models including ρ_{B*t} did not converge, thus we could not evaluate models with time-specific ρ among others in model selection. The best basin-level estimates of S, ρ, and ψ were not time specific, so the information obtained from the MICRA database should be inter-

preted as average annual S, ρ, and ψ probabilities across the basin during the study period. Estimates of S, ρ, and ψ differed among basins (Table 6). The Missouri Basin had the highest S and ρ, the Mississippi River Basin had the lowest S, and the Gulf Basin had the lowest ρ (Table 6). Estimates from the Gulf Basin could not be distinguished from other basins (Table 6). Furthermore, there was no movement recorded to or from the Gulf Basin, likely due to the absence of freshwater connections with other basins; therefore, Gulf Basin parameter estimates will not be discussed further. Wild paddlefish movements on an annual scale appear to be generally confined within a river basin as shown by low ψ probabilities (Table 6), a notion that is further supported by tallies of movements of wild paddlefish (Table 3). Interbasin movements were most common from the Missouri to Mississippi basin and the reciprocal and from the Mississippi to the Ohio basin but not the reciprocal (Table 6). However, although interbasin ψ on an annual scale was low, extrapolating ψ probabilities over time shows that over periods of 10, 20, and 30 years—time periods biologically relevant to paddlefish that can have life spans longer than 50 years—probabilities of emigrating from a basin increase to as much as 0.27 over 30 years (Table 7).

We used interbasin paddlefish movement information from Tables 3–7 to construct swimways: potential spatial management units for paddlefish (Figure 4). Interbasin movements of paddlefish were largely restricted to the Missouri–Mississippi–Ohio basins. We connected the Missouri and Ohio river basins through the Middle Mississippi River (Mississippi River from the confluence of the Missouri and Mississippi rivers to the confluence of the Ohio and Mississippi rivers) as a swimway management unit. Movement between the Lower Mississippi River (below the confluence of the Ohio and Mississippi rivers) and other river basins or between the Upper Mississippi River (above the confluence of the Missouri and Mississippi rivers) and other river basins was not recorded, and these river basins were delineated as separate swimway management units as a result. However, the lack of recorded interbasin movements from paddlefish tagged in the Upper Mississippi River or the Lower Mississippi River may be due to a relatively low number of marked and recaptured paddlefish and not necessarily due to a lack of movement.

DISCUSSION

Interjurisdictional management of paddlefish is currently the exception rather than the rule even though paddlefish frequently traverse management boundaries (i.e., state boundaries). To some degree, this lack of interjurisdictional management has been a consequence of a near complete absence of basic, large-scale data on these fish that could inform biologically relevant management boundaries. This study provides the first description of large-scale movements of not only paddlefish but of any potadromous fish that could be used to create larger, biologically informed management boundaries. In comparison, migratory waterfowl flyways—movement corridors of migratory waterfowl that serve as management boundaries—were established in 1948 based on long-term mark–recapture studies documenting migratory pathways (Boere and Stroud 2006). These movement corridors are the foundation for the administration of harvest regulations and establishment of research and management priorities for migratory waterfowl. Based on the movement data compiled by the MICRA database and the flyway management framework used for migratory waterfowl, we offer a potential swimway management framework for paddlefish (Figure 4). The swimway management unit configuration we offer joins river basins where our analyses show that interbasin paddlefish movement occurs, translating paddlefish mark–recapture information into a potential spatial management framework. Interjurisdictional swimway management for

TABLE 2. Percentages of coded wire tagged paddlefish recaptured by biologists, commercial anglers, sport anglers, and other (i.e., found dead, unknown) methods in each subbasin in the MICRA paddlefish stock assessment study.

	Gulf	Mississippi	Missouri	Ohio
Biologist	99	55	35	52
Commercial	0	11	0	44
Sport	0	34	64	<1
Other	1	<1	1	4

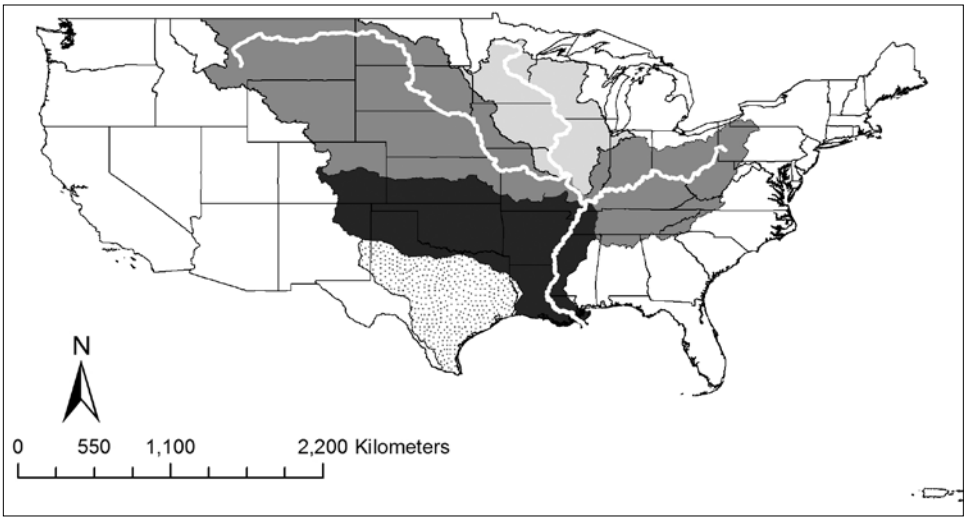


Figure 4. Potential swimway management framework constructed using paddlefish movements recorded in the 1995 to 2009 Mississippi Interstate Cooperative Resource Association paddlefish stock assessment database. Management units are designated as follows: medium gray, Missouri–Middle Mississippi–Ohio management unit; light gray, Upper Mississippi management unit; dark gray, Lower Mississippi management unit; stipple, Gulf management unit.

TABLE 3. Total number of movements and number of coded-wire tagged (CWT) wild-origin paddlefish obtained from the MICRA database by state postal abbreviation. Intrastate movements (marked and recaptured in the same state) are listed on the diagonal with the top number indicating the number of recaptures and the bottom number indicating the total number of paddlefish CWT by a state. Interstate movements (marked in one state and recaptured in a different state) are listed on the off-diagonal where fish were tagged in the state listed in the row and recaptured in the state listed in the column. Light-gray, outlined boxes indicate movement between adjacent states within a basin; medium-gray boxes indicate movement between nonadjacent states within a basin; and black boxes indicate movement between basins.

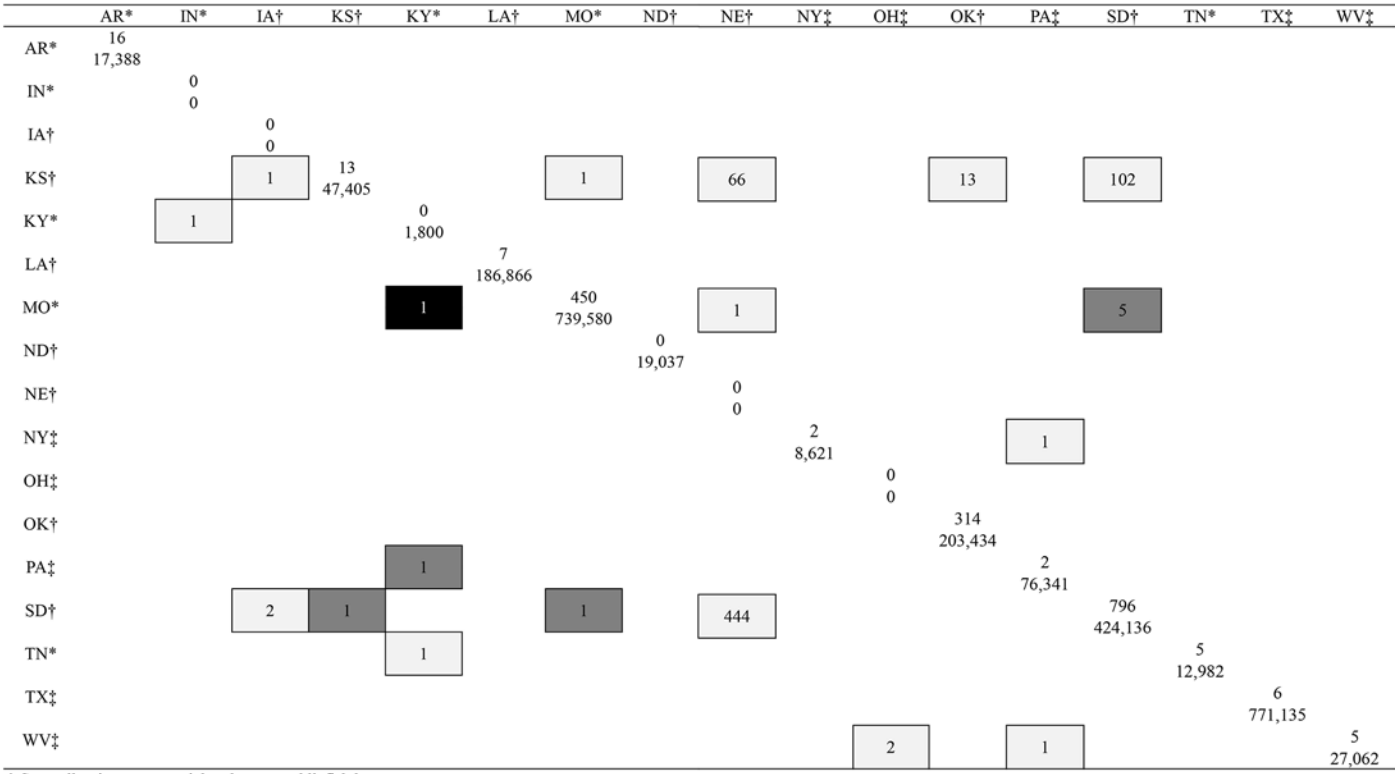
	AR	IL*	IN*	IA†	KS†	KY*	LA†	MN‡	MS*	MO*	NE†	OH‡	OK†	PA‡	SD†	TN*	TX‡	WV‡	WI‡
AR	4 31																		
IL*		190 5,446	6			28				3	3				3	1			
IN*		10	130 2,415			30						10			1				
IA†				138 2,938							2				8				
KS†					0 63														
KY*		6	37			59 2,578						1			1				
LA†							14 682												
MN‡				1				0 35											
MS*						1			0 120										
MO*						1				6 242									
NE†				4						3	172 3,513				339				
OH‡			11			7						39 489							
OK†													0 74						
PA‡														2 3					
SD†		3		3		1				4	110				247 2,717				
TN*						1				1						9 406			
TX‡																	1 29		
WV‡						1						1						0 55	
WI‡				2															0 395

* State allowing commercial and sport paddlefish harvest
† State allowing paddlefish sport harvest
‡ State with paddlefish harvest prohibited

paddlefish of the greater Mississippi River Basin could be administered in a similar fashion to migratory waterfowl flyways where representatives from Canadian provinces and U.S. and Mexican states partake in flyway councils to set broad restrictions for local governing bodies (Boere and Stroud 2006). The flyway management framework allows local governing bodies to be more, but not less, restrictive than the guidelines set forth by the flyway council. Swimway management could be administered in a similar fashion where swimway councils could be assembled to create sets of minimum restrictions that would allow local management entities to be more, but not less, restrictive than the restrictions set forth by the swimway council.

Although transitioning to a larger, interjurisdictional management framework for paddlefish would require a paradigm shift in riverine fisheries management in the United States, our study provides substantial evidence as to why a larger management framework is necessary. Perhaps the most compelling evidence for the need for interjurisdictional management comes from the frequency of movements across jurisdictional boundaries. Management actions conducted by a jurisdiction, such as harvest regulations or stocking plans, are meant to influence populations and, given the high mobility of paddlefish, multiple management jurisdictions can influence populations simultaneously. Large rivers frequently serve as state boundaries, creating border waters that are managed by multiple management jurisdictions. Although some states cooperatively manage border waters (Argent et al. 2009; Mestl and Sorensen 2009), cooperative management frameworks are usually voluntary and can be voided unilaterally by individual states. Movements between bordering states are the most common type of interjurisdictional movement and areas where rivers form jurisdictional borders are where paddlefish populations have the greatest potential of being affected by management disconnects. Ohio and Kentucky, for instance, share the Ohio River as a border. Ohio lists the paddlefish as a state threatened species, whereas Kentucky allows harvest (both commercial and sport). In this case, fishing regulations governing angler take are determined by the side of the river where harvest is occurring: anglers on the Ohio side of the river are prohibited from fishing for paddlefish, whereas anglers on the Kentucky side of the river are allowed to harvest paddlefish with the appropriate permits. It would be naïve to think that in this instance the Ohio paddlefish population is somehow distinct from the Kentucky paddlefish population, particularly due to the high frequency of movements between these two states. Although such dramatic management disconnects as exist between Ohio and Kentucky are currently unique to these states, there is no larger management framework preventing proliferation of such mutually exclusive management objectives in other bordering states in the greater Mississippi River Basin. Moreover, effects of the dramatic management disconnects among states across the species range can be seen at a larger

TABLE 4. Total number of movements of coded-wire tagged (CWT) hatchery-origin paddlefish obtained from the MICRA database by state postal abbreviation. Intrastate movements (stocked and recaptured in the same state) are listed on the diagonal with the top number indicating the number of recaptures and the bottom number indicating the total number of CWT paddlefish stocked by a state. Interstate movements (stocked in one state and recaptured in a different state) are listed on the off-diagonal where the state of capture is listed in rows and the state of recapture is listed in the columns. Recaptures indicating movement of a stocked paddlefish from a state that does not stock paddlefish back into the state that originally conducted the stocking is considered an intrastate movement in this tally. Light-gray, outlined boxes indicate movement between adjacent states within a basin; medium-gray boxes indicate movement between nonadjacent states within a basin; and black boxes indicate movement between basins.



* State allowing commercial and sport paddlefish harvest
† State allowing paddlefish sport harvest
‡ State with paddlefish harvest prohibited

TABLE 5. Competing models for survival (S), recapture (ρ), and movement (ψ) probabilities of wild paddlefish across their range in the greater Mississippi River Basin of the United States from 1995 to 2009 ranked by Akaike's information criteria (AIC), where k is the number of parameters, ΔAIC is the difference between AIC values from each model, and WAIC is the Akaike weight (all weights sum to 1).

Model[a]	*k*	AIC	ΔAIC	W_{AIC}
S_{B}, ρ_{B}, ψ_{B}	12	17,231.53	0.00	1.00
S_{B*t}, ρ_{B}, ψ_{B}	20	17,249.06	17.53	0.00
S_{B}, ρ_{B}, ψ_{B*t}	26	17,504.91	273.38	0.00

[a]Survival as time- and basin-specific (S_{B*t}) or time constant (S_{B}), recapture probability as time constant and basin-specific (ρ_{B}), and movement as time- and basin-specific (ψ_{B*t}) or time constant (ψ_{B}).

spatial scale. For example, the two basins allowing commercial harvest (i.e., Mississippi and Ohio) had the lowest survival probabilities (Table 3) and the highest probabilities of emigration. Taken together, the combination of mortality and emigration evident in the Mississippi River Basin should result in fewer fish. Conversely, states located in the Missouri Basin—the subbasin where no state allows commercial harvest—had the highest survival probability. These differences in survival among basins are influenced by commercial harvest, indicating that state management actions may scale-up to effects at the basin level, further supporting the need for a larger management framework.

Stocking hatchery-origin paddlefish is widespread throughout the greater Mississippi River Basin, and low numbers of recaptures relative to the number of fish stocked leaves us unable to quantify basic vital rates of these fish to the overall population. However, we do know from this study and previous studies that hatchery fish frequently move outside of the jurisdiction that originally conducted the stocking (Pracheil 2010; Pierce et al. 2011). Hatchery rearing of fish has been implicated in individual effects such as reduced fecundity (Chilcote 2003), reduced genetic diversity (Sloss et al. 2009), reduced fitness in the wild, and lower survival when compared to their wild-produced counterparts (Howell 1994) that may upscale to population-level effects including genetic introgression of the wild population (Araki and Schmid 2010). Paddlefish are not exempt from genetic effects of stocking, and reduced genetic diversity has been reported from hatchery-reared paddlefish (Sloss et al. 2009). Moreover, paddlefish are long-lived (>40 years; Scarnecchia et al. 2006; Pracheil 2010), creating the potential for long-lasting population effects if genetic differences between hatchery- and wild-origin individuals have phenotypic expressions. These reasons and others, such as state-by-state variability in management objectives (e.g., stocking for conservation, stocking to supplement sport harvest), stocking strategies (e.g., no stocking, stocking large numbers of fingerlings), and broodstock selection techniques (i.e., selecting the first several fish collected that meet maturation criteria, select-

TABLE 6. Survival (S_B), recapture (ρ_B), and movement (ψ_{rs}) probabilities (95% confidence estimates) by river basin (*B*) for wild paddlefish in the Mississippi Interstate Cooperative Resource Association Paddlefish Stock Assessment Database from 1995 to 2009 where basins listed in rows are originating basin of movement (*r*) and basins listed in columns are basins receiving fish (*s*).

	Receiving Basin			
Origin basin	**Gulf (*G*)**	**Missouri (*Mo*)**	**Mississippi (*Ms*)**	**Ohio (*O*)**
Gulf	S_G = 0.7818[a] (0.5498–0.9132) ρ_G = 0.0018[a] (0.0007–0.0047) ψ_{GG} = 1.0000	ψ_{GMo} = 0[b]	ψ_{GMs} = 0	ψ_{GO} = 0
Missouri	ψ_{MoG} = 0	S_{Mo} = 0.8591 (0.8416–0.8750) P_{Mo} = 0.0288 (0.0260–0.0318) ψ_{MoMo} = 0.9987	ψ_{MoMs} = 0.0013 (0.0002–0.0092)	ψ_{MoO} = 0
Mississippi	ψ_{MsG} = 0	ψ_{MsMo} = 0.0033 (0.0016–0.0072)	S_{Ms} = 0.6448 (0.5890–0.6969) ρ_{Ms} = 0.0095 (0.0074–0.0121) ψ_{MsMs} = 0.9897	ψ_{MsO} = 0.0070 (0.0028–0.0171)
Ohio	ψ_{OG} = 0	ψ_{OMo} = 0.0006 (0.0002–0.0026)	ψ_{OMs} = <0.0001[c]	S_O = 0.7885 (0.7522–0.8207) ρ_O = 0.0113 (0.0094–0.0136) ψ_{OO} = 0.9994

[a] S_B and ρ_B estimates are given on the diagonal.
[b] ψrs estimates between basins are given on the off-diagonal.
[c] 95% confidence interval included.

TABLE 7. Ten-, 20-, and 30-year estimates of the probability of not emigrating (ψ_{rr}) from a river basin (*r*) for wild paddlefish in the Mississippi Interstate Cooperative Resource Association Paddlefish Stock Assessment Database from 1995 to 2009. Basins used in analyses include Gulf (*G*), Missouri (*Mo*), Mississippi (*Ms*), and Ohio (*O*). Period transition rates are calculated as exponential functions of annual rates of not emigrating from Table 4.

Parameter	Annual	10-Year	20-Year	30-Year
ψ_{GG}	1.0000	1.00	1.00	1.00
ψ_{MoMo}	0.9987	0.98	0.97	0.96
ψ_{MsMs}	0.9897	0.90	0.81	0.73
ψ_{OO}	0.9994	0.99	0.99	0.98

ing broodstock based on genetic criteria; Grady and Elkington 2009), suggest that a larger management framework is needed.

CONCLUSIONS

Gathering data at a range-wide scale is exceptionally difficult, particularly due to the autonomous nature of fisheries management in the greater Mississippi River Basin and the voluntary participation of individual states in cooperative management and data collection agreements. The MICRA paddlefish stock assessment effort is therefore an unprecedented, improbable, and heroic effort that has been voluntarily coordinated, funded, and conducted by individual states since the 1990s. Unfortunately, the MICRA paddlefish stock assessment effort has recently been downscaled, jeopardizing this globally unique resource among all potadromous fishes that can be used to inform fisheries management in the face of growing population threats and high future uncertainty. Creating an interjurisdictional management framework using swimway councils to set research and management priorities may be one way to protect this data resource and to create management jurisdictions with biological relevancy.

Threats facing paddlefish are similar to those encountered by managers in other large-scale management scenarios (e.g., migratory birds) that require explicit cooperation among state, federal, and other stakeholders. Creating a movement-based management framework centered on known population connections may be one way to buffer species against these threats. Though we did not focus on the effects of dams on paddlefish population fragmentation in this study, paddlefish movement through dams is common (Brown 1951; Zigler et al. 2003; Pracheil 2010), with literature reports of movement through up to five dams (Stancill et al. 2002). The spatial framework we offer cannot totally ameliorate the effects of population fragmentation caused by large dams that totally or partially block upstream movement. However, the swimway framework would facilitate common management in areas where populations appear connected by movement. Moreover, restoration of large river ecosystems that removes alterations such as dams and channelization at the source of population declines is oftentimes not possible due to the human reliance on the ecosystem services of the altered river. Creating a proactive, interjurisdictional management plan that capitalizes on known population connections may be one of the few mechanisms we have to protect paddlefish stocks from further declines.

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Using the Internet to Understand Angler Behavior in the Information Age

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ABSTRACT: *Declining participation in recreational angling is of great concern to fishery managers because fishing license sales are an important revenue source for protection of aquatic resources. This decline is frequently attributed, in part, to increased societal reliance on electronics. Internet use by anglers is increasing and fishery managers may use the Internet as a unique means to increase angler participation. We examined Internet search behavior using Google Insights for Search, a free online tool that summarizes Google searches from 2004 to 2011 to determine (1) trends in Internet search volume for general fishing-related terms and (2) the relative usefulness of terms related to angler recruitment programs across the United States. Though search volume declined for general fishing terms (e.g., fishing, fishing guide), search volume increased for social media and recruitment terms (e.g., fishing forum, family fishing) over the 7-year period. We encourage coordinators of recruitment programs to capitalize on anglers' Internet usage by considering Internet search patterns when creating web-based information. Careful selection of terms used in web-based information to match those currently searched by potential anglers may help to direct traffic to state agency websites that support recruitment efforts.*

El uso de internet para comprender el comportamiento de los pescadores en la era de la informática

RESUMEN: La declinación para participar en la pesca recreativa es un problema considerable para los manejadores de pesquerías, ya que la venta de licencias de pesca es una importante fuente de ingresos destinada a la protección de recursos acuáticos. Esta declinación con frecuencia se le atribuye, en parte, a que la sociedad depende cada vez más de la electrónica. El uso de internet por parte de los pescadores se está incrementando y los manejadores pesqueros pueden usar internet como un medio único para aumentar la participación de los éstos. Se examinó el comportamiento de búsqueda en internet mediante Google Insights, una herramienta en línea que resume las búsquedas hechas en Google durante el periodo 2004-2011, con el fin de determinar (1) tendencias en internet del volumen de búsqueda de términos generales relativos a la pesca, y (2) la utilidad relativa de términos relativos a programas de reclutamiento de pescadores, a lo largo de los EEUU. Los resultados apuntan a que a lo largo de un periodo de siete años si bien disminuyó el volumen de búsqueda de términos generales de pesca (p.e. pesca, guía de pesca), incrementó el volumen de búsqueda de medios sociales y términos relacionados al reclutamiento (p.e. foro de pesca, pesca familiar). Se invita a los coordinadores de programas de reclutamiento a capitalizar el uso que los pescadores le dan a internet, al momento de generar información disponible en red. Una selección cuidadosa de los términos que se incluyen en información disponible en la red de manera que coincida con el potencial de búsqueda de los pescadores, podría ayudar a dirigir el tráfico hacia las páginas electrónicas de las agencias estatales que patrocinan los programas de reclutamiento.

INTRODUCTION

Declining participation in outdoor activities is a pervasive concern in the United States (Kareiva 2008; Pergams and Zaradic 2008), garnering attention from a wide range of authorities such as federal and state departments of health and education and authors of popular literary works (e.g., Louv 2005). Aside from public health concerns (McCurdy et al. 2010), declining participation in outdoor recreation has a direct and negative impact on natural resource protection. Many natural resource management agencies rely on permit sales, license sales, and usage fees to fund their efforts to maintain and protect natural areas. Declines in participation, and thus funds from license sales, can reduce the ability of these agencies to manage and protect natural resources.

Photo 1. Family fishing day at the lake. Credit: Cliff Wilson.

Like participation in outdoor recreation in general, participation in aquatic recreational activities such as boating and angling is declining (Pergams and Zaradic 2008), leaving natural resource management agencies with the need to market aquatic activities to the public. Decreasing angling participation (U.S. Fish and Wildlife Service et al. 2006) has prompted many state agencies to launch extensive angler recruitment and retention programs (e.g., Nebraska Game and Parks Commission 2008). These often center on activities such as children's and family fishing events and free fishing weekends but also include traditional marketing campaigns. Evidence supporting gains in angler participation as a result of these current angler recruitment and retention programs is lacking. In fact, angler participation continues to decline despite these programs (U.S. Fish and Wildlife Service et al. 2006).

Increased Internet and electronic media use are often identified as critical factors in declining participation in outdoor recreation (Pergams and Zaradic 2006). However, changing means of information gathering by anglers may require aquatic resource management agencies to rely on the Internet for increasing participation in aquatic recreation. For example, anglers once exchanged information about fishing at local cafes, bait shops, and boat ramps, but they now exchange this information through online forums, discussion boards, and Facebook groups. These platforms allow contemporary anglers an expanded array of methods for gathering and sharing information. Moreover, these online platforms provide real-time information, which may come directly from someone currently fishing.

The recent and rapid development of Internet and electronic media resources has outpaced fishery managers' abilities to understand and effectively use search engines, discussion boards, Twitter feeds, and Facebook groups to reach current and potential anglers (hereafter, "angler" will refer to current and potential anglers). We examined patterns of angler behavior as evidenced by Internet search histories to better understand how the Internet might be used for angler recruitment and retention efforts. Specifically, we examined angler-related Internet search behavior using a free web-based tool (Google Insights for Search) that summarizes Google searches since 2004 to determine (1) trends in Internet search volume for general fishing-related terms and (2) the relative effectiveness of terms related to angler recruitment and retention programs found across the United States, based on Google search patterns.

METHODS

Google Insights for Search

Google Insights for Search (hereafter, Google Insights; http://www.google.com/insights/search) is a free, web-based tool that provides index scores for specified terms used in searches. Google Insights uses a proprietary algorithm to calculate a score for each search term that represents the likelihood a random Google user would search for that particular term (Google 2010). Google Insights can be used to compare search volume for up to five terms simultaneously and results can be filtered by any combination of category (entertainment, health, hobbies and leisure, news, etc.), location (worldwide, country, state, or metro), and time (any date range from 2004 to present). The search volume for these terms is then normalized so that the greatest value is set to 100 and all other values are scaled against that observation. Normalized scores are then averaged over the period searched to provide a single score for each search term. Consequently, mean normalized scores are directly comparable only among terms used within a given search.

Google searches are becoming a common source of current trend information in a number of disciplines. The rationale behind using search trends as a surrogate of actual trends is based on the idea that users (i.e., the general public) seek information for immediate use or action. For example, diseases such as influenza can be tracked both spatially and temporally using search volume to gather information before users actually report to the doctor for treatment (Ginsberg et al. 2009). Correlations between search volume and patient records also exist for kidney stone occurrence (Breyer et al. 2011) and the awareness of cancer following a celebrity death (Metcalfe et al. 2011). In the social science literature, search volume has

TABLE 1. List of search terms used to analyze anglers' use of Google searches for gathering information on fishing.

Recruitment and retention terms	Fishing information terms	Social media terms
Free fishing	Fishing report	Fishing forum
Fishing clinic	Fishing conditions	Fishing blog
Fishing schools	Fishing guide	Fishing Twitter
Urban fishing	Fishing license	Fishing Facebook
Family fishing	Fishing rules	Fishing YouTube
Women fishing	Trophy fishing	
Kid fishing	Fishing tournament	

also been found to correlate with unemployment rates (Askitas and Zimmermann 2009) and perceptions of unemployment (Scheitle 2011).

Data Collection and Analysis

Google Insights was accessed on December 15, 2011, and filtered using hobbies and leisure (category), outdoors (subcategory), United States (location), and 2004–present (time). We first examined the general search term "fishing" to explore seasonal trends and magnitude of search volume. We also examined temporal trends in 20 search terms selected by an ad hoc survey of fishery professionals and from one of three categories: (1) terms commonly used in current angler recruitment and retention programs throughout the country (e.g., Arizona Game and Fish Department 2009 and Tennessee Wildlife Resources Agency 2011), (2) fishing information gathering terms, and (3) social media terms (Table 1).

In addition to normalized scores for search volume, Google Insights returns a list of the top search terms. When these top searches included search terms with extraneous or irrelevant information, mathematical operators (+ and −) were employed to include or exclude certain words or phrases in search terms. For example, a Google Insights search for the term "Fishing report—weather," would functionally serve as fishing report NOT weather, excluding searches that included weather from the results. Operators and terms added or excluded from searches are listed in Table 2; any references to particular search terms in discussion will exclude mention of operators.

Because mean normalized scores are not directly comparable across searches, we included either "fishing report" or "fishing forum" in every search to allow comparison of normalized scores across searches. We also compared search volume against time in days since January 11, 2004 (the earliest result displayed by Google Insight), using simple linear regression to evaluate the strength and direction of trends across the survey period.

RESULTS

Overall, searches within the "outdoors" subcategory with the "hobbies and leisure" filter applied have declined since 2004. Fishing was the most-searched term in the outdoors subcategory (Table 2; Figure 1). Search volumes for fishing and terms directly related to fishing—such as fishing guide—decreased through the period (Table 2). Search volume for most of these terms followed an annual pattern, with the greatest search volume occurring during the late spring and summer and less volume during the fall and winter (Figure 2).

Among the 20 terms analyzed, search volume was greatest for "fishing," followed by "fishing report," "fishing license," "fishing guide," and "fishing rules" (Table 2). Internet search volume related to social media sites including "fishing Facebook," "fishing Twitter," and "fishing YouTube" increased over time (Table 2; Figure 2). Terms used in angler recruitment and retention programs were among the least searched in our study (e.g., "urban fishing," "kid fishing," "women fishing," "fishing clinic," "fishing school") and all

Since 2004, the search volume for general fishing terms (e.g., "fishing guide") has declined. However, angling terms related to social media (e.g., "fishing Facebook") and angler recruitment programs (e.g., "family fishing") has increased.

TABLE 2. Google Insights for Search relative search volume score and slope and *P*-value of slope (from type I sum of squares) for the relationship between search volume and time (months since January 1, 2004). Clarifying search terms are joined to primary search terms with Boolean operators and are included in parentheses.

Term	Score	Slope	*P*-value
Low return			
Fishing Twitter	1	0.02	<0.0001
Urban fishing	3	0.01	0.28
Trophy fishing (NOT game)	6	0.04	0.34
Fishing clinic (AND fishing class AND fishing classes)	7	0.05	<0.0001
Fishing blog	7	0.08	<0.0001
Family fishing (NOT guy)	8	0.06	<0.0001
Women fishing (NOT pictures NOT photos NOT pics)	10	0.05	<0.001
Kid fishing (AND youth fishing AND junior fishing NOT games)	11	0.05	<0.0001
Fishing conditions	11	<−0.01	0.86
Fishing Facebook (NOT game)	20	0.37	<0.0001
Fishing school (AND fishing schools NOT high)	20	−0.01	0.73
Fishing YouTube	22	0.32	<0.0001
Free fishing (NOT online NOT games NOT game NOT videos NOT maps NOT boat NOT lures NOT tackle NOT map NOT tips)	30	−0.03	0.45
Fishing forum[a]	57	0.31	<0.0001
Medium return			
Fishing forum[a]	7		
Fishing tournament	8	−0.01	0.13
Fishing rules (AND fishing regulations)	12	−0.02	0.12
Fishing guide (NOT WOW[b] NOT Warcraft NOT cooking)	12	−0.06	<0.0001
Fishing license	40	0.13	0.04
Fishing report (NOT weather)[c]	63	0.09	0.13
High return			
Fishing report (NOT weather)[c]	5		
Fishing	58	-0.27	<0.0001

[a]Term included in searches to compare between low-return and medium-return searches.
[b]WOW = World of Warcraft, a popular video game containing a fishing subroutine.
[c]Term included in searches to compare between medium-return and high-return searches.

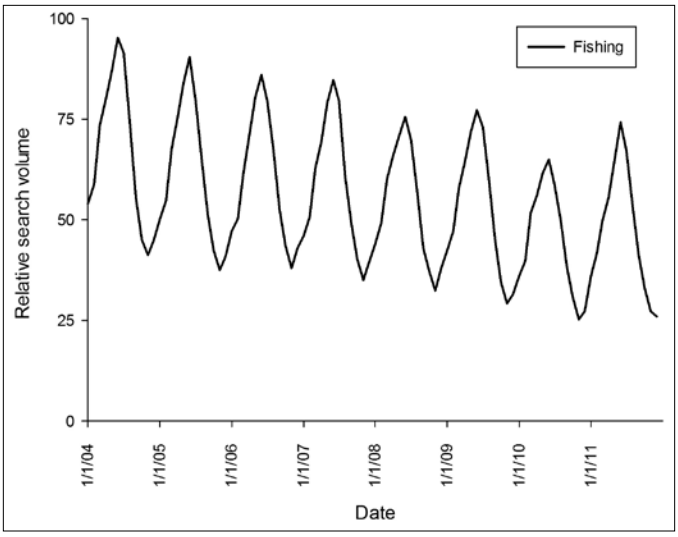

Figure 1. Relative search volume for "fishing" in the outdoors category of Google Insights for Search from 2004 to present.

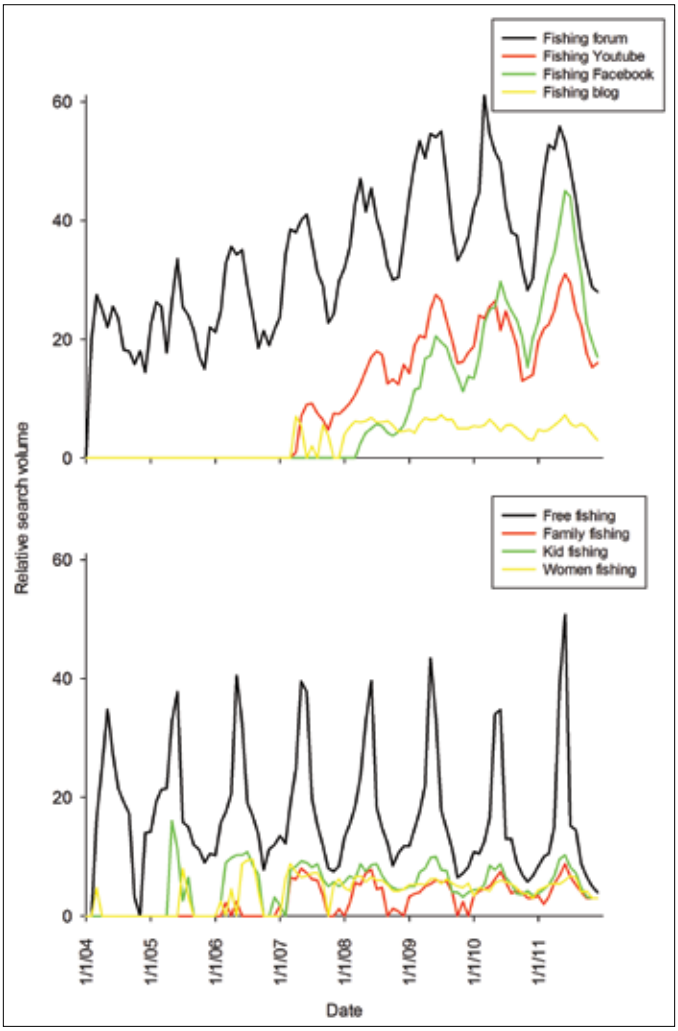

Figure 2. Relative search volume for four social media terms (top panel) and four recruitment and retention program terms (bottom panel) in the outdoors category of Google Insights for Search from 2004 to present.

ranked low in search volume (Table 2). However, search volume for these terms generally increased despite evidence of a declining interest in fishing overall (Table 2; Figure 2).

DISCUSSION

Current and potential anglers use the Internet to find angling-related information as demonstrated by increasing search volume for fishing-related terms. For example, "fishing report," a phrase that could be searched by an angler looking for local fishing conditions, had the highest relative score of any specific term searched in our study. Anglers also commonly use Internet resources as a means of exchanging fishing information, ranging from the basic "what, when, and where" questions of fishing in their area to the intricate questions of "how," including information on fishing licenses, rules, and regulations.

Increases in search volume for fishing in social media outlets provide evidence that forums, blogs, and websites like YouTube and Facebook are becoming increasingly important to anglers. As Internet use on mobile phones increases, social media sites can provide a real-time exchange of information about current fishing conditions and a chance for anglers to share pictures and information while still on the water. Social media outlets appear to be used by both avid and casual anglers but are likely used by anglers in varying capacities (Recreational Boating and Fishing Foundation 2010), and understanding these differences in usage patterns is important for management agencies developing recruitment and retention programs. Casual anglers, for example, are more likely to post their angling experiences on Facebook and Twitter, whereas avid anglers are more likely to participate in discussions on angling blogs and outdoor forum discussion boards (Recreational Boating and Fishing Foundation 2010). Furthermore, there is a switch from use of general search terms such as "fishing" and "recreation" to specific fishing-related social media terms that may be indicative of a shift in the tools that anglers are using to find information. Natural resource management agencies should encourage the use of social media within their organizations and encourage the use of information exchange on social media sites. The private business sector, for example, has found social media presence to serve as a valuable means of advertisement (Mangold and Faulds 2009). This model may also prove valuable to natural resource management agencies.

Agencies using the Internet and electronic media in their recruitment and retention strategies must have a firm understanding of the search terms used by anglers to ensure that the target audience can find information about agency products. Understanding which terms are used in search queries by persons interested in fishing will allow natural resource management agencies to tailor website information to capitalize on existing patterns of angler behavior and ultimately increase information delivery to their target audience. Additionally, if agencies do not use common search terms to describe angler programs on the Internet, interested persons will have difficulty locating that information. Search engines can only search for those terms present on a website; consequently, information re-

Photo 2. First fish of the day. Credit: Cliff Wilson.

Photo 3. Learning about fish. Credit: Cliff Wilson.

garding angler recruitment and retention programs should be presented using unambiguous terms, avoiding jargon, to maximize the chances of potential anglers locating the information. Web pages presenting information on recruitment and retention events, for example, or programs phrased "free fishing" had greater search volume than programs phrased as "fishing clinic," "urban fishing," "women fishing," and "kid fishing." Existing agency programs may benefit from relabeling so they are more likely to include search terms used by anglers. For instance, Internet searches for "fishing guide," a phrase used by many natural resource management agencies to describe documents containing fishing regulations, is used by persons seeking information on guided fishing trips. The inability of anglers to easily locate basic fishing information may lead to confusion, frustration, and potentially alienation. Studying fishing-related Internet searches allows for a simple analysis of the top searches for recruitment and retention terms, thus enabling state agencies to present or label information with the specific search terms used by anglers.

Google Insights can provide an understanding into angler behavior for natural resource management agencies that is now possible at previously immeasurable scales (Arlinghaus and Cooke 2008), although it does have two key limitations. First, the demographics of Internet users and the angling population may be different. Internet use is greater among younger generations (e.g., 87% by millennials) than older generations (e.g., 70% by older baby boomers; Jones 2009). The population of anglers is much older than the population of Internet users. We believe that this bias is minimal in the context of our study because our objective was to examine search terms related to recruitment programs and most recruitment programs are aimed at recruiting young anglers and keeping them in the angling population. Second, results from Google Insights are sensitive to search term selection. It is imperative to examine the top searches listed to look for influential outliers that may need to be excluded. For example, a search for "fishing guide" returns a top search of "wow fishing guide." When searching for this term, we found that this is a user guide for a popular video game, World of Warcraft. Natural resource management agencies must be (as this example demonstrates) especially mindful of terminology used in their Internet sources of information.

Declining participation in outdoor recreation has left natural resource management agencies scrambling to find the new anglers to fund natural resource protection and management. The fate of this funding likely rests with younger people who regularly use the Internet to obtain information that will enhance and improve their activities in their day-to-day lives. Reaching the next generation will require natural resource management agencies to embrace these technologies rather than simply blaming technology for decreasing angler participation. Searches for outdoor recreational activities are increasing at a time when participation is decreasing, thus demonstrating that by eschewing the Internet natural resource agencies may be missing an opportunity and venue to recruit and retain anglers. Strategic use of the Internet now may help natural resource management agencies recruit the next generation of anglers and retain funding for the protection of our natural resources into the future.

ACKNOWLEDGMENTS

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East Is East and …

Mervin F. Roberts

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In 1987, I was asked to go to southwest India to do a feasibility study for shrimp culture to relieve poverty. Startup money would come from an American benevolent organization located in Maine.

Because these shrimp breed naturally only twice a year, it would be necessary to have a hatchery nearby where adult female shrimp had been surgically altered so they would spawn continuously. This is all in the literature, if you must know, but not part of this short homily.

Such a hatchery was already in place nearby in Cochin, India, on the Malabar Coast facing the Arabian Sea. Articles published in scientific journals described the place, the process, and the capacity of "seed" production.

My assigned task was to examine the proposed farm sites and review the financial plans. In Texas this would have taken a few days. In southwest India it took nearly a month. First, there was the obligatory dinner with the bishop and the promoters. Then there were the obligatory visits to the schools with the costumed dancing orphan girls, the home for the handicapped and the leper colony, and the obligatory boat ride through the backwater (which, it turned out, was outside the diocese where the shrimp farming was proposed).

Eventually we did get down to the nuts and bolts. The lay leaders of the diocese had already chosen the location of the farm operation. The demand for shrimp was already established. Next came the demonstration that the waters were compatible with the proposal. A procession of small boats took me and 49 other people to the site. We started in the late afternoon, but with complicated planning and shuffling of the boats it was dark when we got there. Conveniently, a little boy with a lighted Coleman gas mantle lantern was available; he waded into the pond—and quietly waited. Eventually a man with a purse seine arrived and demonstrated his skill. He reminded me of a retired New York City policeman on a tidal creek bridge in Miami casting for his supper. The Indian fisherman caught exactly 12 same-size shrimp on the first cast alongside the little boy with the Coleman lantern. Then the boy extinguished the lantern and we returned to the upland.

I was reminded of stories I had read as a boy growing up, of the salting of California gold mines. I remained silent about what I witnessed but did say that I would like to visit the hatchery in Cochin, perhaps 40 miles away.

That led to much Indian consternation. "The natives are restless." "It is near the holy time of Ramadan." "The Communists may start a riot." "The government must approve such a visit" (meaning the government in Delhi nearly 1,000 miles away). "There must be a written permission" (with, perhaps, an important someone who was authorized to guide me). I listened patiently and finally told the bishop that I could not endorse the plan until I got my feet wet at the Cochin hatchery. The bishop knew me, knew that when I said "endorse," I meant like signing a check. The bishop then offered me his car and driver. All the naysayers then said they, too, would come with me. I firmly said, "No, thank you," and my driver and I went off to Cochin in the bishop's car on purple seat cushions with the Cross of Jesus on the hood.

On arriving at the Cochin land-based office, I introduced myself to the director and told him my mission. He asked to see my curriculum vitae and I reminded him that I was not looking for a job. I was in India to help a bishop help his people. I just wanted to see the facility. He promptly called up a 36-foot cabin boat and had me on board in minutes. I asked if I could take photos. He said he would prefer that I did not.

On an island in Cochin Harbor I saw a modern Western-design shrimp hatchery. Concrete floor, pipe runs overhead, several circular tanks averaging perhaps 15 feet in diameter, and a laboratory. My guide was anxious to show me everything I asked about. I was initially delighted but puzzled. Only one of these tanks was full of water and it was being charged with a rubber garden hose. My shoes were bone dry. The floor was bone dry. There was no water flowing in this hatchery except through that garden hose. I glanced overhead at the pipe runs. The main pipe, about 3 or 4 inches in diameter, was hung properly but the flanges were not connected. There were gaps to accommodate valves, but the valves were missing. I encountered a concrete pedestal appropriate for a large water pump and motor. Appropriate, but the pump and motor were not there.

I asked to see the algae that would feed the *Artemia*—an early step in the propagation of edible shrimp. They showed me a 5-gallon aquarium with algae. For an establishment this size I would have expected a minimum of 500 gallons of green water. I asked to see the *Artemia*. My guide quickly provided one; I believe it was the only *Artemia* in the place. It was in formalin or alcohol and the corked bottle was labeled *Artemia*—Carolina Biological Supply Co. That's all the *Artemia* they had.

As the day drew to a close, I came into a room with about 30 mostly youngish Indian men smoking. Black trousers, white shirts, tin lunch pails, all waiting for the ferry to take them ashore. Among them I spied an anomaly—a tall, blue-eyed, fair-haired chap, who I took to be from a Midwestern U.S. School of

Fisheries. I was wrong. He was a "square-head" from the West Coast and had been engaged around 1982 by his employers, a highly respected designer and builder of aquaculture facilities. He would superintend the construction of this shrimp hatchery.

This chap did just that. He then invited his boss to come to the grand opening. The boss not only refused but he ordered the young man back home across the Pacific Ocean, promptly. This was to be an "All India Project." Fast forward from 1982 to 1987, and we met in Cochin. He told me that the plant could produce shrimp with perhaps a half-dozen staff on the payroll but startup employed about 30. Simple arithmetic shows that about 24 Indian civil servants would lose their jobs if that plant ever produced any shrimp. I never heard of anyone in India who ever lost his job. Here in India there is very little unemployment but a great deal of underemployment.

For those readers who got this far and are wondering what this shrimp business has to do with fisheries, I must say that what I encountered in India in 1987 is going on all over the world in various forms, including fisheries. Improvements must be planned in context with unintended consequences, and in India one must anticipate plenty of unintended consequences.

Who in Seattle, Washington, or Bar Harbor, Maine, would have thought that the number of men on a payroll in a hatchery in Cochin Harbor would influence the farming of shrimp in all of southwest India and tie up seed production for at least 5 years?

About 10 years later, my wife and I revisited my friend the bishop, and my wife shopped for a pair of sandals in a ladies shop. It took seven people serving her to get us out of that store with the purchase of just one pair of sandals. And they all spoke excellent English.

Rudyard Kipling said, "Never the twain shall meet." Maybe he was right.

Second Call for Papers: Little Rock 2013

The Arkansas Chapter of the American Fisheries Society is pleased to announce the second call for symposia, contributed oral, and contributed poster presentations for the 143rd Annual Meeting of the American Fisheries Society to be held in Little Rock, Arkansas! The meeting theme, "Preparing for the Challenges Ahead" is likely to stimulate thoughts and presentations on:

- Challenges facing natural resource agencies regarding mandates to do more with fewer resources
- Challenges facing educators regarding a growing knowledge base, changing student expectations, and teaching to Millennials
- Challenges facing students regarding their roles as future scientists and managers serving increasingly more diverse stakeholders
- Other challenges that confront fisheries and natural resource professionals

AFS 2013 will be 8-12 September in Little Rock, at the Statehouse Convention Center located at the east end of President Clinton Avenue. The River Market District in Little Rock and the Argenta District in North Little Rock offer the best in dining, entertainment, museums, and shopping. Let us show you some southern hospitality next year in Little Rock.

GENERAL INFORMATION

Fisheries and natural resource professional are invited to submit symposia proposals or abstracts for contributed oral, poster, and speed presentations that address the meeting's theme, or on other issues and subjects pertinent to our field. We encourage state and federal fisheries professionals, private biologists, academics, and students to participate. There will be four types of sessions at the meeting: Symposia (oral presentations organized by individuals or groups with a common interest), Contributed Oral Presentations (grouped together into themes), Contributed Poster Presentations (organized to coincide with either symposia or contributed oral presentations themes), and Speed Presentations for students or professionals just beginning research or interested in feedback on a specific issue.

A NEW TIME FORMAT

The Little Rock meeting will be experimenting with a new presentation time format. Regular symposia presentations and oral contributed presentations are designed to fit into 20 minute time slots. However, presenters should plan on presenting for 12 minutes, leaving 3 minutes for questions and 5 minutes for room changes (and further questions). It is important for symposia and oral contributed presenter to plan for, and abide by, this new time format.

SYMPOSIA

The Program Committee invites proposals for Symposia. We are specifically requesting topics related to the meeting theme of "Preparing for the Challenges Ahead." Topics not addressing the meeting theme should be of general interest to AFS members. Symposia that address challenges facing broad groups of fisheries professionals, along with solutions to specific challenges will receive priority.

Symposium organizers are responsible for recruiting presenter, soliciting their abstracts, and directing them to submit their abstracts through the AFS online submission forms. Organizers are not required to recruit a full symposium at the time of proposal submissions. The Program Committee is particularly interested in working with symposium organizers to incorporate into symposia appropriate presentations that are submitted as contributed oral or poster presentations. A symposium should include a minimum of 10 presentations and we encourage organizers to limit their requests to 1-d symposia (about 20 oral presentations). Time slots are limited to 20 minutes, but multiple time slots (i.e., 40 or 60 minutes) may be offered to keynote symposia speakers.

Symposium proposals must be submitted by 11 January 2013. All symposium proposal submissions must be made using the AFS online symposium proposal submission form available on the AFS website (www.fisheries.org). The Program Committee will review all symposium proposals and notify organizers of their acceptance or refusal by 1 February 2013. If accepted, organizers must submit a complete list of all confirmed presentations and titles by 22 February 2013. Symposium presentation abstracts (in the same format as contributed oral or contributed poster presentation abstracts; see below) are due by 15 March

2013. All symposium presenters are expected to deliver PowerPoint presentations.

The Program Committee is developing ways to increase the accessibility of symposia to all potential participants. See future calls for papers, e-mail messages, and the meeting web site for more details.

FORMAT FOR SYMPOSIUM PROPOSALS

(submit using AFS online symposium submission form)

When submitting your abstract, include the following:

- Symposium title: Brief but descriptive
- Sponsors: If applicable, indicate sponsorship. Please note that a sponsor is not required.
- Organizer(s): Provide name, affiliation, telephone number, and e-mail address of each organizer. The first name entered will be the main contact person.
- Chairs: Supply name(s) of individual(s) who will chair the symposium.
- Description: In 300 words or less, describe the topic addressed by the proposed symposium, the objective of the symposium, and the value of the symposium to AFS members and meeting participants.
- Audiovisual requirements: LCD projectors and laptops will be available in every room. Other audiovisual equipment needed for the symposium will be considered, but computer projection is strongly encouraged. Please list special AV requirements.
- Special seating requests: Standard rooms will be arranged theatre-style. Please indicate special seating requests (for example, "after the break, a panel discussion with seating for 10 panel members will be needed").

The Program Committee invites abstracts for contributed oral presentations, contributed poster presentations, or speed presentations. Authors must indicate their preferred presentation format:

- Contributed oral presentation only,
- Contributed poster presentation only,
- Contributed oral presentation preferred, but poster presentation acceptable, or
- Speed Presentation

CONTRIBUTED ORAL AND POSTER PRESENTATIONS

Only one contributed oral presentation will be accepted for each senior author. Contributed oral presentations will be organized by 20 minute time slots (i.e., 12-minute presentation, 3 minutes for questions, and 5 minutes for room changes). All oral presenters are expected to deliver PowerPoint presentations.

We encourage poster submissions because of the limited time available for oral presentations. The program will include a dedicated poster session to encourage discussion between poster authors and attendees. The dedicated poster session will include traditional hard copy posters. In addition, the Program Committee is exploring methods for incorporating electronic posters, such as inclusion of electronic posters in symposia or other sponsored electronic poster opportunities.

SPEED PRESENTATIONS

The Program Committee is interested in organizing one or more speed presentation sessions. Speed presentations would require a brief (2-3 sentences) abstract submitted through the AFS abstract submission site. Speed presentations would be an outlet for students or professionals just beginning their research or interested in feedback on a small specific issue. The format for a speed presentation would be 1 or 2 PowerPoint slides used during a 3-minute presentation, followed by 2 minutes for questions or feedback.

STUDENT PRESENTERS

Student presenters must indicate if they wish their abstract to be considered for competition for a best student presentation (i.e., paper or poster, but not both) award by submitting to the Best Student Presentation competition section. If a student does not wish to be considered, they should submit to the normal contributed abstracts section. Components of the application will include an extended abstract and a check-off from their mentor indicating that the study is at a stage appropriate for consideration for an award. Please note that speed presentations are not eligible for best student presentation.

ABSTRACT SUBMISSIONS

Abstracts for contributed oral and poster presentations and speed presentations may be submitted after 1 February 2013 and must be received by 15 March 2013. All submissions must be made using the AFS online abstract submission form, available at www.fisheries.org. When submitting your abstract:

- Use a brief but descriptive title, avoiding acronyms or scientific names in the title unless the common name is not widely known;
- List all authors, their affiliations, addresses, telephone numbers, and e-mail addresses; and
- Provide a summary of your findings and restrict your abstract to 200 words.
- Use 2-3 sentences for a speed presentation abstract.

All presenters will receive an email confirmation of their abstract submission and will be notified of acceptance and the designated time and place of their presentation by 5 April 2013.

The Program Committee will group contributed oral and poster presentations thematically based on the title and two or three keywords you will choose and prioritize during the abstract submission process. Speed presentations will be combined into separate sessions.

Late submissions will not be accepted. AFS does not waive registration fees for presenters at symposia, workshops, or contributed oral or poster presentation sessions. All presenters and meeting attendees must pay registration fees. Registration forms will be available on the AFS website (www.fisheries.org) in May 2013. There is a cost savings for registering early.

FORMAT FOR ABSTRACTS

Title: An Example Abstract for the AFS 2013 Annual Meeting
Format: Oral
Authors: Lochmann, Steve. Aquaculture/Fisheries Center, University of Arkansas at Pine Bluff, 1200 N. University Dr., Pine Bluff, AR 71601; 870-575-8165; slochmann@uaex.edu
Racey, Christopher. Arkansas Game and Fish Commission, 2 Natural Resources Drive, Little Rock, AR 72205; 501-223-6371; clracey@agfc.state.ar.us
Presenter: Steve Lochmann
Abstract: Abstracts are used by the Program Committee to evaluate and select papers for inclusion in the scientific and technical sessions of the 2013 AFS Annual Meeting. An informative abstract contains a statement of the problem and its significance, study objectives, principle findings, and applications. The abstract conforms to the prescribed format. An abstract must be no more than 200 words in length.
Student presenter: No

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The Steven Berkeley Marine Conservation Fellowship Winners

This annual fellowship was created to honor the memory of Steven Berkeley, who passed away from cancer in June 2007. Throughout his career Berkeley was a passionate advocate of conserving fish populations and improving fisheries management by integrating basic research results and scrutinizing fundamental assumptions about fish stocks. On the East Coast, he examined stock composition and bycatch issues in large pelagic fishes and developed management plans as a staff member of the South Atlantic Fishery Management Council. After moving to the West Coast, he served on the Science and Statistical Committee for both the North Pacific and Pacific councils. His research on maternal effects in rockfishes has been widely recognized in demonstrating the need to protect older females in long-lived species, particularly through management measures such as Marine Protected Areas.

The 2012 recipient of the Berkeley Fellowship is Tony Spitzack from Washington State University Vancouver. Honorable mention awards go to Caitlin Cleaver, University of Maine, and Geoffrey Smith from the University of Florida.

WINNER—TONY SPITZACK

Tony Spitzack is a third-year Ph.D. student at Washington State University Vancouver studying with Dr. Brian Tissot. His dissertation work focuses on the effect of herbivore guild structure and marine protected areas (MPAs) on Hawaiian coral reef resilience. Coral reefs are facing pressure from a myriad of stressors that threaten to degrade reef resilience. Ecosystem managers have looked to increase coral reef ecosystem resilience by implementing MPAs, and herbivore guild structure is thought to be one of the drivers for the connection between MPAs and resilience. However, researchers are still unclear whether MPAs actually enhance resilience. Expanding on a small pilot study, Tony will (1) use exclusion cages as a disturbance to evaluate the relative resistance along an MPA network and (2) use exclusion to manipulate the herbivore guild structure, identifying aspects of the community structure that may be vital to benthic community resistance. Ultimately, this research will inform managers of the effect of herbivore guild structure and MPAs on coral reef resilience. Proximately within Hawaii, the study will provide a baseline assessment of the relative resilience within an established MPA network; identify herbivore guilds especially important to reef resilience, and therefore in need of special protection; and, possibly, present a novel quick assessment method for resilience. These outcomes would be invaluable in providing local managers tools for evaluating and monitoring coral reefs in Hawaii.

HONORABLE MENTION—CAITLIN CLEAVER

Caitlin Cleaver is a graduate student in the University of Maine's School of Marine Sciences marine biology and marine policy dual-degree program. Her thesis research explores both biological and social aspects of Maine's green sea urchin fishery. Through the dual-degree program, she has had the opportunity to interview urchin harvesters and develop a biology project that investigates a hypothesis derived from these interviews. She is exploring the coast-wide pattern of deepwater sea urchin distribution and individual sea urchin movement. She believes that coupling social science with natural science efforts is important in developing more effective conservation strategies that adequately take into account the human aspect of marine issues. Ultimately, she is interested in researching the delicate balance of managing fisheries in the dynamic natural, social, and political systems in which marine resources are inherently embedded. Caitlin has a B.A. in environmental policy from Colby College and a M.P.A in environmental science and policy from Columbia University.

HONORABLE MENTION—GEOFFREY SMITH

Geoffrey Smith is a doctoral student in the Program of Fisheries and Aquatic Sciences at the University of Florida, where he is studying under the advisement of Debra Murie. His doctoral research will investigate the potential impacts of the nonnative pike killifish *Belonesox belizanus* on juvenile common snook *Centropomus undecimalis*. Pike killifish are established in both fresh and estuarine waters of south Florida, where they have been shown to have localized negative ecological impacts. A second population has become established in several tributaries of Tampa Bay. Recent increases in the range and abundance of pike killifish in Tampa Bay waters and overlap in habitat usage has led to concerns about potential competition with, and predation on, juvenile snook. These potential impacts will be investigated in a number of both field and lab studies looking at the following: growth, condition, and diet of early juvenile snook in both the presence and absence of pike killifish; overlap in the diet of these two species; the relative abundance of prey items from locations with and without pike killifish present; spatial habitat utilization by each species; aggressive interactions between these two species; what size snook are vulnerable to attack by pike killifish; and whether the enlarged anal spine of juvenile snook effectively deters attacks by pike killifish. Data from these studies will be incorporated into a population model to investigate the potential loss of early juvenile snook, which could result in further declines or delayed recovery of the stock, resulting from the potential impacts of pike killifish.

From the Archives

Our national diet is one-sided; we eat too much of the fats and carbohydrates and relatively too little protein. This comes from our enormous consumption of highly fattened meats and of sweetmeats. As population becomes denser and economy becomes more necessary we shall have to devote relatively less of the productive power of our land to meat production. If we can replace part of the meat that we consume by fish, it will be greatly to our advantage as regards both health and purse.

W. O. Atwater (1888): The Digestibility of Fish,Transactions of the American Fisheries Society, 17:1, 69-83.

Rotenone Use in Fish Management and Parkinson's Disease: Another Look

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INTRODUCTION

Rotenone is a nonspecific botanical insecticide with some acaricidal properties. As recently as 6 years ago, it was used in home gardens for insect control and for lice and tick control on pets, and historically it has been used in the agricultural production of leafy and fruity vegetables, stone fruits, and berries. Many fish and wildlife agencies in North America, Europe, Africa, Australia, and New Zealand also use rotenone for fish eradications as part of eliminating invasive species and diseases, restoring native species, and managing sports fish (Finlayson et al. 2000, 2010).

Ten years ago, the American Fisheries Society's (AFS) Task Force on Fishery Chemicals (2001) reviewed the available studies on the relationship between Parkinson's disease (PD) and rotenone. This review focused on the implications to fish managers and centered on an Emory University study by Betarbet et al. (2000). We were concerned that the inaccurate and incomplete reporting of this study and others might lead to unfounded fears associated with using rotenone in fish management. These concerns were not unfounded; the PD issue has been brought up by project opponents over the last decade in an attempt to derail and discredit fish management projects involving rotenone, as recently as 2011 in Utah (U.S. Forest Service 2011) and Arizona (Arizona Game and Fish Department 2011).

Since 2001, many other studies have been completed that suggest that we revisit the issue. As was the case in 2001, there is little doubt that rotenone, given excessive and unrealistic exposure, may cause specific damage to nerve cells, inducing symptoms of neutrotoxicity similar to those associated with PD. The quandary remains in how to interpret these studies given that (1) the routes of exposure employed are typically irrelevant to rotenone's use in fish management and (2) the neurological symptoms from rotenone demonstrated in laboratory studies are broader than those typically seen in PD (i.e., cold symptoms can represent many illnesses, including colds). Here we give a broad overview and assessment of the available evidence (detailed information can be found in the referenced studies).

PARKINSON'S DISEASE AND EFFECTS OF ROTENONE EXPOSURE

The U.S. Library of Medicine (in 2012) defines PD as a progressive degenerative neurological disorder characterized by resting tremors, rigidity, inability to maintain posture, and generally slow movement (see http://ncbi.nlm.nih.gov/pubmedhealth/PMH0001762). There are two general types of PD. Familial PD may occur early in life and has a clear genetic (inherited) component. Sporadic PD typically occurs in the elderly, and the incidence increases with age. The pathology of PD involves the progressive loss of dopamine-secreting nerve cells in the middle section of the brain (substantia nigra). The loss of the neurotransmitter dopamine in the brain is associated with overt signs of PD.

Most studies have focused on the controversial use of rotenone, using laboratory animal models, largely to understand the pathogenicity of PD for development of effective treatments. These studies began with the work of Betarbet et al. (2000), who, through intravenous injection of rotenone directly into the brain over 5 weeks, produced damage to brain tissue (microscopic deposits of protein referred to as "Lewy bodies") similar in character to that in PD. Other studies have involved high doses or long periods of subcutaneous, intravenous, or direct brain exposures not directly relevant to human health risk.

ENVIRONMENTAL INFLUENCES AND ROTENONE EXPOSURE

The causes of PD are not well understood and, as noted above, development appears to involve both genetic predisposition and environmental factors. Environmental factors may include relatively common agents such as cigarette smoking, consumption of coffee (McCulloch et al. 2008), and agricultural exposure to pesticides (Brown et al. 2006). In terms of exposure to pesticides, the most consistent relationship noted in epidemiological studies was that increased pesticide exposure caused an increased risk (Drechsel and Patel 2008).

The applicator of liquid and powdered rotenone formulations used in fish management is at greatest risk to exposure from oral, dermal, and inhalation routes. However, these routes of exposure have been significantly reduced, if not eliminated. The application of common sense and good personal hygiene practices will prevent oral exposure. Rotenone is not volatile (vapor pressure of $6 \times 10{-}6$ Pa; Huntingdon Life Sciences 2007) and, thus, inhalation is an unlikely route of exposure from liquid formulations. Powdered rotenone can become airborne, but full-face respirators and semiclosed application systems are required. Rotenone stemming from the commercial CFT Legumine formulation is poorly absorbed (<0.37%) through human skin (Swan 2007), and chemically resistant gloves and protective coverall clothing are required and, thus, dermal is an unlikely route of exposure for either formulation.

TOXICOLOGY STUDIES

Durkin (2008) reviewed numerous studies on the use of rotenone in developing animal models for PD; he noted that all of the early studies involved routes of exposure (subcutaneous infusion, intravenous administration, or direct instillation into the brain) that were not directly relevant to human health risk. The U.S. Environmental Protection Agency (USEPA 2005b, 2006) also noted that these studies were not directly relevant to human health risk relative to expected exposure. For example, Ferrante et al. (1997) indicated damage to brain tissue in rats from intravenous rotenone exposure, but the damage was not specific to PD. In the highly reported study, Betarbet et al. (2000) noted specific damage to the midbrain of rats from intravenous exposure to rotenone that was similar to that of PD, but many studies have contradicted those findings. More recent studies by Allen et al. (2009) and Drolet et al. (2009) also involved routes of exposure not relevant to human health risk.

Few studies have attempted to expose laboratory animals to rotenone in a manner consistent with human health risk, including absorption through the skin (dermal), through the gut (ingestion), and through the lungs (inhalation). Ingestion, inhalation, and dermal exposures significantly slow down the introduction of chemicals into the bloodstream. Rotenone is poorly absorbed through the human skin and normally has a slow rate of gut absorption, likely reflecting its metabolism and/or rapid breakdown in the gastrointestinal tract (Durkin 2008). Rojo et al. (2007) concluded that inhalation of powdered rotenone was the most likely exposure route to humans, but these studies failed to show any PD symptoms in rats following intranasal exposure to powdered rotenone for 30 days. Two studies (Inden et al. 2007; Pan-Montojo et al. 2010) assessed the effect of chronic oral administration of high rotenone doses on the pathology of PD in mice. Pan-Montojo et al. (2010) administered a rotenone solution to mice intragastrically with a stomach tube for 1.5 to 3 months. They found that mice treated with rotenone produced some of the neurological effects associated with PD. However, rotenone was dissolved in the solvent chloroform, a central nervous system depressant, which likely increased its absorption into the gut tissue, which otherwise would have been susceptible to breakdown by stomach acids and enzymes. Inden et al. (2007) reported PD-like effects in mice after oral administration of rotenone but recognized that the evidence did not indicate that rotenone causes PD but only that the results suggest that rotenone-treated mice may be useful in understanding the mechanism of dopamine reduction by neurodegeneration in PD.

In addition to the concerns about the practical applicability of the unnatural rotenone exposures in evaluating human health risk, Lapointe et al. (2004), Ravenstijn et al. (2008), Höglinger et al. (2006), Richter et al. (2007), and Durkin (2008) expressed reservations regarding the use of rotenone as an animal model for PD due to the broader spectrum of neurological effects induced by rotenone relative to the narrower spectrum of effects seen in PD. Regardless of the similarities to PD, rotenone can cause neurological damage given excessive doses and exposures.

EPIDEMIOLOGICAL STUDIES

The Agricultural Health Study (Kamel et al. 2006; Tanner et al. 2011) evaluated the previous use of pesticides by farmers and their incidence of PD. Questionnaires were sent to American farmers to gain information on their pesticide use and medical history (Kamel et al. 2006). The study concluded that increased pesticide use was associated with increased PD risk in farmers and that the use of personnel protection equipment (PPE) decreased this risk. From follow-up investigations of these data, Tanner et al. (2011) concluded that rotenone and paraquat use were associated with increased risk of PD. However, the study participants were exposed to many different pesticides, not just rotenone and paraquat, and pesticide exposures were not actually measured; rather, pesticide exposures were based solely on self-reporting methods. Raffaele et al. (2011) discussed the problems associated with using epidemiological data in environmental risk assessments, specifically citing as examples studies on pesticide exposure contributing to the increased risk of PD. They found inconsistent findings between studies, generic categorization of pesticide exposure, and the use of dichotomous exposure categories (e.g., "ever" versus "never"). They also noted the difficulty in using epidemiological studies to evaluate a disease such as Parkinson's where multiple causal factors (genetic susceptibility, age, and environmental exposures) are present.

RISK: FUNCTION OF TOXICITY AND EXPOSURE

The causality of rotenone in PD is highly debatable based on the available information outlined above. Without rotenone exposure, the risk of developing PD from rotenone is eliminated—and exposure to rotenone can be controlled.

The USEPA (2007) reviewed and considered all public health data on rotenone, including those associated with PD, and issued the Reregistration Eligibility Decision for rotenone. The USEPA was concerned about residential and home garden use of rotenone because nonprofessional applicators may apply material without proper PPE utilized by professional applicators. The home garden and residential uses were voluntarily cancelled by the rotenone registrants, yet the piscicidal use of rotenone was approved for reregistration by the USEPA. The USEPA (2005a) reviewed all poisoning incident data on rotenone from 1984 forward prior to clearing it for reregistration and found only four cases that involved either skin or eye effects. Reigart and Roberts (1999) reported that commercial rotenone products have presented little hazard to humans over many decades, with dermatitis and respiratory tract irritation listed as the symptoms of exposure.

To protect the applicators and the public, the USEPA (2007) required mitigation measures to reduce exposure that included the use of semiclosed mixing and application systems, specific PPE and application techniques, and following the AFS's rotenone standard operating procedures manual (Finlayson et al. 2010). PPE such as respirators, outer clothing (coveralls, gloves), and eye protection (splash goggles, face shields) will virtually eliminate exposure and are required for the application of rotenone in fish management. The public is excluded from the treatment area until rotenone residues subside, and rotenone-treated water leaving the treatment area must be detoxified with potassium permanganate (USEPA 2007). Specific information on proper application procedures and safety equipment are found on rotenone labels and in Finlayson et al. (2010). The AFS also provides annual hands-on training for the safe and effective use of piscicides using the rotenone standard operating procedure manual each May at Utah State University in Logan (see http://www.fisheriessociety.org/rotenone for current scheduled classes).

CONCLUSIONS

Collectively, the toxicology and epidemiological studies present no clear evidence that rotenone is causally linked to PD. Even if there were clear evidence, it would have little impact on the current and proposed use of rotenone in fish management. This is because the toxicology studies demonstrating PD-like effects were conducted using routes of exposure (e.g., intraperitoneal or intravenous injection or oral dosing with solvents) and exposure regimes (e.g., weeks to months) not germane to potential human exposure associated with fishery uses. The epidemiological studies on pesticide use by farmers assessed historical application scenarios that paid little or no attention to personal hygiene, safety, and safety equipment. For the applicator, the use of required PPE will significantly reduce, if not eliminate, exposure. For the general public, restricted access to the treatment area until rotenone subsides to safe levels and the use of potassium permanganate to detoxify water leaving the treatment area will greatly minimize exposure. Although everyone is at some risk of developing PD, the risk of developing PD-like symptoms as a result of rotenone exposure from use in fisheries management is negligible because with recommended care, rotenone exposure has been effectively eliminated.

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From the Archives

The fisheries, in my judgment, have reached a point where no half-measure will answer. What is needed is to look the necessities of the case squarely in the face and provide whole some and sufficient remedies, that will put a stop to the destruction and marketing of immature fish of all valuable kinds; and while it gives nature a chance to help repair the mischief already done, will likewise help to secure to the States the benefits of the artificial propagation and planting.

John H. Bissell (1888): Co-operation in Fish-culture, Transactions of the American Fisheries Society, 17:1, 89-100.

From the Archives

Some time since it was my fortune to pass a number of months in Munich, where, through the courtesy of Professor Voit, Director of the Physiological Institute of the University, I was enabled to make some experiments on the digestion of meat and fish by a man and by a dog. Each lived for three days upon haddock and then for three days upon lean meat, beefsteak. The dog was used to such experiments and got on very comfortably indeed. The meat and fish were each cooked with a little lard. He did not take to the fish at first, but after he got used to it seemed to like it. The first attempt with a man was with the same healthy, rather stolid Bavarian laborer, with whom Dr. Rubher's experiments with meat and bread, above referred to, were performed. He bore up very well through the trials with both the fish and the meat, but the assistant discovered at the end that he had surreptitiously eaten sauerkraut, and the experiment was spoiled.

W. O. Atwater (1888): The Digestibility of Fish, Transactions of the American Fisheries Society, 17:1, 69-83.

Climbing the Slippery Slope

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Sirajo goby. Photo by Patrick Cooney.

A small break in the tropical rainforest canopy frames a distant golden-sand Caribbean beach, far removed from the unforgiving environment we are witnessing. From our perch atop a 100-foot tropical rainforest waterfall, we anxiously crouch in the heavy and humid air awaiting a fish arriving from an arduous journey incredibly disproportionate to the creature's diminutive size.

Just before a drop of salty sweat slips into my eye and clouds my vision, I finally catch a glimpse of what I trekked so far to witness and am working so diligently to protect. As if being reeled in slowly by an upstream force, a turquoise- and tangerine-colored Sirajo ("si-rah-ho") goby, no bigger than a toddler's pinkie finger, nears the top of its improbable climb. Approaching the crest of the waterfall, it strains against the current to hold the slick bedrock with a single fin resembling a suction cup on its underside. We silently cheer it on, for fear that one wrong move would send this sojourner plunging into the mouths of predators lurking in the pool below. Little by little, like an inch worm, it pushes forward, each a victorious step in the struggle to access critical upstream habitat and escape the pressures of predation below.

Climbing a waterfall is the last major hurdle in the voyage of the specialized life cycle of a Sirajo goby. Larvae hatch in high-altitude streams and are swept to the sea. They grow into juveniles while riding ocean currents, storing energy for a climb equivalent to a human scaling the height of six Empire State Buildings. When tides deliver juveniles to the mouth of a river, schools migrate upstream, playing leapfrog along the stream bottom. These fish are built to climb, and tall waterfalls on tropical islands are merely a bump in the road, but artificial barriers like dams and road crossings often have dry downstream faces that pose as impassable obstacles.

Rivers in Puerto Rico rise out of the Caribbean to almost a mile in elevation. The island was once the global epicenter of sugarcane and coffee production, stretching from the coastal plains to the highest peaks. Water is a necessity for plantations; thus, dams of all sizes were built in almost every conceivable location. As those industries faded and others took hold, the human population ballooned, requiring the construction of more dams of even greater sizes. Older dams became forgotten relics across the landscape, often swallowed by the jungle, yet their dry escarpments created permanent barriers to fish migration. The absence of Sirajo gobies in almost all mountain streams created suspicions that derelict dams were widespread and generating migration problems. Therefore, I set out to document every dam and sample fish populations in all 46 river drainages in Puerto Rico to find the dams that were blocking fish migrations. With only six native freshwater fish species in Puerto Rico, protecting any remnant of diversity is imperative.

Water-logged maps, perseverance, and countless tubes of calamine lotion aided in discovering and documenting more than 300 dams, leaving less than 10% of river drainages flowing freely. As we expelled gallons of sweat into our waders, endemic Puerto Rico boa constrictors looked on curiously from the banks while we sampled fish deep in the rainforest where few people have ever ventured. Combining the dam and fish surveys, I quantified that gobies are blocked from 36% of critical upstream habitat. Though goby populations are persisting in some rivers, dam construction continues and threatens further habitat losses. These inventories provide guidance to reduce impacts and allow prioritization for dam removal or fish passage devices to help restore migration corridors.

Back at the waterfall in that rare undammed river, the determined Sirajo goby makes one final lunge, victoriously cresting the waterfall into the shallows by our feet. The challenge of the climb for this individual goby was surmountable, but can the same be said for the bigger challenge of improving migration corridors? The fate of the Sirajo goby is largely dependent on the fate of dams, and addressing Puerto Rico's dam inventory could give the Sirajo goby just the nudge it needs to once again find waterfalls to climb in all rivers of the Caribbean.

Focus on the Positive: How One Little Fish Helps to Sustain Aquatic Biodiversity

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Every spring, the clear upland streams of eastern North America erupt in vivid shades of red, yellow, and blue. These displays are not caused by flowers but by the breeding colors of minnows.

Before the fireworks can begin, a particular type of minnow called the bluehead chub must complete a very important task. After fattening up on insects, adult male chubs (up to 7 inches long) construct large, dome-shaped piles of gravel in the swift current. These mounds are chub nests, and they cost a great deal of energy to make. A large male chub may carry over 7,000 stones, each as large as his head, as far as 25 yards to his nest site. Chub nests can be up to two feet tall and three feet long and are built in as little as a day—quite impressive for a fish the size of your hand!

Much like the nests of birds, chub nests help to attract mates and are a safe hiding place for eggs. But female chubs are not the only fishes attracted to chub nests. Over 30 other minnow species are known to spawn on chub nests. These fishes exhibit some of the most amazing colors found in the fish world. Because of their remarkable coloration, nest associating minnows are prized by aquarists from everywhere.

When laid together on nests, eggs of chubs and other minnows survive better than if they had been spawned alone. Because this relationship is mutually beneficial to participants, spawning aggregations on chub nests are considered to be positive interactions. Until recently, most fish ecologists have focused on negative relationships, such as those between predators and prey. In fact, positive interactions among stream fishes have been nearly entirely ignored.

Workers in other fields of ecology have long understood the importance of conserving positive relationships among species. For example, agronomists understand that the positive interactions between bees and plants are essential for successful crops; plant ecologists appreciate the mutual tradeoffs between soil dwelling fungi and plant roots; and marine biologists recognize that the coral–algae relationship helps sustain the great diversity of marine fishes.

The time has come for fish ecologists to take note of the positive interactions that support freshwater fish diversity. So how do we find the positive side to such a harsh "fish eat fish" world?

The research my colleagues and I have done is beginning to show the positive interactions between chubs and other minnows. We have found that nest-associating minnows appear to be quite rare in nature. Each species typically occurs only in a small geographic area (e.g., only in a few river systems), probably because these fishes depend on chubs to complete their life cycle. Yet nest-associating minnows are distinctly underimperiled. Of 187 imperiled North American fishes, only seven spawn on chub nests. If nest-associating minnows are rare, then why are so few identified as endangered or vulnerable?

Like beavers, chubs create vital habitat for many fishes. By building nests, chubs create patches of the clean gravel that nest-associating minnows require for spawning. My research shows that in degraded urban streams, chub nests are often the only suitable spawning habitat for many minnows. By spawning on chub nests, many minnows can maintain stable populations in habitats where closely related nonassociate species cannot reproduce.

To better characterize the role that chubs play in stream ecosystems, we must first understand why some minnows prefer to spawn on chub nests, while others do not. To do so, I am conducting a large-scale experiment that involves manipulating abundances of chubs, nest-associating minnows, and egg predators. By performing the experiment in pristine and agriculturally degraded streams, this study will shed light onto why human development drives some fishes to extinction while closely related species remain.

Aquatic biodiversity is declining at an alarming rate, especially in North American streams. To properly conserve this diversity, we must first understand the ecological interactions that promote it. My work aims to provide simple tools for targeting conservation efforts in streams where positive relationships have been overlooked. By focusing on the positive, fish conservationists will be better equipped to maintain this rich diversity for generations to come.

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Isolation and Molecular Characterization of a Novel Infectious Pancreatic Necrosis Virus Strain in Returning Atlantic Salmon Salmo salar from the Connecticut River, USA. *Gavin W. Glenney, Patricia A. Barbash, John A. Coll, and William M. Quartz. 24: 63–72.*

[Communication] Effects of Metomidate Hydrochloride Sedation on Blood Glucose and Marketability of Transported Threespot Gourami Trichogaster trichopterus. *Tina C. Crosby, Jeffrey E. Hill, Kathleen H. Hartman, and Roy P. E. Yanong. 24: 73–80.*

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A Single Sea Lamprey Attack Causes Acute Anemia and Mortality in Lake Sturgeon. *Maria S. Sepúlveda, Holly K. Patrick, and Trent M. Sutton. 24: 91–99.*

[Communication] Correlation of Parasites with Growth of Yellow Perch. *Véronique B. Cloutier, H´el`ene Gl´emet, Bastien Ferland-Raymond, Andrée D. Gendron, and David J. Marcogliese. 24: 100–104.*

Determination of the Median Lethal Dose of Botulinum Serotype E in Channel Catfish Fingerlings. *Kamalakar Chatla, Patricia S. Gaunt, Larry Hanson, Dana X. Gao, and Robert Wills. 24: 105–109.*

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[Communication] A *Marteilia*-Like Parasite in Blue Mussels Mytilus edulis in China. *Zhongwei Wang, Xin Lu, Yubo Liang, and Zheng Zheng. 24: 161–164.*

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Pond-Level Risk Factors Associated with Columnaris Disease on Mississippi Commercial Catfish Farms. *Fred L. Cunningham, S. W. Jack, David Hardin, and Robert W. Wills. 24: 178–184.*

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[Communication] Kinetics of Viral Load and Erythrocytic Inclusion Body Formation in Pacific Herring Artificially Infected with Erythrocytic Necrosis Virus. *Jolene A. Glenn, Eveline J. Emmenegger, Courtney A. Grady, Sean R. Roon, Jacob L. Gregg, Carla M. Conway, James R. Winton, and Paul K. Hershberger. 24: 195–200.*

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November 5–9, 2012	International Symposium on Fish Passages in South America	Toledo-Paraná, Brazil	www.unioeste.br/eventos/sympass/
December 4–5, 2012	13th Flatfish Biology Conference	Westerbook, CT	http://mi.nefsc.noaa.gov/flatfishbiology-workshop
December 9–12, 2012	73rd Midwest Fish and Wildlife Conference	Wichita, KS	http://www.midwestfw.org/html/call.shtml
February 21–25, 2013	Aquaculture 2013	Nashville, TN	www.was.org/WasMeetings/meetings/Default.aspx?code=AQ2013
March 26–29, 2013	Responses of Arctic Marine Ecosystems to Climate Change Symposium	Anchorage, AK	seagrant.uaf.edu/conferences/2013/wakefield-arctic-ecosystems/index.php
April 8–12, 2013	7th International Fisheries Observer and Monitoring Conference (7th IFOMC)	Viña del Mar, Chile	www.ifomc.com/
April 25–26, 2013	NPAFC 3rd International Workshop on Migration and Survival Mechanisms of Juvenile Salmon and Steelhead in Ocean Ecosystems	Honolulu, HI	http://www.npafc.org/new/index.html
June 24–28, 2013	9th Indo-Pacific Fish Conference	Okinawa, Japan	http://www.fish-isj.jp/9ipfc
July 14–20, 2013	2nd International Conference on Fish Telemetry	Grahamstown, South Africa	Contact: Dr. Paul Cowley at tagfish@gmail.com

AFS SEEKS JOURNAL EDITOR

The American Fisheries Society (AFS) seeks a scientist with a broad perspective on fisheries to serve as editor of *North American Journal of Fisheries Management* (NAJFM). Editor must be committed to fast-paced deadlines, and would be appointed for a five-year renewable term which begins January 2013. This position requires marine and estuarine fisheries expertise.

Duties include:

1. Deciding on the suitability of contributed papers, and advising authors on what would be required to make contributions publishable, using advice of associate editors and reviewers. Reviewing papers for scientific accuracy as well as for clarity, readability, and interest to the broad fisheries community;

2. Soliciting manuscrips to ensure broad coverage;

3. Setting editorial standards for NAJFM in keeping with the objectives of the publication in accordance with AFS policies, and guidance provided by the Publications Overview Committee and the NAJFM editorial board;

4. Making recommendations to enhance the vitality and prestige of the Journal.

To be considered, send a current curriculum vitae along with a letter of interest explaining why you want to be the Journal editor by e-mail to alerner@fisheries.org. To nominate a highly qualified colleague, send a letter of recommendation to the same e-mail address.

Note: Editors receive an honorarium, and support to attend the AFS Annual Meeting.

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.

Marine Fisheries Science–Quantative
Texas A&M University, Corpus Christi, TX
PhD

Closing: Until filled

Responsibilities: The Department of Life Sciences at Texas A&M University–Corpus Christi is accepting applications for a tenure-track Assistant Professor with a start date of September 1, 2013. We seek applicants in sub-disciplines of fisheries science to complement and further expand our existing Master's Program in Fisheries and Mariculture (www.fama.tamucc.edu) and affiliated Masters International Program, as well as support our rapidly growing doctoral program in Marine Biology (www.marinebiology.tamucc.edu). Review of applications will begin 15 November 2012. The position will remain open until filled.

Qualifications: Preference will be given to applicants with expertise in quantitative aspects of fisheries science with emphasis on larval/early life stages of economically important finfish and/or invertebrates. Successful applicants will be expected to demonstrate their potential to develop a vigorous, externally-funded research program. Other responsibilities will include graduate student supervision and teaching of undergraduate and graduate courses supporting the Department of Life Sciences B.S. and M.S. programs, and the joint Interdisciplinary Doctoral Program in Marine Biology.

Contact: On-line applications should be submitted electronically to the TAMUCC employment opportunities website (https://islanderjobs.tamucc.edu). Applications must include a cover letter, statement of research and teaching interests, curriculum vitae, and the names and phone numbers of four references. Please note: upon notice, finalists will be required to submit four letters of reference in PDF format, e-mailed to geri.fernandez@tamucc.edu.

Faculty Position (Open Rank) – Fisheries & Aquaculture
Univ of Wisconsin–Milwaukee, School of Freshwater Sciences
PhD

Salary: UWM offers competitive salary and startup packages, commensurate with experience.

Closing: Until filled

Responsibilities: The Fisheries and Aquaculture Professor will teach and perform applied research to solve the problems of sustainable freshwater fisheries and aquaculture with an emphasis on urban settings. Successful applicants will also have strong hands on experience and skill in the culture, husbandry, nutrition, and health of fin fish. A full announcement can be found at http://www4.uwm.edu/freshwater/jobopps/. Initial screening November 1, 2012.

Qualifications: Applicants must hold a PhD or equivalent in aquatic science, biology, aquaculture, or a closely related field.

Contact: Dr. John Janssen, Search and Screen Committee Chair at below email.

Email: jjanssen@uwm.edu

Link: https://jobs.uwm.edu/postings/10479

International Policy and Analysis
NMFS/International Affairs, MD
Permanent

Salary: Based on experience

Closing: Until filled

Responsibilities: Provide staffing and technical support for events involving the NOAA Administrator and other Department of Commerce or NOAA leadership. This will entail collecting background materials from appropriate NOAA international staff; compiling memos; writing talking points; and assisting in briefing leadership. Support NOAA's International Affairs Council Indonesia Team; including through facilitating regular meetings of the Indonesia team participants; writing meeting summary reports; liaising with the Department of State Indonesian Embassy and Desk Officers on NOAA's international agreements, responding to the NOAA Management Control Review Process and other related activities.

Email: jobs@oceanassoc.com

Link: http://oceanassoc.com/Jobs/InternationalPolicyAndAnalysis.html

Biologist III or IV
Cramer Fish Sciences, Gresham, OR
Permanent

Salary: $5,265 – $6,046 monthly, plus bonuses; excellent benefits

Closing: Until filled

Responsibilities: Team with our senior scientists to resolve a wide range of problems for salmon and sturgeon populations throughout the West Coast. Responsibilities may include project planning, project supervision, scientific research and literature review, sampling and experimental design, data collection and synthesis, database management, statistical analysis, report and paper writing, and presentations to stakeholder groups.

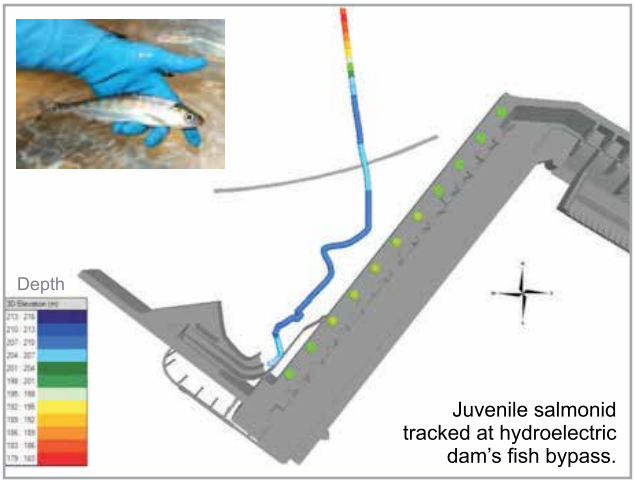
Qualifications: Master's or Doctoral degree in a fisheries related field with minimum five years experience relevant to the position; applied experience with West Coast anadromous or resident salmon, trout, or sturgeon; excellent written and verbal communication skills; excellent computer skills; and strong quantitative and analytical skills. Full job announcement at below link.

Email: hr@fishsciences.net

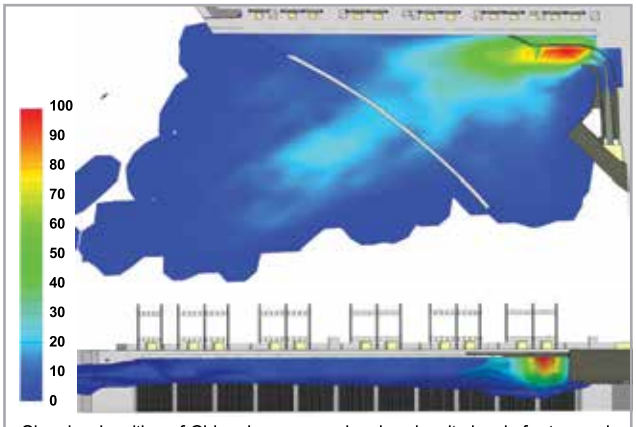
Link: http://www.fishsciences.net/about_us/jobs.php

Helping Chelan County Public Utility District Reach Their Fisheries Survival Goals

Courtesy: Chelan Co. PUD No.1



Juvenile salmonid tracked at hydroelectric dam's fish bypass.



Singular densities of Chinook passage showing density levels for top and side view during both day/nighttime hours combined at Rocky Reach Dam, spring 2011.

Rocky Reach and Rock Island dams are located on the Columbia River, near Wenatchee, WA. Both hydroelectric facilities are owned and operated by Chelan County Public Utility District No. 1 (CPUD). Since the early 1980's CPUD has been exploring ways to enhance juvenile salmon and steelhead downstream migration at their facilities. A long-term habitat conservation plan for protection of salmon and steelhead, including species not currently listed as endangered species, was developed through partnerships with federal, state, and tribal entities responsible for salmon resource management and protection.

In order to evaluate the success of measures taken to increase survival of juvenile salmonids, CPUD required empirical evidence on route specific passage for both Rocky Reach and Rock Island dams. This included measurement of fish bypass efficiency, behavior, and survival. Acoustic tag studies conducted between 2003-2011 provided results related to the development of these protocols, including the three-dimensional swimming paths for each tagged fish approaching the dam.

To reach their objectives, HTI's *Model 290 Acoustic Tag Tracking System* was used. Acoustic tag systems determined the presence/absence of tagged fish and also remotely monitored their 3D behavior in high-resolution. The acoustic tags which operated at 307 kHz have been found to be an optimum frequency with respect to detection ranges and resolution at hydropower dams. All hydrophones operated 24 h/d, 7 d/wk for nearly 3 months each spring. Without tag collisions or false-positives, the resulting acoustic tag data provided salmon and steelhead migration paths for the studies.

Data from the 2003-2011 seasons provided the scientific information for CPUD to assess whether they had effectively met the survival standards set by the utility's federal Habitat Conservation Plan. In 2010 it was determined that Rock Island dam had met the survival requirement for spring salmon and steelhead migrations. The requirements were met in 2011 at Rocky Reach dam. All of these studies were conducted using HTI's *Model 795 Acoustic Tags*.

CPUD is nationally recognized for their dedication to the environment and HTI is honored to support their research efforts. For more details about the tools and techniques used, contact HTI at (206) 633-3383 or support@HTIsonar.com.

Know where fish go.
See fish tracks in motion at
YouTube.com/HTIsonar1

Track Fish Survival, Passage & Behavior with High-Resolution 3D Acoustic Telemetry

(206) 633-3383 support@HTIsonar.com **HTIsonar.com**