Fisheries

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

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Reductionism versus Natural Rights *or* Why Is Effective Natural Resource Management So Difficult?

Bob Hughes, AFS President

AFS President Bob Hughes can be contacted at: hughes.bob@amnisopes.com

Although many North American fish populations and stocks are considered healthy or recovering, many others are not, and an ever-increasing number are considered vulnerable, threatened, or endangered (Nehlsen et al. 1991; Musick et al. 2000; Jelks et al. 2008). I believe that many of these declines are driven by scientific and management reductionism in our profession or the failure to consider fully the effects of human culture (e.g., ethics, economics, demographics) on fish and their immediate environments. Our profession tends to focus on hatchery production, harvest, habitat improvement, and occasionally land/water use. However, external drivers, cultural ethics, and provincial/state and federal policies regarding land/water use, resource consumption, and economic/population growth ultimately determine the structures and processes of the resources we study and manage (Hughes 1997; Hughes et al. 2014; Limburg et al. 2011; Czech 2013). Although we certainly can produce more fish products via aquaculture, we should not expect to be able to feed an ever-expanding human population in perpetuity. Therefore, classic scientific and management approaches that focus only on fish and their habitats are likely to be unsuccessful in protecting those resources over the long term (Lackey et al. 2006).

If we are to do a better job of managing fish and fishery resources, we must do a better job of relating to the public how ethical, economic, and demographic policies affect fish, fisheries, and their environments.

So what can we do about such disconnections? As I discussed previously, it helps to study and manage across large spatial extents and engage multiple scientific disciplines—including the social sciences (Hughes 2013). Similarly, fishery agencies would be wise to collaborate more closely with the forest, range, agriculture, mining, and water management agencies that directly and indirectly alter fish habitat and fisheries. But fishery scientists and managers will also need to contribute more to socioeconomic and environmental policy development and decisions at all governmental levels. Fortunately, university fisheries programs are increasingly requiring coursework in such areas by their students, and some employers are seeking such expertise.

Another area for continued improvement is environmental ethics. As one would expect, human ethics are homocentric and utilitarian—little different from any species that has evolved to maximize its reproductive fitness and numbers. The long-term consequences of such a narrow focus are periodic collapses (Ponting 1991; Marsh 2003; Diamond 2011). However, I remain optimistic about the future of fish species and fisheries because in the past we have periodically recognized the need for expanding the rights of humans and non-humans (Table 1). Nonetheless, such revolutionary changes typically involve considerable disruption of the privileged and the underprivileged, as well as reversals in the original intent of the mandates because of other economic drivers (e.g., Post and Hutchings 2013).

In summary, if we are to do a better job of managing fish and fishery resources, we must do a better job of relating to the public how ethical, economic, and demographic policies affect fish, fisheries, and their environments. We now have the data and analytical expertise to begin documenting those linkages, as indicated by climate change science, for example. As with climate change science, we can also expect considerable resistance to public acceptance of those scientific linkages because

Table 1. Natural rights development in Western culture.

Objective	Mandate
Endangered species	Species at Risk Act (2002)
	Endangered Species Act (1973)
	Marine Mammals Protection Act (1972)
Wild ecosystems	Fisheries Act (1985)
	Wilderness Act (1964)
	Wild & Scenic Rivers Act (1968)
	National Park Service (1916)
African Americans	Voting Rights Act (1965)
	Civil Rights Act (1957)
	Emancipation Proclamation (1863)
Native Americans	Indian Civil Rights Act (1968)
	Indian Citizenship Act (1924)
European American women	Equal Employment Opportunity Act (1972)
	Nineteenth Amendment (1920)
Livestock	Martin's Act (1822)
European American men	Declaration of Independence (1776)
English lords	Magna Carta (1215)
Israelites	Ten Commandments (2500 BP)

Adapted from Nash (1989).

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COLUMN
Letter from the Executive Director

Situational Awareness

Doug Austen

Executive Director Doug Austen can be contacted at: dausten@fisheries.org

Situational awareness is one of those skills developed by any good athlete or, for that matter, soldiers, businesspeople, or animals seeking food or preventing themselves from becoming food. A good soccer player needs to know where his teammates are and where they are going as well as the intent of the other players on the field in order to make the right play. Situational awareness is the ability to identify, process, and comprehend the critical elements of information about what is happening to the team with regards to the mission. More simply, it means paying attention to what is going on around you. There's the obvious spatial component—position and trajectory. For example, an Airbus training manual on the human component of flight operations points out that insufficient horizontal or vertical situational awareness was identified as a causal factor in 52% of flight accidents involving approaches and landings. Knowing what's going on around you keeps you alive.

In our role as an advocate for strong science in fisheries—and to fulfill our mission of the conservation of our aquatic resources—we justifiably need to focus on issues where science can play a strong role in advancing policy.

But there is also the critical issue of intent and a knowledge of the constantly developing strategy that is about to be exercised. For many people, being attentive to the circumstances around them may seem like second nature. These are the competitors who seemingly always find themselves in the position to make the right play or to benefit from an emerging business opportunity. For many of us, though, this sense of awareness needs to be strengthened through training and practice.

So how is this relevant to our current challenges?

Situational awareness has become particularly important if we are to maintain effectiveness and relevance as we move into a new strategic planning process, think about reengaging the American Fisheries Society (AFS) in Washington, D.C.–based fisheries issues, and consider how the AFS fits into a more complicated field of agencies, nongovernmental organizations (NGOs), and science societies. Even among the business of publishing books and journals, or offering other products that traditionally would have been only offered by the AFS, we must constantly be mindful.

As we move forward we will take a fresh look at the AFS and consider the layout of the playing field that surrounds us. For example, the issue of public policy development has always been a challenging topic for our membership to address in a way that properly balances the essential need to maintain scientific integrity in a decision environment of uncertainty and timely relevance. The Society has detailed guidance on advocacy (see fisheries.org/policy_advocacyguidelines), but it leaves substantial room for operating in the complex world of policy development. How do we negotiate the difficult pathway between maintaining the integrity and strength of our science while ensuring that it is utilized appropriately to make decisions? From the situational awareness perspective, in the playing field of conservation there are many other organizations that include fisheries and aquatic systems as a core part of their mission (e.g., The Nature Conservancy [TNC], Trout Unlimited, National Wildlife Federation). The AFS has already begun to develop increasingly effective and complementary working relationships with them in order to collectively attain mutual goals, and we are only at the beginning of this process. In our role as an advocate for strong science in fisheries—and to fulfill our mission of the conservation of our aquatic resources—we justifiably need to focus on issues where science can play a strong role in advancing policy. Yet, where conservation battles move into the arena of political confrontation, or where policy decisions move beyond the question of being fully informed by science, we must also look to others to carry the ball.

In one initial effort to help our leaders and our conservation partners to build a better sense of how the AFS can be effective in this effort, the Society's officers and executive staff worked with the Potomac Chapter this past October to convene an event that we called the Fisheries Leadership Dialogue. The event was basically a lunch discussion group but one that included an impressive assemblage of key fisheries leaders from many of the major federal agencies, NGOs, our state partners in the Association of Fish and Wildlife Agencies, and others in Washington. We had several goals: to enhance the strength of the community of fisheries leaders, to identify areas where the AFS can play an expanded role in advancing this community, and to start identifying key activities where the AFS should focus its efforts to move this forward. As is generally the case, the fisheries staff of the various groups represented at the Dialogue change regularly, yet we were able to meet and initiate the creation of potentially very constructive relationships with all of the guests. The value of this was recognized in the affirmation that the group would like to continue this type of dialogue on some management level

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We're All Leading the Way

Thomas E. Bigford

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Leadership is an essential character trait, whether you're working on fish, their habitat, or any other passion. Leaders develop vision, inspire colleagues, and steady our course on everything from the smallest detail to the grandest plan. They depend heavily on colleagues, many of whom will mature into the next generation of leaders. The American Fisheries Society (AFS) can help develop the next cadre of leaders, participating in new partnerships and ensuring that our hearts and eyes are focused on priority issues.

In the fish habitat world, with new threats (e.g., climate change) and old (e.g., chemicals and hydrological blockages), our community needs leaders in the usual disciplines plus others we might not have imagined in our youth. The steady diet of knowledge, debate, and re-imagination prompted by AFS chapter, division, and annual meetings serves as a great venue for identifying the traits we need in our next habitat leaders, or leaders in any other fish sector.

Though the AFS offers an unparalleled suite of leadership opportunities (all available free of charge, some elected and others yours for the asking), our home offices present valuable occasions to sharpen new perspectives and grow. Between the AFS and our day jobs, there is ample opportunity to develop the skills to represent our primary constituents: the fish. It's safe to assume both our supervisors and the fish will appreciate the effort.

Take time to read the richly illustrated report authored by past AFS President Christine Moffitt (2001) that highlights how your Society evolved to the point of being the most influential fish society in the world. That historical publication coupled with the latest news in *Fisheries* offer invigorating evidence of the roles we can all play. The AFS has the ability to influence through the knowledge of current members and also to add capacity by inviting others to help where we have insufficient numbers. I work in a fish habitat office of more than 100 individuals. Perhaps five of us are AFS members. That ratio is probably not dissimilar to that in your office. Imagine the power, the leadership, the difference we could make simply by doubling that membership count. Tripling would be incredible, but why stop there? That's another leadership opportunity.

Tantalizing as that increased capacity may be, imagine how much stronger we'd be if we aligned our fish habitat efforts with parallel work done by our wildlife partners, the water quality profession, environmental communicators, or others with shared interests? And consider the knowledge we (mostly) shun from those who live much closer to the habitats we love—the fishermen, hikers, nature watchers, beachgoers, and waterfront residents. In my habitat world, I hear regularly from Capt. Monty Hawkins (a charter boat operator in Southern Maryland), a leader among fishermen but the only one who constantly challenges me to go against the narrow norm. Monty offers his logic free of charge via occasional e-mails. I'm building the courage to pursue some of Monty's habitat and protection ideas while also listening for other local experts who can broaden my perspective. In those ways, these educated citizens are valued leaders in their own right.

Habitat is a unifying theme among most AFS members. Among units, the obvious choices for habitat banter are the Fish Habitat Section, Marine Fisheries Section, and Estuaries Section, but think about water quality, socioeconomics, fish culture, fish management, and on and on. Visit fisheries.org to see how habitat themes intersect in meeting agendas, recent publications, policy, education, and more.

New focused and visionary leaders, bolstered by talented teams with expert knowledge, promise better times for habitat of bluegills, bluefish, or blue marlin.

The AFS sits at a prime location to wield significant influence on fish habitat. Agency leaders are striving to address complex issues that I've barely covered in nearly a year of monthly columns. The AFS community needs help from new members with new ideas. Academic institutions, agencies, and the private sector need our help and vice versa. Together we can generate a stronger approach to habitat issues with increased capacity and greater success. We've made progress over the decades, but our expectations continue to exceed our accomplishments. New focused and visionary leaders, bolstered by talented teams with expert knowledge, promise better times for habitat of bluegills, bluefish, or blue marlin.

In the habitat world we have ample opportunity to engage, lead, or influence, so perhaps it is time for habitat programs to give greater thought to chemistry, physics, shifting baselines, etc. Existing mechanisms are doing well to conserve habitats, but once those habitats are protected or restored they underperform because water chemistry compromises their production, turbidity plumes stress their physiology, or underwater noise truncates migratory paths or blasts their innards. We have

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Urban Fishing

Jeff Kopaska

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The theme of this issue of *Fisheries* is urban fishing. This topic has been on the minds of fisheries managers and researchers for many years. A symposium at the 2007 Annual Meeting in San Francisco resulted in an American Fisheries Society publication: *Urban and Community Fisheries Programs: Development, Management, and Evaluation*. If the American Fisheries Society is going to invest the time and effort to publish a book, it's an important topic.

Lots of people live in urban areas, but how many of them fish? It is no secret that fishing license sales fund much of the work done by state agencies and that the number of licenses sold tends to be slipping rather than climbing in most areas of the country. Identifying the issue is easy. Identifying a solution—now that's the challenge.

Recently, I've been investigating recent and historic fishing license purchase patterns in Iowa. During this effort, I uncovered a report written over 50 years ago (1962) on hunting and fishing license sales in Iowa that analyzed human population shifts and trends and recommended strategies for increasing license sales and revenue. Then, and now, a farm pond was the most common place for people in Iowa to fish. In the report, "urban" areas were defined as communities with over 2,500 residents, which resulted in Iowa being urban by 1960. Since 1970, more than 50% of Iowans lived in towns with more than 5,000 residents. Schoolchildren with a classmate who lives on a farm or in the country are likely "rural," and this probably no longer occurs regularly in communities larger than 2,500 or 5,000 residents. In the past, people either lived in areas that had access to farms or they had generational linkages to farms. Local access to residents of farms, and the potential to have access to farm ponds, is a plausible definition of "rural" in this context. With 40 years having passed since this shift occurred, two generations of children have grown up, and the generational link to "grandma and grandpa's farm" and farm pond is now broken.

Iowa's town-based population has continued to grow since 1970. However, Iowa's total population declined from 1980 to 1990 and was stagnant from 1990 to 2000. It is a consistent and increasing trend of population transition from rural regions to populated places throughout Iowa's history that continues today. It also indicates that access to places to fish, in particular great places to learn to fish, is diminishing. Providing urban fishing opportunities is therefore a priority for engaging Iowa's population in fishing in the future.

That brings us to today and what we are doing in Iowa to enhance urban fishing opportunities. Our flagship program is our cool-weather urban trout stocking. Starting in 2004, this program expanded from 3 lakes to 17 lakes, all in or near urban areas (specifically, U.S. Census metropolitan or micropolitan statistical areas). As new lakes were added, new trout privileges were sold in areas near these lakes. Stocking the trout resulted in an initial 30% increase in trout privilege sales in the surrounding area. Furthermore, 24% of the new purchasers were new to the license database. New recruits? With a solid database of fishing license records, we could examine purchases to see that we had both new anglers and anglers new to trout fishing.

Prior to stocking, trout privilege purchasers lived an average of 18 miles away from the lake, but that dropped to 13.5 miles after stocking. We were extremely successful in garnering interest in this program. Lots of people responded, and they lived in close geographic proximity to the lake where the fish were placed. By investigating where people live in a geographic information system, we could document that there was a substantial local response to our stocking program.

Access to places to fish, in particular great places to learn to fish, is diminishing.

Sustaining fisheries programs, however, requires recruitment *and* retention. Though this urban trout program has been a recruiting success, sales data indicate that only 9% of anglers become "avid," purchasing a trout privilege for five consecutive years after local stocking commenced. By examining demographic, socioeconomic, and purchase pattern data, we can refine marketing schemes to retain more anglers, and we can review potential stocking locations to maximize local trout privilege sales.

Join in the online discussion of this topic (and other interesting stuff) on the Fisheries Information and Technology Section web site at www.fishdata.org/blog/digital-revolution-urban-fishing.

Do you have suggestions for topics or questions that need answering? Please write to Jeff at Jeff.Kopaska@dnr.iowa.gov.

Starting the Social Media Science Communication—Online and in Fisheries

Jeremiah Osborne-Gowey, AFS Social Media Guru
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Twitter: @JeremiahOsGo

Jeremiah Osborne-Gowey, an AFS member originating from the Oregon Chapter, is an ecologist interested in the intersection of science and policy, an early adopter of new technologies, and a long-time communication evangelist.

Our world is changing and, in many cases, quite rapidly. The climate, especially at the poles, is shifting. Oceans are acidifying. There are increasing conflicts over water shortages as we struggle to balance supply and demand with instream needs. The U.S. political system is in gridlock. Traditional journalism is in upheaval. Not all of the changes, however, necessarily carry negative connotations. Climate discussions now include meaningful resource reduction and adaptation planning strategies. Catch shares and protected areas are bringing an infusion of ideas (and new recruits) to ocean fisheries. The constitutional deadlock in the United States may bring much-needed changes to an antiquated system of governance that may benefit from reform. The way in which we practice (and communicate) science is becoming increasingly open and responsive to public participation.

A recent survey of our organization's leadership and membership indicated the desire for more (1) public outreach and (2) how-to instruction for using new media tools (e.g., social networking, blogging, wikis, rich media/infographics, etc.). Simple in concept yet complicated in implementation, the field of available media tools is constantly changing. Over the coming year, this column will explore some of the new and exciting ways in which science is increasingly being communicated, provide tips and insights for successful technology adoption, and offer new perspectives and strategic advice to help find the best place for you (or your organization) along the "old-shoe syndrome" to "new-toy mania" spectrum.

Won't you join me in building a bigger community of better science communicators?

Dream big. Innovate. Share.

Fisheries Leaders in Washington Gather for Historic Dialogue

Douglas Austen (standing) speaks with dialogue participants.

An unprecedented group of fisheries science, policy, and conservation leaders gathered in Washington late October 2013 to meet with our new Executive Director Douglas Austen and the officers of the society. The Fisheries Leadership Dialogue included high-ranking representatives from agencies such as the U.S. Fish and Wildlife Service, NOAA Fisheries, U.S. Forest Service, Bureau of Land Management, U.S. Geological Survey, U.S. Environmental Protection Agency, and U.S. Army Corps of Engineers, as well as leaders from nonprofit organizations such as the Pew Charitable Trusts, The Nature Conservancy, Association of Fish and Wildlife Agencies, Trout Unlimited, National Wildlife Federation, American Sportfishing Association, Izaak Walton League, and Theodore Roosevelt Conservation Partnership.

"AFS plans to be more nimble, flexible, and active on more policy and science issues," said American Fisheries Society (AFS) President Bob Hughes. "We can help foster collaboration across multiple agencies and nongovernmental organizations to address the broad-scale issues affecting our fish resources."

Some of the areas that participants noted could benefit from the AFS's scientific expertise and its role as an unbiased forum for collaboration include the effects of climate change, regional fish habitat declines, invasive species control, public outreach on the value of healthy fisheries and habitats, shrinking agency scientific staff capacity, staff training, water usage, authoritative reports on the state of fisheries resources, and prioritization of government funding.

"We're positioning AFS to move fisheries forward," Austen said. "Today's dialogue is the first step in building an ongoing collaboration in Washington to focus on common concerns, challenges, and opportunities to 'move the needle' in a positive direction for fisheries resources."

Philipp and Ditton Inducted into Fisheries Management Hall of Excellence

Brian Bohnsack, Fish and Wildlife Service.
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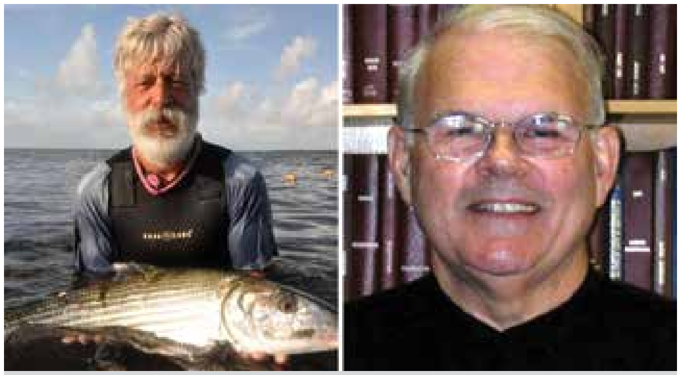

David Philipp and Robert Ditton.

Dr. David Philipp and the late Dr. Robert Ditton were inducted into the American Fisheries Society's Fisheries Management Section Hall of Excellence at the Society's Annual Meeting in September. They became the 41st and 42nd fisheries professionals inducted into the Hall since 1992.

Dr. David "Dave" Philipp, currently the principal scientist at the Illinois Natural History Survey, has been active in the Society for most of his professional career. He has served as president for the Illinois State Chapter and for the North Central Division and was the founder of the Genetics Section, serving as its first president. He has organized several symposia and workshops at various society conferences including the previous Black Bass Symposium, a 4-day event held in 2000 in conjunction with the AFS Annual Meeting. Philipp served as coeditor of the proceedings.

The late Dr. Robert "Bob" Ditton was a pioneer in the human dimensions of recreational fisheries management. Ditton's research began in the 1970s and continued until 2007 when he retired as professor emeritus from Texas A&M University. Ditton's counsel was highly sought after by top state and federal fisheries managers, nongovernmental organizations, industry leaders, and policy makers. In large part due to his efforts, federal and state fish and wildlife agencies have incorporated human dimensions techniques into the normal resource management practices.

A complete list of previous inductees and their contribution to improving our nation's fisheries resources can be found by visiting www.sdafs.org/fmsafs/awards/hall-of-excellence/virtual-hall-of-excellence.

Potomac Chapter Holds Crab Feast at AFS Headquarters

AFS Potomac Chapter members enjoy crabs and bluegrass music.

About 25 members of the Potomac Chapter gathered at AFS headquarters on Saturday, November 2 for their annual Crab Feast. With music provided by the bluegrass band Hollertown, chapter members cracked their way through two bushels of crabs fresh from Maryland's Eastern Shore. Unseasonably warm, sunny weather led to a leisurely afternoon of crab picking and networking under the fall foliage at the AFS office grounds.

Photos: www.flickr.com/photos/americanfisheriessociety/sets/72157637349530525

We Welcome Back … Our Beloved Beth Beard!

Beth Beard can be contacted at bbeard@fisheries.org.

Beth has come back to AFS headquarters to work part-time on the Global Inland Fisheries Conference (see page 10), and to work the rest of the time with Managing Editor Sarah Fox to help develop our new communications strategic plan, which will include readdressing our use of social media and other pertinent ways to get the word out about the AFS. Beth, we're glad you're back!

Cross-Sectoral Conference to Sustain Livelihoods, Food Security, and Aquatic Ecosystems

INLAND FISHERIES: A WORLDWIDE RESOURCE

Freshwater fisheries around the world are facing serious challenges. Inland fisheries are a critical food resource, especially in much of the developing world, yet agricultural, water management, and investment policies are often at odds with maintaining the long-term sustainability of inland fisheries. A lack of reliable data has hampered international monitoring and conservation programs, and management is largely confined to the local level rather than regionally strategic efforts.

In January 2015, a groundbreaking conference in Rome will for the first time address the challenges and opportunities for freshwater fisheries on a global scale. Never before have scientists, policy makers, and the international development community gathered together to discuss the food security, economic, and ecological issues associated with inland fisheries around the world. This global conference is a cross-sectoral call to raise the profile of inland fisheries and better incorporate them in agricultural, land use, and water resource planning through development of improved assessment frameworks and value estimation.

The conference will include commercial, subsistence, aquaculture, and recreational fisheries, as well as the broad context of ecosystem services provided by inland aquatic systems. The inland fisheries conference is sponsored by Michigan State University and will be held at the headquarters of the Food and Agriculture Organization of the United Nations.

CONFERENCE GOALS AND THEMES

The conference will communicate the value of inland fisheries to policy makers and the public; review assessment and valuation strategies; recommend policy commitments; provide policy makers with the means to better integrate inland fisheries into development planning processes; identify critical pathways in water resource allocation, climate change adaptation, food security and nutrition, and biodiversity conservation; develop recommendations for measurable global targets; and synthesize the conference contributions and deliberations into a white paper.

Food security and nutrition will be a major emphasis of the conference. Shown: A fish vendor at the Evening Market, Vientiane, Laos.

The conference is organized into five themes, each with its own panel chair and members:

- Biological Assessment: Explore and develop new approaches to assess the production and status of inland fish stocks and their fisheries.
- Economic and Social Assessment: Explore and develop new approaches to provide monetary and nonmonetary value to fisheries, including importance to human health, personal well-being, and societal prosperity. Showcase proven methods of investment, across various sectors, that can provide a framework to support inland fisheries and other freshwater resource use.
- Drivers and Synergies: Identify synergies between the services that can be made to increase societal gain while maintaining ecological integrity and allowing for the protection of aquatic biodiversity and fisheries production.
- Policy and Governance: Develop methods to assure that governance decisions take into account the contribution inland fisheries make to food security, human well-being, and ecosystem productivity.

MORE INFORMATION

Over the coming year in *Fisheries*, we will be exploring the conference themes and keeping you updated about conference program development. For more information, see the inland fisheries conference website at www.inlandfisheries.org or contact Beth Beard at the American Fisheries Society: beth.beard@inlandfisheries.org.

Follow us on Twitter: @inlandfisheries, Facebook: www.facebook.com/inlandfisheries, and join our discussion group on LinkedIn: www.linkedin.com/groups/Global-Inland-Fisheries-Conference-7402542.

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Edmund Hughes
Jessica Jaxion-Harm
Hannah Johnson
Kevin Klag
David Knuth
Jonathon Krieger
Kevin Kubach
Kerry Kubly
Eric Kuns
Brian Laub
Bryan Legare
Deliang Li
Arunas Liskauskas
Xiaonan Liu
Brent Lofgren
April Londo
Timothy MacDonald
Gary Marston
Ian Matchett
Jacob Mazzone
Jesse McCane
Austin Mccullough
Dusty McDonald
Tyler McFadden
Ryan McGillicuddy
Jeff McNeice
Brian Metzke
Nataly Milbradt
Mike Mischke
Salvador Mondragon
Alexandra Muhametsafina
Jennifer Munhofen
Brent Nichols
Chelsey Nieman
Maio Nishkian
Eric Nuber
Matthew Ogburn
Allysan Olds
Andrew Olson
Ben Page
Joachim Pander
Tiffany Pasco
Molly Payne
Zachary Peterson
Kevin Pitts
Thomas Pool
Gerald Porche
Kate Pospisil
David Post
Victoria Price
Jonathan Puritz
Christine Pyle
Craig Raffenberg
Haley Renze
William Richardson
Kristen Rine
Jonathan Robertson
Anne Gro Vea Salvanes
Katie Sechrist
Colin Shea
Amanda Sills
Leah Sloan
Tracey Smart
Stephanie Smedbol
William Smith
Reese Sparrow
Jason Spillett
Kayla Stampfle
Megan Stavos
Loren Stearman
Carolyn Tarpey
Gina Thompson
Olin Twitchell
Leah VandenBusch
Estevan Vigil
Donna Waller
Stephanie Warpinski
Ryan Waters
Thomas Wells
Zack Whalen
Paul Whitehead
Emily Whitney
Joshua Wisor
Michael Wolf
Tiaoyi Xiao
Kazuya Yamada
Patrick Yerkes
Suzanne Yocom
Robert Zimmer

Diversity in Fisheries

Rahel Marsie-Hazen

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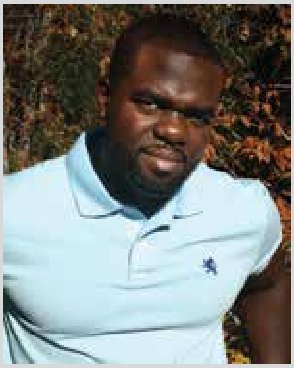
When we work together, embracing every person's unique qualities, culture, and knowledge, we simply work better. The American Fisheries Society has gone the extra mile by setting up programs, sections, awards, etc., for underrepresented persons in our society but, as President Bob Hughes said in his October 2013 "President's Hook," "We can do better." Therefore, we thought we'd introduce you to five American Fisheries Society members who have brought their own unique value to the world of fisheries. Two games of "What's the Catch," a rite of passage involving a raw scallop, a "fair dose of adventure and mishap," and fishing 100 miles off the coast of Cape Cod at 2 a.m. are just a few of the factors that made these people become important in their field.



LARRY ALADE
Research Fisheries Biologist,
Northeast Fisheries Science Center,
Woods Hole Laboratory

Larry Alade

1. What do you do for your organization?

As a fisheries stock assessment analyst, my primary role at the Population Dynamics Branch involves the development of scientific information relative to fish life history characteristics, trends in population abundance, and harvest rates to determine population status for management advice. In simple terms, it is a process that involves turning lots of data into recommendations by determining the health of the fish populations relative to being overfished or experiencing overfishing and forecasting catch levels that correspond to the long-term sustainable harvest of the stock.

2. What did you do in your last position?

Prior to my current position at the Northeast Fisheries Science Center in Woods Hole, I earned a doctoral degree at the University of Maryland Eastern Shore in the Marine Estuary and Environmental Sciences program. During this period, I was fortunate to participate in various fisheries-related internship programs at the Northeast Fisheries Science Center that further prepared me for a career in fisheries science. In 2003, I participated in a 12-week stock assessment internship program where I worked with a team of scientists and fishermen on a regional Yellowtail Flounder cooperative tagging study to evaluate migration and mortality rates in the New England region. The following year, I was accepted into the National Oceanic and Atmospheric Administration's graduate science program as a graduate scholar through the Educational Partnership Program under the National Oceanic and Atmospheric Administration's Office of Education.

3. What did you study in school?

I have a bachelor's in biology, master's in computer science and mathematics, and Ph.D. in marine estuary and environmental science with a focus in fisheries science and management.

4. What made you interested in fisheries or what got you started on this career path?

Like many other minority students who went to college in a science-related field, my original plan was to study premedicine. However, I realized that I had an interest in quantitative science, but I was not aware of related career opportunities in fisheries, nor had I been exposed to a course in ecology or aquatic sciences at the time. Being in the right place at the right time—with access to great mentorship and resources—was the genesis of my career path to fisheries science. The pivotal moment was my stock assessment internship, which exposed me to a broad range of opportunities, from working with talented scientists in the field and in the lab to working with individuals in the fishing industry on collaborative projects.

5. Can you share a defining moment in your career?

I can't truly say that I really had a major defining moment in my career. However, I think the joy of being an assessment biologist is that you can almost always find a defining moment each time you go through the process of conducting an assessment review. Depending on whether the review is an update or a benchmark, each stock and species has a unique set of challenges.

6. What have you done to get more minorities interested in fisheries sciences? What would you suggest others do to get them more engaged?

I make it a point to go back to my alma mater and give lectures. I often collaborate with the Director of Academic Programs at the Northeast Fisheries Science Center, Dr. Ambrose Jearld, and participate in educational programs in which I've mentored several talented minority students. I am the former chair of the Emmeline Moore Award, a career achievement award that recognizes individuals who have successfully supported minority students and professionals in natural resource and fishery sciences. I was also the former president of AFS Equal Opportunities Sections through which I was fortunate to contribute to various policies, programs, and symposiums to continue to enhance the representation and involvement of underrepresented groups in AFS.

7. What are some of your goals along your career path? What do you hope to achieve?

Self-satisfaction is death in science. One of the challenges we face in the world of fisheries science is how to elevate the importance of resource conservation and long-term sustainability in the minds of the general public. Though it is important to ensure economic vitality for the fishing industry, it's equally important to understand that our job contributes to ensuring food security within our national boundaries. It is crucial and incumbent upon us as scientists to continue to improve how we communicate the importance of our mission to the public.

8. What is your favorite fishery science-related story?

It was the first day of a series of day trips, tagging Yellowtail Flounder in the Gulf of Maine and I got seasick. It was also my first experience out at sea. Although embarrassing, I had the opportunity to redeem myself when the fisherman whose boat we were on challenged me to participate in a "fishery rite of passage." I was given the choice to either swim a lap around the boat or eat a raw scallop. Given my experience of not making the Olympic swimming team, the choice was clear. I did glean a huge appreciation for the challenges that men and women at sea face to make a living.

Kate Bonzon

KATE BONZON
Director of the Catch Share Design Center, Environmental Defense Fund

1. What do you do for your organization?

Most know the proverb, "Give a man a fish and you feed him for a day. Teach a man how to fish and you feed him for a lifetime." But all too often, too many people catch too much too quickly until a fishery reaches a point of collapse … and can feed no one. At the Environmental Defense Fund (EDF) I lead a research team to design ways to reverse that.

Under EDF's Oceans Program, our team trains and educates fisheries stakeholders on how to design and implement catch share programs. Our research helps fisheries managers make informed decisions on best practices to produce sustainable and profitable fisheries through performance-based conservation tools. And my team recently created a comprehensive toolkit for fisheries stakeholders. That toolkit can be accessed at catchshares.edf.org.

2. What did you do in your last position?

In my last position, I helped to conceptualize, design, and capitalize the California Fisheries Fund, which makes small business loans to West Coast fishermen at competitive rates so they can grow and improve their businesses. While working for the fund, we raised $4 million from the state of California and two private foundations to pay for low-interest loans for these fishermen.

3. What did you study in school?

I have a bachelor's in human biology and a master's in earth systems with a focus on marine conservation from Stanford. Part of my training was spent underwater and on boats at Stanford's Hopkins Marine Station in Monterey.

4. What made you interested in fisheries or what got you started on this career path?

When I was young, I spent a lot of time on Whidbey Island near Seattle, where my mom's family has vacationed in the same cabin on Useless Bay every summer since 1949. I spent my days walking the tide flats, catching crabs and fish, and exploring the beach. During my junior year of college, I took a course called "Fishing for Solutions." It was my first introduction to catch shares, marine-protected areas, and the Marine Stewardship Council, and I got hooked!

5. Can you share a defining moment in your career?

After many years of trying to explain the challenges with fisheries, I realized it would be much better to let people actually experience it for themselves. So, I started playing a fishing game using candy, cups, and toothpicks, and I asked that people "fish" in sequential "seasons" with different rules. People knock each other over, steal each other's fish, destroy their environment, and more, all while trying to "win" or get as much fish as possible. It quickly shows people their base instincts and helps them understand firsthand what works and what doesn't. I've played the game with fishermen, fishery managers, scientists, schoolchildren, policy makers, members of congress—all over the world and in many different languages. Everyone has fun and comes away with a better understanding of the challenges and solutions.

6. What have you done to get more minorities interested in fisheries sciences? What would you suggest others do to get them more engaged?

EDF has developed the Tom Graff and Howard University Fellowships, which bring leading and diverse talent to our various teams. Upon hearing about our partnership with Howard University, I applied for a communications fellow for the Catch Share Design Center team. I've mentored her along with several other fellows on my team. EDF also has a competitive environmental justice mini-grant program. Our team has applied for and received grants to translate our materials into Bahasa Indonesian and share our knowledge with interested partners in Africa and Indonesia.

7. What are some of your goals along your career path? What do you hope to achieve?

One of my first assignments at EDF was to interview fishermen on the West Coast about their fishing expertise and experience and incorporate that knowledge into policy discussions. After sitting down with several fishermen, I learned that outdated fishing regulations were hurting their businesses and preventing them from being good stewards of the resource. Since then, my main goal has been to be a driving force in the movement to rebuild the world's fisheries and keep fishermen out on the water.

8. What is your favorite fishery science-related story?

It was 2 a.m., 100 miles off Cape Cod, and several fishermen from the Georges Bank Cod Fixed Gear Sector told me to take freshly caught fish off the longline and place it into the ice hold. That's much harder than it sounds. After working 12 hours nonstop, we sat down and it was my turn to fish—for answers. We spent hours talking about the state of the world's oceans and how to improve them. Only through this kind of face-to-face interaction does the work of conservation take on real meaning and remind us why—and for whom—we go to work each day at a laptop. It breaks down barriers of geography and profession. It eliminates suspicion and confusion and reminds us that in our quest for healthy fisheries we're all sometimes, quite literally, in the same boat.

Rod Fujita

ROD FUJITA
Senior Scientist and Director of Research and Development for the Oceans Program, Environmental Defense Fund

1. What do you do for your organization?

I'm the Director of Research and Development for the Oceans Program at EDF, leading a team responsible for helping our staff overcome obstacles that they encounter as they try to improve fisheries and also for identifying important emerging ocean conservation issues and breakthrough solutions.

2. What did you do in your last position?

I was a scientist at the Harbor Branch Oceanographic Institute conducting research on the ecology of coral reefs in the Florida Keys. I lived in an abandoned lighthouse about 5 miles offshore, while studying algae and trying to understand how they adapted to that type of environment.

3. What did you study in school?

I studied biology and math at Pitzer College in California and then went on to study marine ecology with a focus on wetlands and nearshore ecosystems at the Marine Biological Laboratory in Woods Hole, Massachusetts.

4. What made you interested in fisheries or what got you started on this career path?

When I first came to EDF, I had a number of interests and became involved in a lot of different projects. When EDF formed the Oceans Program in 1990, we surveyed the scientific literature and concluded that overfishing and habitat impacts from certain kinds of gear and practices posed the greatest short-term threats to ocean biodiversity. We then brainstormed solutions with EDF economists and policy experts and found two solutions—catch shares and marine reserves—that we thought showed promise for delivering excellent conservation and economic benefits at the same time. These findings have guided my work over the last 22 years.

5. Can you share a defining moment in your career?

In the late '80s, I spent several weeks over the course of a year living in a secluded lighthouse about 5 miles off Key Largo in the Florida Keys studying the Carysfort Reef. I dove and snorkeled around the coral reef, collecting algae samples and analyzing various factors that caused different types of algae to grow in the reef. The experience deepened my relationship with the ocean, moving me beyond intellectual curiosity and into compassion for this reef, which I discovered was threatened by fishing, sewage pollution, and climate change. This compassion motivated me to transition from an academic scientist to science-based environmental advocacy.

6. What have you done to get more minorities interested in fisheries sciences? What would you suggest others do to get them more engaged?

Early in my career, Jesse Jackson, Ben Chavis, and other leaders in the growing environmental justice movement confronted the top 10 environmental organizations for failing to address the environmental struggles of minorities. EDF along with the other organizations sent an employee of color to represent their companies at the First National People of Color Environmental Leadership Summit. I represented EDF at the summit and returned with several great ideas to bring diverse perspectives to EDF's workplace and level the playing field to allow students of color the opportunity to intern with our organization.

My participation in the summit spurred me to work on the implementation of a low-income diversity fund fellowship, which is still in place at EDF today. I also helped to create an Environmental Justice Committee, which focuses on research and raising awareness of environmental issues plaguing urban areas.

7. What are some of your goals along your career path? What do you hope to achieve?

More than one billion people depend on seafood as a primary source of animal protein, and fisheries provide an important means of income for millions. In the United States, if a fishery is failing or depleted, the consequences are painful but people can often fall back on the social safety net or find other kinds of jobs. However, in developing countries, when a fishery collapses, people can lose their only livelihood or even starve. At EDF, we're starting our global push by working in countries like Belize, Cuba, Mexico, and Indonesia to improve the conservation and economic outcomes of fisheries. Before I retire, I hope that we can play an important role in alleviating poverty and food scarcity while at the same time protecting biodiversity and ecosystem health by transforming fisheries around the world.

8. What is your favorite fishery science-related story?

Several years ago, I worked with The Nature Conservancy (TNC), fishermen, and other EDF'ers to take an important step toward a new fishing future for Morro Bay. TNC bought fishing permits and boats from fishermen who were interested in getting out of the trawling business. TNC then leased the trawl permits to fishermen who agreed to fish more sustainably using hook and line gear. This combined with EDF's role in helping to get catch shares implemented for the rest of the West Coast groundfish trawl fleet has aided the fishery in bouncing back. Compliance with sustainable catch limits is now 100%, waste is near zero, 6,000 square miles of spectacular under water habitat is protected in no-trawl zones, and fishermen are getting much better prices for their fish.

Ayana Elizabeth Johnson

AYANA ELIZABETH JOHNSON
Executive Director, Programs and Strategy at the Waitt Institute

1. What do you do for your organization?

As the Executive Director for Programs and Strategy at the Waitt Institute, I provide strategy and vision for our work to empower communities to restore their oceans. This includes being the lead for public affairs, diplomacy, science, and communications.

Until recently, the Waitt Institute focused on ocean exploration, but we have undergone a major shift and now focus on partnering with communities and governments to ensure ecologically, economically, and culturally sustainable use of their ocean resources. I developed and am executing our pilot project in Barbuda (bit.ly/BHI-www), where I have been leading a broad collaboration with the goal of sustainable fisheries management and comprehensive coastal zoning (including a network of no-take sanctuaries).

2. What did you do in your last position?

Prior to the Waitt Institute, I was the Director of Science and Solutions at the Waitt Foundation. At the foundation I primarily evaluated proposals and managed grants. I sought the best ideas and leaders in ocean conservation and tried to figure out how we at Waitt could support them.

3. What did you study in school?

I studied environmental science and public policy at Harvard for my bachelor's degree and did my Ph.D. in marine biology at Scripps Institution of Oceanography at the University of California–San Diego, focused on the ecology, economics, and sociology of how to sustainably manage tropical fisheries. My research was conducted in Curaçao and Bonaire, where I interviewed more than 400 fishermen and SCUBA instructors to understand their views about the state of marine resources and potential management approaches. I also did about 300 SCUBA dives to examine ways to reduce the negative effects of fishing gears, and discovered that putting escape gaps in the corners of fish traps would reduce bycatch by 80% without hurting fishers' incomes (bit.ly/ngblog8).

4. What made you interested in fisheries or what got you started on this career path?

At 5 years old I decided I wanted to become a marine biologist. I grew up in Brooklyn, New York, far from the warm, clear waters I love, but we visited aquaria, went on a few family vacations to the Florida Keys and Bahamas, and had large fish tanks in our living room. I developed a connection to the ocean, which became stronger as I learned the ocean needed more advocates, needed more people with science backgrounds working to develop and promote policies for sustainable management.

5. Can you share a defining moment in your career?

I spent my first year of graduate school studying the dynamics of fish population recoveries within marine reserves. During that project, I realized that reserves are great when you are able to get them established and enforced, but they only make up about 1% of the ocean. Therefore, it is important to think about how to sustainably manage fishing in the other 99%. Reserves can be very effective, but they are just one of many tools for management and alone are not usually enough to sustain a fishery. I started thinking comprehensively about management solutions. For my Ph.D. research I began by studying fish trap and gill-net fisheries from an ecological perspective and then realized sustainability is less about fish and more about fishermen and communities. Since then I have focused on developing a nuanced understanding of the sociocultural contexts within which we try to manage fisheries.

6. What have you done to get more minorities interested in fisheries sciences? What would you suggest others do to get them more engaged?

Most recently, I organized a summer camp for kids in Barbuda that focused on coral reef fisheries. In the past, I have been an EnvironMentor, working with underserved Washington, D.C., high school students on science fair projects. I also simply talk to and encourage young people who express interest in fisheries to pursue those interests.

A less conventional way is by allowing my image to be used publicly if the caption states that I'm a marine biologist. I felt some initial reluctance about this, but I want to contribute to breaking down stereotypes about what a marine biologist looks like. Perhaps even just seeing a brown face in the field will encourage minority students who are interested in ocean science.

7. What are some of your goals along your career path? What do you hope to achieve?

My personal mission statement is to collect, create, actualize, and amplify the best ideas in ocean conservation. I aim to connect ideas, leaders, science, and dollars in order to make the ways humans interact with the ocean increasingly sustainable. Right now, I'm really excited about working directly with governments and stakeholders in locations where the economy is highly dependent on ocean resources to provide the support they need in order to design locally appropriate, sustainable management. If you want to see how this is going, you can find me on Twitter (@ayanaeliza) blogging for *National Geographic* (bit.ly/aej-ngs).

8. What is your favorite fishery science-related story?

My favorite stories aren't about science but about people. The stories that elder fishers tell me about the way fishing used to be—low-tech with abundant catches and a fair dose of adventure and mishap—inspire me to work toward restoring fisheries.

DAYLIN MUÑOZ-NUÑEZ
Research Associate, Environmental Defense Fund

Daylin Muñoz-Nuñez

1. What do you do for your organization?

At EDF I work on a team of researchers who look at lessons learned from successful fisheries around the world to develop sound fishery management solutions and practices. As the liaison between the research team in the United States and the teams on the ground in Mexico and Belize helping to implement catch share fisheries programs, I'm responsible for facilitating collaborative work between both teams while also providing research, training, and design support.

2. What did you do in your last position?

In my last position, I was a marine observer aboard a dredge boat. As you can imagine, animals living close to or at the bottom of the ocean like sea turtles, fish and small sharks were sometimes inadvertently captured by the dredge along with the sand. My job was to monitor the impact of dredging on endangered species, particularly sea turtles, and to identify the animals caught and report the species and number of sea turtles to the National Marine Fisheries Services. It wasn't a part of my job, but when I could, I tried to save the marine animals that were still alive, returning them back to the sea.

3. What did you study in school?

I have a B.S. in biology from the University of Havana in Cuba with a focus on marine conservation and a master's in environmental management from Duke University with a focus on coastal environmental management. While studying in Havana, I worked on the first sea turtle conservation project in mainland Cuba, collecting and analyzing data on the reproductive ecology of green sea turtles and engaging the local communities in the protection of the nests and hatchlings.

4. What made you interested in fisheries or what got you started on this career path?

I'm from a small town in the countryside in Cuba, and since I was a child I've always loved the sea. However, no one in my family owned a car, so once or twice a year, my mother, father, sister, and I would take the 3-hour bus ride to the beach. My parents always instilled in us a deep appreciation and respect for nature.

5. Can you share a defining moment in your career?

While I was studying at Duke, I was looking for an organization to collaborate with on my thesis. I was really hoping to be involved in the research projects of an organization that worked in the Caribbean and whose environmental conservation values were aligned with my own. When I learned that my university would be holding a career fair, I was thrilled to learn that EDF, an organization working to protect marine habitats in Latin America and the Caribbean, would be there. I met two experts from EDF Oceans Program and since then I have been involved with EDF's Latin America and Caribbean team.

6. What have you done to get more minorities interested in fisheries sciences? What would you suggest others do to get them more engaged?

When I arrived to the United States from Cuba, I worked at Sea Camp, a marine science education summer camp for kids in the Florida Keys, where I worked closely with a diverse group of children. It was a very hands-on experience and I was happy to help kids connect with and learn about the environment by doing as opposed to just learning in a classroom. I would like to think that the group of students I worked with, from different cultural backgrounds and ages, were inspired by what I taught them and will move forward with marine or oceans-related careers.

7. What are some of your goals along your career path? What do you hope to achieve?

I hope to become a better translator and interpreter. Specifically, I'm aiming to make fisheries science more accessible to everyone by explaining it with analogies and relevant examples from their day-to-day life. I'd like to facilitate communication and knowledge exchange among different stakeholder groups. In the same way that fishermen need to understand how their fishing effort impacts fish populations, fisheries managers need to understand the traditional ways that fishermen have managed marine resources.

8. What is your favorite fishery science-related story?

In 2010, I visited Sinaloa, Mexico, where, with EDF–Mexico team, I spoke to several fishing communities about sustainable fishing options. To emphasize the need for sustainable fishing practices, I played a game with them called, "What's the Catch?" in which players act as fishery participants, trying out different types of management approaches each round or "season." The game can be played with whatever game pieces one has on hand. To keep things interesting we played with candy. We played the first round of the game open-access style where fishery participants have zero fishing rules or regulations. Usually, it's a free for all, with players rushing to collect as much candy or "fish" as possible. After the first round, with no candy left on the table, we asked the fishermen to reflect on what happened and to provide their own ideas to make the next round a more productive fishing season. I was surprised by one fisherman who set aside a pile of candy, explaining that instead of fishing it all what they needed to do was to leave a certain amount of fish in the sea to reproduce and replenish the stock for future fishing seasons. The whole experience demonstrated once more the importance of including fishermen in finding solutions to fishery management issues.

FEATURE

A Review of Urban Water Body Challenges and Approaches: (1) Rehabilitation and Remediation

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ABSTRACT: *We review how urbanization alters aquatic ecosystems, as well as actions that managers can take to remediate urban waters. Urbanization affects streams by fundamentally altering longitudinal and lateral processes that in turn alter hydrology, habitat, and water chemistry; these effects create physical and chemical stressors that in turn affect the biota. Urban streams often suffer from multiple stressor effects that have collectively been termed an "urban stream syndrome," in which no single factor dominates degraded conditions. Resource managers have multiple ways of combating the urban stream syndrome. These approaches range from whole-watershed protection to reach-scale habitat rehabilitation, but the prescription must be matched to the scale of the factors that are causing the problem, and results will likely not be immediate because of lengthy recovery times. Although pristine or reference conditions are far from attainable, urban stream rehabilitation is a worthy goal because appropriate actions can provide ecosystem improvements as well as increased ecosystem service benefits for human society.*

Revisión de Enfoques y Retos en el Estudio de Cuerpos de Agua Urbanos: (1) Rehabilitación y Remediación

RESUMEN: *se hace una revisión de cómo la urbanización altera los ecosistemas acuáticos, así como también de las acciones que los administradores pueden tomar para remediar el problema de las aguas urbanas. La urbanización afecta los ríos a través de la alteración de procesos longitudinales y laterales que, a su vez, modifican la hidrología, hábitat y química del agua; estos efectos crean factores químicos y físicos de estrés que perturban la biota. Los ríos urbanos suelen estar sujetos a múltiples factores de estrés que colectivamente se conocen como "síndrome del río urbano" en el cual no existe dominancia de un solo factor de degradación. Los administradores de recursos naturales tienen diversas formas de combatir este síndrome. Estos enfoques van desde protección de cuencas enteras hasta rehabilitación de hábitats a gran escala, pero la prescripción debe ser consistente con la escala de los factores que están causando el problema, y es probable que los resultados no sean inmediatos dado que los tiempos de recuperación son prolongados. A pesar de que se está lejos de poder reconstruir las condiciones prístinas o de referencia, la rehabilitación de los ríos urbanos es un objetivo digno de perseguir ya que la toma de acciones adecuadas pueden lograr mejoras a los ecosistemas así como también un incremento en los beneficios que la sociedad humana obtiene de ellos.*

PREFACE

This article and its companion (Hughes et al., 2014) stem from two reports published by Oregon's Independent Multidisciplinary Science Team (IMST 2010, 2012). The IMST was established by Oregon Revised Statute 541.409 in 1997 to provide independent, impartial advice to the state on scientific matters related to the Oregon Plan for Salmon and Watersheds. Previous IMST reports and agency reviews had focused on forest and agricultural land uses, and most of the rehabilitation efforts in the state were focused on those landscapes because of their great extent. The IMST recognized, however, that (1) most Oregon citizens live in cities and rural residential areas, (2) many important salmonid streams and rivers pass through those urban areas, and (3) urban areas play a key role in salmonid rehabilitation. Therefore, IMST (2010) was written to evaluate the science and how actions in urban and rural residential areas might aid salmonid recovery and catchment condition. Following completion of IMST (2010), the IMST held a workshop composed of municipal and state environmental managers and practitioners in 2011 to help fill gaps existing between the published scientific literature and what is known and needed by professionals actively working to rehabilitate aquatic resources in Oregon urban and rural residential areas. IMST (2012) summarized what was learned at that workshop and stimulated these two *Fisheries* articles, as well as a book (Yeakley et al., 2014).

INTRODUCTION

Human societies alter water bodies, the effects of which are dependent on the relative sizes of the urban centers versus the water bodies, their industries, and the natural and historical setting of the city. Because most people now live in cities and water is critical to human health and well-being, it is vital to maintain water quality in socially, economically, and ecologically effective ways. Although ecological effects of urbanization on aquatic ecosystems are described well in the scientific literature, approaches for rehabilitating and mitigating problems have received less attention and have not been considered in a practical, integrated manner. We review and summarize various approaches for reducing the effects of current urbanization on surface waters and discuss their benefits and limitations. Our review is divided into two major sections: (1) effects of urbanization on aquatic ecosystems and (2) actions for rehabilitating aquatic ecosystems in existing urban areas.

Urbanization results in a phenomenon commonly known as the "urban stream syndrome," whereby hydrographs become flashier (i.e., increased flow variability), water quality is degraded, channels are homogenized and incised, biological richness declines, and disturbance-tolerant and alien species increase in prevalence.

EFFECTS OF URBANIZATION ON AQUATIC ECOSYSTEMS

Understanding the effects of urbanization, or any land use, on aquatic ecosystems requires consideration of local- and catchment-scale effects, as well as current and historical effects. Civilizations began with cities around 9,000 YBP in the Middle East and China and 3,000 YBP in Mesoamerica. Many were hydraulic societies that modified their aquatic systems. This review, however, focuses on cities developing within the past 200 years. With over 50% of the world's population living in cities, and trending higher, urbanization is a global phenomenon (United Nations Population Division 2006; Grimm et al. 2008); 80% of U.S. citizens live in urban areas (Coles et al. 2012). High urban population density reduces the transportation cost of goods and services, offers greater employment opportunities, and increases information exchange that supports education and cultural enrichment (Grimm et al. 2008). However, urban areas fundamentally alter aquatic ecosystems—especially their hydrology, water quality, physical habitat quality, hydrological connectivity, ecological processes, and biota (Paul and Meyer 2001; Brown et al. 2005; Walsh et al. 2005; Chin 2006; Kaye et al. 2006; IMST 2010; R. A. Francis 2012; Yeakley et al., 2014). These multifactor stressors and complex ecosystem responses are called "syndromes" (Rapport et al. 1985; Regier et al. 2013). Urbanization results in a phenomenon commonly known as the "urban stream syndrome" (Walsh et al. 2005), whereby hydrographs become flashier (i.e., increased flow variability), water quality is degraded, channels are homogenized and incised, biological richness declines, and disturbance-tolerant and alien species increase in prevalence. This syndrome may begin under even low levels of disturbance; for example, Stanfield et al. (2006) and Stranko et al. (2008) found that only 4%–9% impervious catchment cover sufficed to eliminate salmonids from Ontario and Maryland streams. Residential development also simplifies the riparian and nearshore zones of lakes by installing retaining walls and by reducing riparian vegetation, shoreline complexity, and snags (Jennings et al. 1999, 2003; T. B. Francis and Schindler 2006), which in turn alter fish and macroinvertebrate assemblages (Whittier et al. 1997; Jennings et al. 1999; Brauns et al. 2007). Watershed damage occurs because urbanization alters catchment hydrology (Groffman et al. 2003; Walsh et al. 2005), soil conditions (IMST 2010), vegetation composition and cover (Booth et al. 2002), atmospheric chemistry (Kaye et al. 2006; Grimm et al. 2008), elemental mass balances and cycling (Groffman et al. 2003; Hook and Yeakley 2005), and riparian corridors (Bryce et al. 2002; Hennings and Edge 2003; Ozawa and Yeakley 2007). These alterations result in an urban land syndrome with simplified, compacted, and more mineralized soils having lower water retention capability, increased atmospheric deposition of pollutants, and replacement of natural vegetation structure with anthropogenic structures and impervious surfaces, culminating with replacement of native biota by alien taxa tolerant of anthropogenically altered ecosystems (Grimm et al. 2008). In nine cities studied by Coles et al. (2012), these terrestrial changes consistently resulted in loss of sensitive taxa, beginning at the earliest stages of urbanization (i.e., no resistance to low levels of development). Biological degradation continued at the highest levels of urbanization studied (i.e., no exhaustion threshold), suggesting that resource managers could obtain biological benefits from any appropriate rehabilitation and mitigation measures no matter the extent of catchment urbanization.

Cities often are located on floodplains, commonly at stream junctions; therefore, engineering approaches that minimize flood effects and maintain water supplies have been ubiquitous. Thus, basin-scale flood control and water supply projects are common. Impoundments designed to capture seasonal runoff and deliver water during the dry season or to produce hydropower are often located hundreds of kilometers upstream of urban areas. Such reservoirs homogenize flow regimes, simplify geomorphology, modify stream temperatures, and disrupt processes that deliver sediment and large woody material. They also disturb fish migration timing and behavior via barriers and provide refuges for alien invasive species (Columbia Basin Fish and Wildlife Authority 1991; Ligon et al. 1995; Williams et al. 1996). Frequently, river and stream banks both far from and within cities are channelized, rip-rapped, or leveed to speed water conveyance, limit channel movement, and aid navigation (Sedell and Froggatt 1984; Florsheim et al. 2008). Such changes can impair aquatic vertebrate and macroinvertebrate assemblages far from the impoundments and channel alterations (Poff et al. 1997).

Many current urbanization conditions are affected by historical land and water uses, particularly agriculture and channel alterations. Aboriginal humans altered natural flora and fauna through harvest, fire, and agriculture, and they also built canals and ditches that likely altered aquatic biota locally (Denevan 1992, 2011; Delcourt and Delcourt 2004). Intensive hydraulic engineering projects existed centuries ago in the Americas (Marsh 1976; Helfman 2007; Walter and Merritts 2008) and millennia ago in Europe (Quintela et al. 1987) and Asia (Temple 2007). Thus, the landscapes upon which many cities are built already had been transformed by prior land uses (Harding et al. 1998; Van Sickle et al. 2004; Brown et al. 2009). However, urbanization stresses stream ecosystems to a greater degree than most types of agriculture (Steedman 1988; Wang et al. 2000; Rawer-Jost et al. 2004; Trautwein et al. 2011; Ligeiro et al. 2013). In any case, cumulative effects of land cover changes, from natural vegetation to agriculture to urban, reduce the capabilities of streams to support their native biota (Stanfield and Kilgour 2006; Stanfield and Jackson 2011; Stanfield 2012).

Since the industrial revolution, effects of urbanization accelerated, intensified, and became much more extensive (Petts 1989). Many urban streams now occur only within underground pipes or concrete canals. Urban rivers are typically channelized, rip-rapped, and leveed; littoral zones of residential lakes now have shorelines converted to docks or retaining walls; and once-dense riparian forests are converted to park-like savanna. Navigable estuaries are regularly dredged, with shoreline wetlands converted to wharfs, seawalls, and commercial enterprises. For many urban dwellers these highly altered waterscapes form their images of a typical stream, river, lake, or estuary because they are founded on what they first experienced as youths or they are the only aquatic ecosystems they know (Pauly 1995; Figure 1). However, professional fisheries biologists, aquatic ecologists, and conservationists have different images and expectations for water bodies because of the many ecosystem services they provide (Costanza et al. 1997; Ervin et al. 2012). So what can we do about it? We offer a how-to approach based on identifying root causes and their scale.

REHABILITATING EFFECTS OF EXISTING URBAN AREAS ON AQUATIC ECOSYSTEMS

In this section, we first discuss the general goals of rehabilitating aquatic ecosystems and the limitations of doing so. These limitations include the many existing physical and chemical constraints resulting from urban infrastructure, the complex interwoven types of urban pressures, and the site-scale versus catchment- or basin-scale approaches for rehabilitation. We then discuss four major rehabilitation approaches: reestablishing natural land cover, wastewater and stormwater management, recovering hydrological connectivity and geomorphic complexity, and, finally, small-scale approaches such as bank stabilization (Table 1; IMST 2010).

Figure 1. Top: Amazon Creek, Eugene, Oregon; bottom: Townline Lake, Clare County, Michigan.

The Goal Is to Restore Processes, Not Specific Habitats

The typical objective of most rehabilitation projects is short-term physical habitat improvement. However, the primary goal of restoration is not to jump in and create a habitat but to regain historical ecological structure by naturalizing ecosystem processes that support stable flow regimes, instream habitat connectivity, riparian vegetation, and water quality (Roni et al. 2002; Beechie et al. 2008). An additional goal is to make waters safe for body contact as prescribed by the Clean Water Act in the United States (U.S.C. 33 § 1251) or the Water Framework Directive in the European Union (European Commission 2000).

Of course, in most urban areas, natural processes are highly constrained by infrastructure (Carpenter et al. 2003; Booth 2005; Bernhardt and Palmer 2007), pollution sources (Paul and Meyer 2001), and substantial geomorphic alterations (Jennings et al. 1999, 2003; Brown et al. 2005; Walsh et al. 2005; Chin 2006; T. B. Francis and Schindler 2006; Kaye et al. 2006; R. A. Francis 2012). Consequently, aquatic ecosystems in urban areas cannot be restored to completely unimpaired conditions, but they can be rehabilitated to support desirable biota and water quality (National Research Council 1996; Booth 2005;

Table 1. Common site-scale rehabilitation techniques applied in urban areas.

Bank stabilization
Erosion control focused on stream banks and shorelines
Rip-rap, geotextiles, retaining walls, sea walls
Planting riparian areas and shorelines with native woody plants or grasses
Removal of alien invasive riparian plants
Hydrological connectivity
Improved fish passage at dams
Daylighting of piped streams
Dam and culvert removal and retrofitting
Rip-rap, retaining wall, and seawall removal
Levee and dike breaching and setbacks
Meander and wetland creation
Off-channel habitat and floodplain reconnection
Decreasing the amount of impervious surfaces
Hydromorphological complexity
Placement of large wood, gabions, boulders, or gravel in stream channels
Placement of large wood and brush in lakes and estuaries
Aquatic macrophyte reestablishment in lakes and estuaries
Wastewater and storm water management
Wastewater (industrial, institutional, and domestic) collection and treatment
Storm water collection, separation, and treatment
Erosion control focused on uplands
Reducing the amount of impervious surfaces
Increasing evapotranspiration and infiltration of stormwater
Reestablishing wetlands and riparian vegetation
Installing green roofs, temporary ponds, bioswales, and rain gardens

Simenstad et al. 2005; Roni et al. 2008; Coles et al. 2012). The key is to understand at what scale problems are occurring and then apply a correct prescription that matches the scale of the problem.

Storm water must be controlled at its source (i.e., the catchment), which involves protections via land-use planning and regulation rather than attempts to rehabilitate degraded channels

Know Your Scale

Urbanization alters the biota via multiple pathways operating simultaneously at multiple scales (Figure 2). For example, the presence of a city on a river may result in a local physical or chemical barrier to fish migration that also alters fish populations far from those barriers (e.g., Cooke et al. 2004; Regier et al. 2013). Conversely, well-meaning mitigation projects are implemented at the site or reach scale in streams, lakes, and rivers, when many of the limiting factors are occurring at the watershed scale (e.g., Fausch et al. 2002; Roni et al. 2002; Scott et al. 2002; Strayer et al. 2003; Wang et al. 2003, 2011; Moerke and Lamberti 2006; Beechie et al. 2010; Regier et al. 2013). This is not to say that local projects are meaningless because they can have cumulative effects, especially when it comes to watershed rehabilitation or managing stormwater (Stanfield 2012).

Typically, however, rehabilitation is planned and implemented at the site (10s to 100s of meters) or segment (1,000s of meters to kilometers) scale. Stanfield (2012) suggested that assessing multiple sites along a segment can guide when and where local rehabilitation may be effective. However, it is almost always more effective to perform rehabilitation at watershed or basin scales, with a focus on recovering natural flow regimes (e.g., Frissell and Nawa 1992; Muhar 1996; Poff et al. 1997; Booth 2005; Wohl 2005; Bernhardt and Palmer 2007; Jansson et al. 2007). Therefore, the priority actions for urban rehabilitation are to (1) protect existing upstream high-quality catchments and habitats and (2) reestablish ecosystem processes and connectivity in the altered places (especially water quality and hydrological regime), before attempting to rehabilitate specific sites lower in the watershed (National Research Council 1992, 1996; Booth et al. 2004; Booth 2005; Roni et al. 2002, 2008; Bernhardt and Palmer 2007; Beechie et al. 2008). These are also precepts proposed by McHarg (1969) and Poff et al. (1997), which are similar to recommendations by Noss (2000) for maintaining ecological integrity at regional scales. Of course, resource managers must recognize that lag times for responses may range from 1 to 100 years or longer (Roni et al. 2002, 2008; Bernhardt and Palmer 2007; Beechie et al. 2008), and results may not be evident immediately. In the following five subsections we summarize the major rehabilitation techniques and their known limitations (Table 1).

First: Rehabilitate the Watershed

Watershed rehabilitation involves two distinct issues: management of natural land cover and managing stormwater entering via rapid runoff from impervious surfaces.

Natural Land Cover

In forested ecosystems, watersheds that have experienced timber harvest or conversion to agriculture have generally higher bedloads, embeddedness, sediment loads, and less stable flows (Sutherland et al. 2002). We note that this is the natural condition for streams in dryer ecosystems (Dodds et al. 2004), but most resource managers in temperate regions would likely view achieving a high percentage of native vegetative cover within a watershed as beneficial. However, achieving that goal is challenging from multiple perspectives.

First, watersheds vary in size and complexity and span multiple social, economic, and political boundaries with different human densities, cultural values, and land uses. This makes coordination difficult and regulatory approaches problematic. The solution is often achieved through independent watershed councils that promote stewardship and coordination (e.g., Huron River Watershed Council 2013), but rehabilitating natural land cover requires participation by not only public lands managers but in some cases thousands of private landowners.

A second issue is that it is very difficult to relate specific management actions to outcomes. Most watershed rehabilitation

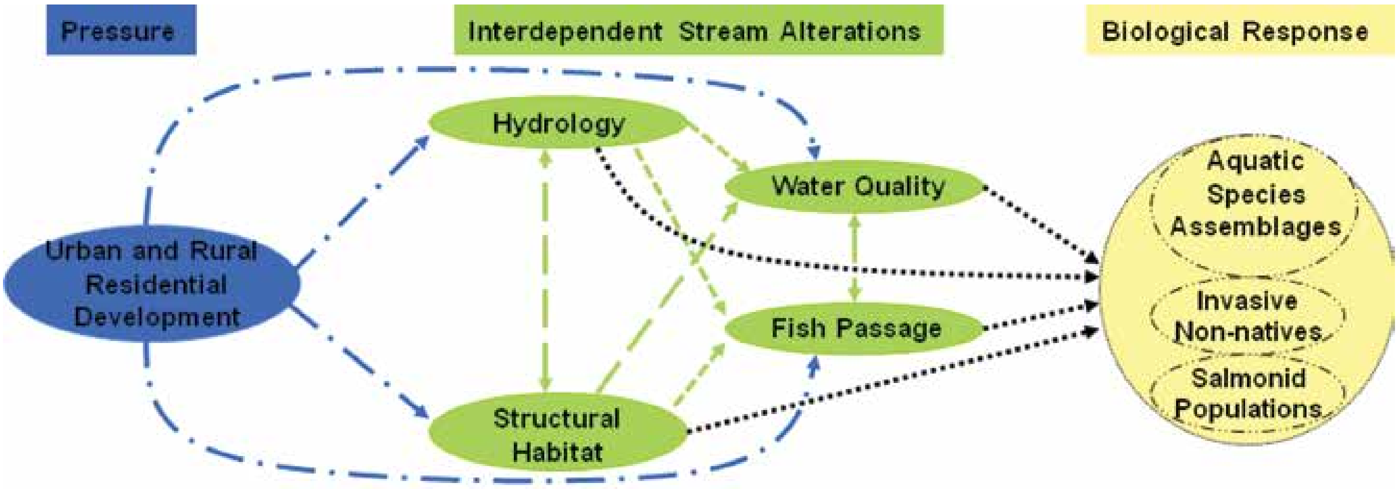

Figure 2. Interrelationships between urbanization pressures, interdependent stream alterations, and biological responses (IMST 2010).

efforts focus on encouraging riparian rehabilitation or best management practices that minimize agricultural runoff or erosion, the former because benefits are disproportionately large for the land area conserved (Quinn et al. 2001) and the latter because conversion of land to less-developed land covers is impractical (Allan 2004). However, the relationship between agricultural land cover and stream conditions is best described as highly variable with nonlinear relationships occurring at multiple scales. Some have reported that agricultural land use seems to have few effects on streams until about 30% to 50% of the watershed is farmed (e.g., Allan 2004), whereas Wang et al. (1997) reported high fish index of biotic integrity scores at sites with 80% agriculture. However, Trautman (1957) noted the demise of sensitive Ohio fishes in watersheds that experienced any loss of forest cover, and Gammon (2005) described how the Wabash River and its fish assemblages were altered soon after the land was cleared for farming. Apparently, other factors are at play, including what one uses as reference conditions and indicators.

So what are resource managers to do? It may be best to focus on riparian rehabilitation because that habitat has the most well-documented effects on stream condition (Naiman and Decamps 1997), and it also confers local habitat benefits at the reach scale (Brewer 2013). However, we note three caveats: (1) riparian rehabilitation can take many forms, depending on local physiographic conditions (a.k.a. one size fits none; Allan 2004); (2) in many watersheds extensive impervious surface coverage can override riparian services (Coles et al. 2012); and (3) extensive pipe networks can bypass riparian zones (Brewer 2013).

Storm Water

Storm water management is critical to small urban streams because runoff effects are especially severe. Some studies suggest that beyond 5%–15% urbanization diversity declines rapidly (Paul and Meyer 2001) because of the presence of impervious surfaces that result in rapid runoff (flashiness) that affects bank stability, hydrological connectivity, and hydromorphological complexity. To be effective, storm water must be controlled at its source (i.e., the catchment), which involves protections via land-use planning and regulation rather than attempts to rehabilitate degraded channels (Cairns 1989; Booth et al. 2004). Although a serious problem, there are a variety of prescriptions available.

The key to storm water management is to break the direct connection between the impervious surface and the stream (Cairns and Palmer 1995). There are a variety of available techniques: reconnecting stream channels to their floodplains, wetland and mini-natural area creation, reestablishing riparian vegetation, reducing the amount of impervious surfaces, and installation of green roofs, temporary ponds, bioswales, and rain gardens (Booth et al. 2004; Brand and Snodgrass 2010; IMST 2010; Schaeffer et al. 2012; City of Portland 2012a; Yeakley et al., 2014). These techniques function by increasing evapotranspiration and infiltration to the groundwater while reducing the volume of water routed directly into streams. Implementation of such green infrastructure also sequesters pollutants that might be flushed directly in high concentrations; however, Pataki et al. (2011) reported that bioswales may be nutrient sources depending on their management.

Storm water management has the added benefit of serving as aquatic habitat. Brand and Snodgrass (2010) determined that storm water retention ponds supported more amphibian breeding and rearing than natural wetlands, which were intermittently wet. Schaeffer et al. (2012) reported that a carefully designed and managed storm water retention pond provided habitat for 9 years for three regionally rare fish species that require clear water and dense aquatic macrophytes.

Second: Further Improve Wastewater Treatment

There is ample evidence that wastewater treatment benefits stream assemblages. In most developed nations, sewage and industrial effluent treatment have become commonplace, reducing waterborne diseases, improving water quality, providing opportunities for water-based recreation, and rehabilitating aquatic biological assemblages. Gammon (1976) and Hughes and Gammon (1987), respectively, reported only minor effects on fish assemblages exposed to treated urban wastewaters along 340 km of the Wabash River, Indiana, and 280 km of the Willamette River, Oregon—although both systems also endured agricultural pollution and channel modification. Weinbauer et al. (1980) found significantly improved water quality, fisheries, and aquatic biota in a 112-km reach of the Wisconsin River, Wisconsin, following treatment of paper and pulp mill effluents. Yoder et al. (2005) reported substantial improvement in Ohio fish assemblages following 20 years of increasingly improved urban sewage treatment. Mulvey et al. (2009) found that the major stressors on stream biotic assemblages in the Willamette Basin, Oregon, were excess temperature, riparian disturbance, and streambed instability, rather than urban sewage.

Although wastewater treatment is effective, we note that it is not universal and many rivers in developing nations suffer from severe pollution. Massoud et al. (2009) concluded that central wastewater treatment options in developing nations were inadequate because of infrastructure expense (especially collection costs); they suggested that decentralized strategies would be far more effective. However, Paulo Pompeu (Departmento de Biologia, Universidade Federal de Lavras, Lavras, Minas Gerais, Brazil, unpublished data) has found that secondary treatment of 70% of the sewage of the Belo Horizonte Metropolitan Region resulted in substantial recovery of the fish assemblage of the Rio das Velhas.

Even though most wastewater in developed nations is treated, two major problems remain. First, storm water flows (containing nutrients and toxins) can rapidly overwhelm treatment facilities, because in many cases storm water and wastewater systems are combined, and untreated water is released during storm events (Field and Struzenski 1972). Because flow separation is problematic and expensive, wet weather retrofits are often applied (Szabo et al. 2005). Second, treated wastewaters deliver untreated personal care products, pharmaceuticals, hormones, fire retardants, plasticizers, property maintenance chemicals, nanoparticles, heavy metals, solvents, and organochlorines (Dunham, 2014; Foster et al., 2014). Up to 200 of these largely unregulated and unmonitored emerging contaminants (many of which are endocrine disruptors) are released by wastewater treatment plants and in storm waters (Ritter et al. 2002). In addition, streams and lakes receiving treated wastewaters still experience increased nutrient loadings, especially where wastewaters comprise much of the flow. In any case, urban managers can become familiar with wastewater systems in their jurisdictions, implement techniques for removing untreated chemicals from the waste stream by regulation and treatment, and know how those systems are operated and their limitations.

Third: Rehabilitate Longitudinal, Lateral, and Vertical Hydrological Connectivity

Improvements in hydrological connectivity result in increased movement of water, sediment, wood, and biota longitudinally, horizontally, and vertically (Pess et al. 2005a). Dam and culvert removal—or retrofitting—improves longitudinal connectivity and fish passage and downstream movement of sediment and large wood (Pess et al. 2005b; Price et al. 2010). Most studies we reviewed have been in forested areas where fish showed rapid positive responses to such changes when those improvements were properly designed; that is, culverts were appropriate for all life stages and most flows (Beechie et al. 2008; Roni et al. 2008). However, urban dam removals and modifications also improve fish passage (Blough et al. 2004).

Improved horizontal connectivity rehabilitates floodplains through levee breaching or setbacks, rip-rap removal, meander creation, and off-channel habitat reconnection (Pess et al. 2005a). Most studies we examined have involved rural and forested streams, and the majority indicated improved physical or biological conditions (Beechie et al. 2008; Roni et al. 2008)—and some studies have found positive effects in urban environments. Levell and Chang (2008) reported physical improvements 2 years after channel restructuring relative to an urban site but found less channel and substrate stability than in a nonurban reference site. Kaushal et al. (2008) reported that a rehabilitated reach of a Baltimore, Maryland, stream had significantly lower nitrate concentrations than an unrehabilitated reach of the same stream. Daylighting (reexposing piped streams to allow flooding and riparian vegetation) has occurred in several U.S. streams, but too few have been monitored to arrive at conclusions concerning ecological effects (Bucholz and Younos 2007). The greatest challenge is that urban infrastructure may constrain such measures (Brown et al. 2009; IMST 2010), but we believe that opportunities exist in many cities that have abandoned or neglected waterfronts and riparian zones. Those areas might be rehabilitated as public green spaces within the historic floodplain (City of Portland 2012b; Yeakley et al., in press).

Vertical connectivity is the exchange between groundwater and surface water in aquatic systems, but techniques for rehabilitating vertical connectivity rarely have been evaluated (Boulton 2007). Kaushal et al. (2008) reported that groundwater in a rehabilitated Baltimore, Maryland, stream reach had significantly lower nitrate concentrations and higher denitrification rates than in an unrehabilitated reach of the same stream. Denitrification was significantly higher in reaches where rehabilitation promoted overland flooding and seepage to groundwater versus seepage in rehabilitated reaches that were unconnected to their floodplains. Groffman et al. (2003) also found that denitrification potential decreased with channel incision and lowered water tables in urban riparian zones. In addition, increased vertical and horizontal connectivity with the water body, as opposed to stream incision or lake drawdown, is necessary for rehabilitating and sustaining riparian woody vegetation versus upland vegetation (Scott et al. 1999; Groffman et al. 2003; Kaufmann et al., in press). We note that among the major rehabilitation techniques, improved hydrological connectivity frequently shows the most immediate responses in fish passage and water quality improvement.

Fourth: Improve Hydromorphological Complexity

Common hydromorphological rehabilitation techniques include placement of large wood, boulders, or gravel into stream channels. In forest streams, those alterations usually increased physical habitat complexity, but their biological effects are uncertain because of insufficient monitoring, method and stream variability, and study design flaws that make increased fish production indistinct from increased fish concentration (e.g., Roni et al. 2005, 2006, 2008; Thompson 2006; Stewart et al. 2009; Whiteway et al. 2010). In addition, urban streams experience more flashiness and poorer water quality than forest streams, which together may override hydromorphological complexity (Larson et al. 2001; Booth 2005; Brewer 2013). Most studies reviewed suggest that local rehabilitation actions have little effect. Larson et al. (2001) reported that adding large wood did not improve benthic macroinvertebrate assemblages in Washington urban streams. Gravel augmentation in a highly disturbed California river increased Chinook Salmon (*Oncorhynchus tshawytscha*) spawning activity (Merz and Setka 2004) and egg-to-alevin survival (Merz et al. 2004) but not macroinvertebrate densities (Merz and Ochikubo Chan 2005). Violin et al. (2011) found no differences between macroinvertebrate assemblages and instream physical habitat of rehabilitated versus degraded urban streams in the North Carolina Piedmont. In summary, restoration of local structural complexity is unlikely to provide benefits and unlikely to persist if flow modifications and hydrological connectivity are not also addressed (Frissell and Nawa 1992; DeGasperi et al. 2009). The rare exceptions may be cases where a stream is so degraded that all within-channel habitat is lacking, but we note that those streams are likely experiencing large-scale problems as well.

Fifth: Last and Least, Stabilize Banks

Several types of erosion control techniques (rip-rap, geotextiles, gabions, retaining walls, sea walls) are employed more to protect economically valuable infrastructure than to rehabilitate natural processes of channel and shoreline erosion and migration. Such techniques transmit the energy of moving water downstream or down current to other shorelines and river banks. Because these bank hardening techniques are directed toward infrastructure protection and typically impair biotic condition and ecological processes (Sedell and Beschta 1991), we do not emphasize them in this review.

Riparian vegetation stabilizes banks and improves conditions for sensitive fish taxa in lakes, streams, and rivers. Vegetation plantings can decrease bank erosion and increase shredder macroinvertebrate diversity (Sudduth and Meyer 2006) while decreasing solar inputs, but the magnitudes of these effects on urban fish assemblages are uncertain. In lakes, Kaufmann et al. (in press) reported that increased littoral and riparian vegetation cover complexity was associated with increased richness of eutrophication-intolerant fish species (Figure 3A) and decreased richness of eutrophication-tolerant fish species (Figure 3B). Groffman et al. (2003) and Roni et al. (2008) emphasized that riparian vegetation is more likely to persist if flow modifications and hydrological connectivity are also addressed; however, additional studies are needed to document those assumptions. In contrast, rip-rap has an opposite effect; however, more controlled and multisite studies are needed. Schmetterling et al. (2001) reported that rip-rap reduced the development of undercut banks, gravel deposits, and riparian vegetation, which provide fish cover, and Kondolf et al. (2006) indicated that rip-rap increased downstream erosion in rivers.

In summary, urban water bodies cannot be restored to predisturbance conditions, but they can be improved to support desirable biota and water quality. Rehabilitation of urban aquatic ecosystems is challenging because of multiple and interacting biophysical urban constraints, as well as continuous inputs from and interactions with urban residents. Multiple rehabilitation measures taken at the catchment scale are most effective if they focus on reestablishing ecosystem processes and rehabilitating natural vegetation, hydrological regimes, and water quality—before attempting to rehabilitate degraded instream hydromorphology at the site scale. Resource managers skilled at diagnosing the scale at which problems are occurring will be able to apply the best prescription. And in urban sites, fisheries professionals working closely with urban planners and wastewater engineers will be able to ameliorate effects of storm water.

Our review focused on rehabilitation of urban streams that had been damaged previously. Urbanization is an ongoing phenomenon, with a progressively larger proportion of humans moving into urban areas that are likely to expand. Thus, more streams are likely to become urbanized in the future. Ideally, there would be a way to prevent damage inexpensively rather than repair extensive damage expensively. We will explore that topic in Hughes et al. (2014) and point to what still needs to be learned about urban streams to make mitigation more effective, including climate change and sociological issues.

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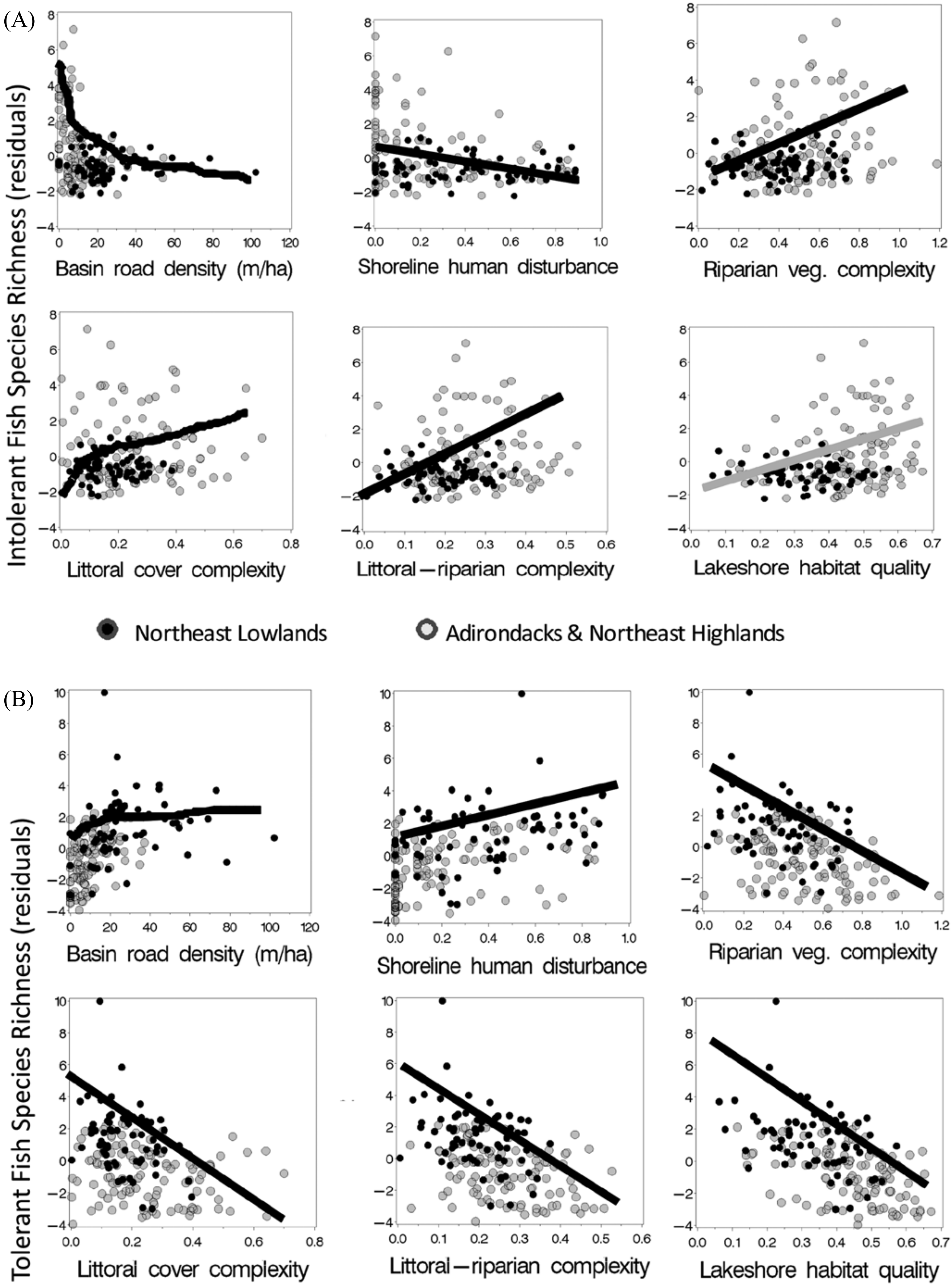

Figure 3. Responses of intolerant fish (A) and tolerant fish (B) to lake littoral and riparian condition (adapted from Kaufmann et al., in press). Richness regression residuals were used to calibrate for the effect of lake area on species richness. Lines are 95th percentile quantile regressions.

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A Review of Urban Water Body Challenges and Approaches: (2) Mitigating Effects of Future Urbanization

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ABSTRACT: *Previously we examined how degraded urban streams can be rehabilitated, with emphasis on identifying solutions that match the scale of the problems (Hughes et al. 2014). Our findings showed that rehabilitation techniques are challenging but that some environmental benefits can nearly always be obtained regardless of existing conditions. Although rehabilitation is useful in many present-day situations, biologists need to consider the future and think about ways of preventing or reducing future environmental damage. We need to reduce future damage because urban areas are likely to expand greatly over the next century; if historical patterns continue, the number and length of streams experiencing urban stream syndrome will increase, with resulting high repair costs. However, there are several ways of avoiding or mitigating damage that are not only cost effective but provide benefits to humans and urban ecosystems.*

Revisión de Enfoques y Retos del Estudio de Cuerpos de Agua Urbanos: (2) Mitigación de los Efectos de la Urbanización en el Futuro

RESUMEN: *previamente se examinó cómo los ríos urbanos degradados pueden ser rehabilitados, con énfasis en la identificación de soluciones consistentes con la escala de los problemas. Los hallazgos mostraron que las técnicas de rehabilitación si bien presentan un reto, casi siempre puede obtenerse un margen de beneficios ambientales independientemente de las condiciones imperantes. Pese a que la rehabilitación puede ser útil en muchas de las situaciones actuales, los biólogos necesitan tomar en cuenta el futuro e idear formas para prevenir o reducir el daño ambiental. Esta reducción resulta indispensable toda vez que se espera que las áreas urbanas se expandan de forma importante en el siguiente siglo; de continuar los patrones históricos, se incrementará el número y extensión de los caudales que sufren del síndrome del río urbano, lo que dará como resultado elevados costos de reparación. No obstante, existen diversas formas para evitar o mitigar los daños; formas que no solo son efectivas en términos de costos sino que también proveen beneficios tanto a los humanos como a los ecosistemas urbanos.*

MITIGATION TOOLS

In this section we discuss the major ways in which future urbanization effects can be mitigated, and explore four tools especially useful to resource managers (Yeakley et al., 2014): (1) futures analyses, (2) regulatory approaches, storm water management, and land-use planning (3) effectiveness monitoring, and (4) education. Although discussed separately and typically involving differing institutions, all four approaches are important for minimizing future urbanization impacts. In the final section, we discuss several research themes that would help us better understand urbanization and its effects on urban water bodies.

Futures Analyses

Futures analyses are maps or graphs that project future conditions based on predictive model forecasts. They have been applied in a number of fields, such as climate change (Intergovernmental Panel on Climate Change [IPCC] 2013), acid deposition (Bulger et al. 1998), biodiversity (Van Sickle et al. 2004; Vorosmarty et al. 2010), and land use (Metro 2000; Nilsson et al. 2003; Baker et al. 2004; Gude et al. 2007; Kline et al. 2007). Forecasts of urbanized conditions are useful tools for planners, decision makers, and concerned citizens, because they indicate the likely types, intensities, timing, and interactions among urbanization effects. Uncertainty within futures modeling is a function of model assumptions and the degree to which the model components accurately represent natural landscapes, socioeconomic forces, and ecosystem processes and structures. Futures forecasts suggest that urbanization is likely to have moderate to severe effects on aquatic and terrestrial ecosystems, depending on the preexisting land use and the extent and type of the urbanization (Brown et al. 2009; Van Sickle et al. 2004).

Futures forecasts are useful to resource managers because they can facilitate efficient planning. Consider three hypothetical coastal cities at river mouths. The green city has a strong tradition of local environmental protection, environmentally oriented infrastructure, and strict zoning laws that protect green space. It is predicted to grow extensively. However, the river basin is unprotected with widely varying land uses. The sprawling city only has relaxed zoning laws, an ineffective environmental department, and degraded stream quality, but most of the basin is forested and protected. The city is predicted to experience substantial manufacturing growth. The mature city has an industrial economy but little or no growth is forecast for the city or its river basin. The futures forecasts assume that the green city is likely to protect its riverine habitat locally but that benefits would be maximized by urban growth boundaries (U.S. Environmental Protection Agency [USEPA] 2004) and upstream watershed conservation to assure a historical flow regime to the downstream habitats that will likely receive protection. Should growth boundaries and basin planning not be implemented, the urban streams are predicted to erode and degrade in water quality. The sprawling city will experience modified flow regimes because of its forested basin coupled with high levels of impervious area; its streams would benefit from approaches that focus on preventing increased pollutant loadings, continued sprawl, and damage to the riparian corridor and floodplain that fall within a new urban growth boundary. The mature city would require little planning because no growth is projected; efforts there would likely focus on revitalizing the existing built environment adjacent to the water bodies and rehabilitating storm water and waste treatment systems. Such mitigating management options need to be clearly presented to decision makers and citizens so that they can make rational decisions about what they want their urban aquatic ecosystems to become.

Regulatory Approaches, Storm Water Management and Land-Use Planning

Regulatory Approaches

Although there are substantial constraints to rehabilitating existing urban areas (Brown et al. 2009; Independent Multidisciplinary Science Team [IMST] 2010; Maas-Hebner, 2014), there are many ways to mitigate the effects of future urbanization (Table 1). Smarter growth practices (Booth 2005; USEPA 2006, 2007) concentrate future development and reduce the amount of impervious surfaces at the catchment scale. One way to achieve smarter growth is to reward developers; concentrated developments can be developed at higher densities than dispersed ones, and permeable paving can be discounted when calculating open-space requirements. This results in lower impact developments that help maintain more natural hydrographs (e.g., USEPA 2007; Dietz and Clausen 2008; Godwin et al. 2008). Another technique is to create mitigation banks to protect especially sensitive areas and to offset losses elsewhere in the catchment (USEPA 2001; BenDor et al. 2009). The protection of sensitive areas can also be achieved via direct regulation/prohibition; for example, some U.S. states such as Oregon and many European countries have strong land-use planning laws and regulations that restrict development to within specific urban growth boundaries and away from sensitive areas such as riparian zones (Hennings and Soll 2010) to discourage sprawl and destruction of productive agricultural and silvicultural lands. Regulatory approaches also include strict regulations regarding the sale and discharge of contaminants designed to keep pollutants out of sewer systems rather than trying to remove them via waste treatment plants.

Futures forecasts suggest that urbanization is likely to have moderate to severe effects on aquatic and terrestrial ecosystems, depending on the preexisting land use and the extent and type of the urbanization.

Storm Water Management

One of the most promising methods of preventing future damage is via better storm water management for new developments. In some regions, new developments are required to simply keep all runoff on-site. This does not necessarily need to be an onerous burden because the technology can be as simple as cisterns or rain gardens. The engineering requirements for large developments are much greater, but all work by sequestering runoff via simple technologies and allowing it to gather in wetlands and percolate into the ground rather than enter sewer systems that also carry wastewater. This reduces the incidence of high combined flows that overwhelm treatment systems, resulting in discharge of untreated sewage. Storm water can also be retained via green roofs or through conversion of impervious surfaces to pervious ones such as permeable paving. Storm

Table 1. Common land-use planning and regulation tools for mitigating urbanization effects.

Pass and implement land-use laws and regulations
Fund and maintain infrastructure improvements
Avoid urbanizing sensitive areas (headwater catchments, lake shores, estuaries, wetlands, riparian corridors, lands with high ecological value)
Concentrate future development within existing urban areas and urban growth boundaries
Regulate the quantity and distribution of impervious surfaces at the catchment level versus the development level
Implement lower impact development techniques to reduce storm water runoff and urban water use and to augment groundwater recharge and natural levels of evapotranspiration
Institute user and development fees that reflect the ecosystem services and social and economic costs to aquatic and terrestrial ecosystems resulting from urbanization
Initiate incentives (tax reductions, subsidies, rules relaxation) for implementing practices that reduce impacts to aquatic ecosystems
Encourage market trading to meet ecological stream flow objectives and water pollution limits set by total maximum daily load regulations at the basin or catchment scale
Establish mitigation banks for sensitive areas to offset loss or deterioration of such areas elsewhere in the catchment or basin
Apply the precautionary principle when predictive modeling and ecological knowledge indicate a high likelihood of substantial negative cumulative effects
Implement adaptive management in a rigorous manner, including written plans, action thresholds, and quantitative monitoring

water systems based on such dispersed site-specific approaches can use existing low-cost technology, which is usually less expensive than designing and building large storm drain systems to deal with entire catchments. For dispersed storm water systems to work well, a large proportion of the developments within a catchment must have those systems installed, and in large stream networks it would require participation of multiple municipalities to be truly effective.

Land-Use Planning

One of the most powerful concepts to emerge in land-use planning is a growing recognition that bringing nature to cities benefits humans in many ways and improves quality of life for urban residents. City planners now make specific provisions for green space. Urban streams are obvious choices for parks, natural areas, and walking and biking trails because they often support remnant riparian habitats that have persisted despite centuries of development. Humans have a natural affinity for such landscapes containing water (Kaplan and Kaplan 1989). Another way to keep nature close to cities is the use of urban growth boundaries and greenbelt parks that enable citizens to easily access and view green areas.

To date, effectiveness monitoring has been inadequate to assess whether the ecological objectives of rehabilitation and mitigation projects have been met.

Education

Education is important for rehabilitating damaged systems, but it is also vital in terms of getting people to consider alternatives to present development patterns that can prevent future damage. It is important to educate and mobilize local government officials, residents, students, and developers regarding how their cumulative individual actions affect aquatic and terrestrial ecosystems—and what they can do together as a community to mitigate those effects (Figure 1). Support for natural resource conservation by urban residents is largely determined by what they learn about nature in the urban areas where they live (Vaske and Kobrin 2001; Coalition of Natural Resource Societies 2012; Projeto Manuelzão 2012). Dunn et al. (2006) and the Coalition of Natural Resource Societies (2012) reported that urban residents experience nature primarily in cities. Although urban dwellers' concepts of nature are strongly colored by limited snapshots of nature within their cities, exposure to nature education can induce more environmentally responsible behavior in most people (Stapp et al. 1969, 1996; Stapp 1970; Vaske and Kobrin 2001). Providing educational opportunities and promoting environmentally responsible behaviors can reduce declines in hydromorphological complexity of streams and lakes, water quality, and biota (USEPA 2004; IMST 2012). Booth et al. (2004) recommended stewardship programs regarding ways in which landowners can improve aquatic ecosystem condition. The USEPA (2004) recommended that local governments and citizen groups organize community events demonstrating the importance of environmentally responsible behavior. Citizen stream walks, stream and lake cleanups, and kindergarten through grade 12 (K–12) field and classroom instruction are annual events in many communities. The City of Prineville, Oregon, for example, included citizens in developing its wetland mitigation/storm water management plan and paid high school students to sample water quality, which expanded support from the students to their parents and then the community (IMST 2012). Oregon Trout (2005) conducts an annual program that integrates salmonid biology and stream ecology into K–12 educational curricula. The Owyhee Watershed Council (2013) conducts outdoor watershed education for all fifth graders in the region of the Owyhee River, Oregon. In Michigan, Ann Arbor Public Schools conduct annual field trips for each grade 1–6 class through use of a paid coordinator and many volunteers; each grade is focused on a different ecosystem component including urban hydrology and wastewater treatment (Ann Arbor Public Schools, 2012).

Assessing Effectiveness through Monitoring

One of the great challenges to preventing future damage is that we need better information about the present so that we can document existing conditions, measure progress or degradation, and learn more about long-term outcomes. Effective catchment planning and adaptive management involve rigorous water body and catchment assessments (Spence et al. 1996; Smith and Jones 2005; Ohio EPA 2012; Wahl et al. 2013) and identification of areas with degraded, threatened, and high-quality conditions. More rigorous ecological, social, and economic monitoring at local and catchment scales is needed to accurately evaluate the cumulative effects of urbanization and mitigation efforts (Palmer et al. 2005; IMST 2010).

Failure to Conduct Monitoring

To date, effectiveness monitoring has been inadequate to assess whether the ecological objectives of rehabilitation and mitigation projects have been met (e.g., Roni et al. 2002; Bernhardt et al. 2005; Alexander and Allan 2006; Palmer and Bernhardt 2006). Bernhardt et al. (2005) and Katz et al. (2007) reported that only 370 of 37,000 U.S. projects and 154 of 23,000 Pacific Northwest projects reported any type of monitoring. Major discrepancies have been reported between managers' evaluations of success and the quality of monitoring data needed to verify that success (Alexander and Allan 2006; Follstad-Shah et al. 2007; Hassett et al. 2007; Katz et al. 2007; Sudduth et al. 2007). Shields et al. (2003) reported that determining the effectiveness of stream rehabilitation projects is hindered by the need for long-term studies and the linear nature and spatial and temporal variability of streams, which create covariance and pseudoreplication issues. Thompson (2006) concluded that only 12 of 79 studies of fish habitat rehabilitation projects included enough data to assess their effectiveness on trout populations, and only 2 of the 12 actually demonstrated an increase in trout populations. However, through use of a meta-analysis of 211 projects, Whiteway et al. (2010) estimated that the projects increased pool area and depth, large wood, and percentage fish

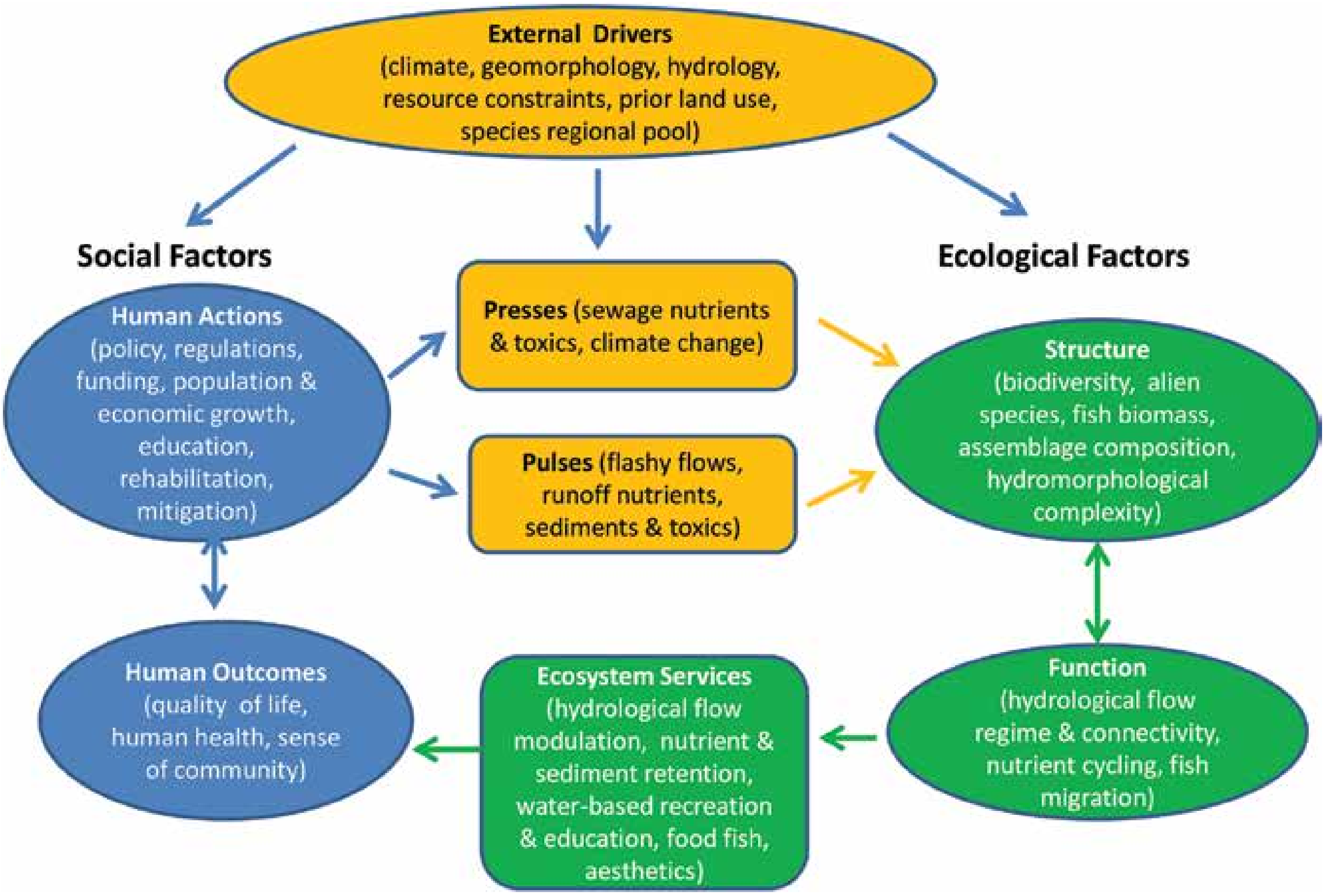

Figure 1. Interrelationships among external drivers, social factors, and ecological factors.

cover while lowering riffle area; those changes were associated with 167% and 162% increases in salmonid density and biomass, respectively.

Inconsistent Approaches to Monitoring

Although various governmental agencies and nongovernmental organizations monitor land-use effects on ecosystems, those programs largely lack common or standard survey designs and indicators, sampling protocols, database management, or reporting units. Those monitoring differences also exist within and among states and provinces. The lack of interagency coordination and standard methods hinders determining the effectiveness of rehabilitation and mitigation efforts to conserve aquatic ecosystems from the effects of urbanization (e.g., Scholz and Booth 2001; Bonar and Hubert 2002; Alexander and Allan 2006; IMST 2007, 2009, 2010; Roni et al. 2008; Hughes and Peck 2008; Stewart et al. 2009). Mulvey et al. (2009) and Stanfield (2012) reported exceptions to this pattern. Twelve different federal, state, university, and local institutions benefited from standard designs, indicators, sampling protocols, and data sharing that encompassed a total of 450 river and stream sites in the Willamette Basin, Oregon (Mulvey et al. 2009). By using a random survey design, standard sampling methods, and a shared database among Ontario biologists (Toronto and Region Conservation Authority 2013), Stanfield (2012) had 704 stream sites along a forest to urban gradient available for analyses. Both these monitoring programs indicated urbanization effects on stream and river fish and macroinvertebrate assemblages that would have been extremely difficult to assess by any single institution.

Ideally, effectiveness monitoring plans should be developed and funded at the same time as the development of rehabilitation and mitigation plans, and the monitoring should be conducted at the catchment and segment scale as well as at the site scale. The monitoring should be directed by quantifiable objectives, involve a minimum set of quantitative measurements, be conducted over multiple years before and after the proposed development or project, and be assessed via standardized, quantifiable indicators (IMST 2006; Hughes and Peck 2008; Paulsen et al. 2008). Possible indicators include decreased bed and bank erosion, increased fish passage and fish cover, decreased nutrient and toxic chemical loads and concentrations, greater numbers of desired species and fewer numbers of undesirable species, higher multimetric index scores for vertebrates and macroinvertebrates, greater cover and complexity by native riparian vegetation, and increased public acceptance of projects and regulation (e.g., Woolsey et al. 2007; Paulsen et al. 2008). Those indicators should be specific, measurable, achievable, relevant, and time-bound (Skidmore et al. 2013). Indicators should be responsive to changes in anthropogenic disturbance level and have societal value, a high signal–noise ratio (high among site variance/resampling variance), a high information–cost ratio, a standard sampling method, and a straightforward analytical approach that converts field data into a single number calibrated for natural variability (Hughes 1993; IMST 2007; Stoddard et al. 2008). One way to achieve this goal would be for local or state agencies to develop minimum monitoring standards and protocols, with data reporting to a common database, that would be agreed upon at the project permit and licensing phase.

Because insufficient funding is a commonly given reason for the lack of effectiveness monitoring, scientists need to communicate clearly to policy makers, environmental managers, and the general public what we do and do not know about the ecological effects of urbanization.

Rigorous standardized effectiveness monitoring incorporating both ecological and economic (e.g., cost–benefit analyses, ecosystem services) perspectives is needed and the data must be made publicly available (IMST 2010, 2012). Because insufficient funding is a commonly given reason for the lack of effectiveness monitoring, scientists need to communicate clearly to policy makers, environmental managers, and the general public what we do and do not know about the ecological effects of urbanization. That communication should be via electronic and print media and field demonstrations and address how we might mitigate those effects and why we need effectiveness monitoring to document results. In addition, greater communication of knowledge and research needs is necessary across scientific disciplines and governmental and nongovernmental institutions concerned with catchment condition and the quality of urban environments (IMST 2010, 2012; Figure 1). Thus, a rigorous effectiveness monitoring program should be long-term, incorporate a large sample size (50+ sites), consider implementation of before–after control–impact as well as probability-based designs at catchment scales, employ standard methods of sampling multiple indicators, and involve interagency collaboration in sampling, data sharing, and public reporting.

In summary, the key approaches for mitigating the effects of future urbanization on aquatic ecosystems are regulatory (regulation, storm water management, land-use planning) and informational (futures analyses, education, effectiveness monitoring). Regulation conserves habitats and flows directly, futures analyses are focused on using modeling to inform citizens, education uses current conditions for that purpose, and effectiveness monitoring is used to determine which mitigation and rehabilitation actions are most cost-effective. We believe that these approaches are critical for reducing urbanization impacts before they occur as opposed to trying to rehabilitate already seriously degraded systems.

MAJOR RESEARCH NEEDS

We identify five major research needs for better understanding and mitigating the effects of urbanization (Yeakley et al., 2014): (1) urban stream syndrome monitoring, (2) effects of low levels of toxic chemical mixtures, (3) key scientific relationships, (4) mitigation effectiveness, and (5) funding. The relative importance of each research need varies geographically, but all four are interrelated and necessary if we are to protect and improve aquatic ecosystems.

Monitor the Entire Urban Stream Syndrome Rather Than Any Single Stressor

The current culture of decision making based on cause and effects works poorly for urban aquatic ecosystems, where cumulative effects of multiple stressors (hydrology, hydromorphology, water quality) on biota can be extremely difficult to disentangle (Paul and Meyer 2001; Walsh et al. 2005; Hering et al. 2006; Johnson and Hering 2009; Justus et al. 2010; Marzin et al 2012b; Schinegger et al. 2013). Although some stressors such as toxic chemicals, excess nutrients, migration barriers, and altered flows may be obvious, they and many other urban stressors co-occur and have synergistic effects—as do the human actions and pressures that generate those stressors. So an alternative approach may be to better document the synergistic ecological effects of multiple stressors and monitor all major stressors, pressures, and ecological responses (i.e., the syndrome) versus any individual stressor or response. Such an approach requires a multidisciplinary research team rather than a single scientist or a single discipline (e.g., Paulsen et al. 2008; Coles et al. 2012; Macedo et al. 2012; Marzin et al. 2012a; Gardner et al. 2013).

We Need Better Understanding of Toxic Chemicals

Toxic chemicals are problematic because they represent a complex set of synergistic stressors within existing urban environments. Although aquatic life criteria exist in the United States for about 150 chemicals and many historically used chemicals have been banned, surface and groundwaters in or near urban areas often are still contaminated by toxic substances and banned toxic chemicals continue to pollute aquatic ecosystems (Kolpin et al. 2002; Sparling and Fellers 2007; Carpenter et al. 2008; Scholz et al. 2011). Conventional sewage and storm water treatments typically fail to adequately remove or neutralize many chemical contaminants, such as polychlorinated biphenyls, polyaromatic hydrocarbons, pesticides, pharmaceuticals, personal care products, metals, and radionuclides. Most of these contaminants lack aquatic life criteria and new compounds are approved for use without aquatic life criteria (Hamilton et al. 2004) or monitoring. Results from short-term laboratory toxicity tests on individual test organisms are difficult to translate into long-term community-level responses to chronic exposures (e.g., Davis 1999; Ellis 2006; Fent et al. 2006; Spromberg and Meador 2006; Liney et al. 2006), and there is little information about additive, synergistic, or antagonistic effects because most toxicity tests focus on single compounds and individual organisms (e.g., Anderson and Lydy 2002; Jin-Clark et al. 2002; Anderson and Zhu 2004; Fresh et al. 2005; Laetz et al. 2009). Toxicities also vary with the pH, hardness, ligand concentrations, and temperature of the water. Chemicals such as endocrine disruptors and radionuclides lack biological no-effect levels (Goffman and Tamplin 1979; Sheehan et al. 1999; Norris 2000; Ellis 2006), and even very low copper concentrations cause cellular damage and interfere with Salmon migration and behavior (Sandahl et al. 2007; McIntyre et al. 2012). In addition, it is extremely expensive to monitor concentrations and assess the behavior of all the toxic substances entering urban waters. The limited existing data indicate that toxic substances likely limit aquatic organisms through effects on gene mutations, reproductive physiology, sensory organs, growth, gene function, development, and behavior (Morace 2006). Resolving these threats is a substantial challenge to protecting urban water quality. Therefore, we need greater knowledge of how low levels of toxic chemicals, particularly endocrine disrupters, radionuclides, and cumulative mixes of chemicals, affect aquatic biota (e.g., Goffman and Tamplin 1979; Colborn et al. 1993, 1996; Hayes et al. 2006; Colborn 2009). In particular, we need better screening methods to assess ambient toxic concentrations, evaluations of chronic toxicities to sensitive biota, and methods of decreasing toxic chemicals in wastewater via production bans, retail sales restrictions, and cost-effective technologies that can remove small amounts of contaminants from large volumes of urban effluents. In addition, although our argument is based on aquatic ecosystem condition, there are potential benefits to humans as well via reducing exposure.

We Need Better Understanding of Key Scientific Relationships

Increased scientific understanding regarding four key research areas could increase the success of mitigation actions. The first (biotic effects of various impervious surfaces) is unique to urban areas. The other three (spatial and temporal variability in ecological effects, surface–groundwater connectivity, and climate change effects) are more general. Of the four, better understanding of how impervious surfaces and water body buffers interrelate probably could lead to the most immediate improvements in urban mitigation and rehabilitation programs. However, because of the potentially catastrophic effects of climate change on aquatic systems and urban infrastructure, improved model projections regarding the likely effects of climate change on those systems are the most critical.

We need greater understanding of how various types of impervious surfaces—particularly their proximity and connectivity to aquatic ecosystems—affect aquatic biota (DeGasperi et al. 2009; Collier and Clements 2011; Kaufmann et al., in press). If the effects of those surfaces on water bodies can be mitigated through use of better storm water management and naturally vegetated and appropriately sized water body buffers, both land values and aquatic biota could benefit (Coles et al. 2012).

As indicated by Brown et al. (2009) and Coles et al. (2012), we need to learn how urbanization affects aquatic biota in various naturally different ecoregions with distinct land-use histories. For example, stream nutrient concentrations increased with urbanization on land that was previously mostly forested, whereas nutrients were high even with low levels of urbanization on land that was previously farmed (Brown et al. 2009; Coles et al. 2012). Likewise, biological responses to urbanization were stronger in previously forested lands than in agricultural lands, presumably because the biota had been previously degraded by agriculture (Harding et al. 1998; Wang et al. 2000; Snyder et al. 2003; Van Sickle et al. 2004; Brown et al. 2009; Coles et al. 2012). Better understanding of the external drivers affecting urbanization impacts will help us in developing more reasonable and cost-effective expectations from urban rehabilitation and mitigation programs.

We need increased understanding of the connectivity of urban surface and near-surface groundwater and the degree to which groundwater is contaminated, or potentially contaminated, by urbanization. Groundwater is an important source of drinking and irrigation water in many communities, and contaminated groundwater is extremely difficult and expensive to monitor and treat effectively. In addition, near-surface groundwater eventually flows to surface waters, sometimes far from the likely contamination sources.

The limited existing data indicate that toxic substances likely limit aquatic organisms through effects on gene mutations, reproductive physiology, sensory organs, growth, gene function, development, and behavior.

Rigorous model projections are needed regarding the likely effects of climate change on drought and flood frequency in urban areas. If the increased incidence and extent of droughts predicted by Meehl et al. (2009) and the IPCC (2013) continue to occur, urban stream flows will likely become even flashier, some permanent streams will become temporary, and temporary streams will cease flowing (Stoddard et al. 2005). Urban water supply reservoir levels and dependability will be reduced. Thermal warming will reduce the ranges of cold- and coolwater fishes (e.g., Meisner 1990; Eaton and Schaller 1996; Mohseni et al. 2003; Flebbe et al. 2006; Battin et al. 2007; Bigford et al. 2010). Such changes in flows and temperatures will hinder rehabilitation and mitigation efforts, make investments in those programs economically wasteful, and may discourage efforts by conservation and angler groups. The same temperature increases that intensify droughts also increase the probability and frequency of severe storms and floods (Climate Central 2012; IPCC 2013). As revealed by recent major hurricanes, superstorms, and more frequent 100-year floods, the infrastructure damage to cities located along seacoasts and in floodplains can sum to millions or billions of dollars and major losses of life. Improved model projections can help citizens and decision makers decide between attempting to stormproof infrastructure or relocating to less hazardous landscapes, as well as how to better invest limited rehabilitation and mitigation funds.

We Need Better Understanding of Mitigation Practices

Greater knowledge is needed concerning how well low-impact development practices, water-quality trading, and mitigation banking protect aquatic biota, and the degree to which those practices are being implemented. In general, it is thought that to be successful, mitigation areas must be larger and higher quality than the disturbed areas they are replacing (Kentula et al. 2004; BenDor 2009; IMST 2010). If mitigation practices are not effective or not being implemented, we need to understand why in order to modify those practices and approaches (e.g., Graham et al. 2009; Lakoff 2002). Determining the locations and numbers of fish passage barriers in urban areas and their removal priorities can improve habitat access and longitudinal hydrological connectivity—or can retard passage of alien invasive species. Lastly, greater knowledge is needed regarding the degree to which urban land-use planning and regulations fail to protect surface waters and other sensitive areas and why such measures are inconsistently implemented (e.g., National Research Council 1992, 2002; Lakoff 2002; Ozawa and Yeakley 2007; Graham et al. 2009). In the latter regard, it may be critical to know how personal interests and population and economic growth pressures influence personal actions and political and planning processes that further environmental impairments (e.g., Limburg et al. 2011; Figure 1).

We Need Collaborative Funding and Management

Despite the greater number of citizens living in urban versus rural areas and the relatively poor condition of urban aquatic ecosystems, proportionally greater federal mitigation funds currently are allocated for agricultural, forestry, and rangeland projects and monitoring (Bernhardt et al. 2005; Roni et al. 2002, 2008), in part because of the relatively smaller fraction of land area that is urbanized (Paulsen et al. 2008; IMST 2010). It is unlikely that federal funding will suffice in the near future for urban mitigation, rehabilitation, and monitoring. In addition, water is used for many purposes in cities and elsewhere; those often-conflicting purposes and their water supply systems are managed by multiple municipal, county/district, state/provincial, and regional/federal entities. Consequently, those government entities would be wise to collaborate to a greater degree to maximize funding, mitigation/rehabilitation, and monitoring opportunities (IMST 2012). For example, in central Oregon, the Crooked River Watershed Council, City of Prineville, Oregon Department of Transportation, Oregon Division of State Lands, Oregon Department of Fish and Wildlife, and the U.S. Army Corps of Engineers worked together to mitigate wetland losses, manage storm water, and restore Steelhead (*Oncorhynchus mykiss*) populations (IMST 2012). Both the City of Portland and Washington County, Oregon, use catchment boundaries to draw utility district boundaries, regulate flood control and urban development, and manage water quality by applying utility revenues to water quality and hydrological impact areas outside the urban zone (IMST 2012). Within cities, the effects of urbanization can be mitigated best by close cooperation and planning across typically isolated city engineering, transit, utilities, parks and recreation, planning, and human resources divisions, together with citizen and university groups.

In summary, we discussed four approaches for better understanding and mitigating the aquatic effects of urbanization: (1) monitoring the entire urban syndrome rather than a single variable; (2) determining the biological effects of low levels of toxic chemical mixtures; (3) increasing our knowledge of scientific processes, particularly climate change; and (4) providing more effective and more collaborative research and mitigation/rehabilitation funding that better reflects the number of people affected by impaired waters.

CONCLUSIONS AND RECOMMENDATIONS

Although arguments can be made for implementing all of the rehabilitation, mitigation, and research actions discussed above, funding is insufficient for doing so. Therefore, we recommend focusing rehabilitation funds on improved hydrological connectivity and wastewater and storm water management because aquatic biota have been reported to be most sensitive to degraded water quality, hydrology, and connectivity. We believe that effectiveness monitoring and land-use planning and regulation are the most effective mitigation measures because they can lead to greater and multiple water body protections. Monitoring is needed to assess the effectiveness of all rehabilitation and mitigation measures; this helps us determine what did or did not work and how we can do it better. We recommend increased research on toxic chemicals and climate change modeling because the former currently threaten aquatic biota and climate change is likely to have catastrophic effects on aquatic systems and urban infrastructure in many urban and exurban areas in the future.

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From the Archives

Now, if there is some influence brought to bear that will lift this state out of the hole or rut into which it has fallen, it will be a blessing, and this committee can certainly lay plans as to how it shall be done. If they cannot get the fish commissioner to do something, they can back up the people; and the people are ready at any time. There never was a time in the history of the state of Ohio when the laws were so good for the protection of fish as this year, there is no question about that. All that Ohio needs is a few good men right behind it, men of experience and men that have been educated in the American Fisheries society, that will push Ohio to the front. I am strongly in favor of Mr. Dickerson's motion.

The President: The chair is inclined to commend your energy in increasing the number of fish in Ohio by introducing the new method of raising them on trees.

Mr. Gunckel: I had to do it, and then they called me a liar. (Laughter and applause). So I started to raise boneless fish, and I have succeeded, I am happy to say, in that also.

John E. Gunckel and President E. E. Bryant (1902): Transactions of the American Fisheries Society, 31:1, 17.

21st Century Metropolises and Fisheries

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*Petit poisson deviendra grand…**

The 21st century is confronted with a major challenge: cities are growing fast—very fast. Population is moving very quickly from rural areas to urban areas, at a rate of 250,000 people every day. That is the size of a medium city. This means that we have to build a medium city for approximately 80,000 families every day. This migration is taking place toward the large metropolitan areas and their subsidiary medium-size satellite cities. Metropolises around the world are growing very fast, some at a rate of 5% every year. That means that their populations double in size every 14 years. Imagine if you had to double the size of New York or Paris or Tokyo, to build that city again and again every 14 years.

Why is this happening? Because metropolises and urban life offer prospects and hope to the incomers. The poor, even the very poor, are better off in the cities (even if that is sometimes difficult to believe after we see the slums in Asia, Africa, Latin America, etc.). But hope is the thrust—hope of better living, amenities, economic opportunities, safety, education, health, opportunities.

Why do the metropolises offer opportunities and growth? They are in strategic locations. Metropolises compare to normal cities because they are on the border between two ecosystems: land and sea, river crossings and mountain ridge passages, etc. Among those, the land–sea comparative location advantage prevails. And when we say land–sea interaction, we are speaking of fisheries.

If those metropolises have a fisher village origin (i.e., New York), their wealth comes out of the access to markets and moving their goods into commerce. This original fisheries-bound activity soon moves into food transformation (preservation) and commercialization. The commercial networks and the industrial base allow for other complementary activities exploiting the turning point of commercial routes into a regional, national, and global economic network.

The fishery-bound activity might remain. There will still be an important fish market platform, like Tokyo or Sidney. Madrid is a very special case. It is a dry land fish market. A fish market in the middle of the desertification-bound land of the Iberian Peninsula plateau: the Meseta—is the second largest fish market (Mercamadrid) in the world after Tokyo. It was founded in the center of Spain to control first the national peninsula in a newly unified country (1492) and then to control the Latin American Empire. Madrid is 400 km away from the seas that surround 80% of the Iberian Peninsula—the Mediterranean to the east and south, the Atlantic to the west and north—so all types of fish and seafood are available to Madrid.

When Madrid was declared the new capital of Spain (1582), the Empire of Philip II built an extensive system of roads to link the city to the four cardinal points of the sea's outskirt territories of the kingdom. These are the same highways (once small roads) that the fish trucks take during the night in order to bring the daily catch to be auctioned in the seaports at 8 p.m. in the Madrid market. By 4 a.m., the catch can be found in Mercamadrid, with people having them for lunch in the restaurants and at family gatherings. The Mercamadrid Market was built in 1982, to replace the Legazpi Market (1935), to replace La Cebada (16th century), to replace the market in the main Guadalajara (River of Stones in Arabic) Gate of the 900's Arab Madrid, before the Christian expansion made it the central Plaza Mayor. This succession of markets in time, size, and location follow a perfect exponential curve encompassed with the growth of a village into a metropolis. Madrid has been a fish market since medieval times, when salted fish and marinated octopus were transported in by the Maragatos as a transport-specialized ethnic group as far back as Roman times.

Some metropolises built around strategic locations are fish bound. But the fishing activity will give rise to complementary activities and productions. To become a worldwide metropolis, fishing will be removed, because the limited added value of fishing activities will not grow the wealth of a metropolis. Higher value-added activities will be sought after. There might still be a fisher market hub, controlling the dealings between supply and demand, but not providing the product only. Fisheries might be at the origin of their strategic location and wealth development, but at a certain point there is the shift from economic primary sector into secondary, tertiary, and even quaternary financial economies.

Small fishery villages will become metropolises, comparative location and collective intelligence allowing.

Article written by Pedro B. Ortiz, author of The Art of Shaping the Metropolis, *published by McGraw Hill, 2013 (www.ShapingTheMetropolis.com). Ortiz is also a consultant to the World Bank.*

* *French saying: "Petit poisson deviendra grand, pourvu que Dieu lui prête vie" (Small fish will grow God's allowing)*

JOURNAL HIGHLIGHTS

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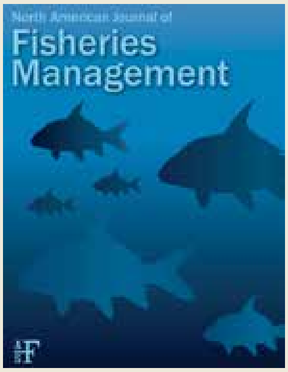

[Management Brief] Venting and Reef Fish Survival: Perceptions and Participation Rates among Recreational Anglers in the Northern Gulf of Mexico. *Steven B. Scyphers, F. Joel Fodrie, Frank J. Hernandez Jr., Sean P. Powers, and Robert L. Shipp*. 33:1071–1078.

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[Management Brief] Effects of Fixed and Fluctuating Temperature on Hatch of Round Whitefish and Lake Whitefish Eggs. *Paul H. Patrick, Elaine Chen, Jason Parks, Jennifer Powell, J. S. Poulton, and Cherie-Lee Fietsch*. 33:1091–1099.

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[Management Brief] Spatial and Temporal Variation in Efficiency of the Moore Egg Collector. *Thomas A. Worthington, Shannon K. Brewer, and Nicole Farless*. 33:1113–1118.

Evaluation of Transmitter Application Techniques for Use in Research of Adult Eulachon. *Kyle C. Hanson and Kenneth G. Ostrand*. 33:1119–1124.

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Effects of Flow Reduction on a Whitespotted Char Population in a Japanese Mountain Stream. *Tomoyuki Nakamura*. 33:1142–1148.

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[Management Brief] Tributary Spawning by Endangered Colorado River Basin Fishes in the White River. *P. Aaron Webber, Kevin R. Bestgen, and G. Bruce Haines*. 33:1166–1171.

Efficacy of AQUI-S 20E as a Sedative for Handling and Cortisol Suppression in Pallid Sturgeon. *Carlin M. Fenn, David C. Glover, and Brian C. Small*. 33:1172–1178.

[Management Brief] Physiological Responses of Adult Rainbow Trout Experimentally Released through a Unique Fish Conveyance Device. *Matthew G. Mesa, Lisa P. Gee, Lisa K. Weiland, and Helena E. Christiansen*. 33:1179–1183.

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[Management Brief] The Rapid Upstream Migration of Pre-Spawn Lake Sturgeon following Trap-and-Transport over a Hydroelectric Generating Station. *C. A. McDougall, C. L. Hrenchuk, W. G. Anderson, and S. J. Peake*. 33:1236–1242.

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Habitat, Fish Species, and Fish Assemblage Associations of the Topeka Shiner in West-Central Iowa. *Bryan D. Bakevich, Clay L. Pierce, and Michael C. Quist*. 33:1258–1268.

Spawning Success of Bull Trout Transported above Main-Stem Clark Fork River Dams in Idaho and Montana. *Patrick W. DeHaan and Shana R. Bernall*. 33:1269–1282.

Modeling Population Dynamics and Fish Consumption of a Managed Double-Crested Cormorant Colony in Minnesota. *Douglas W. Schultz, Andrew J. Carlson, Steve Mortensen, and Donald L. Pereira*. 33:1283–1300.

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they threaten the status quo—just as the expansion of natural rights did for other underprivileged entities outlined in Table 1.

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of future such events. We also explored key issues where the unique role of the AFS can add value to the current suite of fisheries issues. These issues included the convening of legislative briefings on key concerns, the critical need to support development of policy expertise and exposure in students at the undergraduate and graduate levels and faculty as well, and the identification of key AFS policy issue updates and new policies that reflect the always changing set of aquatic conservation issues that we must address. By all measures, and keeping in mind that only a very finite agenda can be addressed in such a short event, the Dialogue was a good first event and the AFS will continue to seek new ways in the future to enhance our relevance and effectiveness on behalf of our fisheries resources.

Continued from page 5

anoxic dead zones near the nation's largest wetlands, with huge implications to shrimp and other valued species. We need to worry more about water and sediment chemistry, ambient vessel noise, grander insults from blasting bedrock in harbors or fracking under trout waters, or sediment loads carrying toxic chemicals. Those issues and others may now be more important than coastal fills and docks. Maybe.

The AFS could assist with this awakening, by fostering a new cohort of habitat professionals. Maybe trade a few wetland ecologists for more acousticians—or maybe several coastal geomorphologists who think about entire streams rather than one aspect of complex watersheds. And we mustn't forget about organic chemistry and genetics so we can grasp what's happening with endocrine disrupters, sexual dimorphism, and population changes. While we ponder the next set of priorities, think also about leadership styles. They vary mightily from academia to government, from science to policy, and from local to international. Again, there's something for everyone.

Become active! Consider offering your skills through leadership positions, regardless of your technical niche. Strive to master Robert's Rules as you did those college ichthyology texts or nautical charts of your favorite sampling station or fishing hole. Deepen your leadership portfolio in your office, where employers offer equally diverse options. Remind your colleagues of how the AFS helps to lead the way. And because we all can't—and shouldn't—lead on every task, dedicate time to learning how to be more effective team members—how to challenge without threatening, when to offer game-changing facts, and how to assemble interdisciplinary teams. Just think about the prospects. The opportunities are boundless. So are the needs.

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CALENDAR
Fisheries Events

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

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

More events listed at www.fisheries.org

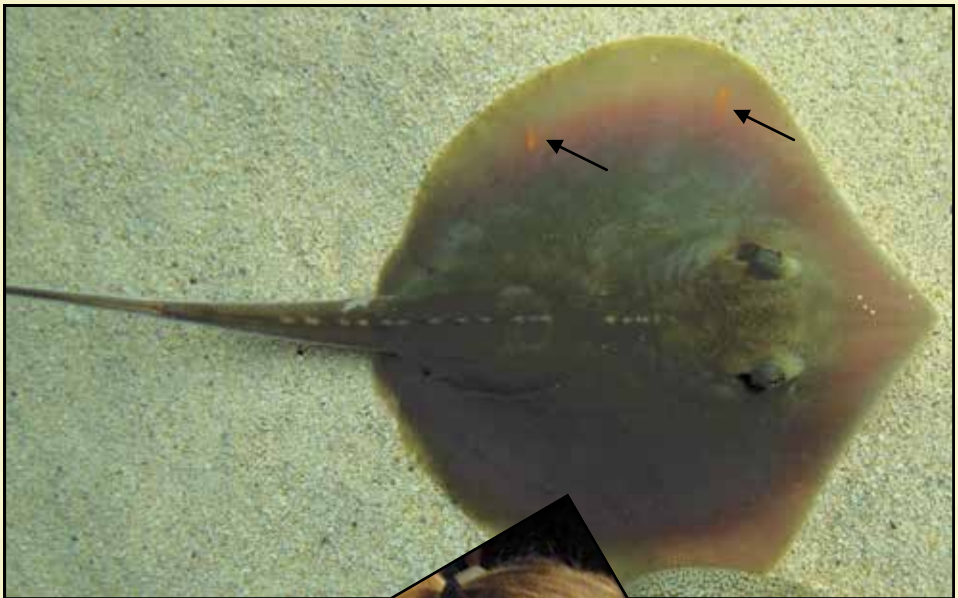
DATE	EVENT	LOCATION	WEBSITE
January 22, 2014	Southen New England Chapter's Winter Meeting	Hadley, MA	snec-fisheries.org
January 22–26, 2014	Southern Division Spring Meeting	Charleston, SC	sdafs.org/meeting2014
January 26–29, 2014	K-State Student Subunit of AFS/Midwest Fish and Wildlife Conference	Kansas City, MO	k-state.edu/ksuafs/events.shtml
January 29–31, 2014	Texas Aquaculture Association 44th Annual Conference and Trade Show	Fredericksburg, TX	texasaquaculture.org
February 4, 2014	2014 Annual Meeting, Ohio Chapter of the American Fisheries Society	Columbus, OH	anthony.sindt@dnr.state.oh.us
February 5–7, 2014	Annual Meeting of the New York Chapter	Geneva, NY	newyorkafs.org
February 9–12, 2014	Aquaculture America 2014	Seattle, WA	
February 11–13, 2014	Georgia Chapter AFS Annual Meeting	Athens, GA	gaafs.org
February 18–20, 2014	Florida Chapter Meeting	Ocala, FL	sdafs.org/flafs
February 24–26, 2014	Michigan Chapter Annual Meeting	Holland, MI	www.fisheriessociety.org/miafs/upcoming_meet.html
February 25–27, 2014	Wisconsin Chapter Meeting	Green Bay, WI	wi-afs.org
February 22–26, 2014	Water Reuse for Fish Culture - The Conservation Fund's Freshwater Institute	Wenatchee, WA	www.ncwctc.com
March 27–31, 2014	Japanese Society of Fisheries Science	Hakodate, Hokkaido, Japan	
April 7–12, 2014	The Western Division Meeting's 2nd International Mangroves as Fish Habitat Symposium	Mazatlan, Mexico	fishconserve.org/email_messages/Mangrove_Symposium.html
May 19–23, 2014	AFS Piscicide Class	Logan, UT	fisheriessociety.org/rotenone/Piscicide Classes.htm or sjohnston@fisheries.org
June 7–11, 2014	World Aquaculture Adelaide 2014	Adelaide, South Australia	
July 7–10, 2014	Fisheries Society of the British Isles Meeting & Call for Papers-Integrated Perspectives on Fish Stock Enhancement	Hull, England	fsbi.org.uk
July 30–August 3, 2014	American Society of Ichthyologists and Herpetologists Annual Conference	Chattanooga, TN	asih.org/meetings
August 3–7, 2014	International Congress on the Biology of Fish	Edinburgh, United Kingdom	icbf2014.sls.hw.ac.uk
August 17–21, 2014	AFS Annual Meeting 2014	Québec City, Canada	afs2014.org
August 17–21, 2014	38th Annual Larval Fish Conference (AFS Early Life History Section)	Québec City, Canada	larvalfishcon.org
August 31–September 4, 2014	AFS Fish Health Section – International Symposium on Aquatic Animal Health (ISAAH)	Portland, OR	afs-fhs.org/meetings/meetings.php
February 19–22, 2015	Aquaculture America 2015	New Orleans, LA	
May 26–30, 2015	World Aquaculture 2015	Jeju Island, Korea	
February 22–26, 2016	Aquaculture 2016	Las Vegas, NV	
February 19–22, 2017	Aquaculture America 2017	San Antonio, TX	

From the Archives

It seems to me there is one matter which this association has always neglected and that is the matter of creating a public sentiment in favor of fish culture. We began in Michigan a year and a half ago in a systematic way to educate our people in the state in the interest of fish culture; we have already profited by it; it is a matter that has never been discussed by this association, a matter that has never been taken up, and we ought to devise some way of systematically educating the public in favor of fish culture. Every state where fish culture is carried on to any extent needs attention in that direction. When a farmer comes to the legislature, if fishing in his immediate vicinity is of no great importance, he looks on raising little fish as child's play; he votes against the appropriation because he does not see any need for the work in his own neighborhood; he takes no interest in the matter. The opposition in our legislature comes from those gentlemen who live in districts where there is no water in their immediate vicinity and where they derive no direct benefit near their homes from an appropriation in the interests of fish culture; and for that reason, to properly conduct the work (and we cannot conduct it properly unless we get sufficient appropriations with which to conduct it) it is necessary, in my judgment, to begin in a systematic manner to make public sentiment in the interests of fish culture; and I want to suggest that that matter be discussed here so far as it possibly can, and I will offer a motion that the chair appoint a committee to recommend at our next meeting the best method or methods of interesting the public and creating public sentiment in favor of fish culture.

F.B. Dickerson (1902): Transactions of the American Fisheries Society, 31:1, 14.

Tracking Zoo Animals



Like so many zoos across the United States, the Point Defiance Zoo & Aquarium in Tacoma, WA has a mission to promote and conserve wild animals, both in their native habitats and at the zoo. While it is easy to recognize individual tigers or bears, it can be very difficult to recognize individual fish, amphibians, or reptiles. However, it is helpful to track which individuals or groups are receiving a certain food or treatment, how long they have been on display, which ones came from a particular place, or when they arrived. For zoo based breeding programs, it is crucial to be able to recognize the released animals so that their survival and contribution can be measured.

Visible Implant Elastomer (VIE) tags are injected beneath transparent or clear tissue so that they remain visible. The tags are available in a variety of colors which can be combined with tag location to make a coding scheme. The tags are easy to apply, have little effect on the host, and can be injected into even very small animals. For display animals, VIE is relatively inconspicuous compared to many other types of tags.

Biologists at Point Defiance selected VIE to identify individual stingrays. Each animal was given two tags and all tags were still present 7 months later. None of the stingrays reacted adversely to the handling or tagging, and some of them are reproducing in this very popular exhibit.

We have helped zoos and aquariums across the United States identify their collections of fish, frogs, lizards, mice and other animals. Please contact us if we can help with yours.

Northwest Marine Technology, Inc.

www.nmt.us

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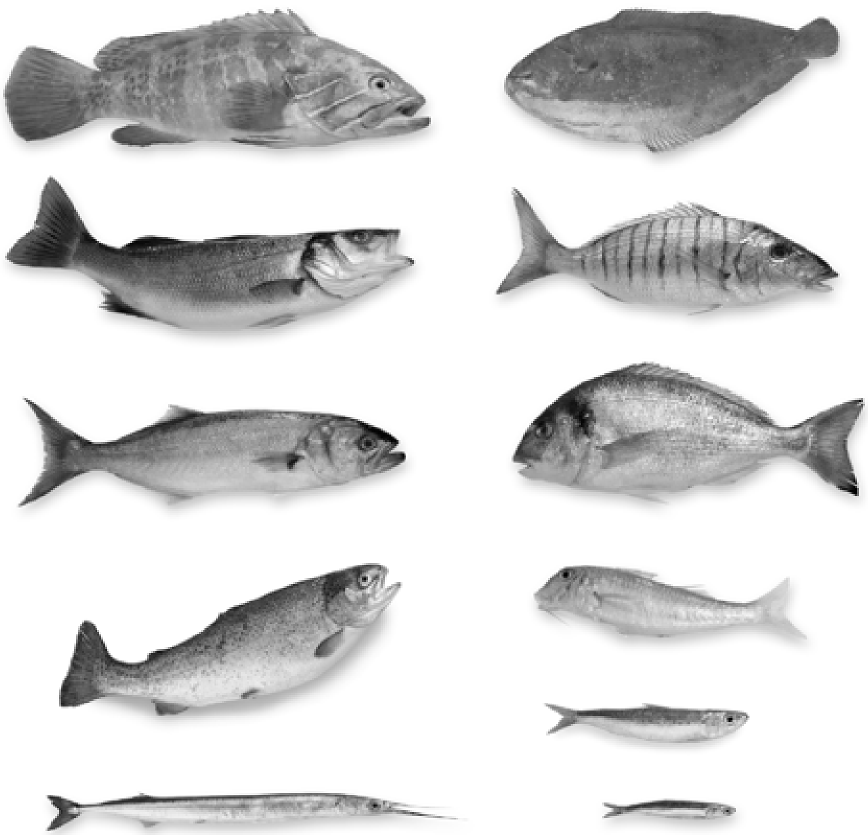

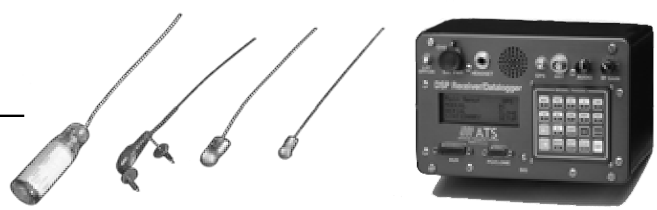


Do you ever feel like we're being watched?
Yeah, it's like they know our every move or something.
Pacific Coho Salmon in Stillwater Creek. Image Credit: Roger Tabor (USFWS)