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Fish Meat Gives Viewers Plenty to Digest
A review of the film Fish Meat, a documentary about aquaculture by Ted Caplow and AFS member Andy Danylchuk.
Jesse Trushenski

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The international event that calls attention to the need to restore the connections in rivers for migratory fish to achieve healthy fish stocks and productive rivers.

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A retrospective case study of the survival and failure of road-stream crossings in Vermont following Tropical Storm Irene makes the case for substantial societal and economic benefits from investing in stream simulation designs for aquatic organism passage.
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Extirpation and Tribal Reintroduction of Coho Salmon to the Interior Columbia River Basin
Is it possible that some Coho Salmon are adapting to their new environments and founding local naturalized populations?
Peter F. Galbreath, Michael A. Bisbee, Jr., Douglas W. Dompier, Cory M. Kamphaus, and Todd H. Newsome

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A mature female Coho Salmon that has returned for natural spawning in the Methow River. Photo credit: Robert Farley.
A Plea for a Steady-State Economy

Bob Hughes, AFS President


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.

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).

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).
Annual Meetings and Money
Doug Austen, Executive Director
Bob Hughes, AFS President

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

Continued on page 91
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, unserved 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
Smartphones in Fisheries

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

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.

What is Social Media?

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).

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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
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Florida

COLUMN
The Communication Stream
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.
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

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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 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

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
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.
There is considerable controversy surrounding aquaculture, or fish farming, as well as a good bit of misinformation 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.

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 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.
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, douracia, 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 public’s 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 IUNSN 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 hermen@wanningenwaterconsult.nl
Phone 0031-6-182 725 72
Web www.worldfishmigrationday.com
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 pre-flood levels (Kirn 2012). Barring anthropogenic alteration of in-stream habitat with heavy machinery, Brook Trout populations would be expected to return to pre-flood population structure within 2–3 years (Kirn 2012). Studies by Dolloff et al. (1994) in North Carolina and Carlene 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.
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).
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,
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 constrain 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-km² 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.

<table>
<thead>
<tr>
<th>Road no./name</th>
<th>Traditional culvert/replace in kind ($)</th>
<th>Betterment/AOP stream simulation replacement ($)</th>
<th>Anticipated % cost increase for AOP stream simulation design</th>
<th>Actual construction cost ($)</th>
<th>Actual % cost increase for AOP stream simulation design</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR42.050 over Bingo Road</td>
<td>92,950.00</td>
<td>142,050.00</td>
<td>53</td>
<td>113,738.00</td>
<td>22</td>
</tr>
<tr>
<td>FR42B.000 over Bingo Brook</td>
<td>112,175.00</td>
<td>156,775.00</td>
<td>40</td>
<td>Never constructed, road decommissioned</td>
<td>NA</td>
</tr>
<tr>
<td>FR49.005 over Boyden Brook</td>
<td>93,800.00</td>
<td>140,700.00</td>
<td>50</td>
<td>Never constructed, Irene damaged site access road</td>
<td>NA</td>
</tr>
<tr>
<td>FR92.000 Over Goshen Brook</td>
<td>106,635.00</td>
<td>172,200.00</td>
<td>61</td>
<td>119,835.00</td>
<td>12</td>
</tr>
<tr>
<td>FR92A.000 over Hale Brook</td>
<td>104,700.00</td>
<td>130,250.00</td>
<td>24</td>
<td>113,725.00</td>
<td>9</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Forest road no.</th>
<th>Road name</th>
<th>Stream name</th>
<th>Drainage area (km²)</th>
<th>Bankfull width (m) based on regional curves</th>
<th>Failed structure type and size</th>
<th>Ratio of structure to bankfull width</th>
<th>Approximate repair cost due to crossing failure ($)</th>
<th>Approximate total road repair cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR394</td>
<td>Townsend Brook</td>
<td>Townsend Brook</td>
<td>1.3</td>
<td>3.0</td>
<td>Native stringer bridge with approximately 1.5-m opening</td>
<td>0.50</td>
<td>81,000</td>
<td>104,000</td>
</tr>
<tr>
<td>FR226</td>
<td>Corporation Brook</td>
<td>Corporation Brook</td>
<td>4.4</td>
<td>5.0</td>
<td>2.0-m culvert</td>
<td>0.40</td>
<td>10,000</td>
<td>105,000</td>
</tr>
<tr>
<td>FR45</td>
<td>Chittenden Brook</td>
<td>Chittenden Brook</td>
<td>14.8</td>
<td>8.6</td>
<td>Bridge 11.6 m</td>
<td>1.35</td>
<td>175,000</td>
<td>190,000</td>
</tr>
<tr>
<td>FR35</td>
<td>Upper Michigan</td>
<td>Michigan Brook</td>
<td>19.9</td>
<td>9.8</td>
<td>3.7-m culvert</td>
<td>0.38</td>
<td>247,000</td>
<td>247,000</td>
</tr>
<tr>
<td>FR39</td>
<td>Texas Falls</td>
<td>Texas Falls Brook</td>
<td>NA</td>
<td>NA</td>
<td>Numerous 46- to 60-cm cross-drain culverts</td>
<td>n/a</td>
<td>82,000</td>
<td>82,000</td>
</tr>
</tbody>
</table>

| Totals          |                 |             |                     |                                             |                                 |                                      | 595,000                                       | 728,000                               |

Source: Dan McKinley (GMNF, personal communication).

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

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

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

<table>
<thead>
<tr>
<th>Example of costs incurred to the town of Rochester at Churchville Road from debris plugging and failure of a single undersized culvert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
</tr>
<tr>
<td>Culvert</td>
</tr>
<tr>
<td>Churchville Rd.</td>
</tr>
<tr>
<td>Unmaintained road improvement</td>
</tr>
<tr>
<td>Traffic delay costs (gas, lost work time, etc.)</td>
</tr>
<tr>
<td>Total cost</td>
</tr>
</tbody>
</table>
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 km² 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 strewn 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 USFS 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 non-government 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.

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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.

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).

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

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 drásticas 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 autóctonas 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.

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
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 precollonial returns of hundreds of...
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)
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...
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).
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.

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.
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.

<table>
<thead>
<tr>
<th>Juvenile release year</th>
<th>Hatchery origin</th>
<th>Natural origin</th>
<th>Total smolts</th>
<th>Total adults</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Smolts</td>
<td>Adults</td>
<td>SAR (%)</td>
<td>Smolts</td>
</tr>
<tr>
<td>2000</td>
<td>331,503</td>
<td>3,546</td>
<td>1.07</td>
<td>1,432</td>
</tr>
<tr>
<td>2001</td>
<td>134,574</td>
<td>166</td>
<td>0.12</td>
<td>40,605</td>
</tr>
<tr>
<td>2002</td>
<td>155,814</td>
<td>669</td>
<td>0.43</td>
<td>19,859</td>
</tr>
<tr>
<td>2003</td>
<td>139,135</td>
<td>505</td>
<td>0.36</td>
<td>9,092</td>
</tr>
<tr>
<td>2004</td>
<td>148,810</td>
<td>2,405</td>
<td>1.62</td>
<td>18,787</td>
</tr>
<tr>
<td>2005</td>
<td>204,728</td>
<td>2,646</td>
<td>1.29</td>
<td>31,631</td>
</tr>
<tr>
<td>2006</td>
<td>204,602</td>
<td>2,203</td>
<td>1.08</td>
<td>8,298</td>
</tr>
<tr>
<td>2007</td>
<td>260,455</td>
<td>4,132</td>
<td>1.59</td>
<td>20,131</td>
</tr>
<tr>
<td>2008</td>
<td>416,708</td>
<td>8,835</td>
<td>2.12</td>
<td>43,046</td>
</tr>
<tr>
<td>2009</td>
<td>496,594</td>
<td>5,153</td>
<td>1.04</td>
<td>25,108</td>
</tr>
<tr>
<td>2010</td>
<td>341,145</td>
<td>7,216</td>
<td>2.12</td>
<td>35,158</td>
</tr>
<tr>
<td>2011</td>
<td>333,891</td>
<td>4,948</td>
<td>1.5</td>
<td>24,108</td>
</tr>
</tbody>
</table>

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 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.

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

ACKNOWLEDGMENTS

Production of this manuscript was financed in part by the Bonneville Power Administration through the Columbia Basin Accords Project No. 2009-009-00. Numerous tribal fishery agency managers, biologists, and technicians have participated in the Coho Salmon reintroduction programs; however, the authors wish to acknowledge in particular Paul Ward, David Fast, Steve Parker, Tom Scribner, Keely Murdoch (Yakama Nation) and David Johnson, Becky Johnson, Jay Hesse, and Scott Everett (Nez Perce Tribe). The authors also acknowledge the helpful input from two anonymous reviewers and the Fisheries science editor and staff.

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


Evaluating the Barrier Assessment Technique Derived from FishXing Software and the Upstream Movement of Brook Trout through Road Culverts. Shad Mahlum, David Cote, Yolanda F. Wiersma, Dan Kehler, and Keith D. Clarke. 143:39–48.


Spatially Varying Population Distributions and Fishery Characteristics of Lake Erie Walleyes Inferred from a Long-Term Tag Recovery Study. Christopher S. Vanderghoot and Travis O. Brenden. 143:188–204.


[Note] Lack of Temporal Variation in Egg Size in Landlocked Fall Chinook Salmon from Lake Oahe, South Dakota. Matthew M. Wipf, Michael E. Barnes, and Dan Durben. 143:289–293.

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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


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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.

Continued from page 53
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 area. 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


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<td>Florida Chapter Meeting</td>
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<td>Japanese Society of Fisheries Science</td>
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<td>April 7–12, 2014</td>
<td>The Western Division Meeting’s 2nd International Mangroves as Fish Habitat Symposium</td>
<td>Mazatlan, Mexico</td>
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<td>May 19–23, 2014</td>
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<td>June 7–11, 2014</td>
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<td>July 7–10, 2014</td>
<td>Fisheries Society of the British Isles Meeting &amp; Call for Papers-Integrated Perspectives on Fish Stock Enhancement</td>
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<td>July 30–August 3, 2014</td>
<td>American Society of Ichthyologists and Herpetologists Annual Conference</td>
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<td>August 3–7, 2014</td>
<td>International Congress on the Biology of Fish</td>
<td>Edinburgh, United Kingdom</td>
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- Work in a highly collaborative manner with one other Chief Science Editor to manage the science component of *Fisheries*.
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- Assign an appropriate science editor for approximately half of the scientific manuscripts submitted to *Fisheries*.
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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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