Fisheries

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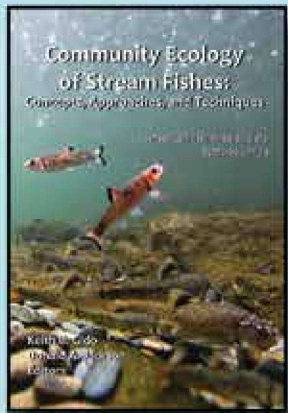

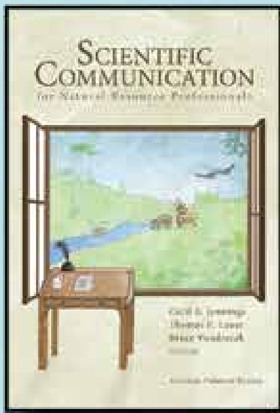

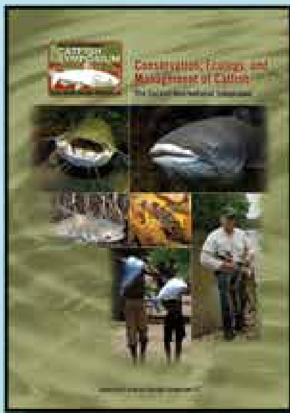

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Fisheries

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77 A mature female Coho Salmon that has returned for natural spawning in the Methow River. Photo credit: Robert Farley.

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Cover: Road failure at a 3-m culvert placed within a 6-m bankfull width stream, Green Mountain National Forest. Photo credit: Dan McKinley, Green Mountain National Forest

Fisheries

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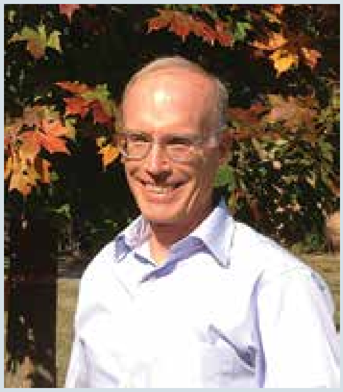
COLUMN
President's Commentary

A Plea for a Steady-State Economy

Bob Hughes, AFS President



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

Recent news stimulated my writing of this commentary. Pope Francis and President Obama decried the growing gap in income disparity globally and in the United States (www.huffingtonpost.com/2013/12/04/obama-quotes-pope-francis_n_4386622.html). China largely abandoned its one-child policy to stimulate economic growth (www.huffingtonpost.com/alexandra-paul/a-new-one-child-policy_b_4324236.html), despite being the top CO_2-emitting nation on Earth (www.pbl.nl/en/publications/2012/trends-in-global-co2-emissions-2012-report). The Warsaw Climate Change Conference produced no clear commitments to reduce greenhouse gas emissions because of threats to economic growth (http://reason.com/archives/2013/11/25/warsaw-climate-change-conference-inconcl). Canada gutted its Fisheries Act (Post and Hutchings 2013) and the Oregon Congressional delegation introduced bills to markedly weaken aquatic resource protections in the Northwest Forest Plan (Frissell 2013). Both of the latter actions are designed to stimulate economic growth at the expense of fish, fisheries, and aquatic ecosystems.

As long as resource scientists and managers fail to honestly discuss the limits to economic growth and the effects that growth has on ecosystem conditions, those ecosystems will continue to unravel. Piecemeal conservation actions can certainly delay the inevitable, but at some point we must clearly help society recognize that denial and Band-Aid approaches do not prevent degradation. As Limburg et al. (2011; Figure 1) documented, there is a very high correlation between economic growth and listings of species as threatened and endangered. These listed species, like melting glaciers and ocean acidification, are indicators of fundamental ecosystem deterioration and the potential collapse of essential ecological functions.

Species losses led to the 1973 Endangered Species Act, in which the U.S. Congress declared that "various species of fish, wildlife, and plants in the United States have been rendered extinct as a consequence of economic growth" (7 U.S.C. § 136, 16 U.S.C. § 1531 et seq.). U.S. citizens understand that there are trade-offs between economic growth and environmental protections and generally tend to favor the former during a recession or periods of low economic growth (www.gallup.com/poll/153515/americans-prioritize-economic-growth-environment.aspx). The degree to which economic growth is favored over environmental protections is highest among Republicans and those over 65 years old, whereas environmental protections are favored over economic growth among Democrats and persons under 30 years old. What seems unclear to citizens is that economic growth cannot continue in perpetuity (Daly 1997; Czech 2013). We can hope that technological progress (or manna from heaven) will keep pace with eventual resource scarcities and environmental degradation. However, that is like us embarking on a long backpacking trip through an unknown landscape without any food or water and hoping that we will find sufficient amounts on the way.

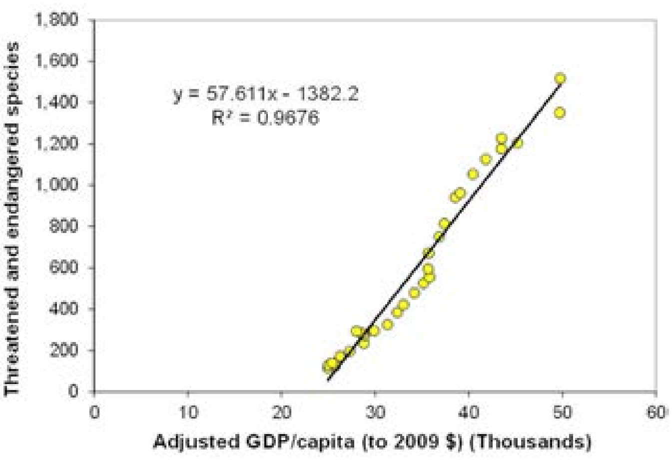


Figure 1. Total threatened and endangered species in the United States versus per capita gross domestic product, adjusted to 2005 dollars (adapted from Limburg et al. 2011).

These listed species, like melting glaciers and ocean acidification, are indicators of fundamental ecosystem deterioration and the potential collapse of essential ecological functions.

So what is the answer for avoiding a very nasty future for our descendants and the planet? A steady-state economy is needed if we seek environmental protection, sustainable economies, and reduced national and international instability (Daly 1997; Czech 2013). A steady-state economy would entail reducing and stabilizing natural resource use and waste production, reducing and stabilizing human population size, providing full employment and education, creating more equitable wealth and income distribution, and measuring progress in noneconomic growth terms (Dietz and O'Neill 2013; Costanza et al. 2014). Current economic growth rates, whether in putative communist, socialist, or capitalist economies, tend to benefit the powerful and wealthy more than others (Daly 1973; Ehrlich et al. 1977). And this is true of nations as well as citizens (Perkins 2005). The sooner that the United States serves as a model for reducing its ecological footprint (Wackernagel and Rees 1996) and

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COLUMN

Letter from the Executive Director

Annual Meetings and Money

Doug Austen, Executive Director
Bob Hughes, AFS President

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

It's a major event in the annual cycle of fisheries professionals. The Annual Meeting, that is, where one to four thousand professionals gather together to talk science, policy, management, administration, and the affairs of the AFS. It's also an important revenue generator for keeping on the lights of Society and the hosting Chapter(s) and Division. Why is that so? A little examination under the hood into the inner workings of the annual conference will provide some insights that are important for all members to be aware of.

Our annual conferences are a big deal. They are an irreplaceable forum for sharing of science information, developing ideas that will shape a multi-billion-dollar industry, and helping to conserve invaluable natural resources.

AFS Finances 101 is the start. Like all professional societies, the AFS gets funds from some key sources: publishing (50%), membership (25%), grants and contracts (10%), meetings (10%), and other sources (10%). These vary somewhat from year to year and each society may emphasize one area over another. But we're all fairly similar in the sources of income—meaning that meetings, conferences, and workshops are a large part of what we do to fund and advance the fisheries profession. A good way to get a sense of the general budget framework of an organization is to check out either the annual report or the IRS tax filing statements that most nonprofits put on their websites (fisheries.org/annual-report). The IRS 990 statement is a very useful tool for examining nonprofits and provides one of the few consistent ways to compare one to another. For an example, The Wildlife Society provides this information at www.wildlife.org/who-we-are/finances. The AFS website currently doesn't provide the IRS information or our annual audit but will in the near future as part of our effort to provide much more complete information to members.

If you've been to more than a few Annual Meetings you know that they vary greatly in size and complexity. Typically, our meetings are in the 1,200 to 2,000 person range. Some, such as Seattle, Anchorage, and those in more tourist-oriented destinations or those with more fisheries professionals, have higher attendance. It's also important to recognize that an immense part of the planning and organization of these meetings is carried by the host Chapter and, clearly, some have greater capacity than others. As a reflection of this, the revenue for the AFS varies with the size and location. Seattle, with over 4,000 registrants, returned a net revenue of $381,000, whereas Little Rock, with about 1,100 registrants, resulted in a net of under $100,000. However, a larger meeting is no guarantee of greater income. The meeting revenue is then split between the AFS (70%), Chapter (20%), and Division (10%), with this split often being modified slightly to reflect the various levels and numbers of units involved.

These conferences are not trivial events. Total budgets often exceed $1 million ($1.3 million for Seattle, our largest meeting) but more typically are in the $700,000–$900,000 range. They involve extensive negotiations and contracts with hotels, convention centers, caterers, and reception locations. We deal with a trade show and vendors for everything from laying carpet to renting furniture. In many cases union rules must be respected. There have been many stories of state agency biologists pulling boats and trucks into convention centers to be part of a display only to be stopped by the union representatives to inform them that driving and parking that electrofishing boat is the job of a union employee and not the state agency biologist. It makes for an interesting dynamic and places agency staff and other AFS volunteers in totally unfamiliar positions.

You'd probably never guess it, but when you look at a $1 million budget for a meeting, one of the highest expense categories is catering—coffee breaks, receptions, setup, and local taxes and fees. This is typically about one-third or more of the meeting budget. For example, at the upcoming Québec City Annual Meeting, we'll spend around one-third of a million dollars on catering costs (receptions and coffee breaks). Two items are important to know. First, that cup of coffee typically costs us $4–$6. Second, the convention center or hotel generally provides us all of those wonderful meeting rooms for free with the offset being that we are obligated to spend a certain amount of funds on catering. Thus, one expense balances out the other. If you've never been involved in planning any type of large event such as this, these numbers may be shocking. But the AFS and our counterparts are actually quite small players in the conference world. The American Geophysical Union, for example, holds its annual fall meeting every year in San Francisco. It brings in 22,000 people. The AFS doesn't even come close to making the top 50 list of major medical conferences (www.hcea.org/?page=research_top50). Yet our business is regularly coveted. Just in my four months in Bethesda, we've been visited by representatives from the Convention and Visitors Bureaus

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COLUMN
Fish Habitat Connections

Great Expectations

Thomas E. Bigford

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Since May 2013 this space has been dedicated to fish habitat. I've approached the subject from angles ranging from science to management to communications to leadership. This column has provided a timely platform to raise overall awareness of issues at the core of both our professional work and what inspires us as AFS members. With increasing need to improve our resource management record, habitat is emerging as a key factor in models, litigation, budget priorities, and planning, each a tantalizing topic in its own right. So with my one-year hitch as a habitat columnist approaching the end, I've been encouraged by the *Fisheries* editors to continue writing and to expand beyond fish habitat into some of those other topics. This month marks the beginning of that transition.

My motivation as a federal program manager has always been to make best use of the opportunities afforded to us as natural resource trustees. After nearly 40 years of daily skirmishes and larger battles, and a year of writing for *Fisheries*, I find myself wondering about our overall expectations and progress. What constitutes success? How do we set a course for fish nirvana? When can we expect to arrive? Simple questions but with difficult answers whether you approach the challenge in your day job or while moonlighting with an AFS unit.

With much of our aquatic environment in a precarious state, our challenge is grand. We need to rebuild commercial and recreational fish stocks inhabiting waters from the smallest ponds to our bordering oceans. Beyond stocks with social value, we must include forage species that join habitat at the base of the aquatic food pyramid. The nation's hydrology needs to be evaluated, especially as human uses drain aquifers and climate change shifts seasonal precipitation patterns. Imperiled species need immediate attention to avoid extirpation. We need to restore habitats degraded by catastrophic events such as the *Deepwater Horizon* oil spill and chronic, worsening threats like wetland loss. Across all arenas, we must protect our investments or Mother Nature will force a replay, each time at higher costs, usually with declining results and with lost opportunity benefits in the interim.

Our success in this chess match hinges on expectations. Victory is not measured by persistence but by progress toward a long-term vision for a healthier environment that will support native fish stocks, sustain reasonable exploitation rates, and reflect our social, cultural, and economic objectives. What are our expectations for habitat quantity and quality, and are we basing our work on traditional fishery management approaches, one of the newer strategies based on ecosystem perspectives, or one of several long-term plans for aquatic systems? It's difficult to divine a simple path, but I'll try by focusing on improving native species in their preferred habitats and natural range. Introduced species, artificial habitats, climate change, and other factors are influential complications, but I'll defer those issues for a future column.

So, for fish habitat, what are our long-term visions, overall objectives, specific goals, and short-term milestones? How must we calibrate our expectations across ecosystems so that we can connect habitat work with fishing mortality? How do we connect harvest targets to achieve socioeconomic goals?

This goal setting arena is complex yet shared with every other sector. We can learn from everyone, and they can learn from us. As the premier fishery society on the globe, the AFS must lead. We have the knowledge, skills, and technology to succeed—but what does that mean? With those tools, we need to also be the best at setting goals and charting a course to achieve them. But sometimes we surrender that right—and sometimes for the wrong reasons.

What constitutes success? How do we set a course for fish nirvana? When can we expect to arrive?

Whether for political gain or just convenience, some goals seemed to be crafted with mixed respect for reality. Consider the need to restore Chesapeake Bay rivers to migrating fish. In the 1990s the Chesapeake Bay Program set its sights on opening 2,010 new miles of passable waterways by 2010. A numerical goal mirroring the deadline certainly helped me recall their charge, but the arbitrary nature casts suspicions on the scientific rigor of the entire exercise. Dedicated fisheries professionals deserve better, and they received that when, after not achieving the 2010 goal, the revised goal was raised 40% to 2,807 river miles by 2014 (Chesapeake Bay Program 2012). The Chesapeake Bay Program is now 91% of its way toward a much higher goal that hopefully has a stronger scientific basis and with a bit of luck will be reflected in healthier stocks and a more productive bay ecosystem.

The fish passage arena also yields a second type of trap that affects expectations. In the hydroelectric licensing arena, dams with turbines kill a majority of the fish passing upstream

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Smartphones in Fisheries

Jeff Kopaska

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An outstanding recent article in *Fisheries* (Gutowsky et al. 2013) summarized information about fisheries professionals utilizing smartphones and digital tablets.The use of these devices by the public, by anglers, and in the education realm is pervasive. Examples also abound regarding changes that agencies are making so that the information they provide on websites is more easily consumed by mobile devices (e.g., Minnesota Lake Finder, Texas Fishing Regulations). The ironic part of this situation is that while agencies are striving to provide information that is easily consumed by these devices, agency staff can be limited in their ability to acquire or utilize such devices for their work. Implementing new technologies within the public sector in a timely fashion has become a nearly insurmountable hurdle.

The topics of smartphones and tablet computers are interesting and timely. In an e-mail conversation I had with Lee regarding his article, he indicated that it seems that government agencies are hesitant to embrace new technologies. To a degree, that might be true. However, I also believe that internal bureaucracies within government agencies are adding to this perceived “hesitance.”

Cell phones and smartphones are a regular part of everyday life for Americans. The Pew Internet and American Life Project (www.pewinternet.org) indicated that as of May 2013, 91% of American adults owned a cell phone and 56% owned a smartphone. Smartphone ownership had increased from 35% in May 2011 to 56% in May 2013. To see how state agencies stacked up, I conducted an unscientific e-mail poll of some fisheries administrators to determine how prevalent state-issued smartphones were among their staff. Some state agencies were quick to allow staff to utilize smartphones, and some do not yet allow such use. Some agencies have recently updated their policies to allow greater use, whereas others have placed moratoriums on smartphone distributions to their staff. Society has forged ahead, but agencies are not necessarily following suit.

Access to real-time weather radar in your pocket, as well as localized weather warnings delivered to you immediately, may be the greatest benefits that these devices can provide to fisheries professionals. However, utilizing these devices for full-blown data entry from a fisheries survey may not be feasible. Staff still seem more accustomed to viewing data form entries for field surveys when they fit on a piece of paper as opposed to a small screen. However, not all types of surveys that fisheries professionals undertake are overly complex. For example, with a tool like EpiCollect there are some people already utilizing smartphones to perform creel surveys, and others are documenting a completed stocking delivery. A current and real use of smartphone technology is the fish culture calculation apps that have been developed by the AFS Fish Culture Section.

In general, it looks like agencies are moving in the direction of allowing their staff to have greater access to smartphones. In reality, they are small computers that just happen to include a telephone service (they acquire information via cell phone data services). This is an extremely important point. Because these devices do not directly connect to (and in many cases are banned from physically connecting to) agency computer networks, they function outside the realm of agency IT policies. It is this characteristic of smartphones that has allowed them to grow more quickly within agency circles.

Next month, we will contemplate tablet devices and IT policies—the Gordian knot preceding electronic field data collection. Stay tuned!

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

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

REFERENCE

Gutowsky, L. F. G, J. Gobin, N. J. Burnett, J. M. Chapman, L. J. Stoot, and S. Bliss. 2013. Smartphones and Digital Tablets: Emerging Tools for Data Collection and Education in Fisheries. Fisheries 38(10):455–461.

COLUMN
The Communication Stream

What is Social Media?

Jeremiah Osborne-Gowey, AFS Social Media Guru
E-mail: jeremiahosbornegowey@gmail.com
Twitter: @JeremiahOsGo

In the January issue of *Fisheries*, in this column I referenced results from a recent survey of our membership. Guess what? Many in our membership are eager to engage in social media but do not know how. Yet others want more info before deciding to take the plunge. Let's start there …

Just what is social media, anyway? At its most basic level it is simply a collection of websites and applications designed to build and enhance online communities for networking and sharing information. It really is no different from hanging around the water cooler exchanging the latest news, sharing a pint after work talking about "the game," or having friends over to just hang out and "talk shop." The only difference in social media is that these interactions occur online.

There is no shortage of social media platforms that you can participate in. In fact, the social media landscape, at first glance, can feel a bit overwhelming. There are literally hundreds of websites and applications to wade through. Selecting one or two to dig into, however, need not be too big a challenge. The trick is finding the one(s) that stay true to the core of the work that you and your organization do. If that includes communicating with other members, scientists and the public, consider adopting one of the established online networking platforms like Twitter, Facebook, StumbleUpon, YouTube, or developing a blog. Which one is right depends on your level of commitment.

Curating a YouTube channel is a fantastic way to spread video-based science messages but also takes some know-how and someone to regularly shoot/edit video. If that's in your plans but not yet feasible, consider developing a blog. The great people over at The Fisheries Blog are doing a bang-up job with their (relatively) new blog and recently wrote about adopting social media! You'll notice, however, that they are spreading the work around (there are currently four of them with several guest bloggers). If you only have one person willing/able to jump into social media, consider creating a Facebook page or a Twitter feed that can be relatively easily curated by one person (unless your organization and its network is quite large).

Regardless of the social media platform you adopt, just remember that communication is most fruitful as a consistent, two-way street, not a one-way, occasional conversation. Treat your social media the same and good things are bound to happen.

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.

Letter to the Editor

Dear Editor,

As always, I read the October 2013 edition of *Fisheries* with keen interest, particularly the article "Avoiding Bycatch" (O'Keefe and DeCelles, pp. 434–444). As is one in about every eight males, I am red–green colorblind, thus unfortunately making several of the graphs in this excellent article nearly impossible to discern in the printed version (the electronic version is a bit more distinguishable). If the approximate 8% red–green colorblindness rate holds true in the AFS ranks, then some 720 other members couldn't properly discern those graphs as well. Understandably, not many "normal" color seeing scientists think about the use of red and green together, but for us "eight percenters," figures and charts in various formats can be difficult to differentiate results. One simple solution: don't use red and green together unless accompanied with symbols or the like. Further, I would recommend the AFS put forth a policy, include in the style guide for publications, or at least request that authors select different colors for use in their charts. In the meantime, please be cognizant of this issue amongst your fellow scientists and wider audiences who greatly appreciate being able to fully discern your graphs and figures in your papers and presentations.

Chad W. Hanson
chanson@pewtrusts.org
Florida

CANDIDATE STATEMENTS
Second Vice President

Reginal M. Harrell

All AFS members will receive an email with instructions on how to vote online. (Only current members can vote. To become a member, visit: www.fisheries.org/afs/membership.html)

BACKGROUND

I am a professor of Fisheries and Wildlife Sciences with the University of Maryland Department of Environmental Science and Technology. From 1977 to 1984 I was a biologist with the South Carolina Department of Natural Resources, working with coastal river enhancement of striped bass populations. I have seen the best of both worlds from a state agency and an academic perspective. My B.S. in zoology (1975) and M.S. in wildlife biology (1977) came from Clemson University and my Ph.D. in biology (1984) from the University of South Carolina. I also have an MBA from Salisbury University (2005) and an MDiv in ethics from Southeastern Baptist Theological University (2011). Since 1984, my roles have included being a researcher, teacher, extension specialist, and administrator, including department chair, research center director, and research associate dean. My current research is in ecological and natural resource ethics. I advise graduate students and teach numerous courses in fish and wildlife science, management, sustainability, research methodology, and ethics. I have been fortunate to publish over 120 peer-reviewed articles and extension fact sheets and edit or coedit several books, including the AFS publication *Culture and Propagation of Striped Bass and Its Hybrids*. I am currently working on a fourth book, *Ecological and Natural Resource Ethics*. I have collaborated in Egypt and Great Britain teaching aquaculture and studying ecological ethics and served on an international committee examining strategies for managing coastal ground stocks of nonsalmonid fishes with colleagues from the United States, Canada, and Norway. I have served on committees reviewing the national fish hatchery program and as a member of the board of directors for the Northeastern Regional Aquaculture Center at the federal level and on stock assessment committees at the state level and as a scientific representative on two councils: the state of Maryland's Aquaculture Council and Harmful Algal Bloom Council. I am also a Fellow with the American Institute of Fisheries Research Biologists.

AFS INVOLVEMENT

As a life member and certified fisheries scientist, I have been active in the AFS since joining the Society in 1974. In essence, I grew up within the Society and attribute my professional milestones to the friends, colleagues, and peers with whom I have had the pleasure of working with over my 39-year involvement in the AFS. I have been a long-standing member of several Society sections but have been most active in the Fish Culture, Genetics, Physiology, and Education Sections. I am honored to have served as president of the Southern Division, the Fish Culture and Genetics sections, and the South Carolina Chapter. These roles afforded me the opportunity to serve three times on the Society's Governing Board and once on its Management Committee. Other roles in the AFS have included being a journal associate editor and a member of too many divisional and section standing and technical committees to cover here. Most recently, I cochaired and moderated a half-day symposium at the 2013 Annual Meeting.

VISION

Before committing to be considered for this important AFS leadership position, I had a conversation with our new executive director, Doug Austen, about his vision for the Society. I also reread the Vision Statements of our current AFS officers. In both cases I found myself wondering what value I could bring if I were to represent our membership and simultaneously complement the efforts we already have underway. If I have the privilege of receiving your vote, I would like to take a two-tiered approach to integrating my contribution to the Society's mission and vision.

First, we must remember our roots. I hope to ensure that we remain relevant to our state and federal agency members. As I talk with my agency colleagues there is a sense of declining, meaningful engagement with the AFS. The AFS with which I grew appears to have weaned itself from supporting agencies for professional development. No doubt the economy is a driver, but there is a realized cost–benefit value to professional development. I desire to work with our Fisheries Administration Section, other agency directors, and our divisional leadership (including technical committees) to ensure that we are providing the value that helps us both turn the tide and regain whatever lost relevance we may have incurred.

Second, how can we help our society's future, especially our student members, be prepared to enter a career that does not have the traditional boundaries that my generation grew up experiencing? Because of today's integrated, multidisciplinary approach to science and management, the answers we seek have only grown more complex. I would like the AFS to establish core linkages with more professional groups, beyond what we already have with other international fisheries societies. Other societies, such as The Wildlife Society, the Society of American Foresters, the World Aquaculture Society, American Society for Ichthyologists and Herpetologists, and the Coastal Estuarine Research Federation all have interests similar to those of the AFS. Almost all of these professional organizations put a premium on students, student activities, and young professionals. Coupling these interests with other overlapping discipline concerns, we can capitalize on the opportunity to broaden our capacity to develop united fronts on issues important to us all. We owe this effort to our students, our members, and our profession.

I thank the Nominating Committee for the confidence expressed in my nomination, and I consider it the highest privilege and honor to be able to serve my society as one of your national officers. I would appreciate your vote.

Steve L. McMullin

All AFS members will receive an email with instructions on how to vote online. (Only current members can vote. To become a member, visit: www.fisheries.org/afs/membership.html)

BACKGROUND

Like many of my peers, I entered the fisheries profession in the 1970s because I love to fish, and while taking a class at the University of California–Davis I discovered that I could have a career working with fish. Over a nearly 40-year career that has taken me from Davis to the University of Idaho, to the state of Montana, and eventually to Virginia Tech, that passion for fishing and fisheries as both vocation and avocation continued to grow. Countless times in my career I have marveled that I get paid to do incredibly interesting things, often in spectacular places. After earning my B.S. and M.S. degrees from the University of Idaho, I worked for the Montana Department of Fish, Wildlife and Parks as a fisheries biologist, regional manager, and chief of the Fisheries Management Bureau. I always enjoyed the public interaction aspects of my jobs in Montana, and in mid-career I made the leap from the agency to academia, earning my doctorate and refocusing on human dimensions, policy, and leadership development for natural resource professionals. I currently serve as interim department head of Fish and Wildlife Conservation at Virginia Tech and as director of our College of Natural Resources and Environment Leadership Institute. I am approaching the end of my second career and looking forward to my third career as a part-time trainer and consultant in leadership development while I indulge my fly-fishing passion more frequently. I am honored to be considered as a candidate for American Fisheries Society (AFS) office and, if I should be elected, I will serve during a period in my life when I am able to devote the time and effort needed to do the job.

AFS INVOLVEMENT

I have been active in the AFS since 1978 and I learned early about service to the profession, working closely with two AFS presidents on my graduate advisory committees and a third as my supervisor in Montana. I have served as president of the Virginia Tech and Virginia chapters, as well as the Southern Division of the AFS. I served on many committees, including the Continuing Education Committee (one year as chair), the Task Force on Professional Certification that revised certification requirements, the Certification Review Board, and the Special Committee on Educational Requirements. Due to my interest in leadership development, I have also helped to teach the Leading at All Levels in AFS workshop offered every year at the Annual Meeting, assuming leadership of the course in 2013.

VISION

As discussed during the 2013 Annual Meeting plenary session, the AFS (and the rest of the world) is in the midst of tremendous demographic change. We are experiencing the same generational change that is affecting the rest of the world and I believe that the AFS should actively engage in shaping its future. Shaping the future of the AFS should include enhanced involvement and mentoring of younger AFS members; maintaining and enhancing networking among members through our publications, social media, meetings, and governance; and a steadfast focus on maintaining the standards of professionalism in fisheries. We can enhance involvement and development of younger members by ensuring that students and young professionals are actively included in all AFS committees and by emphasizing the career benefits of actively engaging in the society. Networking opportunities abound in the AFS, and many experienced members cite networking with other fisheries professionals as one of the primary benefits of AFS involvement. We should strive to ensure that the AFS continues to provide abundant opportunities for networking among fisheries professionals, young and old. Although generational change and budget constraints may challenge us to develop creative ways for members to participate at a distance, we should always strive to have vibrant meetings that maximize opportunities for face-to-face interaction. We define professionalism by setting standards through our certification program, which should be revisited after the Special Committee on Educational Requirements finishes its work. We also must continue to produce the highest quality publications, effectively use social media to disseminate information, and focus our policy and advocacy efforts on ensuring that fisheries policies have sound technical underpinnings. I welcome the opportunity to help shape the future of the AFS.

AFS Genetics Section Update: Parentage-Based (Genetic) Tagging in the Spotlight at the Western Division Annual Meeting

Wesley A. Larson

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For over a century, salmon researchers have been physically tagging fish to track their stock or hatchery of origin throughout their complicated life cycles. This type of information can inform fisheries management and improve our understanding of salmon ecology. In the past, tagging has involved inserting physical tags such as coded wire tags or passive integrated transponder tags into fish, but fish already have their own unique identifier—their DNA sequence!

Tagging large numbers of fish based on their genetic signatures was difficult until the mid-2000s, when advances in high-throughput genotyping technology made it possible to rapidly assay thousands of fish. This technology has facilitated a new form of tagging termed "parentage-based tagging" (PBT). PBT uses high-throughput genotyping and parentage analysis to assign hatchery-produced salmon to their hatchery and brood year of origin. Assignment to rearing treatment, release strategy, or even incubation tray is all possible with appropriate record-keeping. First suggested on a large scale by fisheries geneticists in 2005, PBT can be a cost-effective and efficient alternative to traditional physical tagging methods (e.g., coded wire tags, passive integrated transponder tags; Anderson and Garza 2006). In addition to providing the stock of origin for tagged fish, the data can be used to assess genetic diversity, reproductive success, and/or the heritability of specific traits.

PBT is now common in both the Sacramento and Columbia rivers, and it is ubiquitous in the Snake River Basin, where all hatchery broodstock are genetically tagged.

PBT was in the spotlight at the recent AFS Western Division meeting in Boise, Idaho, with an entire symposium dedicated to the topic. Because PBT is still relatively novel, several talks centered on statistical validation of the method, but at least a handful of talks discussed practical applications of the technique. Brian Leth from the Idaho Department of Fish and Game, for example, presented results from a project focused on estimating escapement of Chinook Salmon in the Snake River basin. His results were encouraging, demonstrating that PBT provided better estimates of stock-specific escapement and harvest rate compared to previous methods using passive integrated transponder tags. Christine Kozfkay, also from the Idaho Department of Fish and Game, used PBT in an alternative manner to evaluate relative reproductive success and aid in choosing broodstock for a hatchery program in an endangered population of sockeye salmon.

PBT is now common in both the Sacramento and Columbia rivers, and it is ubiquitous in the Snake River Basin, where all hatchery broodstock are genetically tagged. This regional application of PBT effectively tags millions of hatchery origin smolts annually (Steele et al. 2013). In the future, it is likely that the majority of cultured salmon from the Sacramento River, Columbia River, and many other river systems will be tagged using PBT. These large-scale analyses could greatly improve our ability to identify adaptively relevant traits, revealing important aspects of salmon evolution.

REFERENCES

Anderson, E. C., and J. C. Garza. 2006. The power of single-nucleotide polymorphisms for large-scale parentage inference. Genetics 172:2567–2582.

Steele, C. A., E. C. Anderson, M. W. Ackerman, M. A. Hess, N. R. Campbell, S. R. Narum, and M. R. Campbell. 2013. A validation of parentage-based tagging using hatchery steelhead in the Snake River basin. Canadian Journal of Fisheries and Aquatic Sciences 70:1046–1054.

Challenges with Defining Fisheries Targets in Large Urban Systems—The Chicago Area Waterways System

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Jennifer Wasik

Metropolitan Water Reclamation District Greater Chicago, Chicago, IL.

Serving as a Water Quality Section (WQS) president provided me with a great sense of personal and professional accomplishments and I intend to continue to provide service to the Section and the AFS in various capacities in the coming years. I strongly encourage students and junior and midlevel scientists to become actively engaged in the AFS at some level for the opportunity to meet smart, experienced, and influential colleagues, if not for professional contacts. Although the mission of the WQS is diverse (www.fisheriessociety.org/wqs), I feel particularly aligned with the WQS because my work primarily focuses on urban and industrial environments and regulatory *issues pertaining to the goals of the Clean Water Act. Members of the WQS plan to contribute several additional articles to* Fisheries *in 2014 highlighting the diverse projects with which we are involved. The WQS kicks off our article series with a study conducted by LimnoTech with the Metropolitan Water Reclamation District of Greater Chicago (the District). Developed from a Water Environment Federation conference presentation, "Urban Rivers Restoration 2010," the full manuscript is available on the WQS website.*

—Douglas Bradley

In 1889, the Illinois State Legislature created the District to provide flood control and wastewater management for the Chicago-land area to protect drinking water in Lake Michigan and to connect the Great Lakes with the Mississippi River to expand commerce. Construction of the Chicago Area Waterways System (CAWS) was completed in the early 1900s, nearly 80 miles of heavily modified and hydrologically controlled channels. Since construction, the District has built and operated numerous facilities along the CAWS, including water reclamation plants, flow control works and pumping stations, massive aeration stations, and construction and operation of three Army Corps of Engineers navigational locks. Treated wastewater discharged to the CAWS accounts for approximately 70% of the annual system flow. As advanced wastewater treatment technologies were implemented, water quality within the CAWS improved. In 2007, the Illinois Environmental Protection Agency proposed new water quality standards for aquatic life uses (ALU) in the CAWS as follows:

> *CAWS ALU A Waters:* Waters capable of maintaining aquatic life populations predominated by individuals of tolerant or intermediately tolerant species that are adaptive to the unique physical conditions, flow patterns, and operational controls necessary to maintain navigational use, flood control, and drainage functions of the waterway system.

> *CAWS ALU B Waters:* Waters capable of maintaining aquatic life populations predominated by individuals of tolerant species that are adaptive to the unique physical conditions, flow patterns, and operational controls designed to maintain navigational use, flood control, and drainage functions in deep-draft, steep-walled shipping channels.

There was a concern that the proposed ALUs remained vague and presented a misconception that the biota is primarily limited by the treatment technologies and not the constructed design and physical operations of the system. In 2008, The District implemented studies within the CAWS to better characterize physical habitat and to identify a target fish community to better describe and measure CAWS management efforts.

The major conclusions drawn from the habitat analysis were as follows:

1. Aquatic habitat is inherently limited in the CAWS by the system's form, function, and management.
2. Six physical habitat attributes appeared to account for most of the variability in the fish community across the CAWS.

Cluster analysis was applied to the fish data and provided information about the current fish communities that exist in the CAWS and might support appropriate biological endpoints (that is, target fish communities) for system management and habitat restoration efforts.

One cluster included the majority of the most abundant fish species (e.g., Largemouth Bass, Bluegill, Common Carp, and other minnows and sunfish species). This dominant community was observed at every station in the CAWS.

Overall, most of the variability in long-term fish data in the CAWS appears to be explained by the physical habitat characteristics and temporal and spatial variation in the fish community data, whereas water chemistry explained very little.

This dominant community is indicative of naturally successful populations that are tolerant to current uses, severely limited habitat conditions, and navigation impacts. The community, which appears to have achieved a sustainable balance within this large urban system complex, represents multiple trophic levels and contains species important to the public (as a nonconsumptive recreation opportunity) that are responsive to the key stressors within the CAWS. Evaluation of physical, chemical, and biotic data provides strong evidence for incorporation of this dominant fish community into the CAWS ALU designation.

Although the CAWS case issues remain challenging, results should support development of clearly defined, achievable goals and provide valuable insights for other large urban systems.

Fish Meat Gives Viewers Plenty to Digest

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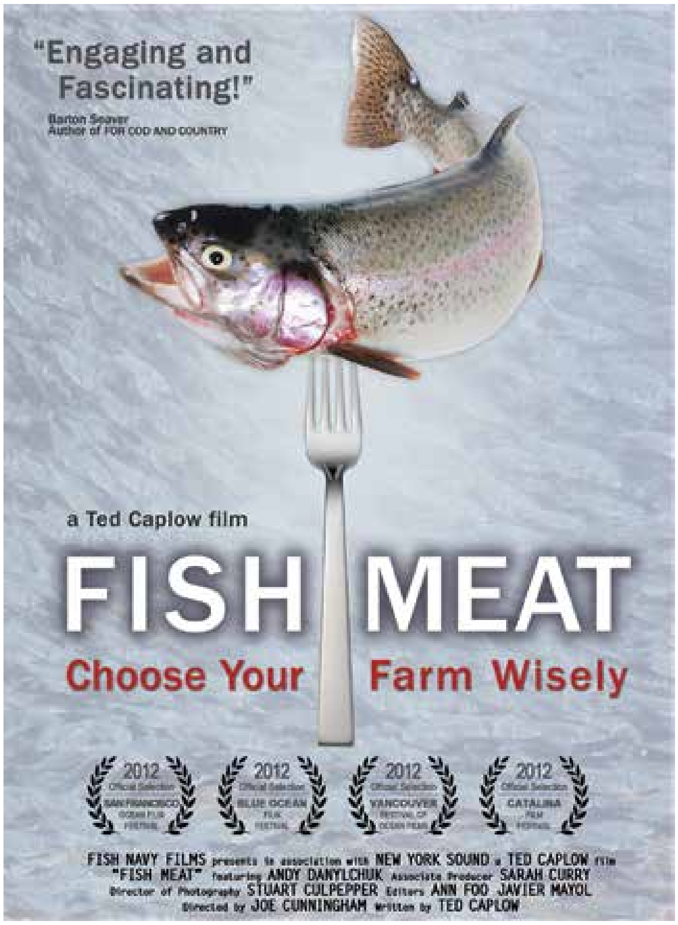
There is considerable controversy surrounding aquaculture, or fish farming, as well as a good bit of mis- and disinformation in popular media about aquaculture practices and farmed fish. In their film, *Fish Meat*, Ted Caplow and AFS member Andy Danylchuk address some of the issues by exploring several types of fish farming in Turkey, visiting a tuna fattening operation and farms raising sea bass, trout, and carp. The filmmakers' central thesis is that by returning to some of the simplest and oldest forms of aquaculture, such as carp farming, we can avoid the perils sometimes associated with more modern, industrialized fish farming. Beautifully filmed and scored, *Fish Meat* has been screened at many film festivals, was recently aired on PBS in Florida, and was recognized as the "Best Overall" extended film at the Beneath the Waves Film Festival in March 2013.

As an outspoken advocate for smart, sustainable aquaculture, I was somewhat disappointed by the shortened festival version of the film—the picture was being painted with pretty broad strokes and I bristled at what I considered oversimplifications. But what the short form got wrong, the full-length version got mostly right, and I ended up sharing the film with my Introduction to Aquaculture class near the end of the semester as a way to get them to start thinking more broadly about the concepts that we had discussed in class.

Farming fish is no longer a question of 'If?,' it's a question of 'How?.'



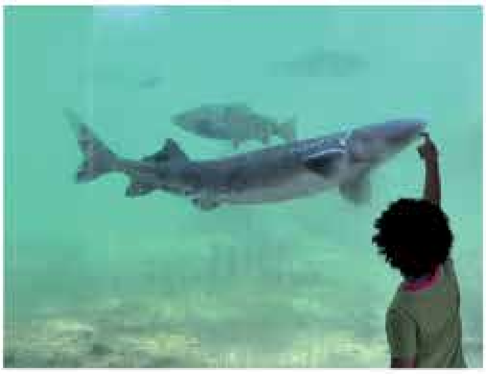
One of the issues raised is related to efficiency, feeding practices, and feed conversion ratios (FCRs). In the film, it's said that sea bass farms typically operate at FCRs of 3 to 4, meaning that for every pound the fish gain, they have to eat 3 to 4 pounds of feed. As a rule, fish farms can't and don't operate at these poor rates of conversion efficiency, and sea bass farms in Turkey reduced their conversion efficiencies to approximately 2 more than 15 years ago (http://om.ciheam.org/om/pdf/c14/96605649.pdf) and may operate at even greater efficiencies today (http://om.ciheam.org/om/pdf/c63/05600064.pdf). Still, their broader point is well-taken—fish culturists should use every means available to maximize feeding efficiency, which can include automated feeding systems like those featured in the film.

In truth, the issues associated with aquaculture are too complex for a 30-minute film to explore in any depth. Entire careers (say, my own) are spent investigating just feeds and feeding practices—even if the entire film was about feed formulations and FCRs, someone like me is still likely to say, "Yes, but …" while the credits roll. The larger point that Caplow and Danylchuk aim to make is nonetheless fair and important: aquaculture is essential, but we should support farms that emphasize sustainability. The film makes the necessity of aquaculture clear: "Farming fish is no longer a question of 'If?,' it's a question of 'How?.' And it's not a question of whether I should buy farmed fish, but 'Which of these farmed fish should I buy?'"

"The general public … they see the fillet, they don't see the whole fish. They don't see where it's come from. They don't see what's gone into making that fish," Danylchuk says. *Fish Meat* is one way to help ourselves and the general public to see the bigger picture.

Fish Meat, including the short and full-length versions, is available on DVD via Amazon. For more information about *Fish Meat* or the group's next film, *Raising Shrimp*, visit Fish Navy Films at www.fishnavy.com.

WORLD FISH MIGRATION DAY



Are you working on rivers, water and migratory fish and looking to enhance public awareness? Are you concerned about the health of our rivers?

Take part in **World Fish Migration Day 2014** on the **24th May**. This international event calls attention to the need to restore the connections in rivers for migratory fish, to achieve healthy fish stocks and productive rivers.

WHY DO WE CARE?

Migratory fish (like salmon, trout, dourada, shad, lamprey, giant catfish, sturgeon and eel) are threatened by barriers such as weirs, dams and sluices; built for water management, hydropower and land drainage. Around the world millions of people rely on these fishes as their primary source of protein and for their livelihoods. Water and resource managers, and conservationists are striving to improve migration routes between and within rivers, deltas and the oceans. These 'fishways' are vital for their survival.

World Fish Migration Day is held to improve the publics' understanding of the importance of migratory fish and their needs, as well as healthy rivers. Raising awareness, sharing ideas, securing commitments and building communities around river basins are essential aspects of fish passage and river restoration.
On this day, we will connect celebrations and events that start in New Zealand, and follow the sun; ending as the sun sets on the west coast of North America. More than 250 locations will be connected worldwide and we are looking for organizations that want to join this inspiring initiative.

WOULD YOU LIKE TO ORGANIZE AN EVENT?

Participating organizations will organize their own event (e.g. activity sessions, workshops or talks) and outreach communication, under the umbrella of the World Fish Migration Day. Educational material will be available to share with your visitors. Wanningen Water Consult & LINKit consult, partnering with WWF (NL), The Nature Conservancy and the IUNCN SSC/Wetland International Freshwater Fish Specialist Group, will take care of the central coordination, international publicity, and maintain the main website. All projects will be highlighted on this website, social media and in the press.

For more information or to organize an event:
Email herman@wanningenwaterconsult.nl
Phone 0031-6-182 725 72
Web www.worldfishmigrationday.com

PARTNERSHIP

The Nature Conservancy — Protecting nature. Preserving life.
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FEATURE

Flood Effects on Road–Stream Crossing Infrastructure: Economic and Ecological Benefits of Stream Simulation Designs

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ABSTRACT: *Stream simulation design is a geomorphic, engineering, and ecologically based approach to designing road–stream crossings that creates a natural and dynamic channel through the crossing structure similar in dimensions and characteristics to the adjacent natural channel, allowing for unimpeded passage of aquatic organisms, debris, and water during various flow conditions, including floods. A retrospective case study of the survival and failure of road–stream crossings was conducted in the upper White River watershed and the Green Mountain National Forest in Vermont following record flooding from Tropical Storm Irene in August 2011. Damage was largely avoided at two road–stream crossings where stream simulation design was implemented and extensive at multiple road–stream crossings constructed using traditional undersized hydraulic designs. Cost analyses suggest that relatively modest increases in initial investment to implement stream simulation designs yield substantial societal and economic benefits. Recommendations*

Efecto de las inundaciones en la infraestructura de pasadizos fluviales: beneficios económicos y ecológicos de los diseños de simulación de arroyos

RESUMEN: *el diseño de simulación de arroyos es un enfoque geomórfico, de ingeniería y con consideraciones ecosistémicas en el que se crean pasadizos erigiendo un canal natural y dinámico entre arroyos a través de estructuras de paso similares en dimensiones y características al canal natural adyacente, permitiendo así el paso irrestricto de organismos acuáticos, debris y agua durante distintas condiciones de flujo, incluyendo inundaciones. Se llevó a cabo un caso de estudio retrospectivo acerca de los éxitos y fracasos de la construcción de pasadizos entre arroyos en la parte alta de la cuenca del Río Blanco y el parque Nacional Montaña Verde, en Vermont, justo después de las inundaciones sucedidas tras el paso de la tormenta tropical Irene, en agosto de 2011. El daño fue en gran parte evitado en dos pasadizos donde se implementó el diseño de simulación de arroyos, no así en distintos pasadizos que fueron construidos mediante el diseño hidráulico tradicional, en los que el daño fue extensivo. El análisis de costos sugiere que incrementos relativamente pequeños en la inversión inicial, destinados a implementar un diseño de simulación de arroyos, dan como resultado considerables beneficios sociales y económicos. Se presentan recomendaciones que podrán ayudar tanto a las agencias como los participantes genuinamente interesados en el tema, a mejorar los pasadizos fluviales mediante un incremento en la coordinación que promueva las metodologías del diseño de simulación de arroyos, aumento de los fondos y la flexibilidad de las agencias y participantes para actualizar aquellos pasadizos cuya resiliencia a las inundaciones haya fallado y expandir los talleres de capacitación dirigidos a participantes federales, estatales y locales.*

are presented to help agencies and stakeholders improve road–stream crossings, including increasing coordination to adopt stream simulation design methodology, increasing funding and flexibility for agencies and partners to upgrade failed crossings for flood resiliency, and expanding training workshops targeting federal, state, and local stakeholders.

BACKGROUND

Hundreds of thousands of road–stream crossings exist in the United States (Coffman et al. 2005), and fragmentation of aquatic habitat from road–stream crossings has a well-documented impact on salmonids and aquatic diversity (Rieman et al. 1997; Hudy et al. 2005), including eastern Brook Trout (*Salvelinus fontinalis*). In the past decade, the U.S. Department of Agriculture Forest Service (USFS) surveys of national forests in Virginia, Washington, Oregon, and Alaska indicated that half to two-thirds of road–stream crossings were barriers to fish passage at some life stage (Coffman 2005; Heller 2007). Research in the Northeast (Nislow et al. 2011) demonstrated that stream sections located above impassable culverts had fewer than half the number of fish species and less than half the total fish abundance compared to stream sections above and below passable culverts.

During storm events, road–stream crossings may fail catastrophically when floodwaters exceed the hydraulic capacity of a culvert and/or sediment and debris plug the culvert. The subsequent damage to road infrastructure and adjacent property can deliver large pulses of sediment to stream channels (Furniss et al. 1997; Nelson et al. 2012). In many forest environments, the dominant failure mechanisms for road–stream crossings are wood and sediment accumulation at the inlet, typically initiated by small woody debris (e.g., twigs, sticks, and branches) not much longer than the culvert diameter and often not exceeding the width of the channel (Cafferata et al. 2004; Flanagan 2004). Researchers have linked observed increases in flood frequencies and intensities in the Northeast to anthropogenic climate change and have cautioned that current infrastructure requirements will need to be reevaluated based on new flood-risk information (Spierre and Wake 2010). Culvert failure probability during flood events can be reduced through appropriate sizing and configuration (Furniss et al. 1997; Flanagan et al. 1998), particularly when replacing undersized structures with appropriately designed culverts and bridges (Furniss et al. 1998).

In addition to causing severe impacts to human safety, property, and infrastructure, large flood events have profound effects on wild trout and aquatic biota due to higher water velocities and increased sedimentation (Trombulak and Frissell 2000; Angermeier et al. 2004). Numerous studies have linked abundance of age-0 trout to the timing and magnitude of flood events (e.g., Seegrist and Gard 1972; Carline and McCullough 2003; Warren et al. 2009). Though young fish are often more susceptible to loss during flood events, high mortality of adult trout has been documented as well (Carline and McCullough 2003). In

Figure 1. Road failure at a 3-m culvert placed within a 6-m bankfull width stream, Green Mountain National Forest. Photo credit: Dan McKinley, Green Mountain National Forest.

the absence of barriers, however, habitat is recolonized in several years by individual fish from metapopulations (e.g., Dolloff et al. 1994; Letcher et al. 2007; Nislow et al. 2011). Studies of several wild Brook Trout populations by the Vermont Fish and Wildlife Department (VFWD) in the White River, Mad River, and Dog River watersheds found that flooding from Tropical Storm Irene reduced total trout populations to 33%–58% of preflood levels (Kirn 2012). Barring anthropogenic alteration of instream habitat with heavy machinery, Brook Trout populations would be expected to return to preflood population structure within 2–3 years (Kirn 2012). Studies by Dolloff et al. (1994) in North Carolina and Carline and McCullough (2003) in West Virginia indicate that though individual habitat units changed, overall habitat composition and complexity persisted and in some cases improved after floods.

The upper White River watershed was selected as a case study for this article because of the extensive flood damage experienced in five valley towns during Tropical Storm Irene (Irene) on August 27–28, 2011, a portion of which was related to failure of undersized hydraulic design road–stream crossings and associated road damage incurred by communities beyond the structure replacement costs (Figure 1). The extensive damage to culverts on town lands adjacent to the Green Mountain National Forest (GMNF) allowed for comparison of crossing failures and associated impacts between older traditional hydraulic designs and newer stream simulation designs (Stream Simulation Working Group [SSWG] 2008). Before Irene struck, two stream simulation designs had just been completed in the watershed adjacent to the upper White River and in a nearby watershed within the Connecticut River basin that sustained similar precipitation levels and flood damage. An additional crossing that approached stream simulation design standards within the upper White River watershed on the GMNF avoided damage as well. Survival of these three GMNF road–stream crossings designed for aquatic passage highlights the broader benefits of ecologically beneficial stream crossing designs, including reduced rates of crossing failure and storm damage to roads and property, reduced costs of road maintenance, and reduced likelihood of adverse impact to communities and businesses caused by flood damage. The U.S. Fish and Wildlife Service (USFWS), which has been active across the watershed in post-storm response with local partners such as the White River Partnership (WRP), has used fish passage as its primary objective when partnering on upgrading road–stream crossings. It employs a range of ecologically beneficial approaches to achieve aquatic organism passage and improved flood resiliency, including the stream simulation design method (J. Rowan, USFWS, personal communication).

ROAD–STREAM CROSSING DESIGN APPROACHES

Aquatic organism passage (AOP) at road–stream crossings has been the subject of engineering, fisheries, hydrology, and wildlife specialists' concern for many decades, beginning with federal and state agencies involved in fish management and road and highway construction in Alaska, California, Oregon, Idaho, and Washington (Orsborn et al. 2002; Clarkin et al. 2005). Prior to the 1970s, a hydraulic design approach to road–stream crossings focused on efficiently conveying flood flows with minimal or no concern for the movement and habitat needs of fish (Figure 2a). In the 1970s and 1980s, hydraulic design structures were modified to create hydraulic conditions that allowed for passage of adult fish including fishways, baffles, and weirs (Figure 2b; Cenderelli et al. 2011). Structures substantially narrower than the width of the adjacent natural channel, however, were only partially successful in allowing passage for the targeted adult fish species, and they did not address the passage needs of multiple species occupying the stream corridor at different life stages and flow conditions. Into the 1990s, hydraulic engineers continued to study and provide design advice to agency fisheries biologists. As Endangered Species Act listings for Pacific Coast salmonids increased in the 1990s and understanding of river and stream geomorphology among agency staff improved, inventories of road system crossings and design improvements to provide passage of all aquatic species, not just adult salmon and trout, increased. Recognizing the limitations of hydraulic design approaches for meeting the passage needs of multiple species occupying the stream corridor at different life stages and flow conditions, a stream simulation design approach was developed (Figures 2c–2e).

Gradually, federal agencies such as the USFS, USFWS, Natural Resources Conservation Service, Bureau of Land Management, and National Oceanic and Atmospheric Administration developed or recognized fish passage programs specific to road–stream crossings. In recognition of the pervasive problem of undersized culverts inhibiting the passage of aquatic organisms, wood, sediment, and debris across the country's vast road network, especially on public lands, the USFS and other agency technical specialists convened a cadre of hydrologists, watershed scientists, geomorphologists, road engineers, and fisheries biologists who further developed and refined the concept of stream simulation design in the 1990s (SSWG 2008; Cenderelli et al. 2011). In 2008, the USFS identified stream simulation design as its preferred approach for all national forest road–stream crossings on fish-bearing streams and integral to meeting the intent of the Clean Water Act (to restore and maintain the chemical, physical, and biological integrity of the nation's waters; 33 U.S.C. § 1251(a)) and the Endangered Species Act (to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved 16 U.S.C. § 1531(b)) (USFS 2008).

STREAM SIMULATION DESIGN

Stream simulation designs are recognized as more effective in facilitating juvenile and adult fish and other AOP than traditional culvert designs (House et al. 2005; Cenderelli et al. 2011) or low-water fords (Bouska and Paukert 2011). The premise of stream simulation design is that by creating channel dimensions and characteristics through a road–stream crossing that are similar to those in the natural channel, fish and other aquatic organisms will experience no greater difficulty moving through the

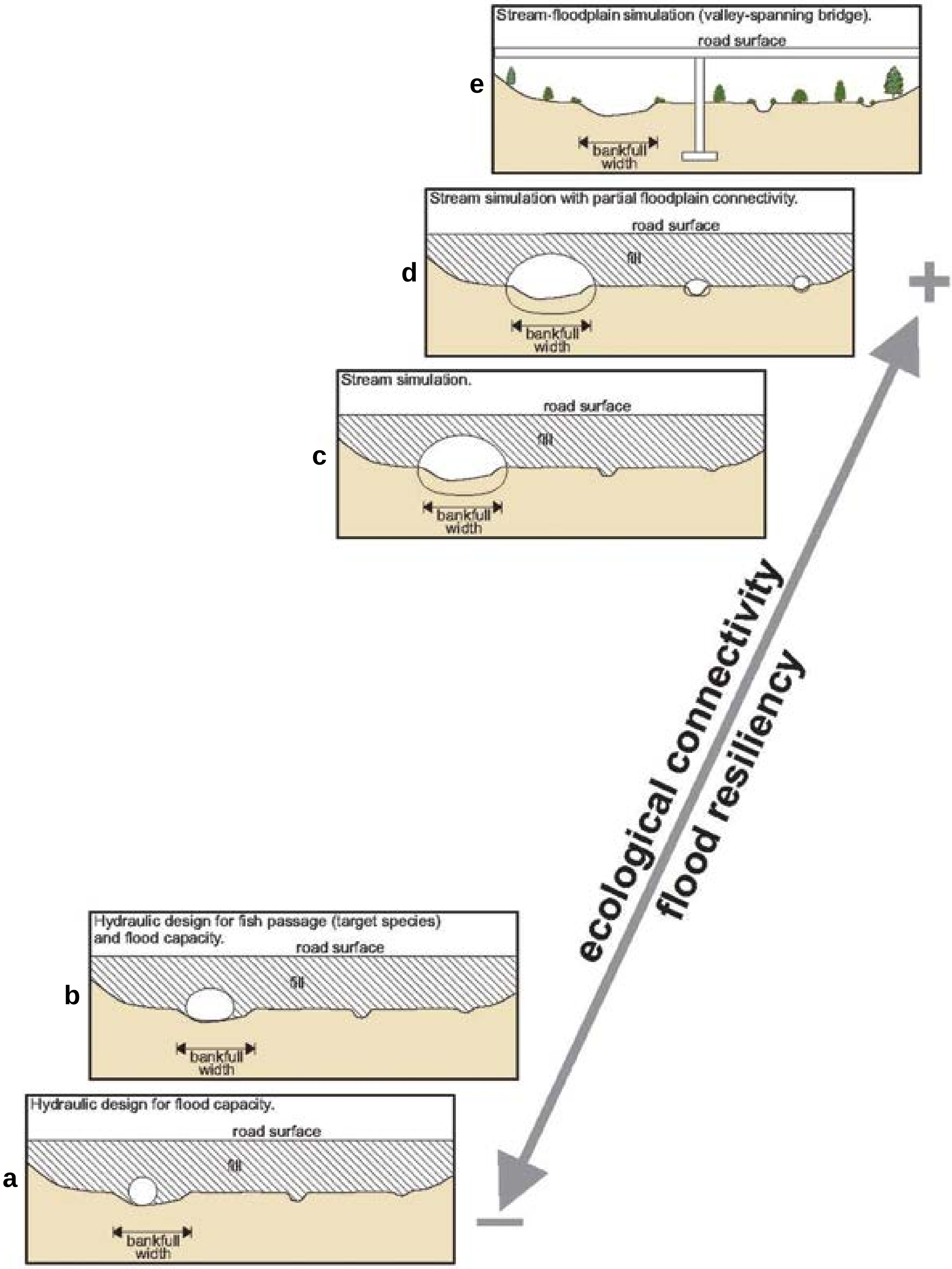

Figure 2. An ecological connectivity and flood resilience continuum for different design approaches at road-stream crossings (adapted from SSWG, 2008). The stream-floodplain simulation design (top graphic) provides passage for all aquatic and terrestrial species all at flow levels and minimal interference of stream and floodplain processes, resulting in greater ecological connectivity and flood resiliency. The stream simulation design (middle graphic) provides for fully functioning floodplain processes, passing floodwater, sediment and woody debris and all aquatic species for a broad range of flows. The hydraulic design for flood capacity (bottom graphic) only provides for partial functioning of stream processes, impedes passage of some floodwaters, sediment, and woody debris during high flows, and impedes passage of most aquatic species for most flows, consequently providing low ecological connectivity and flood resiliency.

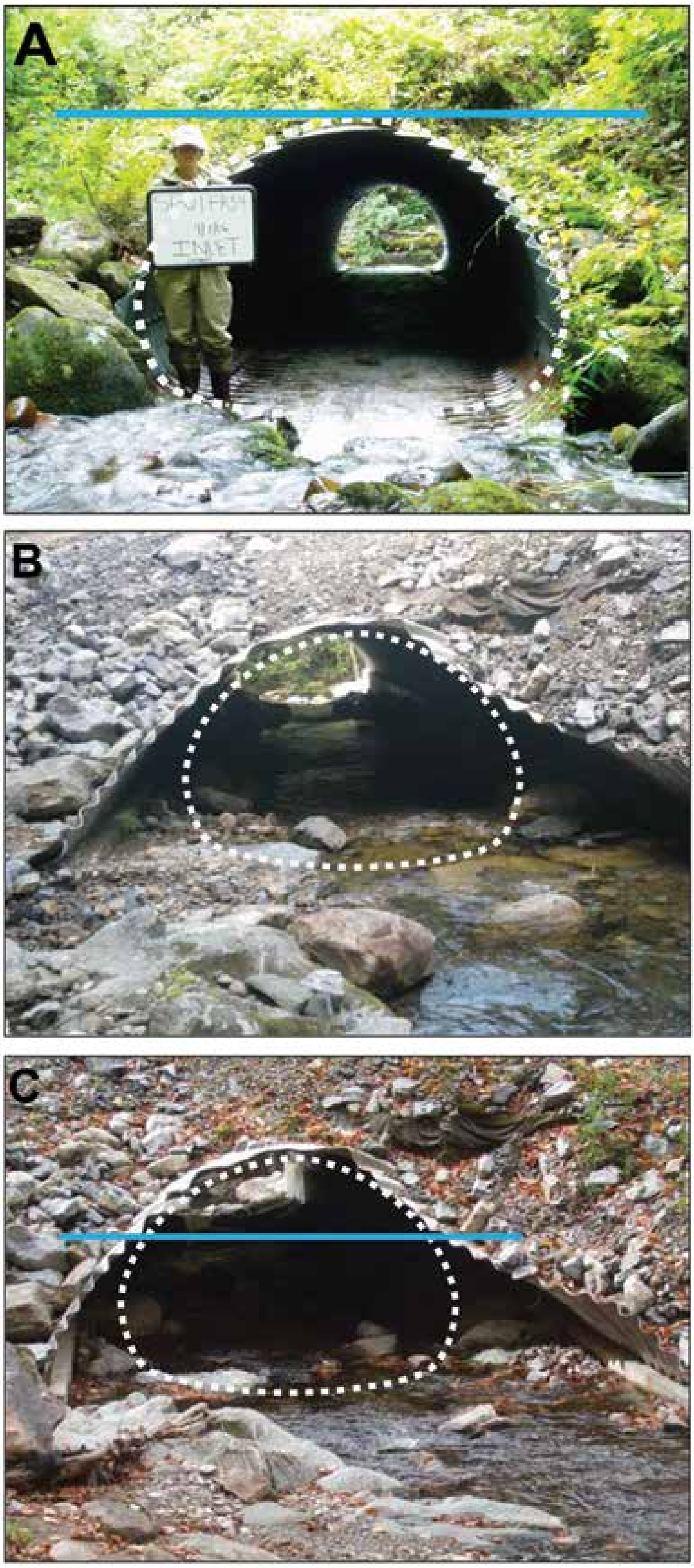

Figure 3. Sparks Brook road-stream crossing located on the Green Mountain National Forest, showing (a) original hydraulic design pipe-arch built in late 1960's, with a 2.5 m span and 1.9 m rise; (b) stream simulation design open-bottom arch structure built in 2010 with 4.5 m span, 1.62 m rise and footers extending 2.7 m below channel bed; (c) replacement structure after Irene flood. The blue line illustrates the actual peak flood water-surface elevation as well as the estimated peak flood elevation if the original culvert had been in place. Photo credit: Dan McKinley, Green Mountain National Forest.

structure than if the crossing did not exist (SSWG 2008). Stream simulation crossings are designed to maintain geomorphic and hydrologic continuity with the adjacent natural channel by building a "design channel" through a road–stream crossing structure with gradients, cross-sectional widths and shapes, bed forms, flow depths, and sediment size characteristics that are similar to those of a stable, nearby reference channel (SSWG 2008). The stream simulation design approach is applicable on any channel type or gradient and in most environmental settings (Cenderelli et al. 2011). To avoid constricting flood flows, the width of a stream simulation design structure is equivalent to or exceeds the bankfull width of the natural channel. For channels with wide, adjacent floodplains, the stream simulation approach recommends installing floodplain relief culverts to facilitate partial floodplain flow continuity through the road fill and reduce the concentration of water through the main crossing structure during floods greater than bankfull flow. The replacement structure type and size, which can include a bridge or variety of culvert configurations, are determined by the stream simulation channel dimensions as well as any projected vertical and lateral adjustments of the stream over the service life of the structure. The mobility of the constructed channel bed material as well as the stability of key particles used to build grade controls in the bed of the road–stream crossing structure are analyzed to ensure that they have properties (mobility and stability) similar to those in the natural reference channel (Cenderelli et al. 2011).

The proposed design structure is also evaluated to provide sufficient hydraulic capacity and passage of debris during the 100-year recurrence interval design flood. Stream simulation structures are required to have headwater-to-depth ratios less than 0.8, meaning that adequate space exists between the 100-year flood elevation and the top of the road–stream crossing structure (Figures 3 and 4). This clearance provides room for debris transport and reduces the likelihood of ponding or backwatering on the upstream side of the crossing, which can create pressurized flow within the structure during large-magnitude floods. Observations and analyses of stream simulation structures show that the headwater-to-depth ratio for the 100-year design flood discharge is typically between 0.5 and 0.7. In other words, stream simulation structures typically have the ability to convey water and debris through the structure for flows well in excess of the 100-year flood. A road–stream crossing sized using the stream simulation method reduces or eliminates backwatering or ponding at the inlet during floods and makes those areas less prone to sediment and debris accumulation. Like a natural channel, a stream simulation channel is able to adjust its dimensions in response to a wide range of floods and sediment or wood inputs without compromising the movement needs of aquatic organisms or the hydraulic capacity of the structure (Gubernick and Bates 2003; Cenderelli et al. 2011).

Figure 4. Typical hydraulic design double culvert over Jenny Coolidge Brook, May 2010. Green Mountain National Forest showing estimated height of 100-flood design discharge in red. Photo credit: Brian Austin, Green Mountain National Forest.

The hydraulic capacity design method differs from the stream simulation design method in fundamental ways (Figure 5). Stream simulation design determines the size of the structure based on the physical dimensions of the natural channel first and foremost and evaluates hydraulic capacity as a secondary check to ensure sufficient conveyance of the 100-year flood with additional clearance for debris transport. In contrast, traditional hydraulic design methods give no consideration of the actual physical dimensions of the natural channel when sizing the road–stream crossing structure. Hydraulic design structures are sized to pass a design flood (e.g., Q10 flood, Q25 flood, Q100 flood) with headwater-to-depth ratios typically at 1.0 or greater (Hotchkiss and Frei 2007). Design flood discharge estimates are usually determined using regional regression equations that typically have standard error estimates greater than 40%. Additionally, regional regression equations used to predict design discharge were typically developed for larger drainages and are not necessarily applicable to small drainages, which add to the uncertainty of the discharge estimates. Recent analyses and predictions under a changing climate suggest that the set of return interval floods underlying hydraulic capacity designs are no longer valid. In New England, trends in measures of precipitation intensity (Huntington et al. 2009) and frequency of larger precipitation events increased by 85% since 1948 (Madsen and Wilcox 2012), and the recent record-breaking storm events such as Tropical Storms Irene, Lee, and Sandy (Douglas and Fairbank 2011) and the projected increases in total annual precipitation (Intergovernmental Panel on Climate Change 2007) and rain on snow events (Douglas and Fairbank 2011) strongly suggest the need for changing flood discharge estimates.

COST COMPARISON OF TRADITIONAL HYDRAULIC VS. STREAM SIMULATION DESIGNS

There continue to be significant challenges to designing and installing road–stream crossings for aquatic organism passage and flood resilience. The choice of a suitable design method to replace a failed road–stream crossing is almost always influenced by budgetary constraints, but the true cost of a crossing failure is rarely considered. The cost of a failure includes not only the cost to replace the structure itself but also the cost to replace other affected infrastructure and property (e.g., roads, houses) and delay costs from disruption in commerce and travel. These delay costs are often not considered in the replacement cost because they are experienced by traffic users, homeowners, and businesses and are not a direct expense to an agency's budget (Perrin and Jhaveri 2004). Failures during a major flood can be particularly problematic for towns because emergency replacement costs are generally higher than planned replacement costs. The loss of a road–stream crossing or associated damage to road infrastructure also threatens human health and safety by creating hazards and disrupting access by emergency services. Lastly, widespread road closures and detours can be detrimental to the tourism industry by creating the perception that the area is not "open for business," as was the case across much of Vermont during the fall foliage season following Irene (Lunderville 2011).

Stream simulation design options typically have higher up-front installation costs than traditional hydraulic designs,

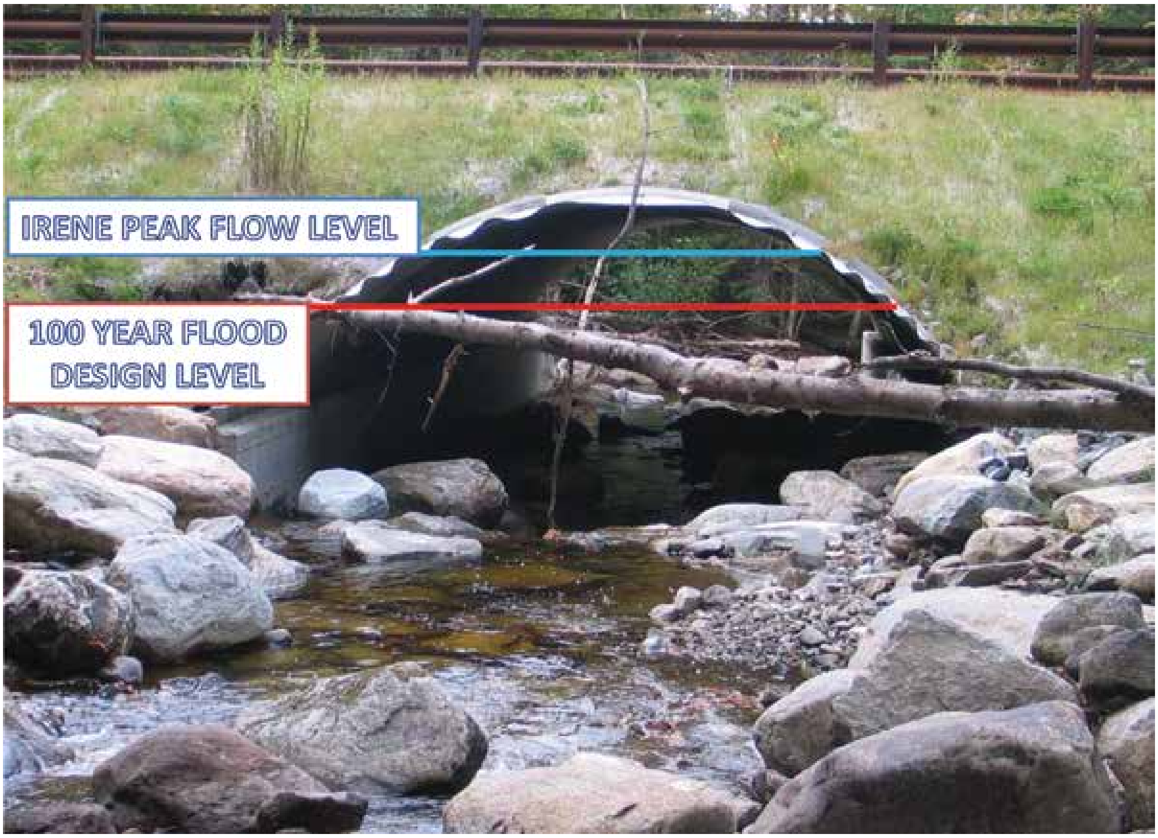

Figure 5. Stream simulation design culvert at Jenny Coolidge Brook, installed in June 2010, showing height of 100-year design discharge in red and height of Tropical Storm Irene flood level in blue. Photo credit: Brian Austin, Green Mountain National Forest.

making them appear less economical, particularly for highway and road maintenance departments facing chronic budget shortfalls. The installation cost of a structure (e.g., bottomless arch culvert) designed using the stream simulation approach varies with the type and size of the crossing selected and project site characteristics. Data from across the northwest United States suggest that a 50% increase in structure width results in a 20%–33% increase in total project cost (Gubernick 2011). A review of 2008 GMNF cost comparisons (Table 1) for the traditional and stream simulation designs on the GMNF found that stream simulation designs increased construction costs between 9% and 22%. Though a $20,788 cost increase is significant, as was the case for the Bingo Road crossing, this increase quickly becomes more economical when compared to costs exceeding $100,000 on road repairs after a flood (Tables 2–4).

Long-term maintenance and replacement costs should also be considered. Hydraulic designs (Figures 2a and 3) that constrict the stream channel can incur a yearly maintenance cost from debris removal and pose a greater risk of unexpected replacement costs from failure during large magnitude floods (Furniss et al. 1997). In contrast, stream simulation designs that span the bankfull channel (Figures 2c–2e and 4) have demonstrated minimal or no annual maintenance costs and are flood resilient and are likely to last longer than their projected service life (Long 2010). Galvanized steel culverts installed using the stream simulation design method have an anticipated service life of 50 to 75 years because the constructed stream channel bed and margins protect the structure from abrasion as bed load moves through the crossing. By comparison, traditional galvanized steel culverts installed using the hydraulic design method typically last 25 to 50 years depending on the gauge of steel, water chemistry, and rate of abrasion by bed load movement (State of Idaho 1965). An agency or landowner should weigh the higher installation cost of using a stream simulation design method with the long-term costs of likely repeated replacement and repair of undersized culverts (Long 2010).

TROPICAL STORM IRENE CASE STUDY

On August 27–28, 2011, Tropical Storm Irene brought significant rainfall to much of New England and eastern New York, with many areas receiving over 16 cm of rain (Vermont Agency of Natural Resources 2011) that caused considerable damage throughout the Northeast United States. Over the 42-hour period across New England, total rainfall reached over 30 cm in many locations, inundating entire watersheds and drainage basins simultaneously. Record river levels were reached at 37 stream gages in New York, eight stream gages in Vermont and western Massachusetts, five stream gages in New Hampshire, and at least one stream gage in Connecticut and Maine. Flow magnitudes exceeded predicted 100-year discharge in many catchments. For example, the gage on the Ayers Brook at Randolph, Vermont, with a 79-km^2 drainage area and flow record of 71 years, recorded a peak discharge that greatly exceeded the 500-year flood flow estimate (Lunderville 2011).

Table 1. Cost comparison of traditional hydraulic design vs. AOP stream simulation design in the Green Mountain National Forest.

Estimated costs from damage survey reports					
Road no./name	Traditional culvert/replace in kind ($)	Betterment/AOP stream simulation replacement ($)	Anticipated % cost increase for AOP stream simulation design	Actual construction cost ($)	Actual % cost increase for AOP stream simulation design
FR42.05.0 over Bingo Road	92.950.00	142,050.00	53	113,738.00	22
FR42B.00.0 over Bingo Brook	112,175.00	156,775.00	40	Never constructed, road decommissioned	NA
FR49.00.5 over Boyden Brook	93,800.00	140,700.00	50	Never constructed, Irene damaged site access road	NA
FR92.00.0 Over Goshen Brook	106,635.00	172,200.00	61	119,835.00	12
FR92A.00.0 over Hale Brook	104,700.00	130,250.00	24	113,725.00	9

Table 2. Costs to repair damages to National Forest System roads resulting from stream crossing failures in the upper Whiter River Watershed, Vermont, during Tropical Storm Irene, 2011.

Forest road no.	Road name	Stream name	Drainage area (km^2)	Bankfull width (m) based on regional curves	Failed structure type and size	Ratio of structure to bankfull width	Approximate repair cost due to crossing failure ($)	Approximate total road repair cost ($)
FR394	Townsend Brook	Townsend Brook	1.3	3.0	Native stringer bridge with approximately 1.5-m opening	0.50	81,000	104,000
FR226	Corporation Brook	Corporation Brook	4.4	5.0	2.0-m culvert	0.40	10,000	105,000
FR45	Chittenden Brook	Chittenden Brook	14.8	8.6	Bridge 11.6 m	1.35	175,000	190,000
FR35	Upper Michigan	Michigan Brook	19.9	9.8	3.7-m culvert	0.38	247,000	247,000
FR39	Texas Falls	Texas Falls Brook	NA	NA	Numerous 46- to 60-cm cross-drain culverts	n/a	82,000	82,000
						Totals	595,000	728,000

Source: Dan McKinley (GMNF, personal communication).

Table 3. Summary of town road infrastructure damages from Tropical Storm Irene, 2012.

Town	Total culvert inventory	Total number of failed culverts	Estimated cost of culvert repairs ($)	Town minimum culvert standard	Typical culvert type
Granville	Town has no records	18	60,000 (pipes) and 39,000 (additional damages)	18-in. minimum diameter for town roads, Q25 hydraulic design for state roads	Spiral arch or pipe
Hancock	Town has no records	4	1.1 million (Churchville Rd.)	Same as above	Steel pipe
Pittsfield	237	25	114,000 (pipes and labor)	Same as above	Plastic pipe
Rochester	Town has no records	31	197,000 (four priority culverts)	Same as above	Steel pipe
Stockbridge	Town has no records	5	No records	Same as above	Varies

Table 4. Churchville Road culvert failure estimated costs to the Hancock community.

Example of costs incurred to the town of Rochester at Churchville Road from debris plugging and failure of a single undersized culvert	
Structure	Estimated cost ($)
Culvert	0 (no damage to culvert)
Churchville Rd.	1.1 million
Unmaintained road improvement	84,000
Traffic delay costs (gas, lost work time, etc.)	To be determined
Total cost	1,184,000+

Commercial, residential, and transportation infrastructure across the region was significantly damaged from high water, debris, and erosion. Flood damage was the most severe along tributaries to Lake Champlain in Vermont and the Adirondacks of northeastern New York, as well as in the Connecticut River Valley in western Massachusetts, New Hampshire, and Vermont. Thirteen towns in Vermont became isolated from bridge and culvert washouts (Lunderville 2011). The state of Vermont incurred damage to over 200 state road segments and 200 state bridges, and towns reported over 2,000 road segments, 277 bridges, and nearly 1,000 culverts damaged or destroyed by flooding from Irene. Vermont went into disaster mode and state and federal emergency management agencies began responding to 225 of Vermont's 251 municipalities (Lunderville 2011). Across the state, there were multiple instances where undersized culverts failed. This type of widespread infrastructure damage from large flood events and the persistence of undersized road–stream crossings is not unique and has occurred across the country in Maine, New York, Massachusetts, Pennsylvania, both South and North Dakota, and Alaska (J. Rowan, USFWS, personal communication).

DAMAGES IN THE UPPER WHITE RIVER WATERSHED

The White River is Vermont's fourth largest subbasin, draining an area of 1,839 km^2 within the Connecticut River Basin (Figure 6). Elevation ranges from 1,067 m along the spine of the Green Mountains at the western edge of the watershed to approximately 183 m at the confluence with the Connecticut River on the eastern edge of the watershed (Ruddell et al. 2007). As the longest undammed tributary to the Connecticut River, the White River has been very important to state and federal efforts aimed at revitalizing Atlantic Salmon (*Salmo salar*) populations (WRP 2012). The White River watershed was designated as a Special Focus Area of the USFWS Silvio O. Conte National Fish and Wildlife Refuge in part because the watershed provides nursery and rearing habitat for juvenile Atlantic Salmon and potential spawning habitat for adults (WRP 2012). Eastern Brook Trout are the dominant species in the headwater tributaries and are a focus of USFWS and USFS aquatic connectivity and habitat restoration efforts.

The upper White River main stem comprises approximately 38.6 km of stream extending from the headwaters of the White River in Ripton to the confluence with the Tweed River in Stockbridge (Ruddell et al. 2007). The five valley towns of Stockbridge, Rochester, Hancock, Pittsfield, and Granville are located along the upper White River and bordered to the west by the GMNF. Each town has its own independent government and town populations range from 298 to 1,139 (U.S. Census Bureau 2010). The GMNF includes 40% of the upper White River watershed north of Stockbridge. Development occupies approximately 5% of the watershed and has occurred mostly along the river corridor and has negatively impacted water quality and aquatic habitat (WRP 2012).

Between 2004 and 2007, the VFWD inventoried 1,501 road–stream crossings statewide on streams greater than 2.4 m bankfull width. It found that that only 5.3% provided full passage of aquatic organisms, and nearly 91% significantly constricted the natural channel width (structure width to bankfull width ratio less than 0.75). A subset of the inventory is located in the upper White River subbasin. Of the 43 culverts surveyed, 15 failed during Tropical Storm Irene, provided either reduced or no AOP, and had culvert width to bankfull width ratios ranging from 0.27 to 0.90, with an average of 0.54. Based partially on the inventory data, in 2009 the VFWD produced AOP guidelines for the state that identified stream simulation design as its preferred approach for road–stream crossings (VFWD 2012).

On the entire GMNF, Irene damaged 40 km of transportation infrastructure at an estimated repair cost of $6.4 million. In the upper White River watershed, the GMNF suffered $728,000 in road damage, with an estimated 70% due to debris plugging at road–stream crossings (Table 2). Three of four road–stream crossings that failed were hydraulic designs with crossing width to bankfull width ratios less than 0.52. These undersized hydraulic culverts were also identified aquatic organism passage barriers. The fourth crossing, a bridge over Chittenden Brook located on an alluvial fan (a natural depositional zone), was constructed in 2010 with a span greater than bankfull width for increased flood capacity and AOP. During Irene, large bank failures upstream delivered a tremendous amount of woody debris downstream, which settled on the alluvial fan and plugged the bridge, causing the stream to overtop the bridge and wash out the bridge approach—the design failure point—leaving the bridge undamaged. The Chittenden Brook example underscores how no road–stream crossing design can guarantee avoidance of damages during large floods but that site location and adopting an ecological approach with flood resiliency as a primary objective can reduce infrastructure damage considerably.

The towns of Rochester, Hancock, Pittsfield, and Granville suffered damage to or complete loss of 70 road–stream crossings. These communities were left isolated without power and water for three days due to road damage and road–stream crossing washouts. Following a presidential disaster declaration, the towns were eligible to apply for financial assistance through the Federal Emergency Management Agency's (FEMA) Public Assistance Grant Program for the repair or restoration of infrastructure and facilities to predisaster condition (Lunderville 2011). Coauthor Campbell met with either the road foreman or town administrator for each of these towns during April 2012 to obtain flood impact information (Table 3). Where possible, they provided Irene-induced crossing failure information, such as culvert size and location, cost data from FEMA project worksheets, and descriptions of major failures.

The towns of Rochester and Hancock provided several specific examples of extensive impacts from the failure of a single road–stream crossing. The failure of a 3.4-m-diameter culvert at Nason Brook in Rochester resulted in an estimated $1 million in damages to Woodlawn Cemetery. During Irene, the culvert became plugged with debris and then redirected a large volume

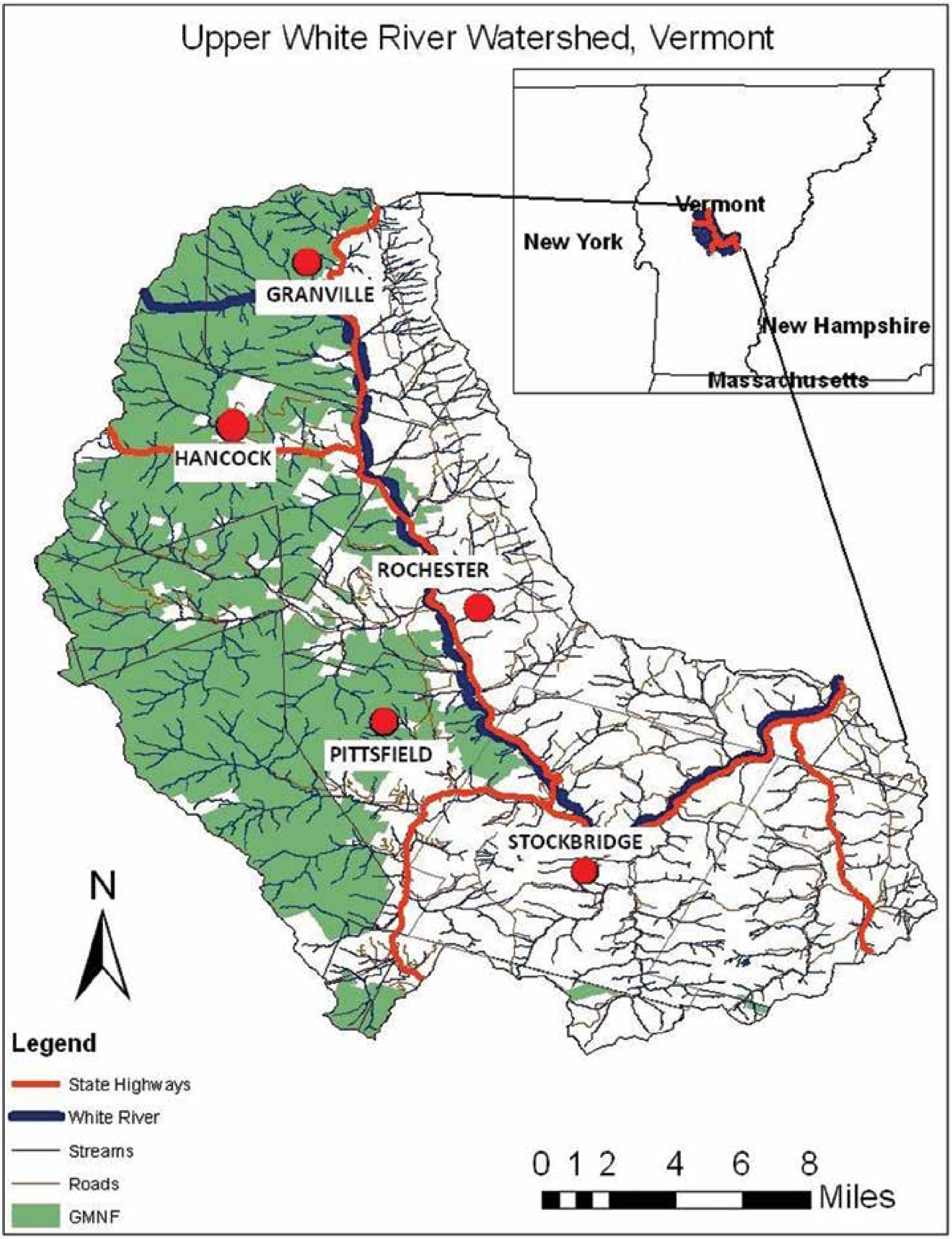

Figure 6. Upper White River watershed study area.

of water onto the cemetery grounds, unearthing 50 caskets and strewing their remains throughout downtown Rochester (Davis 2011). The USFWS and the WRP are currently working with FEMA and Rochester to replace the failed culvert. The cost for this culvert to be upgraded to a flood resilient 9.7-m bridge is approximately $50,000, which the USFWS was able to obtain specific to this site at a lower than average cost.

In Hancock, on Churchville Road, a 3.6-m-diameter steel pipe, originally designed to pass a 25-year recurrence interval flood, failed and resulted in long-term travel disruption and major damage costs. Though the culvert itself remained intact, the floodwaters overtopped it and washed out more than 350 m of Churchville Road, which was not replaced until August 2012, with a repair cost of approximately $1 million. A nearby unmaintained road had to be upgraded in order for residents to regain access to the main highway, at a cost of approximately $84,000, with residents bearing the cost of driving an additional 2 miles each way to reach Vermont Route 100. The total cost of the culvert failure and associated damage is at least $1,184,000, excluding traffic and delay costs (Table 4). In both examples, had the culverts been appropriately sized, it is unlikely that these damages would have been as disruptive and costly.

THE LINK BETWEEN AQUATIC ORGANISM PASSAGE AND FLOOD RESILIENCE

In contrast to the extensive damage experienced by towns in the Vermont case study, two stream simulation design culverts that were installed on the GMNF before Irene not only survived the storm but incurred no maintenance or replacement costs. USFS fisheries and engineering staff had targeted the upgrade of these two hydraulically designed pipes on Forest Service roads for replacement in 2010 and 2011 because they were barriers to the upstream movement of eastern Brook Trout and other aquatic organisms and because they were identified as a risk for debris plugging and failure in large storm events. These two crossings located on Sparks Brook (Figure 3), immediately adjacent to the upper White River watershed, and on Jenny Coolidge Brook (Figures 4 and 5), also in the Connecticut River Basin, were designed to span the bankfull dimensions of the natural channel, resulting in structures with sufficient hydraulic capacity to convey flows in excess of the Q100 peak flow while providing additional headwater clearance for debris transport. Preliminary hydraulic analysis of Jenny Coolidge Brook estimates peak storm discharges during Irene exceeded the 500 year recurrence interval (R. Gubernick, USFS, personal communication). In addition, on Joe Smith Brook in the upper White River watershed, a hydraulic design culvert was recently replaced with a Q100 bottomless arch to provide greater flood capacity and a natural bottom for AOP. Though this road–stream crossing upgrade was not strictly a stream simulation design with regard to gradient, channel banks, and substrate size, the structure still spanned the bankfull dimensions of the natural channel and it also survived Irene undamaged. Three additional stream simulation crossings located on GMNF listed in Table 1 were still in the early stages of construction when Irene hit and were not included in the flood resiliency analysis but will allow for a more robust comparative analysis with traditional culvert designs during future floods.

Though additional monitoring is needed, other examples demonstrate the flood resilience of road–stream crossings designed for aquatic organism passage across the region impacted by Irene. In Worthington, Massachusetts, a double 3-m box culvert, which prevented Brook Trout and resident darter passage on a 9-m bankfull section of Bronson Brook, a tributary of the Westfield River, catastrophically failed in an August 2003 storm. A 12-m arch culvert replacement has since survived several major storms, including Tropical Storm Irene, without damage to the structure, road or adjacent stream banks (A. Singler, American Rivers, personal communication). In Hancock, New York, between 1996 and 2005 three flood events caused damage to an undersized and perched pipe culvert on Big Hollow Creek, which was a barrier to trout movement. In those 9 years, Delaware County spent over $70,000 to repair damages to the culvert as well as the road and adjacent ditches. In addition, the detour length associated with closure of the road for repairs was 18 miles. Late in 2005, with hazard mitigation funding assistance from FEMA, the county installed a more ecologically beneficial three-sided concrete box culvert with a natural bottom, designed to convey a 100-year storm and provide fish passage at all flow levels, for a cost of $143,000. The improved crossing has survived seven federally declared flood disasters, including Irene, without significant damage since its replacement in 2005 (W. Reynolds, Delaware County Department of Public Works, personal communication).

The flood resilience of stream simulation designs has been documented during significant flow events elsewhere. On the Siuslaw National Forest on the Oregon coast, eight stream simulation design crossings installed in 2003 have weathered floods up to a 20- and 25-year recurrence interval range. Though adjustment of the streambed constructed beneath the road crossing ranged from negligible to significant, all eight crossings have maintained AOP, successfully passed sediment and debris, and avoided any infrastructural damage (B. Ellis-Sugai, USFS, personal communication). In southeast Alaska, the Tongass National Forest installed 93 stream simulation design crossings since 1998 (94% installed between 2000 and 2005) that have survived flood events in the estimated 25- to 50-year recurrence interval range without major failure and have maintained fish passage to state standards at 98% of locations (J. McDonell, USFS, personal communication).

BARRIERS TO IMPLEMENTING ECOLOGICALLY BENEFICIAL ROAD–STREAM CROSSINGS

Extreme events such as Tropical Storm Irene can create a window of opportunity for increased investment in disaster mitigation; however, for the towns in the White River Valley, existing regulations and funding mechanisms hindered the replacement of damaged road–stream crossings to increase aquatic organism passage and flood resilience. Under the Public Assistance Program, FEMA funds between 75% and 90%

of the estimated cost for a culvert replacement if it passes the "50% rule" (a structure is eligible for replacement if the repair cost exceeds 50% of the replacement cost). Otherwise, FEMA provides financial assistance at the 75%–90% rate to repair the original structure but not necessarily the costs to repair roads or other structures damaged by the culvert failure. In some cases, the culvert itself may remain in place while the road fails, but because the culvert is technically undamaged it will not pass the 50% rule. For example, Hancock was ineligible to receive public assistance funds to replace the Churchville Road culvert because the structure survived the flood but was eligible to receive public assistance funds to repair the road damaged by the plugged culvert. When a culvert is eligible for replacement, FEMA only provides financial assistance to rebuild the structure to its predisaster condition or up to passing the Q25 with 0.3-m clear space and 0.61-m embedment. If a town chooses to upgrade a failed culvert and does not have specific guidance from a state natural resources agency, FEMA reimburses the estimated cost of repairing or replacing the original culvert and the town must bear the cost difference for the upgrade. Towns face difficulties meeting these rules and simultaneously funding the additional costs to upgrade to stream simulation designs in the midst of expensive disaster recovery efforts.

Towns and counties may apply for funding to replace or upgrade road–stream crossings through FEMA's Hazard Mitigation Grant Program (HMGP), but this grant money is not available until 6 months after the disaster declaration, and total funding made available is not determined until a full year after the disaster. The amount of money available through this program is based upon the total amount paid out under emergency assistance in the months following the declared disaster. More important, the state prioritizes use of the funds and may not necessarily include road–stream crossing upgrades among eligible projects. Applying for HMGP funding requires a cost–benefit analysis and a demonstration of three historic losses at the site (Munroe and Crosby 2012). In order to meet this requirement, towns need to maintain detailed records of previous failures. FEMA does not maintain an accessible database of this information. In addition, FEMA only requires that project worksheets be kept by an applicant for three years from the date the state closes a grant (FEMA 2011), decreasing the likelihood that towns have the necessary information for HMGP eligibility if previous failures occurred before that time period.

Based on the information we observed, local governments face significant barriers to upgrading undersized road–stream crossings that obstruct aquatic organism passage and present chronic failure risks. These impediments include inconsistent and poorly defined crossing standards and limitations on FEMA assistance for structure upgrades and replacements. For example, three separate hydraulic standards apply to the towns in the upper White River watershed. The 1998 Vermont Department of Transportation *Hydraulics Manual* (VTrans 2001) requires state highway crossings to have a minimum design capacity of Q50 and town highway and local road crossings to have a minimum of Q25. The Vermont Department of Transportation revised the Town Road and Bridge Standards in 2011 to recommend that towns adopt a 45.7-cm-diameter and a Q25 conveyance as their minimum requirement for new road–stream crossings, allowing for structures to span less than half of bankfull width. For a stream alteration general permit, the Vermont Agency of Natural Resources requires crossings to be at least 1.2 times bankfull width, although applicants can apply for an individual permit to include a smaller crossing. Following Tropical Storm Irene, FEMA allowed a minor increase in culvert size of 0.3 m for debris and 0.61 m for embedment and replaced to the lowest standard adopted by an individual town. Because Pittsfield had recently changed the town culvert standard to 46 cm, it was eligible to upgrade eighteen 38-cm diameter culverts to 46-cm-diameter pipes under FEMA's Public Assistance funding. Granville did not upgrade its town culvert standard and was only eligible to replace 13 of 18 destroyed culverts with in-kind replacements funded through FEMA's Public Assistance program. The observation that all documented failed crossings in the study area had crossing width–to–bankfull width ratios of less than one and that these crossings met state minimum criteria underscores the need for a revised approach to achieve greater flood resiliency.

Economic justification for traditional hydraulic design has focused on short-term costs and not long-term persistence. The economic, societal, and natural resource costs of these failed road–stream crossings and the adjacent infrastructure are not included in up-front cost calculations. At the federal, state, and municipal levels, the increased benefits of building ecologically beneficial crossings for AOP and greater flood resiliency are not calculated. Time constraints and pressures to reopen failed roads and return emergency services to communities generally drive quick repair of infrastructure to a working condition rather than long-term flood resiliency.

Other cultural and political factors impede a systematic approach to replacing culverts and road crossings to ecologically beneficial standards. In Vermont and across New England, independent town governance and highway departments discourage application of uniform techniques and the effective transfer of skills and training in river dynamics, engineering, hydraulics, and aquatic ecology needed to design and build flood resilient road–stream crossings. In addition, the misperception that "fish-friendly" crossings have no economic or societal benefit outside of natural resource protection is commonly heard in New England following flood events.

RECOMMENDATIONS

Based on the upper White River watershed case study, the following recommendations are presented to federal and state agencies, communities, and nongovernmental organizations in order to better integrate ecological objectives into road–stream crossing design and provide more effective flood resiliency across the country.

Prioritization

- Target “repeat offenders”: Before the next major storm, replace undersized culverts that have caused extensive road and property damage and/or failed more than once. This will require better record-keeping by communities.
- Identify priority sites at a watershed scale for aquatic health or critical populations and road–stream crossings that have high social significance; for example, high-volume traffic, major commuting delays, provision of critical emergency services, etc. In southeastern Massachusetts, The Nature Conservancy and a regional planning agency collaborated to identify key locations in the transportation network where both river continuity and public welfare were impacted by existing structures; these were included in the Regional Transportation Plan as priorities for improvement (Southeastern Massachusetts Metropolitan Planning Organization 2012).

Regulatory

- Work with FEMA and affected agencies to address regulatory road blocks to restoring infrastructure that would be more resilient to flood events in future years.
- Coordinate among federal and state agencies, including FEMA, the Natural Resources Conservation Service, state emergency management, departments of transportation, and environmental agencies to adopt as a standard the latest technologies that incorporate multidisciplinary, ecologically beneficial approaches to road–stream crossing such as stream simulation design.
- Change regulatory preference for in-kind emergency repair to upgrading road-crossing structures based on flood resiliency through strong guidance on interpreting FEMA Sections 404 and 406 funding, particularly the definition of what constitutes a road–stream crossing failure. It is currently common practice to reuse clearly undersized culverts that have been washed out by a flood and simply rebuild the road with new materials.
- Consider changes to language in U.S. Army Corps of Engineers 404 Nationwide Permit process to provide more prescription for ecologically beneficial road–stream crossing criteria consistent with the intent of the Clean Water Act, which requires the protection and restoration of the physical, chemical, and biological integrity of the nation’s waters.

- Adopt consistent state and town standards for road–stream crossings that incorporate AOP concerns and increased flood resiliency. FEMA replaces structures to the lowest standard adopted by the local government.

Funding

- Adopt an incident command structure for flood-affected areas modeled after the National Incident Management System approach to wildfires and other disasters impacting communities and/or regions. Place high priority on deployment of an interagency flood response “Strike Team” composed of fluvial restoration, engineering, and fisheries experts to flood-affected regions immediately (see Sidebar).
- Allow other federal agencies to contribute to the state and town cost shares of 12.5% typically required by FEMA for projects that serve a role in providing multiple benefits and flood resilience. Higher upfront project costs are an impediment to towns when they are forced to replace many structures at once.
- Increase Hazard Mitigation Grant Program share beyond the current 10%–15% of total cost of disaster reimbursement monies.
- Use a collaborative whole watershed approach similar to the USFWS’s Irene recovery effort when prioritizing road–stream crossing upgrades in order to leverage resources, focus efforts, and address impacts at the watershed scale (see Sidebar).

Education and Future Research

- Expand interagency workshops to increase understanding of ecologically beneficial approaches to road–stream crossing design, true life cycle costs analysis, and river dynamic principles modeled after the highly successful USFS stream simulation design and USFWS fish-friendly crossing workshops. Target state and county transportation, engineering staff, and heavy equipment operators who are routinely contracted for postflood remediation work. Consider development of an interagency-approved certification program for such workshop attendees for ecologically beneficial approaches to designing and constructing road–stream crossings.
- Conduct further research of life cycle cost analysis for federal and state reimbursement criteria for failed structures to include likelihood of failure based on crossing width : bankfull width ratio.
- Track crossing failures and crossing : bankfull width ratios nationally to help agencies better understand failure causes and identify trends of failure associated with this metric (Perrin and Jhaveri 2004).

In summary, this article makes the case that adoption of the stream simulation design approach provides multiple benefits to communities, state, and federal governments, particularly as extreme weather events become a more common occurrence. Road–stream crossing infrastructure represents large investments that are currently susceptible to catastrophic failure during large flood events, resulting in significant economic and societal costs to communities. This case study suggests that investing in stream simulation designs with flood resiliency as a primary objective has the potential to reduce these economic and societal costs through reduced failure rates and lower maintenance costs while maintaining important ecological values. Increased interagency coordination and prioritization of geomorphic, engineering, and ecologically based designs for road–stream crossings are needed across federal, state, county, and municipal scales to help prevent a recurrence of this kind of extreme damage and disruption experienced by Vermont and much of New England following Tropical Storm Irene.

USFWS AND MOBILIZATION OF A PILOT "STRIKE TEAM"

In September 2011, the USFWS Northeast Region mobilized various technical field staff for immediate post-emergency engineering and technical support for fish passage and stream restoration recovery needs following Tropical Storm Irene in Vermont and New York. The USFWS dedicated roughly $132,600 to the upper White River watershed response, including $32,584 for staff time through the month of October 2011 and $100,000 in project funding to the local grassroots organization the White River Partnership (WRP) that focused on the town of Rochester through an agreement funded by the National Fish Passage Program. Based on previous surveys to prioritize aquatic organism passage needs for Atlantic Salmon and eastern Brook Trout in collaboration with the WRP, the USFWS staff provided review of nine road–stream crossing sites, restoration of two sites, data collection on four other sites, and a technical review of all projects. The USFWS has already developed design plans to restore fish passage at five additional sites in Rochester. The upgrades involve replacing traditional hydraulic designs with bottomless arch culverts that exceed measured bankfull width, as well as the diameter of the standard Q25 hydraulic design width by a range of 1.3 to 2.4 times and the flow area of the Q25 hydraulic design by 2.4 times on average. In all cases the USFWS provided towns with design plans to improve both fish passage and flood resilience in conjunction with repair and cost estimates from FEMA.

In the case of the upper White River watershed, the USFWS response to local communities was enhanced through partnership with the USFS GMNF, which provided additional technical expertise and project funding. Identification, organization, and deployment of interagency as well as intra-agency strike teams in collaboration with local and state governments and nongovernment organizations has the potential to increase response capability in terms of speed and duration, provide for comprehensive support across broader geographic areas, and establish continuity from the federal government to local governments. Yet efforts to address a larger storm or respond to a wider area of damage would have exhausted agency capacity to deliver critical services, underscoring the need for coordinated interagency deployment of technical experts to respond to flood-damaged communities.

REFERENCES

Angermeier, P. L., A. P. Wheeler, and A. E. Rosenberger. 2004. A conceptual framework for assessing impacts of roads on aquatic biota. Fisheries 29(12):19–29.

Bouska, W. W., and C. P. Paukert. 2010. Road crossing designs and their impact on fish assemblages of Great Plains streams. Transactions of the American Fisheries Society 139:214–222.

Cafferata, P., T. Spittler, M. Wopat, G. Bundros, and S. Flanagan. 2004. Designing watercourse crossings for passage of 100-Year flood flows, wood, and sediment. California Forestry Report No. 1. Sacramento, California.

Carline, R. F., and B. J. McCullough. 2003. Effects of floods on brook trout populations in the Monongahela National Forest, West Virginia. Transactions of the American Fisheries Society 132:1014–1020.

Cenderelli, D. A., K. Clarkin, R. A. Gubernick, and M. Weinhold. 2011. Stream simulation for aquatic organism passage at road–stream crossings. Journal of the Transportation Research Board 2203:36–45.

Clarkin, K., A. Connor, M. J. Furniss, B. Gubernick, M. Love, K. Moynan, and S. W. Musser. 2005. National inventory and assessment procedure for identifying barriers to aquatic organism passage at road–stream crossings. USDA Forest Service, San Dimas Technology and Development Center, San Dimas, California.

Coffman, J. S. 2005. Evaluation of a predictive model for upstream fish passage through culverts. Master's thesis. James Madison University, Harrisonburg, Virginia.

Coffman, S., M. Minter, J. Zug, D. Nuckols, C. Roghair, and C. Dolloff. 2005. Fish passage status of road–stream crossings on selected National Forests in the Southern Region. Unpublished file report. U.S. Department of Agriculture, Southern Research Station, Center for Aquatic Technology Transfer, Blacksburg, Virginia.

Davis, M. 2011. Irene Flood rips open cemetery in Rochester. Vermont Public Radio. Available: www.vpr.net/news_detail/91833/irene-floods-rip-open-cemetery-in-rochester. (September 2012).

Dolloff, C. A., P. A. Flebbe, and M. D. Owen. 1994. Fish habitat and fish population in a southern Appalachian watershed before and after Hurricane Hugo. Transactions of the American Fisheries Society 123:668–678.

Douglas, E., and C. Fairbank. 2011. Is precipitation in New England becoming more extreme? A statistical analysis of extreme rainfall in Massachusetts, New Hampshire, and Maine and updated estimates of the 100-year storm. Journal of Hydrologic Engineering 16:203–217.

FEMA (Federal Emergency Management Agency). 2011. Frequently asked questions, FEMA Public Assistance Program 4022-DR-VT. Available: www.vlct.org/assets/News/Irene/FEMA-PA_Program-FAQs.pdf. (September 2012).

Flanagan, S. A. 2004. Woody debris transport through low-order stream channels of northwest California—implications for road–stream crossing failure. Master's thesis. Humboldt State University, Humboldt, California.

Flanagan, S. A., M. J. Furniss, S. Theisen, M. Love, K. Moore, and J. Ory. 1998. Methods for inventory and environmental risk assessment of road drainage crossings. USDA Forest Service Technology and Development Program 9877-1809-SDTDC. San Dimas Technology & Development Center, San Dimas, California.

Furniss, M. J., M. Love, and S. A. Flanagan. 1997. Diversion potential at road stream crossings. USDA Forest Service Technology and Development Program 9777-1814-SDTDC. San Dimas Technology & Development Center, San Dimas, California.

Furniss, M. J., T. S. Ledwith, M. A. Love, B. McFadin, and S. A. Flanagan. 1998. Response of road–stream crossings to large flood events in Washington, Oregon, and Northern California. USDA Forest Service, Technology and Development Program. 9877-1806-SDTDC. San Dimas Technology & Development Center, San Dimas, California.

Gubernick, R. 2011. Flood damage assessment: Green Mountain National Forest. Region 9 TST. USDA Forest Service, internal publication.

Gubernick, R., and K. Bates. 2003. Designing culverts for aquatic organism passage: stream simulation culvert design. International Conference of Ecology and Transportations Proceedings, Lake Placid, New York.

Heller, D. 2007. A strategic approach for the identification and correction of fish passage on National Forest lands in the Pacific Northwest. Page 187 *in* C. Leroy Irwin, Debra Nelson, and K. P. McDermott, editors. Proceedings of the 2007 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina University, Raleigh, North Carolina.

Hotchkiss, R. H., and C. M. Frei. 2007. Design for fish passage at roadway–stream crossings: synthesis report. U.S. Department of Transportation, Publication No. FHWA-HIF-97-033. Federal Highway Administration, McLean, Virginia.

House, M. R., M. R. Pyles, and D. White. 2005. Velocity distributions in streambed simulation culverts used for fish passage. Journal of the American Water Resources Association 41:209–217.

Hudy, M., T. M. Thieling, N. Gillespie, and E. P. Smith. 2005. distribution, status and perturbations to Brook Trout within the eastern United States. Final report to the steering committee of the Eastern Brook Trout Joint Venture. Trout Unlimited, Arlington, Virginia.

Huntington, T. G., A. D. Richardson, K. J. McGuire, and K. Hayhoe. 2009. Climate and hydrological changes in the northeastern United States: recent trends and implications for forested and aquatic ecosystems. Canadian Journal of Forest Research 39(2):199–212.

Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pages 75–76 *in* S. Solomon, D. Qin, and M. Manning, editors. Cambridge University Press, Cambridge, United Kingdom, and New York, New York.

Kirn, R. 2012. Impacts to stream habitat and wild trout populations in Vermont following

Tropical Storm Irene. Vermont Fish and Wildlife Department Annual Report, Project No. F-36-R-14. Vermont Fish & Wildlife Department, Montpelier, Vermont.
Letcher, B. H., K. H. Nislow, J. A. Coombs, M. J. O'Donnell, and T. L. Dubreuil. 2007. Population response to habitat fragmentation in a stream-dwelling brook trout population. PLOS One 2(11):e1139. DOI: 10.1371/journal.pone. 0001139.
Long, S. 2010. The economics of culvert replacement: fish passage in eastern Maine. Natural Resources Conservation Service, Maine. Available: ftp://ftp-fc.sc.egov.usda.gov/Economics/Technotes/EconomicsOfCulvertReplacement.pdf. (October 2013).
Lunderville, N. 2011. Irene recovery report. A stronger future. A report to the governor of Vermont. State of Vermont, Montpelier, Vermont.
Madsen, T., and N. Wilcox. 2012. When it rains, it pours: global warming and the increase in extreme precipitation from 1948 to 2011. Environment Texas Research and Policy Center. Available: http://www.frontiergroup.org/sites/default/files/reports/When%20It%20Rains,%20It%20Pours%20vUS.pdf. (October 2013).
Munroe, D., and C. Crosby. 2012. After Irene: Adaptation, Policy, and Management. Middlebury College, Spring Environmental Studies Seminar. Available: www.middlebury.edu/sustainability/news-events/news/2012/NL12/node/423397. (September 2012).
Nelson, N., R. Cissel, T. Black, C. Luce, and B. Staab. 2012. Legacy Roads and Trails Monitoring Project: road decommissioning in the Granite Creek watershed, Umatilla National Forest. U.S. Forest Service, Rocky Mountain Research Station, Boise, Idaho. Available: www.fs.fed.us/GRAIP/downloads/case_studies/LegacyRoadsUmatillaNF_Granite2008DecomissionFinalReport.pdf. (July 2012).
Nislow, K. H., M. Hudy, B. H. Letcher, and E. P. Smith. 2011. Variation in local abundance and species richness of stream fishes in relation to dispersal barriers: implications for management and conservation. Freshwater Biology 56:2135–2144.
Orsborn, J. F., M. Witecki, and J. Toohey. 2002. Culvert design flows for fish passage and structural safety in East Cascade and Blue Mountain streams. Prepared for Washington State Department of Transportation and in cooperation with U.S. Department of Transportation, Federal Highway Administration. Research Project T1804, Task Order 4. Available: http://www.wsdot.wa.gov/research/reports/fullreports/545.2.pdf. (October 2013).
Perrin, J., and C. S. Jhaveri. 2004. The economic costs of culvert failures. Prepared for the Transportation Research Board. Transportation Research Board 2004 Annual Meeting, Utah.
Rieman, B. E., D. C. Lee, *and* R. F. Thurow. 1997. Distribution, status, and likely future trends of bull trout within the Columbia River and Klamath River basins. *North American Journal of Fisheries Management* 17:1111–1125.
Ruddell, D., E. McLane, and B. Machin. 2008. Upper White River Corridor Plan. White River Partnership. Royalton Village, Vermont.
Seegrist, D. W., and R. Gard. 1972. Effects of floods on trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101:478–482.
Southeastern Massachusetts Metropolitan Planning Organization (SMMPO). 2012. Environmental coordination and climate change. Pages 16-1–16-7 *in* 2012 Regional Transportation Plan. SMMPO, Taunton, Massachusetts. Available: http://www.srpedd.org/manager/external/ckfinder/userfiles/files/Transportation/Regional%20Transportation%20Plan/full_tplan2012.pdf. (January 2014).
Spierre, S., and C. Wake. 2010. Trends in extreme precipitation events for the Northeastern United States 1948–2007. Carbon Solutions New England. Available: http://www.amwa.net/galleries/climate-change/2010_NortheastExtremePrecip.pdf. (September 2013).
State of Idaho. 1965. A study of the durability of metal pipe culverts. State of Idaho Department of Highways, Research Project No. 16, Boise, Idaho.
Stream Simulation Working Group (SSWG). 2008. Stream simulation: an ecological approach to designing road–stream crossings. San Dimas Technological Development Center, San Dimas, California.
Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18–30.
U.S. Census Bureau. 2010. 2010 Census interactive population search. Available: 2010.census.gov/2010census/popmap/ipmtext.php?fl=50. (August 2012).
USDA Forest Service. 2008. Consistent national guidance for aquatic passage designs. USDA Forest Service, File Code 7700/2600, Washington, D.C.
Vermont Agency of Natural Resources. 2011. Lessons from Irene: building flood resiliency as we rebuild. Available: http://www.anr.state.vt.us/anr/climatechange/Pubs/Irene_Facts.pdf. (October 2013).
Vermont Department of Transportation (VTrans). 2001. Hydraulics Manual. Vermont Agency of Transportation, Montpelier, Vermont.
Vermont Fish and Wildlife Department (VFWD). 2012. Fisheries programs. Available: www.vtfishandwildlife.com/fisheries_AOP.cfm. (October 2012).
Warren, D. R., A. G. Ernst, and B. P. Baldigo. 2009. Influence of spring floods on year-class strength of fall- and spring-spawning salmonids in Catskill Mountain streams. Transactions of the American Fisheries Society 138:200–210.
WRP (White River Partnership). 2012. About the White River watershed. Available: www.whiteriverpartnership.org/index.php/watershed. (April 2012).

From the Archives

The efforts of the United States in reference to the introduction of useful food fishes should not be limited to the salmonidae already mentioned (to which the various species of trout, salmon, white-fish and smelts belong) and to the shad, as many other kinds yet remain for consideration. The land-locked salmon, the European char and the smelt, will be available for all ponds or lakes of a certain extent and temperature. In these they will pass the greater part of their time, running up into the tributaries or outlets to spawn. The great Danube salmon, which sometimes reaches the weight of 100 pounds, would find a perfectly suitable residence in the Mississippi river and its tributaries, feeding on the worthless chubs, suckers and cat fish so abundant therein. The alewife can be propagated to a much greater extent than at present. The sterlet, a kind of small sturgeon found in the Volga and in Russia, is esteemed far beyond the turbot, will thrive in the Mississippi valley and in the lakes. The gourami, an East India fish, can be placed to great advantage in the mill-dams, ponds, etc., of the south, thriving as it does in very warm water and feeding entirely on vegetable matter. It attains a weight of twenty pounds or more, grows with great rapidity, and is unsurpassed in the excellence of its flesh.

Spencer F. Baird (1873): National Fish Culture, Transactions of the American Fisheries Society, 2:1, 25-32.

Extirpation and Tribal Reintroduction of Coho Salmon to the Interior Columbia River Basin

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ABSTRACT: *Harvest of anadromous salmonids in the Columbia River basin has been fundamental to the nutrition, economy, and cultural and religious beliefs of the regional Native American tribes. Agricultural development, dam construction, urbanization, and overharvest following colonization by European-origin settlers, however, resulted in dramatic reductions in salmon runs and negative impacts to the well-being of tribal peoples. Federal and state fishery agencies attempted to mitigate for the loss and to rebuild some salmonid populations but deemed Coho Salmon of lesser importance for upriver fisheries and allowed them to go functionally extinct. In the mid-1990s, fishery agencies of the Columbia River Treaty tribes spearheaded efforts to reestablish the extirpated Coho Salmon, beginning in the Yakima, Wenatchee, Methow, and Clearwater rivers. The programs were initiated with juveniles from composite lower Columbia River hatchery stocks, acclimated or direct released near potential spawning habitat, then were transitioned to producing juveniles with broodstock collected in-basin. Increasing numbers of fish are now returning to these rivers, a portion of which is the product of natural spawning. Results suggest that the Coho Salmon are adapting to their new environments and founding local naturalized populations.*

Extirpación y reintroducción de salmón plateado por tribus autóctonas en la cuenca del Río Columbia

RESUMEN: *la captura de salmónidos anádromos en la cuenca del Río Columbia ha sido fundamental para la nutrición, economía, cultura y creencias religiosas de las tribus nativas de Norte América. El desarrollo de la agricultura, la construcción de presas, urbanización y sobre pesca que siguieron a la llegada de los colonizadores europeos, dieron como resultado reducciones dramáticas de las corridas de salmón y causaron un impacto negativo en el bienestar de la gente tribal. Las agencias pesqueras federales y estatales trataron de mitigar estas pérdidas y de reconstruir algunas poblaciones de salmónidos, sin embargo clasificaron al salmón plateado como de menor importancia para las pesquerías, permitiendo así que llegara a la extinción funcional. A mediados de la década de 1990, tanto las agencias pesqueras como las tribus oriundas del Río Columbia encabezaron esfuerzos para restablecer el extirpado salmón plateado, comenzando con los ríos Yakima, Wenatchee, Methow y Clearwater. Los programas se iniciaron utilizando individuos juveniles de los stocks cultivados en la parte baja del Río Columbia, mismos que se aclimataban o se liberaban directamente cerca de hábitats potenciales para el desove. Posteriormente, en una etapa transitoria, se produjeron juveniles a partir de reproductores recolectados en las cuencas. En la actualidad, cada vez más peces están regresando a estos ríos, una parte de los cuales es el producto de desoves naturales. Los resultados sugieren que el salmón plateado se está adaptando a sus nuevos ambientes y está creando poblaciones locales naturales.*

INTRODUCTION

Before European settlement, the Columbia River Basin in the Pacific Northwest supported runs of anadromous salmonids averaging 7 to 16 million fish annually (Chapman 1986; Schalk 1986). These salmonids included five species (estimated proportion of total return): Chinook Salmon (*Oncorhynchus tshawytscha*; spring, summer, and fall runs; 50%), Sockeye Salmon (*O. nerka*; 30%), Coho Salmon (*O. kisutch; 8%*), steelhead (*O. mykiss; 6%*), and Chum Salmon (*O. keta*; 6%). While Chum Salmon were unable to pass Celilo Falls at river kilometer (rkm) 320, the other four species were widely distributed through the middle and upper Columbia River and Snake River basins (Figure 1; Chapman 1986).

Native American Indian tribes long occupied the interior Columbia Basin, and harvest of the abundant salmon was fundamental to their nutrition, economy, and cultural and religious beliefs (Craig and Hacker 1940; Netboy 1980; DeVoto 1997; Johnsen 2009). Tribal creation stories recount how salmon offered themselves up as food for the newly arrived humans, and fishing is viewed as an integral part of the natural life cycle of both the tribal peoples and the salmon (Landeen and Pinkham 1999). In counterpart, the tribes recognized their responsibility toward the salmon and traditionally managed their fishing practices to assure sufficient escapement to the spawning grounds. While the Indians harvested large numbers of fish annually, they did so in a sustainable manner for over 10,000 years (Johnsen 2009).

Colonization of the region by European-origin settlers, however, had devastating effects on the ecosystem and on tribal

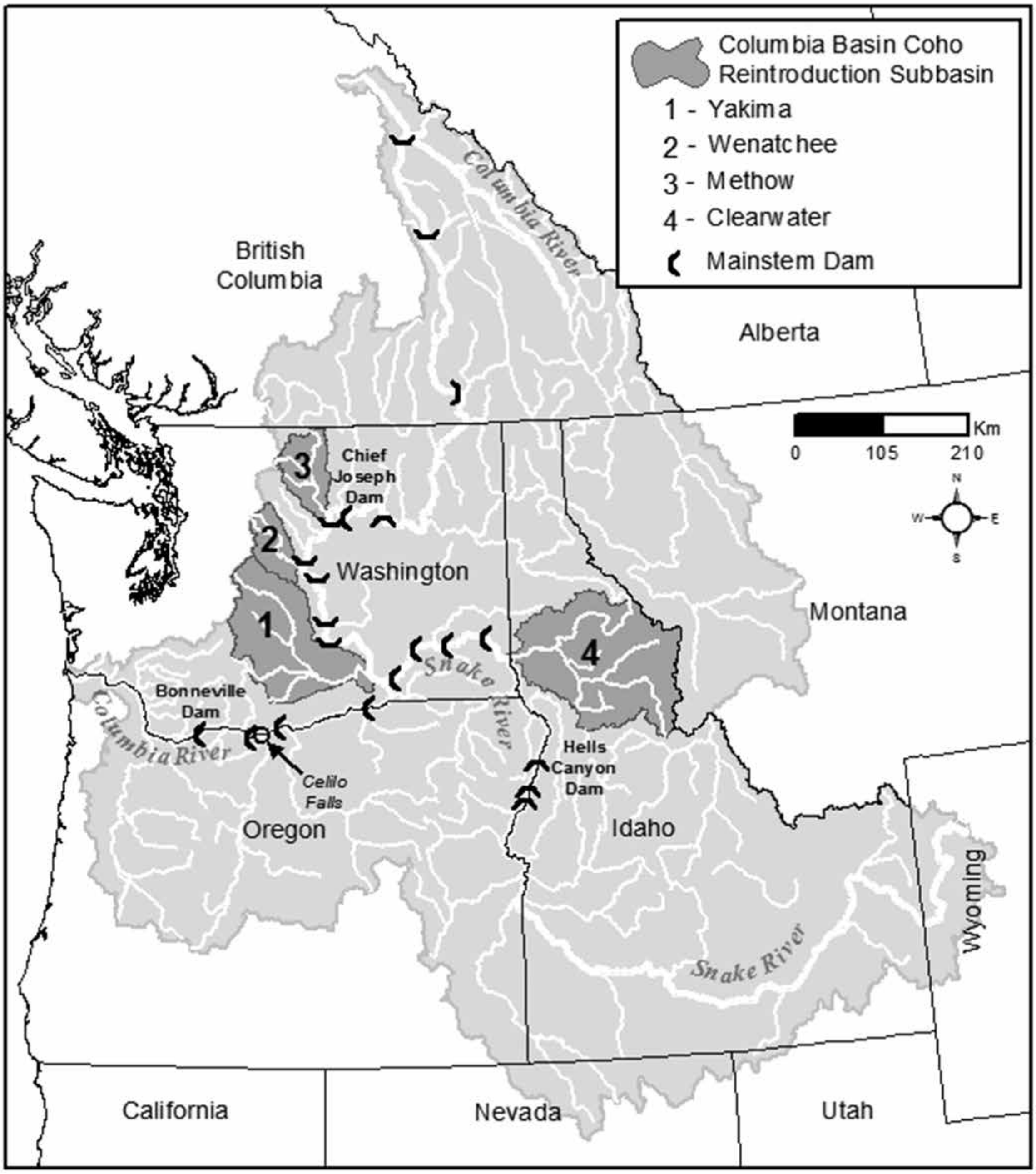

Figure 1. Map of the Columbia Basin showing the location of Celilo Falls, Columbia River, and Snake River main-stem dam and subbasins in which the tribes have enacted programs to reintroduce Coho Salmon.

well-being. Large-scale agriculture, urbanization, overfishing, and construction of dams for hydroelectric power and irrigation severely diminished the salmon runs and, in turn, tribal fishing opportunities. Among the main-stem hydroelectric dams, Chief Joseph Dam (Columbia River rkm 878) and Hell's Canyon Dam (Snake River rkm 398) were impassable and excluded salmon from over 55% (2740 rkm) of previously accessible habitat (Figure 1; Craig and Hacker 1940; Netboy 1980; Cone and Ridlington 1996; Lichatowich 1999).

In 1938, the U.S. Congress passed the Mitchell Act to provide federal and state fishery management agencies with resources to mitigate loss of salmon associated with construction of the main-stem hydroelectric dams (Mitchell Act 1938; Cone and Ridlington 1996). The primary mitigation activity funded by the Act was construction and operation of hatcheries. However, these facilities were essentially all located along the main-stem Columbia in proximity to or below Bonneville Dam (rkm 235; the lowest of the main-stem dams), to support coastal and lower river nontribal commercial and sport fisheries. The Act did little to rebuild depressed interior populations or support upstream tribal fisheries, despite promises made to the tribes (Dompier 2005).

EXTIRPATION OF COHO SALMON FROM THE INTERIOR COLUMBIA RIVER BASIN

While returns for all Columbia River salmonids diminished throughout the 20th century, interior Coho Salmon runs were particularly hard hit. From precolonial returns of hundreds of

Photograph 1. Mobile Coho Salmon acclimation tank installed along Rattlesnake Creek, tributary to the Naches River in the Yakima River subbasin. Photo credit: Todd Newsome.

thousands, the first Coho Salmon count at the newly constructed Bonneville Dam in 1938 was already only 15,000. By the mid-1900s, escapement to the interior Columbia had diminished to 2,000 to 3,000 fish (Fish Passage Center 2013), most of which were strays from lower river hatcheries (Mullan 1983).

In the mid-1900s a program was enacted to rebuild Coho Salmon returns to the interior basin. The program involved transfers of fertilized eggs of lower Columbia River (LCR) stocks from Mitchell Act hatcheries for incubation and rearing at five federal and state hatcheries located in the Mid-Columbia region, upstream of the confluence with the Snake River. Intensive stocking began in the 1960s, and substantial increases in adult returns were quickly observed (Wahle and Pearson 1984). However, juveniles were released directly from the hatcheries or into the main-stem Columbia, and little natural spawning of the returning adults resulted (Fulton 1970; Horner and Bjornn 1981). In this same period, sportfishing for steelhead and spring Chinook Salmon became increasingly popular. To provide additional hatchery resources for these species, the Coho Salmon program was phased out, beginning in 1969 and ending by 1981 (Horner and Bjornn 1981; Wahle and Pearson 1984; Dompier 2005). Main-stem dam counts rapidly diminished, and natural populations of Coho Salmon in the region were soon deemed functionally extinct (Nehlsen et al. 1991).

Two smaller Coho Salmon programs were initiated in the 1960s in the Snake River basin, by the Idaho Fish and Game Department (IDFG) in the Clearwater River and by the Oregon Department of Fish and Wildlife in the Grande Ronde River. Both programs involved out-planting of fertilized LCR eggs from Mitchell Act hatcheries. Adult returns, however, were poor and the programs were terminated within 6–7 years. Subsequently, as in the Mid-Columbia, Coho Salmon populations in the Snake River were determined to be extinct.

By the 1990s, natural populations of other salmonid stocks in the interior Columbia had fallen to such highly depressed levels that the National Marine Fisheries Service proposed them for listing under the Endangered Species Act (ESA; National Oceanic and Atmospheric Administration [NOAA] 2004). With their new threatened or endangered status, regulatory protections and funds for rebuilding became available. In contrast, interior Coho Salmon had already been extirpated and were not petitioned for listing; thus, there were no ESA-related legal obligations to enact restoration measures. The tribes, however, viewed extinction of any member of the Columbia River salmon family as unacceptable.

POLICY ISSUES AND TRIBAL RESPONSE

Disputes generated by attempts of tribal members to continue traditional fishing activities in the Columbia basin resulted in several court cases through the 1900s, culminating in decisions in the tribes' favor under the ongoing *U.S. v. Oregon* proceedings. An initial decision (*U.S. v. Oregon* 1969)

Photograph 2. Coulter Pond—a beaver pond located on Coulter Creek in the Wenatchee subbasin, used for acclimation of Coho Salmon juveniles. Photo credit: Cory Kamphaus.

recognized the reserved "right of taking fish" at all "usual and accustomed" fishing locations of the four Columbia River treaty tribes—the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Yakama Nation (YN), and the Nez Perce Tribe (NPT)—as written in their 1855 treaties with the U.S. Government. In 1975, a decision in a related case (*U.S. v. Washington* 1974) clarified the tribal share to be 50% of the harvestable portion of the run destined for tribal usual and accustomed fishing locations, and this percentage was applied to the portion of Columbia River run destined for areas upstream of Bonneville Dam. In 1977, the court requested creation of a forum in which the tribes would participate as co-managers alongside state and federal agencies for negotiating fishery policies, harvest sharing, and hatchery production levels, and the first interagency harvest management agreement was established (Straub et al. 1977). The same year the Columbia River Inter-Tribal Fish Commission (CRITFC) was created by resolution of the four tribes to provide technical, policy, and legal support. Subsequently, each of the tribes developed their own fisheries agencies to facilitate management of programs within their ceded territories (Dompier 2005).

With their strengthening technical and management capabilities, the tribes increased pressure for rebuilding interior Columbia Basin salmon and steelhead, including restoration of Coho Salmon. In 1988, a new agreement was established, the Columbia River Fish Management Plan (Goldschmidt et al. 1988), in which the tribes negotiated an annual program to transport 1,000,000 early run LCR Coho Salmon juveniles for release in the Umatilla River and another 700,000 in the Yakima River. However, the states insisted that the objective of these programs be limited to tributary harvest and maintained language from the prior agreement that the tribes forego claims to a 50% allocation on Coho Salmon. The agreement also set restrictions on gill-net mesh size in main-stem fisheries to protect migrating steelhead (Straub et al. 1977) that preclude effective harvest of the similarly sized Coho Salmon (Dompier 2005).

Eight years later, however, the YN redesigned their program to also facilitate establishment of a natural Coho Salmon population within the Yakima River. Between 1996 and 1999, the tribe shifted from direct release of LCR smolts in the lower river to acclimation and release from upriver facilities in closer proximity to natural spawning habitats. Additionally, returning adults were collected for use as broodstock, to develop a localized stock for continued supplementation. During this same period, the YN began a similar reintroduction program in the Mid-Columbia Methow and Wenatchee rivers, as did the NPT in the Clearwater River (Figure 1).

There have been differences in approach among the three programs, largely related to availability of rearing, acclimation, and monitoring facilities. However, common to each was initiation with acclimation and release of out-of-basin LCR smolts, followed by transition to production of smolts from

Photograph 3. A mature female Coho Salmon that has returned for natural spawning in the Methow River. Photo credit: Robert Farley.

adults returning in-basin to create a new localized stock. In the 15+ years since initiation, annual counts of returning adults and the number and distribution of redds have risen dramatically. A brief description of the design and results for each program is provided below, followed by a discussion on use of an out-of-basin hatchery stock to reintroduce an extirpated population.

TRIBAL PROGRAMS TO RESTORE COHO SALMON

Restoration of Coho in the Yakima River

The Yakima River (Figure 2A) once supported runs of Coho Salmon between 44,000 (Kreeger and McNeil 1993) and 150,000 (Yakama Indian Nation et al. 1990), though the fish were extinct by the mid-1990s. In 1988, the YN and Washington Department of Fish and Wildlife developed the Yakima/Klickitat Fisheries Project—a comprehensive project to restore healthy populations of anadromous and resident salmonids to the Yakima and Klickitat rivers funded by the Bonneville Power Administration (BPA). Though the project focused on spring Chinook Salmon and steelhead, the YN also incorporated the Columbia River Fish Management Plan Yakima River Coho Salmon program under the Yakima/Klickitat Fisheries Project. Beginning in 1997, the release locations of the LCR smolts were moved further upstream near better spawning and juvenile rearing habitat, with the objective of reestablishing a natural population. The initial two phases of this three-phase program are complete. Over this period, hatchery origin adults that returned in-basin were increasingly used as broodstock to create a local strain of Coho Salmon. Returning adults are captured at Prosser Dam and spawned at Prosser Hatchery (Figure 2A). The hatchery facilities are limited, so a portion of the eggs is transferred out-of-basin for incubation and rearing but returned to the Yakima River for acclimation and release as smolts. As of 2010, the transition was complete and stocking of LCR juveniles was eliminated.

In Phase I (1997–2006), release sites for the LCR smolts were primarily earthen or concrete ponds located adjacent to the main-stem upper Yakima and Naches rivers (Figure 2A), where the fish were held 4–6 weeks prior to release. Mature adults from the initial releases successfully returned and were observed spawning in both subbasins, generally near the acclimation ponds (Bosch et al. 2007). Returns estimated from counts at Prosser Dam have increased from a few hundred strictly hatchery origin fish in the 1980s and 1990s to several thousand currently of both hatchery and natural origin. Additionally, hundreds of redds are now observed annually and a portion of the return is naturally spawned fish (Figure 3A; YN 2011).

Tagging data indicate that out-migration survival from site of release to McNary Dam for progeny of adults collected in-basin ranged from similar to substantially higher than their LCR counterparts (Bosch et al. 2007). Estimates of smolt-to-adult return rates (SARs) for natural origin fish were consistently higher than for hatchery origin (LCR and in-basin combined) fish (Table 1; Bosch et al. 2007; YN 2011).

To address concerns regarding possible negative effects of reintroduced Coho Salmon on ESA-listed spring Chinook Salmon, marked Coho Salmon smolts were released in areas with known high densities of newly emergent spring Chinook Salmon fry. Over 2,000 smolts were recaptured downstream in a rotary screw trap and stomach contents were examined. Only two contained fish remains identified as *Oncorhynchus* spp., and postrelease predation was deemed insignificant (Dunnigan 1999).

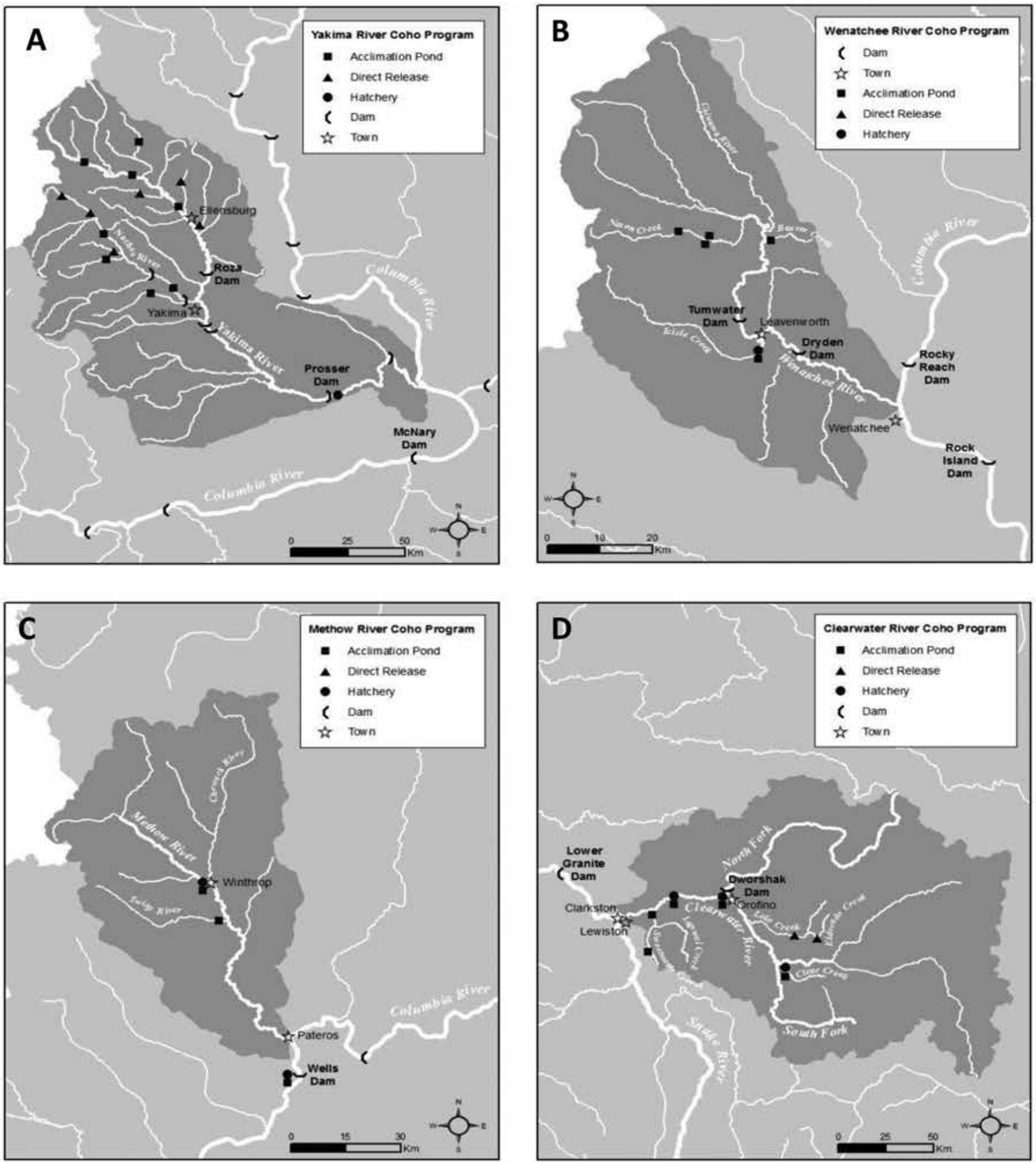

Figure 2. Maps of the tribal Coho reintroduction programs in the (A) Yakima River subbasin, (B) Wenatchee River subbasin, (C) Methow River subbasin, and (D) Clearwater River subbasin.

In Phase II (2007–2102), alternative approaches that would expand the area into which Coho Salmon might establish themselves were investigated. Some smolts were released from temporary mobile acclimation facilities operated in upstream locations in tributary streams of the Naches and upper Yakima rivers. The mobile acclimation units are portable aluminum raceways that hold up to 10,000 smolts. Data from tagged fish over four consecutive years indicated that juvenile survival and subsequent adult return rates to McNary Dam were similar within years to rates for smolts released from the main-stem acclimation ponds (YN 2011). In other streams where acclimation facilities do not exist or would be logistically difficult to establish, juveniles were released as parr and allowed to overwinter within the streams before out-migration. Parr releases have the additional advantage of substantially reducing hatchery rearing costs. Data for the direct released parr indicated that out-migration survival was generally similar to that for fish delivered to the acclimation ponds and also suggested that returning adults demonstrated high homing fidelity to their release streams (YN 2011).

At the end of Phase II the tribe submitted the Yakima Basin Coho Salmon Master Plan for final review by the Northwest Power and Conservation Council (NPCC). Activities described in the plan for Phase III include construction of a conservation hatchery in the upper Yakima River near Ellensburg, Washington (Figure 2A); increasing the proportion of natural origin adults in the broodstock; and phasing out use of the main-stem acclimation sites in favor of releases in tributary streams. Supplemented streams will be monitored to assess juvenile survival

Table 1. Prosser Dam estimates of Yakima River Coho Salmon smolt out-migrants, adult returns, and smolt-to-adult return (SAR) rates for fish of hatchery origin (a mix of lower Columbia River and in-basin stocks) and in-basin natural origin (figures updated from those reported in Bosch et al. [2007]; na = not available/applicable). SAR values are estimated from time of out-migration passage at Prosser Dam to adult return to Prosser Dam; the estimates do not account for survival from time of release to arrival at Prosser Dam, which can vary widely between release locations

Juvenile release year	Hatchery origin			Natural origin			Total smolts	Total adults
	Smolts	Adults	SAR (%)	Smolts	Adults	SAR (%)		
2000	331,503	3,546	1.07	37,359	1,432	3.83	368,862	4,978
2001	134,574	166	0.12	40,605	309	0.76	175,179	475
2002	155,814	669	0.43	19,859	1,523	7.67	175,673	2,192
2003	139,135	505	0.36	9,092	1,820	20.0	148,227	2,325
2004	148,810	2,405	1.62	18,787	472	2.51	167,597	2,877
2005	204,728	2,646	1.29	31,631	1,562	4.94	236,359	4,208
2006	204,602	2,203	1.08	8,298	1,049	12.6	212,900	3,252
2007	260,455	4,132	1.59	20,131	459.1	2.28	280,586	4,591
2008	416,708	8,835	2.12	43,046	982	2.28	539,640	9,817
2009	496,594	5,153	1.04	25,108	573	2.28	366,253	5,726
2010	341,145	7,216	2.12	35,158	802	2.28	369,049	8,018
2011	333,891	4,948	1.5	24,108	550	2.28	268,611	5,498

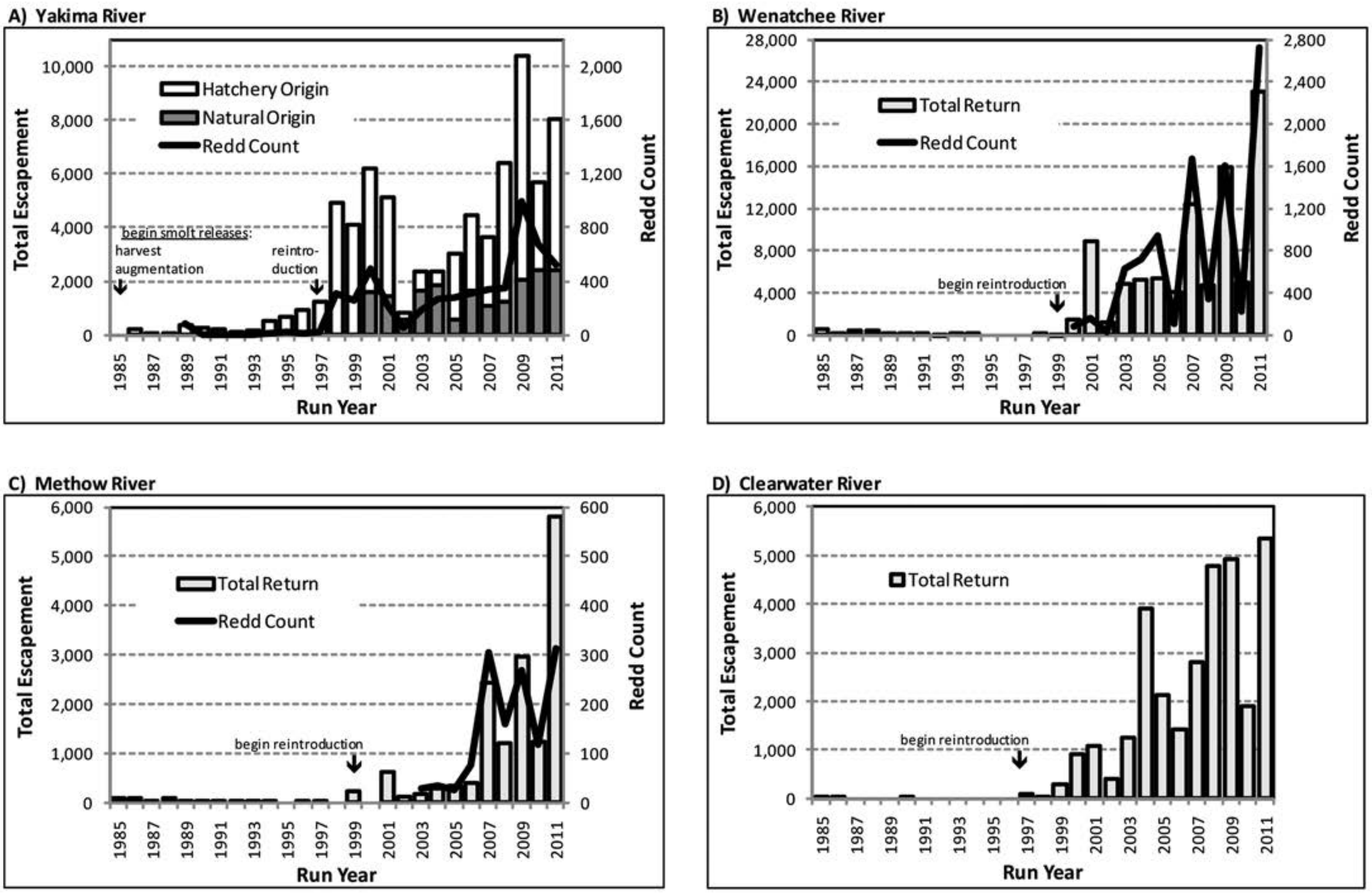

Figure 3. Annual adult returns of reintroduced Coho Salmon (differentiated between hatchery origin and natural origin when data available) and annual redd counts in the (A) Yakima River subbasin, (B) Wenatchee River subbasin, (C) Methow River subbasin, and (D) Clearwater River subbasin.

and relative natural productivity of hatchery versus natural origin adults. The plan sets an intermediate goal for a 3-year average annual return (hatchery and natural origin combined) of 5,000 fish. Once the conservation hatchery is operational, the plan sets an annual escapement goal of 3,500 natural origin fish to the upper Yakima Basin, which, if consistently achieved, will permit eventual phasing out of the supplementation program.

Restoration of Coho in the Wenatchee and Methow Rivers

Estimated historical returns of Coho Salmon to the Methow and Wenatchee subbasins in the mid-Columbia region (Figures 2B and 2C) ranged between 23,000 to 31,000 and 6,000 to 7,000, respectively (Mullan 1983). In 1995 the YN launched a program, also funded by the BPA through the NPCC Fish and Wildlife Program, to test the feasibility of reestablishing natural Coho Salmon runs in this region. The program began in the Methow River with transfers of LCR smolts for rearing and release from Winthrop National Fish Hatchery (NFH; rkm 81; Figure 2C). However, initial returns were insufficient to create a localized Mid-Columbia River (MCR) broodstock. Although releases continued in the Methow River, the tribe shifted focus in 1999 to supplementing the Wenatchee River, with Leavenworth NFH located on Icicle Creek (confluence at rkm 35) as the primary release site. Higher return rates were expected due to a shorter main-stem migration distance and fewer hydroelectric facilities to navigate, and multiple collection facilities within the watershed provided greater likelihood of capturing adults for broodstock. The feasibility study was also designed to initiate natural reproduction in areas of low risk to ESA-listed spring Chinook Salmon and steelhead while studying potential interactions between reintroduced Coho Salmon and these endangered species.

Without facilities for direct counting of fish in-river, adult Coho Salmon escapement has been estimated using passage counts at main-stem Columbia River dams. Return to the Wenatchee River is calculated as the difference between passage at Rock Island Dam and Rocky Reach Dam—the main-stem Columbia River dams located immediately downstream and upstream of the Wenatchee River confluence, respectively (Figure 2B). Methow River escapement is estimated as the passage count above Wells Dam, located just downstream of the Methow River confluence (Figure 2C).

Though with substantial year-to-year variability, adult returns to both subbasins have increased dramatically (Figures 3B and 3C; Yakama Nation Fisheries Resource Management 2012). Within a few years after reintroduction, enough adults were collected to fully meet broodstock needs. As of brood year 2003 in the Wenatchee River and 2006 in the Methow River, import of LCR smolts was eliminated, and all releases have since been of MCR origin. Of significance, the 2009 returns were sufficient to open a limited tribal and nontribal fishery in Icicle Creek—the first such fishery in over half a century. This was followed by another record return in 2011, and a fishery was opened in Icicle Creek, the lower Wenatchee River, and the Methow River.

Natural spawning of returning adults within both subbasins has generally increased, as assessed by redd counts conducted during annual spawning ground surveys (Figures 3B and 3C; Yakama Nation Fisheries Resource Management 2012). Monitoring data suggest that SARs in both the Wenatchee River (Table 2) and Methow River for fish produced from MCR broodstock have been comparable to those for other salmon species from hatchery programs in their respective basins during the last 10 years (M. Tonseth, Washington Department of Fish and Wildlife, personal communication) and that SARs for natural origin smolts tend to be greater than their MCR hatchery counterparts. Results from studies to assess interactions with ESA-listed spring Chinook Salmon and steelhead indicate that the reintroduced Coho Salmon had little or no negative impact. These included evaluations of predation on fry of spring Chinook Salmon, superimposition by spawning Coho Salmon

Table 2. Smolt-to-adult return (SAR) rates of Wenatchee River Coho Salmon produced from lower Columbia River (LCR) or Mid-Columbia River (MCR) origin broodstock or fish of in-basin natural origin (NO) for brood years 1997 to 2005 (na = not available/applicable). SAR values are estimated from time of release for hatchery smolts or time of capture for natural origin smolts to adult return. SAR values for subbasin are calculated for smolts from all release sites averaged together.

Brood year	Release year	Release site	SAR		
			LCR (%)	MCR (%)	NO (%)
1997	1999	Icicle Creek	0.23	na	na
1998	2000	Icicle and Nason creeks	0.18	na	na
1999	2001	Icicle and Nason creeks	0.08	na	na
2000	2002	Icicle Creek	0.30	0.54	na
		Nason and Beaver creeks	na	0.41	na
		Subbasin	0.30	0.49	0.38
2001	2003	Icicle Creek	0.45	0.44	na
		Nason and Beaver creeks	na	0.32	na
		Subbasin	0.45	0.38	0.43
2002	2004	Icicle Creek	0.36	0.27	na
		Nason and Beaver creeks	0.40	0.42	na
		Subbasin	0.37	0.31	0.90
2003	2005	Icicle Creek	na	0.20	na
		Nason and Beaver creeks	na	0.10	na
		Subbasin	na	0.18	0.15
2004	2006	Icicle Creek	na	0.53	na
		Nason and Beaver creeks	na	0.39	na
		Subbasin	na	0.49	1.64
2005	2007	Icicle Creek	na	0.15	na
		Nason and Beaver creeks	na	0.12	na
		Subbasin	na	0.14	0.15
2006	2008	Icicle Creek	na	0.52	na
		Nason and Beaver creeks	na	0.45	na
		Subbasin	na	0.50	1.36
2007	2009	Icicle Creek	na	0.20	na
		Nason and Beaver creeks	na	0.10	na
		Subbasin	na	0.32	0.36
2008	2010	Icicle Creek	na	0.69	na
		Nason and Beaver creeks	na	0.77	na
		Subbasin	na	0.72	0.79

Photograph 4. Tish Whitman, Nez Perce Fisheries technician, strip spawning a mature female Coho Salmon captured at Dworshak NFH. Photo credit: Michael Bisbee.

on spring Chinook Salmon redds, and competition for habitat between juvenile Coho Salmon, spring Chinook Salmon, and steelhead (Murdoch et al. 2005).

With positive results observed during the feasibility phase, the YN recently finalized a master plan for the Mid-Columbia reintroduction program and submitted it to the NPCC Fish and Wildlife Program (Yakama Nation Fisheries Resource Management 2012). The plan calls for renovation of current acclimation sites and construction of additional facilities in locations in the upper watershed and in major tributary streams. Habitat models were used to identify locations suitable for spawning and rearing and established release numbers based on estimated carrying capacities. Construction of a new broodstock holding and spawning facility in the Wenatchee basin that will operate with increasing proportions of natural origin fish into the broodstock was proposed. The plan set target goals for 3-year mean escapement to both subbasins of 1,500 natural origin Coho Salmon. It is hoped that in as few as five generations the goal may be reached, though this will be contingent on the success of continued actions to improve in-basin habitat, as well as estuarine habitat and hydrosystem survival.

Restoration of Coho in the Clearwater River

Though no quantified estimates of historic Coho Salmon returns to the Snake River Basin have been reported, it is known that substantial spawning occurred, primarily in the Tucannon, Clearwater, and Grande Ronde rivers. Through an agreement under *U.S. v. Oregon*, the NPT secured an allotment of LCR Coho Salmon eggs in 1994, which they transported to their Sweetwater Springs facility near Lapwai, Idaho, for incubation and rearing. The following year they direct released 622,000 parr among five streams in the Clearwater subbasin (Figure 2D; Everett et al. 2006). The IDFG opposed the reintroduction effort and was successful in blocking delivery of a second egg allotment in 1996 (Dompier 2005). However, the tribe prevailed in this dispute; by the next year IDFG dropped their objections and juvenile releases recommenced in 1998 (Everett et al. 2006).

Currently, approximately 800,000 age-1+ Coho Salmon smolts are released annually. Some of the fish are reared and released at Dworshak and Kooskia NFHs. The remaining individuals are reared out-of-basin and then brought back to Idaho as they approach the smoltification stage. Half of them are released directly into Lapwai Creek and Eldorado Creek (a tributary to Lolo Creek), and the other half are taken to Kooskia NFH for release following a 4- to 6-week acclimation period (Figure 2D).

In 1997, 94 Coho Salmon from the initial 1995 parr releases were observed at Lower Granite Dam (LGD; Snake River rkm 173). Returns have grown since then, and the average over the past 5 years was 4,000 fish (Figure 3D). In 2011 returns above LGD were sufficient for the tribe to open a small in-basin fishery, offering their members the opportunity to harvest Coho Salmon locally for the first time since the mid-1900s.

In 1999 the tribe began use of returning adults for broodstock, to develop a local Clearwater stock (CLS). The adults are collected in ladders at Dworshak and Kooskia NFHs and at a temporary weir on Lapwai Creek (rkm 1) near Spalding, Idaho (Figure 2D). In 2009, managers were able to fully meet broodstock needs in-basin, and since then (with the exception of a shortfall in 2010) only CLS juveniles have been released.

The Clearwater program has been financed through an annual allocation to the tribe from the Pacific Coast Salmon Restoration Fund (PCSRF). Though the amount is adequate to cover basic hatchery expenses, few resources remain for monitoring and evaluation activities. The only monitoring data consistently available have been counts of returning adults at LGD, plus some qualitative information on Coho Salmon redd and carcass distribution opportunistically acquired during spawning surveys for fall Chinook Salmon.

The NPT submitted a master plan for the Coho Salmon reintroduction program (Everett et al. 2006) to the NPCC Fish and Wildlife Program for funding from the BPA. The plan proposed continued development of the localized stock through incorporation of natural origin fish, construction of additional in-basin juvenile rearing facilities at the Nez Perce Tribal Fish Hatchery (rkm 35), increase in the number of tributary streams into which smolts are released (using a rotating program for release for three generations followed by no supplementation for three generations), and tagging and monitoring to assess juvenile survival and adult return rates. Though in agreement with the objectives, the NPCC has yet to approve the program for funding. The tribe was successful, however, in procuring a recent allocation of Mitchell Act funds to finance construction of an acclimation facility on Lapwai Creek (rkm 1). This allocation will also finance a limited number of annual spawning surveys to better characterize the extent and distribution of natural spawning.

Despite the funding constraints, increases in adult escapement have been dramatic and the program has gained much favorable public attention. The relative success of the program led to its inclusion among the Example PCSRF Grantee Projects in the NOAA's Report to Congress on the PCSRF program for FY 2000–2008 (NOAA 2009).

SUMMARY

In each of the tribal programs to reintroduce Coho Salmon, annual adult escapement has increased from near zero to several thousands. The increase suggests that the programs are increasingly contributing to tribal and nontribal fisheries in the lower Columbia, and the tribes have recently been able to reopen fisheries within the subbasins. The number and distribution of redds have generally increased. Transition from importing LCR juveniles to releasing juveniles produced from adults collected in-basin is complete. Over the coming years, the localized nature of these new stocks will be enhanced through increased incorporation of natural origin fish into the hatchery broodstock. Available monitoring data indicate that juvenile survival rates and SARs for local stock smolts are generally greater than for LCR smolts and that SARs for natural origin smolts generally exceed those for hatchery origin smolts (Tables 1 and 2). Together, the results suggest that the out-of-basin hatchery stocks used to initiate the reintroductions are adapting to the local environment and creating new natural populations.

Fraser (2008) reviewed published manuscripts and agency reports for 31 salmonid reintroduction programs relative to their ability to establish self-sustaining natural populations. He cautiously concluded that long-term evidence is yet lacking, because in essentially all cases, programs have been in place for an insufficient number of generations and/or environmental perturbations continue to constrain natural productivity. Similarly, the tribal Coho Salmon programs are relatively new, and though harvest is now managed, effects from degradation of freshwater and estuarine habitat and elevated hydrosystem mortality persist. Continued supplementation and habitat restoration will therefore be necessary for some period before self-sustainability may be achieved.

Nonetheless, the rapidity with which the reintroduced hatchery Coho Salmon appear to be adapting to the new stream environments is notable. Concern has been expressed within the scientific and public communities regarding negative effects that hatchery rearing has on natural reproductive capabilities of fish and on long-term genetic fitness of natural populations supplemented with hatchery-reared fish (e.g., Independent Scientific Advisory Board 2003; Araki et al. 2008; Chilcote et al. 2011). The Coho Salmon available to the tribes for the reintroductions was an out-of-basin composite LCR hatchery stock that had undergone at least 20 successive generations of segregated rearing. One might presume these fish too highly domesticated to be of use for reintroduction. However, in each program a portion of the reintroduced Coho returned as mature adults, some spawned naturally, and within two generations are creating nascent natural populations. Genetic effects on natural fitness that may have accrued within the LCR stock are apparently susceptible to reversal in the face of natural selective processes, and judicious hatchery broodstock and rearing management.

The Columbia River Treaty tribes—the Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Reservation of Oregon, NPT, and YN—understand well that present circumstances will not permit Columbia Basin salmon and steelhead runs to return to precolonial levels. Nonetheless, they maintain a holistic vision as described in *Wy-Kan-Ish-Mi Wa-Kish-Wit*, Spirit of the Salmon (CRITFC 1995), for restoration of watersheds within their reservations and ceded territories to conditions that support abundant and productive populations. Through a combination of efforts to carefully manage harvest, to petition for continued improvements in hydrosystem survival and freshwater and estuarine habitat, and to appropriately manage hatchery programs, the tribes are progressing toward their goal to "put the fish back in the rivers" (CRITFC 1995, Executive Summary, p. v), including Coho Salmon and all other indigenous aquatic species.

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REFERENCES

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery reared salmonids in the wild. Evolutionary Applications 1:342–355.

Bosch, W. J., T. H. Newsome, J. L. Dunnigan, J. D. Hubble, D. Neeley, D. T. Lind, D. E. Fast, L. L. Lamebull, and J. W. Blodgett. 2007. Evaluating the feasibility of reestablishing a Coho Salmon population in the Yakima River, Washington. North American Journal of Fisheries Management 27:198–214.

Chapman, D. W. 1986. Salmon and steelhead abundance in the Columbia River in the nineteenth century. Transactions of the American Fisheries Society 115:662–670.

Chilcote M., K. Goodson, and M. Falcy. 2011. Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Canadian Journal of Fisheries and Aquatic Sciences 68:511–522.

Columbia River Inter-Tribal Fish Commission (CRITFC). 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit, The spirit of the salmon. The Columbia River anadromous fish plan of the Nez Perce, Umatilla, Warm Springs, and Yakama tribes, Vol. I and II. Columbia River Inter-Tribal Fish Commission, Portland, Oregon. Available: http://www.critfc.org/fish-and-watersheds/fish-and-habitat-restoration/the-plan-wy-kan-ush-mi-wa-kish-wit/. (September 2006).

Cone, J., and S. Ridlington, editors. 1996. The northwest salmon crisis: a documentary history. Oregon State University Press, Corvallis, Oregon.

Craig, J. A., and R. L. Hacker. 1940. The history and development of the fisheries of the Columbia River. Bureau of Fisheries, U.S. Department of the Interior, Bulletin No. 32, Washington, D.C.

DeVoto, B. A., editor. 1997. The journals of Lewis and Clark. Houghton Mifflin Company, New York.

Dompier, D. 2005. The fight of the salmon people, blending tribal tradition with modern science to save sacred fish. Xlibris Press, Philadelphia, Pennsylvania.

Dunnigan, J. L. 1999. Feasibility and risks of coho reintroduction in mid-Columbia monitoring and evaluation. Project No. 1996-04000, BPA Report DOE/BP-12540-1. Bonneville Power Administration, Portland, Oregon. Available: https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=12540-1. (August 2012).

Everett, S., C. Beasley, R. Johnson, C. Davenport, R. Larson, and FishPro Division of HDR Engineering. 2006. Nez Perce Tribal Hatchery project; Coho Salmon master plan, Clearwater River Basin, 2003–2004 Annual Report. Project No. 198335000, BPA Report DOE/BP-00004035-1. Bonneville Power Administration, Portland, Oregon. Available: https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=00004035-1. (April 2012).

Fish Passage Center. 2013. Adult salmon annual totals - Coho Salmon annual adult passage at Bonneville Dam. Fish Passage Center, Portland, Oregon. Available: http://www.fpc.org

Fraser, D. J. 2008. How well can captive breeding programs conserve biodiversity? A review of salmonids. Evolutionary Applications 1:535–586.

Fulton, L. A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and Chum Salmon in the Columbia River Basin—past and present. National Oceanic and Atmospheric Administration, U.S. Department of Commerce, National Marine Fisheries Service, Special Scientific Report, Fisheries No. 618, Washington, D.C. Available: www.nwfsc.noaa.gov/assets/11/7375_08042010_145310_Fulton.1970-rev.pdf. (April 2013).

Goldschmidt, N. (Governor Oregon) et al. 1988. Columbia River Fish Management Plan, as amended by the court.

Horner, N., and T. C. Bjornn. 1981. Status of upper Columbia River and Snake River Coho Salmon in relation to the Endangered Species Act. A report prepared for the U.S. Fish and Wildlife Service, Idaho Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho. Available: http://catalog.streamnetlibrary.org/cgi-bin/koha/opac-detail.pl?biblionumber=17564. (April 2012).

Independent Scientific Advisory Board. 2003. Review of salmon and steelhead supplementation. Report prepared for the Northwest Power Planning and Conservation Council, National Marine Fisheries Service, and Columbia River Basin Indian Tribes, ISAB 2003-03, Portland, Oregon.

Johnsen, D. B. 2009. Salmon, science, and reciprocity on the Northwest Coast. Ecology and Society 14:43–53. Available: www.ecologyandsociety.org/vol14/iss2/art43. (January 2010).

Kreeger, K. E., and W. J. McNeil. 1993. Summary and estimation of the historic run-sizes of anadromous salmonids in the Columbia and Yakima rivers. Prepared for Yakima River Basin Coalition, Yakima, Washington.

Landeen, D., and A. Pinkham. 1999. Salmon and his people—fish & fishing in Nez Perce culture. Confluence Press, Lewiston, Idaho.

Lichatowich, J. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, D.C.

Mitchell Act P.L. 502 of May 11, 1938 (52 stat. 345) as amended August 8, 1946 (60 stat. 932). Available: www.house.gov/legcoun/Comps/Mitchell%20Act.pdf. (June 2005).

Mullan, J. W. 1983. Overview of artificial and natural propagation of Coho Salmon on the mid-Columbia River. Fisheries Assistance Office, U.S. Fish and Wildlife Service, Report No. FRI/FAO-84-4, Leavenworth, Washington.

Murdoch, K., C., S. Prevatte, and C. Kamphaus. 2005. Mid-Columbia Coho reintroduction feasibility study: monitoring and evaluation. 2004–2005 Annual Report, Project No. 199604000, BPA Report DOE/BP-00016988-2. Bonneville Power Administration, Portland, Oregon. Available: http://docs.streamnetlibrary.org/BPA_Fish_and_Wildlife/00016988-2.pdf. (January 2008).

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4–21.

Netboy, A. 1980. The Columbia River salmon and steelhead trout, their fight for survival. University of Washington Press, Seattle.

NOAA (National Oceanic and Atmospheric Administration). 2004. Endangered and threatened species: Proposed listing determinations for 27 ESUs of West Coast salmonids; Proposed rule. Department of Commerce, Federal Register 69(113):33102-33171. Available: www.gpo.gov/fdsys/granule/FR-2004-06-14/04-12706/content-detail.html. (August 2005).

———. 2009. 2009 Report to congress, Pacific Coastal Salmon Recovery Fund FY 2000–2008. Available: www.nwr.noaa.gov/publications/recovery_planning/salmon_steelhead/pcsrf/pcsrf-rpt-2009.pdf. (March 2013).

Schalk, R. F. 1986. Estimating counts of salmon and steelhead usage in the Columbia Basin before 1850: the anthropological perspective. Northwest Environmental Journal 2(2):1–29.

Straub, R. W., governor, Oregon et al. 1977. A plan for managing fisheries on stocks originating from the Columbia River and its tributaries above Bonneville Dam.

U.S. v. Oregon. 1969. 302 F. Supp. 899.

U.S. v. Washington. 1974. 69384 F.Supp. 312.

Wahle, R. J., and R. E. Pearson. 1984. History of artificial propagation of Coho Salmon, *Oncorhynchus kisutch*, in the mid-Columbia River system. Marine Fisheries Review 46:34–43.

Yakama Indian Nation, Washington Department of Fisheries, and Washington Department of Wildlife. 1990. Yakima River sub-basin salmon and steelhead production plan. Columbia Basin Fish and Wildlife Authority, Portland, Oregon. Available: http://docs.streamnetlibrary.org/Subbasin_Plans/Columbia_Plateau_North/Yakima90.pdf. (June 2012).

YN (Yakama Nation). 2011. Yakima/Klickitat Fisheries Project monitoring and evaluation, Prepared for Bonneville Power Administration, Project No. 1995-063-25, Contract No. 00042445, Final report for the performance period May 1, 2010 through April 30, 2011, Portland, Oregon. Available: https://pisces.bpa.gov/release/documents/documentviewer.aspx?doc=P122475. (October 2012).

Yakama Nation Fisheries Resource Management. 2012. Mid-Columbia Coho restoration program master plan. Prepared for Northwest Power and Conservation Council, Portland, Oregon. Available: www.fws.gov/pacific/fisheries/hatcheryreview/Reports/leavenworth/MC--010YakamaMid-ColumbiaCohoMasterPlan1-27-05.pdf. (February 2013).

Québec Meeting Update: The Québec Convention Center

Conveniently located in the heart of Québec City, the Québec City Convention Centre is the perfect place for conventions, trade shows, and meetings. Underground tunnels link the Centre to two four-star hotels, with a further 3,000 rooms nearby. Over 4,000 indoor parking spaces are also available. No wonder it is one of Canada's top convention destinations. What sets the Centre apart is its hospitality and exceptional service, cutting-edge technology, and creative cuisine inspired by the rich culinary traditions of North America's fine dining capital.

Convention attendees can look forward to an exceptional experience at the Centre itself, but they will also fall in love with Québec City—an anything-but-conventional convention destination. A lively, safe walled city teeming with culture and activities, Québec City charms visitors with its European feel, rich history and culture, nearby natural wonders, fine dining, and friendliness.

At the Québec City Convention Centre you're only steps away from a host of attractions—museums, parks, walking tours, boutiques, theaters, concert venues, bars and restaurants, and historic neighborhoods like Place-Royale and the Old Port. And don't forget the magnificent vistas that seem to follow you wherever you go.

Get ready to enjoy the Québec City Convention Centre flexible, eco-friendly facilities and signature round-the-clock service from a team proud to be anything but conventional!

DISCOVER QUÉBEC CITY!

No matter why you came, get ready to be smitten just like the millions of visitors who flock to this premiere tourism and business destination every year. Québec City is a UNESCO World Heritage Site, the only walled city north of Mexico, and hands-down the most European-feeling city in North America.

Make the most of your stay by exploring Québec City's natural, cultural, and historic treasures and strolling around its history-steeped old quarters. But Québec City is about so much more than history. There is no shortage of epithets to describe it—business centre, technology hub, city of festivals, gourmet capital, romantic getaway, winter wonderland, city of innovation…the list goes on. One thing is for sure: Québec City is gathering accolades around the world as the perfect venue for large-scale events.

Québec City's charming shopping streets won't disappoint either: try Rue Saint-Jean, Rue du Trésor, Rue Saint-Paul, Promenades du Vieux-Québec, or the Petit-Champlain neighborhood, the oldest commercial district in North America. You'll find shopping centres nearby as well.

As many visitors' first stop in North America, Québec City boasts top notch tourism facilities and irresistibly dynamic, eclectic street life. No matter when a convention is held, you are sure to overlap with one of the major festivals, sporting events, or other highlights the city is famous for.

With the great outdoors just 30 minutes from downtown, there's no excuse not to head off into an enchanting setting to try your hand at sports, hit the links, or enjoy your favorite outdoor activities.

Questions regarding AFS 2014 meeting and Québec City, please contact info.afs2014@gmail.com or visit www.afs2014.org and www.facebook.com/afs2014.

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JOURNAL HIGHLIGHTS

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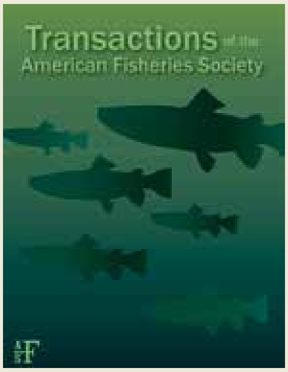

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moving toward a steady-state economy, the more likely the U.S. economy and the world economy will become sustainable.

REFERENCES

Costanza, R., I. Kubiszewski, E. Giovannini, H. Lovins, J. McGlade, K. E. Pickett, K. V. Ragnarsdóttir, D. Roberts, R. De Vogli, and R. Wilkinson. 2014. Time to leave GDP behind. Nature 505:283–285.

Czech, B. 2013. Supply shock: economic growth at the crossroads and the steady state solution. New Society Publishers, Gabriola Island, British Columbia, Canada.

Daly, H. E. 1973. The steady-state economy: toward a political economy of biophysical equilibrium and moral growth. Pages 149–174 *in* H. E. Daly, editor. Toward a steady-state economy. Freeman, San Francisco.

Daly, H. E. 1997. Beyond growth: the economics of sustainable development. Beacon Press, Boston.

Dietz, R., and D. O'Neil. 2013. Enough is enough: building a sustainable economy in a world of finite resources. Berrett-Koehler Publishers, San Francisco.

Ehrlich, P. R., A. H. Ehrlich, and J. P. Holdren. 1977. Ecoscience: population, resources, environment. Freeman, San Francisco.

Frissell, C. A. 2013. Aquatic resource protections in the Northwest Forest Plan: evaluating potential consequences of proposed riparian reserve reductions for clean water, streams and fish. Coast Range Association, Corvallis, Oregon. Available: www.coastrange.org. (December 2013).

Limburg, K. E., R. M. Hughes, D. C. Jackson, and B. Czech. 2011. Population increase, economic growth, and fish conservation: collision course or savvy stewardship? Fisheries 36:27–35.

Perkins, J. 2005. Confessions of an economic hit man. Plume, New York.

Post, J. A., and J. R. Hutchings. 2013. Gutting Canada's Fisheries Act: no fishery, no fish habitat protection. Fisheries 38:497–501.

Wackernagel, M., and W. Rees. 1996. Our ecological footprint: reducing human impact on the Earth. New Society Publishers, Gabriola Island, British Columbia, Canada.

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from Sacramento, California; Halifax, Nova Scotia; and Wichita, Kansas, to bring our events to their cities and facilities.

Our annual conferences are a big deal. They are an irreplaceable forum for sharing of science information, developing ideas that will shape a multi-billion-dollar industry, and helping to conserve invaluable natural resources. Just keep in mind that, like everything else that we do, there are associated costs. We do go to great lengths to make the meetings efficient, productive, and economical. Come join us in Québec City and, while enjoying the event, remember to thank the hosts for all of their work to make the event the best possible while keeping the costs reasonable for all attendees.

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or downstream. Licenses are issued for many decades, often 30 to 50 years. Many of our nation's existing hydroelectric dams were constructed before much of today's environmental standards were passed to address societal interests related to water, fish, endangered species, or power generation. When first constructed in the 19th or 20th century, many of the issues that a typical AFS member would find repugnant generated very little worry. Many of those early dams greatly alter river hydrology and often kill up to 90% of the fish passing each dam. With multiple dams on most rivers, those 90% kill rates per facility multiply to be a major reason why fish stocks suffer greatly in dammed rivers.

Making matters worse is what happened next. And what is appalling is that it continues happening today during this era of heightened awareness—when each hydropower license comes up for review and old facilities that are relicensing are subjected for the first time to newer natural resource laws. But the opportunity to apply improved knowledge is vacated by agency policy to use as the baseline for environmental assessments of the river with the constructed dam. This is a classic example of a "shifting baseline." Each license procedure at each dam moves fish and fishery managers further from restoring healthy stocks and sustainable fisheries. A goal based on a balanced consideration of all societal values, including both harvested and protected species, and not skewed toward energy production, should be a reasonable expectation of our profession. This is not a simple issue because hydropower is billed by some as renewable energy similar to solar or wind, but the significantly greater environmental impacts cannot be ignored.

One final example has been unfolding for decades. President George H.W. Bush proclaimed a policy in 1989 of no net loss of wetlands. Twenty years later it appeared that our nation had achieved that goal, with benefits to fish, birds, and people from coast to coast. But there was a sinister subplot to that success story. National numbers did show that we had greatly reduced the loss of inland wetlands, mostly by investing in prairie potholes and other freshwater systems. Lost in those numbers was the continued loss of coastal wetlands. Indeed, losses are accelerating. Dahl and Stedman (2013) found that losses from 2004 to 2009 were actually 25% higher than losses from 1998 to 2004. Turns out that "no net loss" is a matter of perspective. Those who work along the coast have a difficult road ahead as they attempt to decipher the causes of continued losses and then seek to reverse that scary trend. And our nation must not feel comfortable with an asterisk on the goal set by the first President Bush. Superstorm Sandy and Hurricane Katrina have shown too well how important those wetlands are to society, fish, and our future. No net loss remains a lofty national goal, but getting there will be more difficult than first thought.

The lessons here are several. We must set goals so that we know where we're headed. But we mustn't set those goals without a careful assessment of what each number means and doesn't mean. We also need to be careful that we don't surrender valuable resources by settling for a goal based on something less than we might accept in our personal life or some other arena. Shifting baselines is a concept far more complicated than presented here, but we must remain cautious and vigilant. With a precautionary approach we can achieve successes and push onward. I'm not certain that I'd recognize fish nirvana if I had a front-row seat, but I sure would like to catch a glimpse of where we ought to be headed.

REFERENCES

Chesapeake Bay Program. 2012. Chesapeake Bay Program: Reopening Fish Passage. Available: www.chesapeakebay.net/indicators/indicator/reopening_fish_passage. (January 2014).

Dahl, T. E., and S. M. Stedman. 2013. Status and trends of wetlands in the coastal watersheds of the conterminous United States 2004 to 2009. U.S. Department of the Interior, Fish and Wildlife Service and National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Available: www.fws.gov/wetlands/Documents/Status-and-Trends-of-Wetlands-In-the-Coastal-Watersheds-of-the-Conterminous-US-2004-to-2009.pdf. (December 2013).

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
February 18–20, 2014	Florida Chapter Meeting	Ocala, FL	sdafs.org/flafs
February 22–26, 2014	Water Reuse for Fish Culture - The Conservation Fund's Freshwater Institute	Wenatchee, WA	www.ncwctc.com
February 24–26, 2014	Michigan Chapter Annual Meeting	Holland, MI	fisheriessociety.org/miafs/upcoming_meet.html
February 25–27, 2014	Dakota Chapter Meeting	Chamberlain, SD	
February 25–27, 2014	Wisconsin Chapter Meeting	Green Bay, WI	wi-afs.org
March 3–5, 2014	Minnesota Chapter Meeting	Mankato, MN	mnafs.org
March 4–6, 2014	Illinois Chapter Meeting	Bloomington, IL	illinoisamericanfisheriessociety.weebly.com/2014-annual-meeting.html
March 10–14, 2014	North American Wildlife and Natural Resources Conference	Denver, CO	wildlifemanagementinstitute.org
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/PiscicideClasses.htm or sjohnston@fisheries.org
June 7–11, 2014	World Aquaculture Adelaide 2014	Adelaide, South Australia	www.was.org
June 24–27, 2014	Iberian Congress of Ichthyology	Lisbon, Portugal	sibic.org/jornadas/2014/inicio_en.html
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 16–20, 2014	AFS Annual Meeting 2014	Québec City, Canada	afs2014.org
August 16–20, 2014	38th Annual Larval Fish Conference (AFS Early Life History Section)	Québec City, Canada	larvalfishcon.org
August 31–September 4, 2014	AFS-FHS – International Symposium on Aquatic Animal Health (ISAAH)	Portland, OR	afs-fhs.org/meetings/meetings.php
January 26–30, 2015	Global Inland Fisheries Conference	Rome, Italy	inlandfisheries.org
February 19–22, 2015	Aquaculture America 2015	New Orleans, LA	
May 26–30, 2015	World Aquaculture 2015	Jeju Island, Korea	
August 16–20, 2015	AFS Annual Meeting	Portland, OR	
February 22–26, 2016	Aquaculture 2016	Las Vegas, NV	
February 19–22, 2017	Aquaculture America 2017	San Antonio, TX	

NEW AFS MEMBERS

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AFS Seeks Co-Chief Science Editor for Fisheries Magazine

The American Fisheries Society (AFS) seeks a scientist with a broad perspective on fisheries to act as Co-Chief Science editor to work as part of a two-person leadership team to oversee the science content of *Fisheries*. The Editor must be committed to fast-paced dead-lines and would be appointed for a five-year renewable term which begins in early 2014. Duties include:

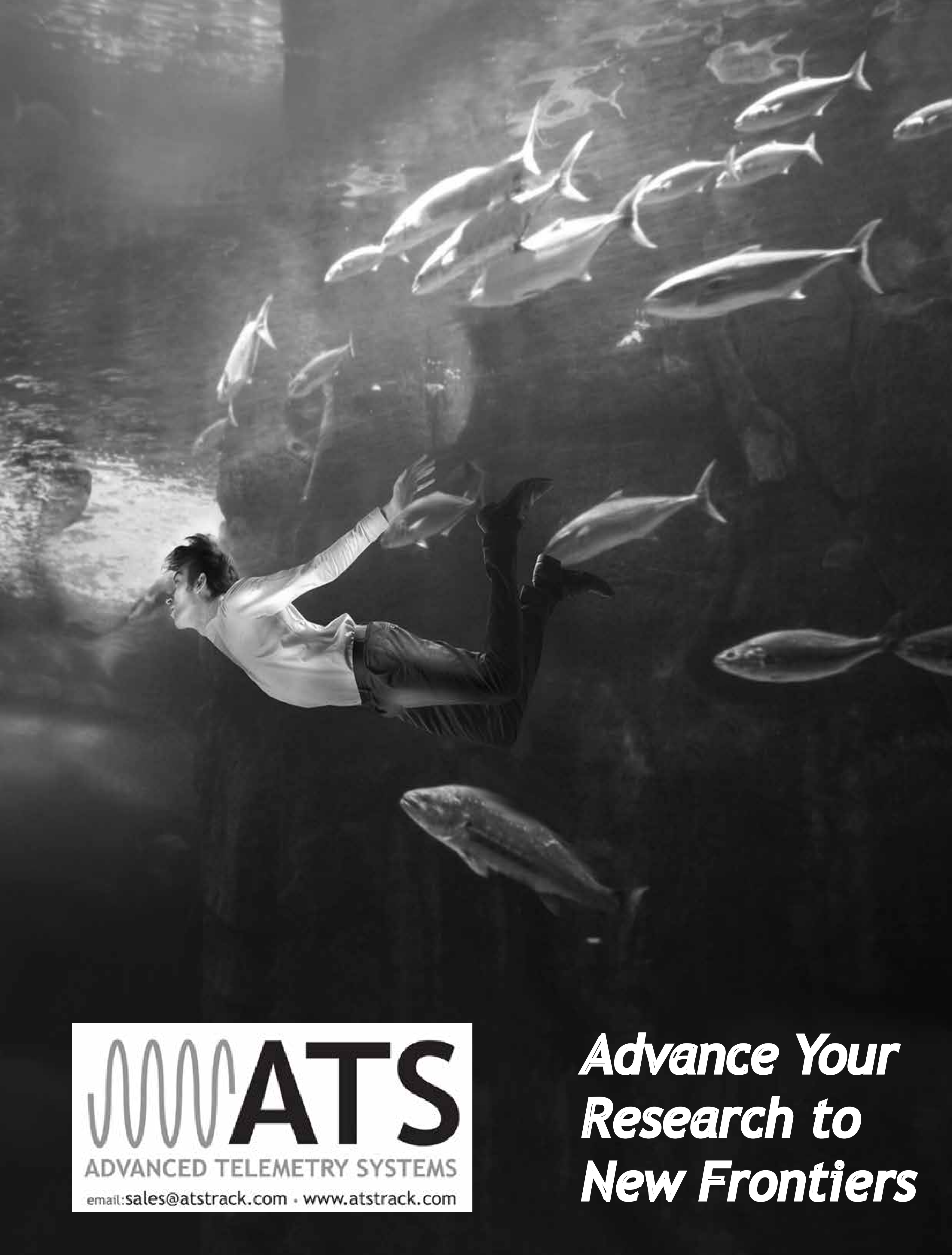
- Work in a highly collaborative manner with one other Chief Science Editor to manage the science component of *Fisheries*.
- Work with the Managing Editor, the Senior Editor and others as part of the overall creative leadership of *Fisheries*.
- Assign an appropriate science editor for approximately half of the scientific manuscripts submitted to *Fisheries*.
- Make final publication decisions based on peer reviews orchestrated by science editors.
- Help to ensure the veracity of each issue's total scientific content.
- Help recruit and retain science editors and provide them with mentoring and guidance.
- Solicit cutting-edge submissions as well as ensuring broad coverage.
- Work with *Fisheries* Managing Editor and AFS Publications Director on the content, themes, and direction of the scientific aspects of *Fisheries*

Qualifications: AFS seeks an established fisheries or aquatic science professional with substantial writing and editorial experience. As part of building an editorial leadership team, we seek skills and/or experience complementary to those of the current Co-Chief Science Editor but are not restricted by that desire. To be considered, send current curriculum vitae along with a letter of interest to alerner@fisheries.org by April 19, 2014. Please also feel free to contact Jeff Schaeffer at jschaeffer@usgs.gov or 734-214-7250 for further information about the position

Note: The Chief Science Editor receives an honorarium, and support to attend the AFS Annual Meeting.

Correction

On page 565 in the December 2013 issue of *Fisheries*, a photo of Abby Lynch has the description "Jesse Trushenski" attached to it. However, make no mistake. That's Abigail Lynch!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