Fisheries

Vol. 40 • No. 3 • March 2015

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Fisheries

Vol. 40 • No. 3 • March 2015

102 A very large Barrens Topminnow collected at the type local pool. Photo credit: P. Bettoli, USGS.

104 Pumpkinseed Sunfish *Lepomis gibbosus*. Art credit: Maynard Reece.

114 A salmon parr-smolt acclimation site, net pens in a lake. Photo credit: Todd N. Pearsons.

Fisheries

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

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AFS NEWS (continued)

INTERVIEW

BOOK REVIEWS

JOURNAL HIGHLIGHTS

BACK PAGE

COVER

Chinook Salmon *Oncorhynchus tshawytscha* alevins. Photo credit: Todd N. Pearsons

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AFS President Donna Parrish
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AFS Membership: How Much Should it Cost?

Donna Parrish, AFS President

Many professional societies have experienced declining membership in recent years. In American Fisheries Society (AFS), membership numbers are currently lower than some previous years but not all. We know that AFS membership often varies with attendance at the Society Annual Meeting. Attractive meeting locations draw new members to AFS who wish to take advantage of the lower meeting registration fees that membership confers. For example, attendance at the 2011 Annual Meeting in Seattle was the largest in AFS history with over 4,000 attendees, and AFS membership was higher that year than any recent year because of the large number of new members who attended the Annual Meeting.

Regardless of the number of members who join for the explicit purpose of reduced meeting registration fees, or the students who never become young professionals or regular members, AFS exists because of the committed members of the Society. Many members recognize that AFS is our professional lifetime home. We belong because we believe in the Society's mission, and we volunteer to be on committees, serve as officers, and organize symposia and other sessions because those activities are what professionals do to support the Society. Dedicated fisheries professionals support the Society through their membership dues, and the Society, in turn, supports fisheries professionals throughout their careers through publications, meetings, and many unit (section, committee, division, and chapter) activities.

So, how much should AFS membership cost? On membership surveys, some have commented that AFS dues are too costly. This is nothing new. There are always those who do not recognize the costs of running the Society and the need for all members to cover those costs. Membership dues in other professional organizations indicate that AFS dues are not greater than those of our peer organizations (Table 1). Our Society has a much stronger commitment to keeping membership costs low for students than the other societies. The membership dues for AFS young professionals are also lower than others shown. If some of our members cannot afford a regular membership in AFS, then we should consider other options. Would regular members with higher salaries be willing to pay higher annual dues to support those members who make less? The Ecological Society of America has used a sliding scale for many years. Given that regular AFS members already subsidize student and young professional memberships, would members who earn more than US$100K per year be willing to pay $120 or $150 in annual dues?

We joke about the frugality of most fisheries biologists. We are known for having exceptional skills in scoring free food at any event! However, many of us would be willing to pay higher annual dues to retain lower paid members in the Society. Nevertheless, we should consider that AFS dues have increased only by $4 since 1999 and thus have not kept pace with inflation. So, we have to wonder whether this is a "real problem" or one of not understanding or acknowledging the costs of professional society membership.

Table 1. Annual membership dues for the most common categories of AFS and other professional societies.

Professional Society	Membership Categories							
	Career			Annual Salary				
	Student	Young Professional	Regular	<$40K	$40–60K	$60–100K	$100–150K	>$150K
American Association for the Advancement of Science	50		99					
American Fisheries Society	20	40	80					
Ecological Society of America	35			64	98	118	144	169
Entomological Society of America	36	73*/108**	144					
Society of Freshwater Science	40	55	75					
The Wildlife Society	41	51	81					

*Transition dues = two years post-student
**Young professional dues = next three years after transition

COLUMN
POLICY

AFS Policy Director
Thomas E. Bigford
tbigford@fisheries.org

Our Renewed Effort to Make the Most of Science

Thomas E. Bigford, AFS Policy Director

This spring marks the end of an important experiment at the American Fisheries Society (AFS). No, Doug Austen has not implanted PIT tags in AFS staff (to my knowledge), and no, we did not design genetically-modified snakeheads to serve as Society mascots. But we have been testing a hypothesis of how to strengthen our role in the fisheries realm.

Society historians recalled times more than a decade ago when AFS sponsored interns, fellows, and other short-term positions accomplished tasks beyond the ability of existing staff and volunteers.

Our Society has been developing policy statements since 1973 and has supported a Resource Policy Committee (RPC) since 1991 (and an Environmental Concerns Committee since 1978). Those commitments are reflected in the Society bylaws, which mandate a process for developing new policies and regular reviews of the scientific basis of each existing policy every five years. That approach translates into a growing workload with a new policy every year or two and a steady stream of new science. With only volunteers to support its mission, the RPC has struggled to review the old and write the new. Our experiment was to evaluate options and implement a solution to address the highest priorities among our 35 policies. The early results provide our best glimpse at how to make AFS policy a stronger tool in our efforts to apply science to management questions.

This experiment was hatched a decade ago with the realization that every single AFS policy was well beyond the mandatory five-year review cycle. While the RPC began to tackle that reality in the late 1990s (under the leadership of then-Chair Heather Blough), the Society charged the committee to complete a new policy on dam removal and initiate work on new policies on recreational fishing tackle and climate change. The need for a realistic workload appraisal was becoming more evident in each RPC work plan and with every Governing Board meeting. Solutions were offered, priorities were established, and RPC members received their assignments. The RPC's stalwart team of volunteers gave their best, but the workload proved daunting. A new approach was essential.

The most promising, and logical, options centered on increased RPC capacity and narrowed priorities. Society historians recalled times more than a decade ago when AFS sponsored interns, fellows, and other short-term positions accomplished tasks beyond the ability of existing staff and volunteers. The AFS collaborated with National Oceanic and Atmospheric Administration Sea Grant to hire Lee Benaka to focus on fish habitat, leading to the hugely successful symposium on essential fish habitat at the 1998 Annual Meeting in Hartford and the best publication on the topic. We arranged for Nature McGinn to edit the proceedings of the climate change symposium in Phoenix in 2001 that was useful when Colleen Caldwell finished an effort, initiated by Kim Hyatt, to develop a new AFS policy on climate and fish. And Steve Leathery, Alesia Read, Jessica Geubtner Snowden, and Christine Fletcher (Patrick) were hired to support policy and science work across several AFS programs. The lesson learned was that hiring new talent offered the most expedient path to completing special projects while nurturing promising AFS members. From that history evolved a consensus to resurrect the AFS Fellows Program.

The need for and structure of an AFS Fishery Policy Fellowship were debated by the AFS Governing Board in early 2014. The RPC, then led by Chair Jesse Trushenski, was instrumental in identifying the most out-of-date policy statement(s), building on Heather Blough's work a decade earlier. The AFS officers considered dozens of options (duration, pay rate, academic and professional experience, in-house or virtual, name for the position, etc.) for this new fellowship. The selected strategy was a half-time position for six months under the direct supervision of new RPC Chair Leanne Roulson, with a focus on converting our three overlapping endangered/threatened species policies (#10, 19, and 27 at fisheries.org/policy_statements) into one comprehensive policy statement supported by an updated background document. Executive Director Doug Austen, President Bob Hughes, and the AFS officers approved a stipend comparable to a research

Continued on page 139

Calling All Reviewers—The AFS Editorial Board

Jeff Schaeffer
AFS Co-Chief Science Editor
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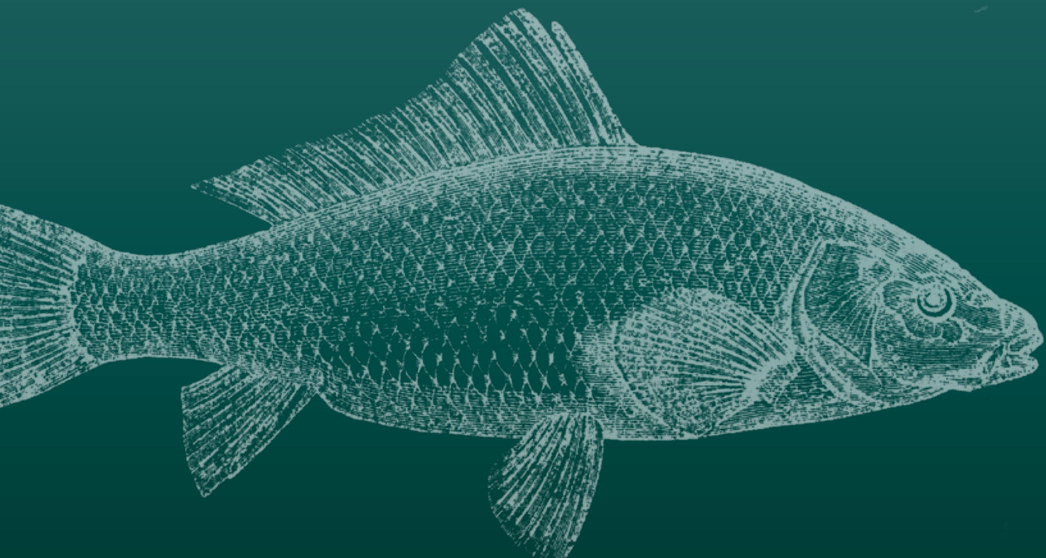
One of the most valuable contributions that you can make as an AFS member is to serve as a referee for AFS publications. Constructive peer reviews provided by AFS members are the backbone of our publication process, and it is likely the single most important factor in maintaining journal quality and our reputation as a professional society.

That being said, we do not have enough reviewers. This is a growing problem faced by many professional societies, and there are several reasons for this. There has been a proliferation of new journals, and people active in helping with reviews are often besieged by requests. And we all seem to be doing two or more jobs these days, so time is limited. There is also a trend that the people who do take the time to do constructive manuscript reviews tend to develop reputations as go-to reviewers; thus, a small number of people get many review requests and end up carrying that burden for all AFS members.

But the greatest impediment of all is that many AFS members, especially students, believe that they do not have the talent or expertise to review manuscripts. This comes from a mistaken belief that you can only provide constructive reviews if you are a seasoned professional with years of writing experience and a lengthy publication list. While you should have some experience as a fisheries professional (graduate study counts here), becoming a good reviewer is a process, and the best way to become a good reviewer is to start doing reviews.

But why should you do this? Well, it is a very good way to provide a highly valued service to AFS that does not require an onerous time burden, conference calls, or travel to meetings. You also get first glance at cutting edge science, and we dare to suggest that reviewing manuscripts will help make your own writing and manuscripts better. And when an article appears in print, you will gain immense satisfaction that you helped the author(s) craft a good story that benefits both fisheries science and fisheries resources. And without exception, every journal editor began their editorial career by reviewing manuscripts. You may be one of our future journal editors, and this is the place where it all begins.

How do you start the process? Simply visit mc.manuscriptcentral.com/fisheries and click on the Register here button. You will be asked to fill out a short form with contact information, expertise, and interests. That is all there is to it. The signup page is specific to *Fisheries* magazine, but your information is linked to all of our journals. You may not start receiving reviewer invitations immediately, but a signup starts the process by getting your name on the list of potential reviewers. AFS

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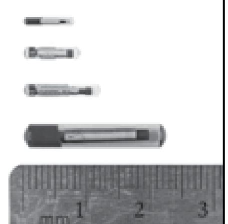


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AFS Journals Support Sustainable Aquaculture

Jeff Schaeffer
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The science of aquaculture has been on a long journey toward sustainable practices, and two recent articles from two different American Fisheries Society journals showcase this progress. One of the great problems in aquaculture is that to raise fish, it has long been thought that you need to feed them animal protein or animal derived lipids; in many cases, this involves fish meal or fish oil-products that raise questions about ecological impacts on the food web and sustainable fisheries. However, Kenson Kanczuzewski and Jesse T. Trushenski found that piscivorous hybrid Striped Bass (*Morone saxatilis x M. chrysops*) thrived on diets where hydrogenated soybean oil was substituted partially or entirely for fish meal. High concentrations of soybean oil resulted in only slight differences in growth and fatty acid composition among treatments, and even those results could be nullified during a short finishing period when fish were fed traditional diets. While some fish oil was likely required, the technique suggests that large reductions in animal-derived dietary components are possible.

Another issue is the use of antibiotics, but Sevdan Yılmaz and Sebahattin Ergün found that the addition of allspice to prepared diets used to feed Mozambique Tilapia *Oreochromis mossambicus* reduced their susceptibility to infection. Yes, allspice, and you likely have some in your pantry. Fish fed on diets with varying concentrations of allspice were challenged by exposure to Streptococcus. They found that a dietary allspice level of only 10 g/kg in the food ration reduced mortality after the challenge exposure, and it also improved growth performance. Traditionally, those fish might have been treated with antibiotics, but culturists can now consider a common household spice as an alternative with multiple benefits. The only downside to their research is that readers may find themselves with an unexplained craving for pumpkin pie, gingerbread, and spice cake.

Our newer aquaculture and fish health journals likely receive fewer views than our long-established journals. This is a shame, because they feature research that has a solid connection to big issues and the Society's mission. Check them out on the web, and you will be surprised at what you find.

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FROM THE ARCHIVES

While the slaughter, for such it was, was in progress, the catch of bass, pike, pickerel, and crappie was very large, immense quantities shipped all through adjoining states to good market.

In 1870 to 1880 the decrease in supply of buffalo was marked, in fact, had decreased to an extent that most of the larger fish dealing companies had gone out of business. The bass were notably scarce, pike and pickerel practically extinct and all game varieties had greatly decreased. Attention had been called to the matter by this time and in the early seventies legislative action was asked for and some tentative laws passed covering spawning seasons. The harm, however, had been accomplished and fish were scarce.

Then came the introduction of the carp. Carp increased, so did the opportunity for "cuss words" and complaints without number, that the carp were destroying and driving out game fish, yet carp increased, so did the bass. Carp furnishes the great bulk of commercial fish and bass are more plentiful than ever known on Illinois river. On the Mississippi river, owing to the peculiar conditions of the overflows, not so general or complete, the banks being as a rule higher, carp have not shown nearly so rapid an increase and bass equally as scarce.

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Predicting Brook Trout Presence at the Local Level, Where it Counts

Jeff Schaeffer
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Brook Trout *Salvelinus fontinalis* are a popular sport species, but their conservation status is of great concern because many eastern populations have declined. Brook Trout are a paradox. From a basin perspective, they are still present throughout most of their range, but at a watershed or subwatershed scale, many populations are now extinct via local factors that may operate at the reach scale. Therein lies the problem; to conserve Brook Trout fisheries, managers need local information at the smallest scale possible, but up to now that has been largely unobtainable because it would require expensive and extensive field data from individual stream reaches. However, a new approach by Jefferson DeWeber and Tyler Wagner allows prediction of Brook Trout occurrence with the extremely fine resolution that has long been needed.

DeWeber and Wagner used hierarchical logistic regression with Bayesian estimation to predict Brook Trout occurrence probability. The probability of occurrence was predicted from landscape-level variables but with a twist: they used a novel neural network ensemble model to predict stream temperatures directly, rather than rely on surrogate variables such as air temperature, latitude, or altitude. That allowed them to make predictions within individual stream reaches, and results compared favorably with field data not only from stream surveys but also with a prior mapping effort by the Eastern Brook Trout Joint Venture developed through empirical observations and expert knowledge. DeWeber and Wagner also found that agricultural activity and soil permeability influenced Brook Trout distributions, with agriculture having a stronger effect in reaches with warmer temperatures.

While their predictive model did not account for biotic interactions and other local stressors, their approach gives managers a better way of comparing potential restoration sites than was available previously. Higher occurrence probabilities are likely associated with better habitat, and their model can be used as a tool to prioritize restoration efforts, either through more directed sampling or actual stream restoration activities.

REFERENCE

DeWeber, J. T., and T. Wagner. 2015. Predicting Brook Trout occurrence in stream reaches throughout their native range in the eastern United States. Transactions of the American Fisheries Society 144(1):11–24. AFS

THE LAST STAND OF THE BARRENS TOPMINNOW

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Tucked away on the Highland Rim physiographic province in middle Tennessee is the Barrens Plateau region, home to one of the state's most floristically diverse natural areas. This region is fairly unique in that it harbors plants from the Atlantic and Gulf Coastal Plains as well as species common to Midwest tall grass prairies. Early Anglo settlers named these savanna-like areas the "barrens" because of the scarcity of trees relative to surrounding areas. The undisturbed landscape was a mosaic of open canopy woodlands with a grassy understory and areas of essentially treeless grasslands. Barrens are also found in southern Kentucky along the Highland Rim of the Cumberland Plateau. Wildfires or fires intentionally set by Native Americans were a frequent feature of the barrens in both states, which favored grasses over trees. In precolonial times, bison and elk were also a part of the landscape, and their grazing and trampling would have favored grasslands and maintained the prairie-like character of the barrens. Tennessee's Highland Rim and Barrens Plateau regions, due to geological complexity and an abundance of drainage systems, are also home to the most diverse fish fauna of any region of comparable size in North America.

The barrens region is dissected by many surface streams and is underlain by subterranean channels that carve through the limestone geology. Prominent features of this landscape are numerous caves and springs. The waters seeping from these karst springs average about 15°C year-round. If you were to fly low and slow over the barrens region, you would see innumerable springs bubbling up in open pastures, connected to adjacent streams by runs of a few meters or up to several hundred meters in length. Small rocky outcropping and copses of shrubs and small trees in the open landscape would be prime spots to locate springs. Depending on recent rainfall, spring discharges might be imperceptibly low or substantial (>0.5 cms). Natural spring pools can be small, perhaps a square meter or so, whereas inundated sinkholes and dammed spring pools might be several hundred or several thousand square meters in size. These springs and spring-influenced habitats in the barrens region support fishes such as the Spring Cavefish *Forbesichthys agassizii*, Flame Chub *Hemitremia flammea*, and Barrens Topminnow *Fundulus julisia*. The last two species are granted Greatest Conservation Need status in Tennessee, but the Flame Chub is in no imminent threat of extinction. The same cannot be said of the Barrens Topminnow. Due to its limited distribution (the species is endemic to the barrens of Tennessee) and the scarcity of undisturbed habitats, the Barrens Topminnow has long been considered one of the most critically endangered fishes in eastern North America.

A very large Barrens Topminnow collected at the type locale pool. Photo credit: P. Bettoli, USGS.

The features of the landscape where this species evolved into a prototypical spring-habitat species may have contributed to its imperiled status. The gently rolling terrain and soils where the Barrens Topminnow is making its stand are very conducive to settlement and landscape manipulation, especially agriculture in the form of pastureland and plant nurseries. Spring ponds and runs are natural watering holes for livestock and the destruction of riparian habitat and aquatic vegetation would be an obvious problem for any species inhabiting those habitats. Additionally, an important feature of the barrens region that would be obvious to even a casual observer is the large number of plant nurseries. In fact, this region of Tennessee is touted to be the Nursery Capital of the World, with over 300 wholesale nurseries in operation. Suitable soils and precipitation contributed to the influx of nursery operations to this region; perhaps more important, it is too warm for plant nurseries further south to grow northern species, and nurseries in the barrens region have a longer growing season to work with than northern nurseries. No direct links have been identified between nursery operations and loss of Barrens Topminnow habitats, though early authors concluded that such large-scale habitat changes were probably limiting already rare spring dwelling fishes to only a few sites compared to precolonial times.

When the Barrens Topminnow was first described as a new species in the early 1980s, there were at least 14 populations. Those early surveys noted a common feature of the spring habitats supporting Barrens Topminnows: lush aquatic vegetation such as watercress *Nasturtium officinale*, water primrose *Ludwigia palustris*, and milfoil *Myriophyllum* spp. Vegetation, especially mats of filamentous algae, is used as spawning substrate for the handful of eggs the female deposits during each spawning act. The crystal-clear waters discharging at a near constant temperature, fertile soils, and little shade provide ideal conditions for aquatic vegetation to flourish in springs of the barrens region.

Subsequent distribution surveys revealed a plummeting number of populations, and now only three wild populations are known. Those surveys documented a feature of the landscape that probably plays the most important role in the extirpation of Barrens Topminnows at many sites: swarms of invasive Western Mosquitofish *Gambusia affinis*. Western Mosquitofish have been implicated in the decline of native fishes in other locales including other topminnow species. Mosquitofish are aggressive; in aquaria, they have been observed harrying juveniles and consuming larval Barrens Topminnows. Being livebearers capable of producing several broods per year, Western Mosquitofish rapidly overwhelm low-density Barrens Topminnow populations, especially in small springs. Status surveys since the 1980s also revealed another threat to Barrens Topminnows: drought. In fact, the type locale for the species (a small pool created by a private landowner who dammed the outflow from a spring) has completely dried up on occasion, which prompts “rescuing” Barrens Topminnows and holding them in captivity until spring flows return. The type locale pool had once been stocked with Rainbow Trout *Oncorhynchus mykiss* (thankfully, that practice ceased years ago), and the small dam prevents the colonization of the site by Western Mosquitofish.

The Barrens Topminnow does not currently enjoy federally protected status. However, it has benefited from the efforts of a long-running partnership between nonprofit conservation groups, university researchers, private landowners, and state and federal agencies to keep it from becoming extinct. Those efforts include annual monitoring of the few remaining wild populations and propagating and stocking juvenile Barrens Topminnow into existing or newly created spring habitats to establish a metapopulation throughout the barrens region. Working closely with landowners, the partners committed to protecting the Barrens Topminnows have erected fencing to protect riparian zones, installed watering systems for cattle, and investigated the use of barriers to prevent colonization of stocked sites by Western Mosquitofish. Thousands of Barrens Topminnows have been reared in hatcheries, tagged, and stocked into dozens of spring pools and runs and monitoring efforts continue. Finally, the looming threat of droughts to Barrens Topminnows has prompted efforts to understand and model the relationships between aquifers, surface waters, and water use in the barrens region.

A natural spring pool chosen as a stocking site for hatchery-reared Barrens Topminnows. Photo credit: P. Bettoli, USGS.

Two small pools were excavated at this springhead in a pasture to create habitat for stocked Barrens Topminnows. Photo credit: P. Bettoli, USGS.

ACKNOWLEDGMENTS

The Tennessee Cooperative Fishery Research Unit is jointly sponsored by the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the Tennessee Wildlife Resources Agency, and the Tennessee Technological University. In preparing this essay I reviewed information from various sources, especially the theses and reports coauthored by two of my graduate students (Andrea Johnson and Cory Goldsworthy), two Tennessee state government websites (www.state.tn.us/environment/natural-areas/natural-areas/may/; www.tn.gov/environment/conservationist/archive/grass.htm), and the works of Rakes (1989. Life history and ecology of the Barrens Topminnow, *Fundulus julisia* Williams and Etnier [Pisces, Fundulidae]. Master’s Thesis. University of Tennessee, Knoxville), Williams and Etnier (1982. Description of a new species, *Fundulus julisia*, with a redescription of *Fundulus albolineatus* and a diagnosis of the subgenus *Xenisma* [Teleostei: Cyprinodontidae]. Occasional Papers of the Museum of Natural History. University of Kansas, Lawrence), and Etnier and Starnes (2001. The fishes of Tennessee. University of Tennessee Press, Knoxville). AFS

Quillback Carpiodes cyprinus. Art credit: Maynard Reece.

ESSAY

Brushes with Greatness:
Preserving Original Maynard Reece Fish Art

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Recently, the Iowa Chapter of the American Fisheries Society awarded a Fisheries Project Grant for the restoration of the original Maynard Reece fish prints housed at the Rathbun Fish Hatchery. The grant award will be used in conjunction with a $20,000 grant from the Iowa Department of Cultural Affairs, Historical Resource Development Program award.

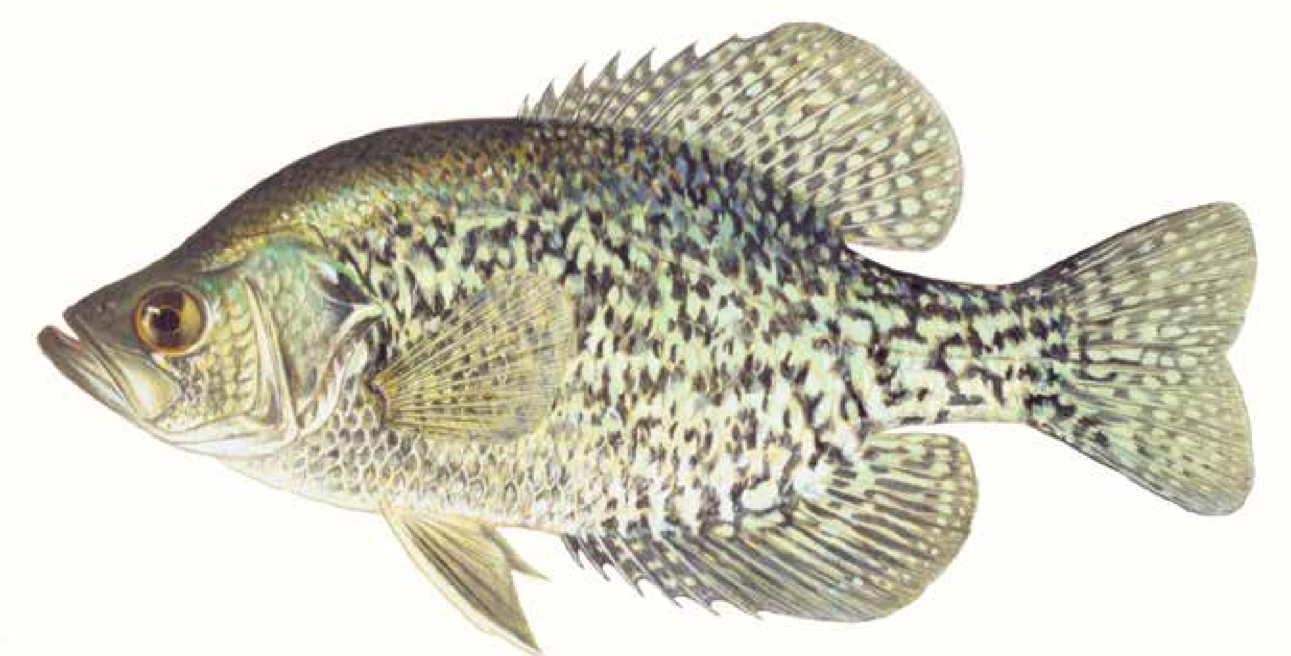
Maynard Reece is one of Iowa's preeminent artists, on a level below only Grant Wood and on par with Ding Darling, Marvin Cone, Andrew Clemens, and Christian Petersen. He began his career as a graphic artist with the Meredith Corporation in Des Moines at the age of 18 in 1938. At that time, he began meeting with and became the protégé of Ding Darling. In 1940, he took a position with the State Historical Museum and by 1942 had painted the color plates for the book *Waterfowl in Iowa*. Following his World War II service, Reece returned to the State Historical Museum in 1946 and undertook the work of illustrating the color plates for *Iowa Fish and Fishing*. His work concluded sometime between the printing of the second edition in 1951 and the third edition in 1956, which included all of the paintings. His efforts resulted in 18 separate paintings, including 63 different fish species. These 18 original paintings are the property of the Fisheries Bureau of the Iowa Department of Natural Resources (DNR) and have been on display at the Rathbun Hatchery since it opened in the 1970s.

The work illustrating these two books for the Iowa Conservation Commission resulted in Reece being invited to submit a design for the 1948–1949 Federal Duck Stamp competition. This was his first experience in the competition, and he won. He would go on to win a record five Federal Duck Stamp competitions—a mark unrivaled and unlikely to ever be exceeded. His success in these competitions led to him being dubbed "The King" of duck stamps. Reece was commissioned to create the first Iowa State Duck Stamp in 1972 and won the 1977 and 1993 Iowa Duck Stamp competitions. He has also won state stamp competitions in Arkansas, Idaho, Illinois, Missouri, Texas, and Washington.

Reece gained fame for his artwork portraying birds, and his biography as a Legend of the Outdoor Writers Association of America christened him the "artist with the feather touch." His work exhibits a commitment to detail of the animal, its habitat, and behavior. As an example, every bird has the right number of feathers on the wing, correctly shaped and colored. The results of his meticulous nature and artistic talent include prestigious awards such as being named the Ducks Unlimited Artist of the Year in 1973; the Master Wildlife Artist of Leigh Yawkey Woodson Art Museum, International Birds in Art show since 1989; and a Distinguished American Artist by *American Artist* magazine.

Reece's attention to detail transcends species. His fish paintings have the correct number of scales on the lateral line and the correct number of spines and rays on the fins. His initial work on *Iowa Fish and Fishing* led *Life* magazine to commission him to paint a portfolio of freshwater fish in 1955

Slimy Sculpin *Cottus cognatus*. Art credit: Maynard Reece.



Black Crappie *Pomoxis nigromaculatus*. Art credit: Maynard Reece.

and a subsequent portfolio of saltwater species in 1957. In 1961, he provided the artwork for Maurice Walsh's story, "A Seven-Pound Trout," in the *Saturday Evening Post*. Utilizing these experiences, Reece wrote, illustrated, and provided photographs for the book *Iowa Fish and Fishing*, which was published by Meredith in 1963. In addition to all his fame as a bird artist, he was the preeminent fish artist of his time.

Reece is a supremely skilled artist who enhanced his skill with the research necessary to capture the essence of the subject matter: hours in a duck blind; miles of walking, shotgun in hand, through marshes and prairies; and hundreds of thousands of casts, photographs, and live and preserved specimens. Experiences and mental pictures earned through a lifetime spent in the field. These are the stripes of honor earned from a commitment to his craft and to conservation. In 1963, Reece was Chair of the Governor's Committee on the Conservation of Outdoor Resources for Iowa. Since then, he has provided numerous works of art to conservation organizations for use in fundraising. He has always been a supporter of the Iowa Natural Heritage Foundation (INHF); in recent years, he painted an eastern goldfinch (Iowa State Bird) and wild rose (Iowa State Flower) and committed 25% of the print sales to the INHF. His commitment to conservation resulted in the INHF naming a restored wetland area for him, the Maynard Reece Marsh in northern Iowa, which is now managed by the Iowa DNR.

The act of conserving things that are important brings us back to the fish prints. Many years ago, Iowa DNR Fish Culture supervisor Mike Mason mentioned that the fish prints in the interpretive area at the Rathbun Fish Hatchery were the Maynard Reece originals. At the time, I thought that was cool but didn't think much more of it. Last fall while viewing an art show, entitled *In Pursuit of Wildlife Conservation: The Art of Jay N. Darling and Maynard Reece* at Iowa State University's Brunnier Museum, the importance of what we had at Rathbun dawned on me. It turns out that it is nearly a miracle that these prints are even around today.

Pumpkinseed Sunfish *Lepomis gibbosus*. Art credit: Maynard Reece.

After starting this project, I sent a note to retired fisheries bureau chief, Marion Conover, telling him about what I was up to and asking what he knew. He related to me the following:

> *I was a biologist at Clear Lake when the Rathbun Hatchery was being built. I called Ken Formanek who worked in Information & Education back then. Ken remembers doing an inventory back in the late 60's of things at the Iowa State Fairgrounds and found two big boxes filled with Maynard Reece originals! They had sat there for years. They were simply framed with no matting at the time of discovery.*
>
> *Contact was made with Maynard Reece and he suggested using The Art Store for reframing and matting. A guy at the store had done work for Maynard. ... The originals were matted and framed in what Formanek says is archival condition sometime around 1970–72. They were placed on display in the interpretive area at Rathbun Hatchery and have remained there. Ken believes the folks doing the conservation work will find they are generally in very good condition save for exposure to light over the years.*
>
> *It's good this preservation work is being done. There is a better place for the originals, and prints will work just fine at the hatchery* (personal communication, December 19, 2013).

Over the next year, the original paintings will be sent to an art conservator to be treated and restored. After completion, we will create digital images, archive the originals, and create a new display for the State of Iowa Historical Museum and produce prints for continued display at the Rathbun Fish Hatchery. The new high-resolution digital images will allow us to create new prints in the future as needed and will allow us to use these images on the website, in publications, and on educational materials for the foreseeable future, all of which greatly enhance their utility to the Iowa DNR. Furthermore, by restoring and

preserving these irreplaceable pieces and archiving them at the State Historical Museum, they will be available to future generations to enjoy.

Thank you to the Iowa Chapter of AFS for assisting in this project.

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Maynard has artwork in the holdings of the National Museum of Wildlife Art
www.wildlifeart.org/collection/artists/artist-maynard-reece-449

Maynard Reece Gallery
www.maynardreecegallery.com/AboutUs.htm

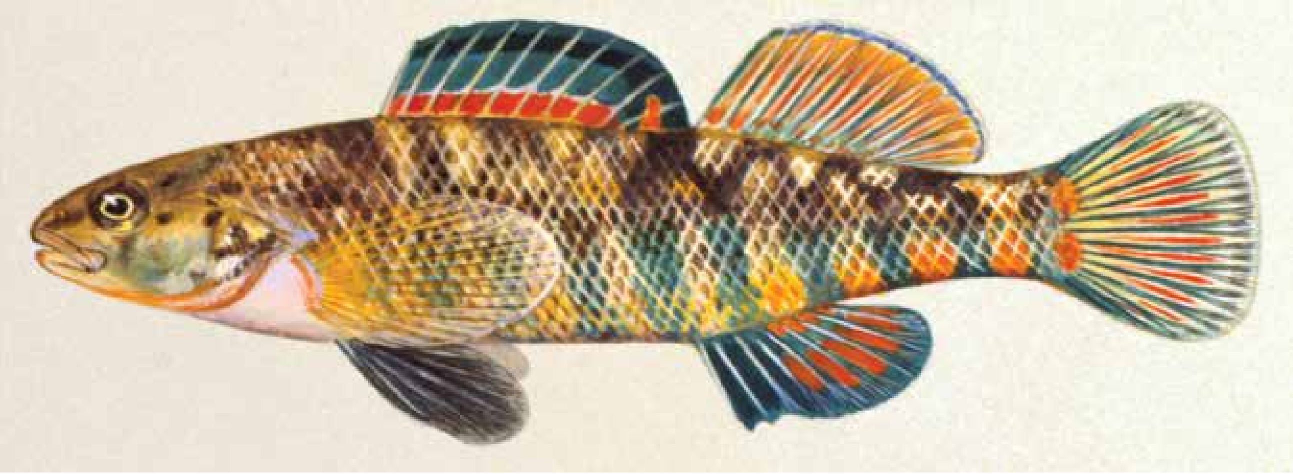
Wikipedia site
en.wikipedia.org/wiki/Maynard_Reece

Des Moines Register listing of famous Iowans
data.desmoinesregister.com/famous-iowans/maynard-reece

Outdoor Writers Association of America—Legends
owaa.org/owaa-legends/maynard-reece-artist-with-a-feather-touch

MAYNARD REECE HONORS

National Fish and Wildlife Foundation stamp, 1988
Ducks Unlimited Artist of the Year, 1973



Rainbow Darter *Etheostoma caeruleum*. Art credit: Maynard Reece.

1982 Iowa Trout stamp. Art credit: Maynard Reece.

Distinguished American Artist by *American Artist* magazine
Master Wildlife Artist, Leigh Yawkey Woodson Art Museum, International Birds in Art show, 1989
Commissioned to create the first Iowa Duck Stamp, 1972
Commissioned to create the first Missouri Turkey Stamp, 1983

MAYNARD REECE STAMP PRINTS

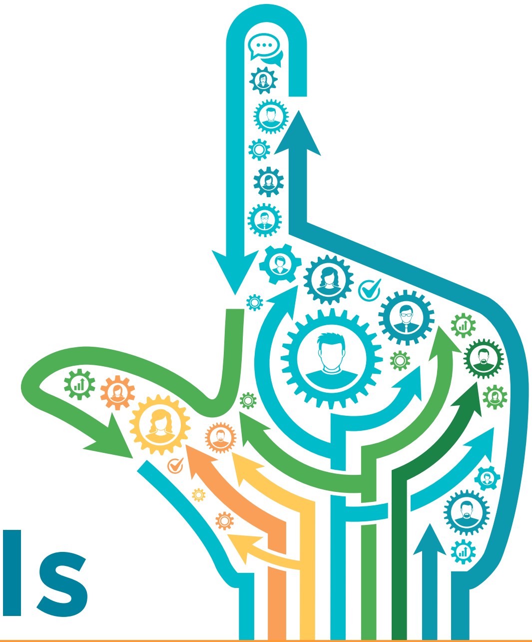
Federal Duck Stamp

1948-1949 Federal Duck Stamp Print—Bufflehead
1951-1952 Federal Duck Stamp Print—Gadwalls
1959-1960 Federal Duck Stamp Print—Labrador Retriever
1969-1970 Federal Duck Stamp Print—White-winged Scoters
1970-1971 Federal Duck Stamp Print—Cinnamon Teal

Stamp Prints

1972 Iowa Duck Stamp Print—Mallards
1977 Iowa Duck Stamp Print—Lesser Scaups
1981 Iowa Habitat Stamp Print—Bobwhites
1982 Iowa Trout Stamp—Rainbow Trout
1982 Arkansas Duck Stamp—Wood Duck
1982 Bass Research Foundation—Largemouth Bass
1983 Texas Duck Stamp Print—Wigeon
1983 Ruffed Grouse Society—Ruffed Grouse
1983 Missouri Turkey Stamp Print
1984 Chesapeake Bay—Canada Geese
1984 International Quail Foundation—Bobwhite Quail
1985 Ducks Unlimited—Mallards
1985 Arkansas Turkey Stamp Print
1988 National Fish & Wildlife—Mallards
1988 Arkansas Duck Stamp Print—Pintails
1989 Washington Duck Stamp Print—American Wigeon
1989 Iowa Ducks Unlimited Sponsor Print—Canada Geese
1992 Quail Unlimited Stamp—Bobwhite Quail
1993 Iowa Duck Stamp Print—Mallards
1997 Illinois Habitat Stamp Print—Ring-necked Pheasants
1998 Illinois Habitat Stamp Print—Doves
1998 Idaho Duck Stamp Print—Canada Geese
1999 Illinois Habitat Stamp Print—Turkeys
2000 Illinois Habitat Stamp Print—Whitetail Deer
2000 Quail Unlimited Dove Conservation Stamp Print—Doves
2013 Arkansas Duck Stamp—Mallards AFS

Aiming to Support Young Professionals



Submitted by Hilary Meyer
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In February 2014, the Fisheries Management Section (FMS) charged a committee to address the specific needs and issues facing young professionals in the fisheries field. The newly formed Young Professional Committee (YPC) was tasked with identifying potential bottlenecks in the recruitment and retention of young professional (YP) members to the American Fisheries Society (AFS). Even before the formal designation of the YPC, its members exchanged ideas and information via e-mail and conference calls and met during AFS annual meetings in 2013 and 2014. Invitations were extended to the Education Section and the Student Subsection to join the YPC effort, resulting in two representatives from the Education Section and one representative from the Student Subsection joining the committee. In 2014, the YPC drafted a list of goals and objectives. The goals of the YPC are to:

1. Prepare and support young fisheries professionals to remain active and engaged in AFS, and to bring resource expertise and leadership into their workplace.
2. Increase coordination/involvement between FMS and other AFS units to engage and support young professional membership in AFS.

Along with drafting goals and objectives, the YPC has been working on a project to update the FMS Hall of Excellence. We have been pairing young professionals with Hall of Excellence inductees to conduct video interviews to create an interactive version of the virtual Hall of Excellence (fms.fisheries.org/awards/hall-of-excellence/virtual-hall-of-excellence). In addition to the benefits of this project to the FMS Hall of Excellence, we are encouraging YPs to take advantage of these face-to-face meetings with some of the most influential people in the fisheries field as mentoring opportunities. To see an example of footage from these interviews, go to youtube/IKyBIO9dnFQ.

The YPC is also developing a survey of fisheries professionals (AFS members and non-members) in order to learn about their transition from student to young professional. The aim is to better understand why some fisheries professionals do not retain AFS membership after graduation and to more accurately describe the transition from student to professional. During the development of the survey, the committee identified multiple potential bottlenecks (temporary jobs, limited travel funding, etc.) that may be creating obstacles for participation in AFS. These bottlenecks may indicate that the current three year post-graduation period underrepresents the transition from student, to young professional, to professional. This time frame is rather short considering that YPs often accept temporary positions that are rarely an extension of their student research emphasis. Time is required to settle into the routine of new employment, identify questions relevant to assigned responsibilities, and compete for limited resources to develop relevant evaluation projects.

Hopefully, these efforts will begin to provide an understanding of how AFS units can better support young professional development. For example, the FMS has provided monetary support to the YPC for the Hall of Excellence project as well as offering free section membership to YPs starting in 2015.

If you would like to become involved or share your experience, please contact Quinton Phelps (Chair) at phelps@mdc.mo.gov and watch for more news in future issues of *Fisheries* magazine as well as on the FMS website. Feel free to visit our website (fms.fisheries.org) for the most current information and more details on membership bottlenecks, strategies, and objectives. AFS

Q&A: Black Bass Diversity: Multidisciplinary Science for Conservation

Michael D. Tringali, James M. Long, Timothy W. Birdsong, and Micheal S. Allen, editors. 2015.
American Fisheries Society, Symposium 82, Bethesda, Maryland.

To purchase *Black Bass Diversity: Multidisciplinary Science for Conservation*, visit fisheries.org/shop.

Why did you decide to write this book?

Habitat degradation and introductions of nonnative species threaten a number of endemic species and genetically unique forms of black bass with limited geographic ranges. In 2009, the National Fish and Wildlife Foundation (NFWF) initiated the development of a conservation program for these species, and scientists quickly realized that there was a lack of information about their biology, life history, ecology, behavior, and genetic diversity. The good news was that results from ongoing fisheries research projects were filling these data gaps, but much of this information had not yet been published. It was the perfect time to organize a symposium and publish a book to provide essential information to develop black bass conservation programs. This includes NFWF's Southeastern Native Black Bass Keystone Initiative that initially focused on conservation and research programs for Guadalupe Bass *Micropterus treculii*, Shoal Bass *M. cataractae*, and Redeye Bass *M. coosae*. There is also a growing interest in the conservation of black bass among stakeholders: anglers, conservationists, and river-keeper organizations. The Bass Anglers Sportsman Society promoted a Bass Slam in the July/August 2009 issue of *Bassmaster Magazine*, which broadened the appeal of all black bass species to bass anglers. As a result, we felt that there was an unfulfilled source of collective information not only for scientists but for anglers and conservationists as well.

Black bass conservation committee members on site visit to the Devils River, Texas (L-R: Tim Birdsong, Tim Churchill, Joe Slaughter, Mike Allen, Jim Long, Wes Porak, and Mike Tringali), June 2012. Photo credit: Megan Bean.

What will the reader learn from this book?

Readers will find a source of information on many of the rare black bass species compiled in one source. But more important, readers will find that black bass management is more than length-limit regulations and how a focus on these enigmatic species can lead to conservation of non-game species and whole ecosystems. The book contains 46 contributions that cover (1) the biology, ecology, and life history of black bass; (2) conservation genetics; (3) habitat restoration and management; and (4) fisheries management. There are also species profiles with range maps and illustrations by Joe Tomelleri.

What other fisheries book has inspired you in your career and why?

It's difficult not to point to the original *Black Bass Biology and Management* (1975) edited by Stroud and Clepper as a source of inspiration. It was published almost 40 years ago and is still a valuable reference. In fact, after writing the foreword for our upcoming book, we found a passage from that book on the role of stocking and genetics that is ominously prescient today.

What needed fisheries book do you feel hasn't been written yet?

A book on aquatic invasive species seems to be the most lacking. While there are books about some of the species themselves, there seems to be a lack of one related to the whole suite of issues related to invasive species from risk assessment to regulations and management.

What's next on your plate?

Many of us on the planning committee for the book will be involved with updating the business plan for the Southeastern Native Black Bass Keystone Initiative at NFWF. While we view the book as a great source of information, funding programs like that developed at NFWF help to translate that information into on-the-ground conservation.

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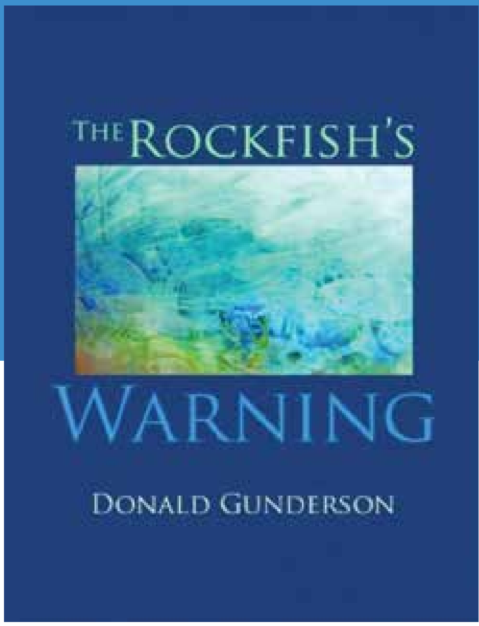

The Rockfish's Warning

Donald Gunderson. University Book Store Press. Seattle, WA. 2011. 211 pages. US$13.95 (paperback).

This unusual book addresses a diverse audience and defies categorization. Its gripping text is firmly stamped by the author's background in aquatic biology, making it particularly attractive to readers of *Fisheries*. However, the book is further characterized by an extensive interweaving of resource management, evolutionary biology, and history. Coupled with the passion of an evangelist and the authority of a scholar, these attributes support the broader attention of all responsible and concerned readers.

The title, based on the author's opening verse, accurately anticipates a message that is often disturbing but never dull. Using well-documented and vivid examples, humanity's conflicting dark and enlightened qualities underlie dynamic and ever-shifting effects from tropical and temperate marine ecosystems to the Wild West and its contemporary legacies. Ample evidence is presented that this duality is dominated by the darker component. Repeatedly, through ignorance and greed, short-term and narrow economic goals drive the destabilization of viable resources toward extinction rather than sustainability. The tragedy of Easter Island is extrapolated to global humanity, free-falling in a trajectory toward resource exhaustion and cultural collapse.

An increasingly visible voice of enlightenment guides the reader toward urgency rather than total despair to moderate this projected free fall. Sufficient text, including a major section on natural resource management, elevates the book from muckraking toward viable alternative action. With particular emphasis on sustainable ecosystems, the historic and destructive boom and bust management of marine fisheries is contrasted with, for instance, the more selective and limited harvest of Pacific Halibut *Hippoglossus stenolepis*. Ecosystem-oriented legislative mandates, such as the Endangered Species Act, shift economic responsibilities for sustainability and restoration of public resources from taxpayers toward exploiters. Nevertheless, the author warns that "… without constant public vigilance, environmental laws can be poorly enforced, ignored, or even overturned when they conflict with the goals of the powerful…"

Of two presented alternatives—continued free fall or a general reversal of depleting natural resources toward a sustainable soft landing—only the latter is acceptable. The final pages envision such an achievement. As a bottom-up process, primary requirements for a soft landing include a society-wide understanding, acceptance, and perpetual will for its implementation. Given the bleakness of free fall (and including its complacent acceptance), the soft landing's implementation is a mandate for action.

The book's spiritual closing warrants repeating:

> *In the world of the soft landing, all people share a common gratitude for the legacies they have been granted, many a Reverence for Life. They pursue happiness on their own terms, but live in harmony with the ecosystems that support them. They take no more renewable resources than they can find substitutes for, produce no more waste than their ecosystems can absorb. Their own use of the earth's resources is never allowed to compromise the prospects for future generations. It is a world of sacred landscapes.*

The Rockfish's Warning promises to be widely read as a document to guide such sustainability and as an admonition should this vision be ignored.

Fred Utter
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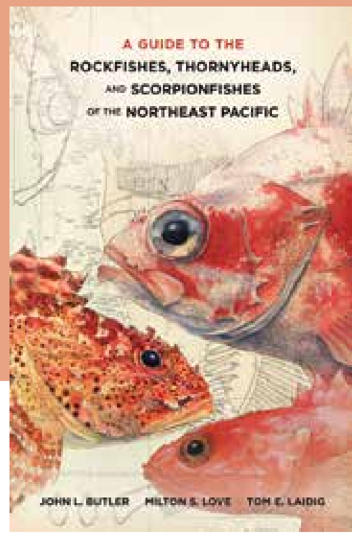
BOOK REVIEW

A Guide to the Rockfishes, Thornyheads, and Scorpionfishes of the Northeast Pacific



John L. Butler, Milton S. Love, and Tom E. Laidig. University of California Press, Berkeley, CA. 2012. 185 pages. US$29.95 (paperback).

This beautiful book has been long awaited by anyone attempting (or tempted) to identify rockfishes and their kin underwater. The high diversity and variable color among rockfishes in the eastern North Pacific is daunting, and the authors have succeeded in providing a succinct, casually written, but accurate guide to all species recorded in the region. The text is authoritative and informative. Although I have studied these fishes for nearly two decades, I learned a bit more about many of these species. It is also entertaining—watch for the delicious tidbits of humor scattered throughout in surprising places.

Species accounts begin on the left page and continue over two pages, wisely laid out to aid anyone picking up the book to quickly identify a live rockfish underwater. For all the common species, and many of the rarer ones, several photos show much of the known range in color variability in the species. For a few of the rarest species, only a photo of a freshly caught individual on deck is provided. Each account provides the scientific name and authority, official common name, maximum length in metric and English units, geographic range with notes on where the species is most common, depth ranges for adults and juveniles in metric and English units, habitat, descriptions of adults and juveniles, and extensive notes on similar species. A brief glossary of select terms follows the species accounts. An Appendix comprising small color plates of each species of *Sebastes* is provided. Finally, and happily for ichthyologists like me who, as the authors note, deal with dead fishes in hand, an Appendix with our "beloved" counts is also provided for each species.

My only complaint is about the ordering of the species. Apparently they are arranged according to their overall similarity with other species. However, this is nowhere stated, and only a brief Table of Contents (without a species list) is provided so that the reader is left to figure out the plan and then search for the species of interest among similar species. Of course, the reader can simply turn to the back of the book for the Index, but that seems a somewhat backwards approach. Appendix 1 is the "Comparison of similar species" providing a series of plates in the same order as they appear in the book. A better and clearer organization would have been to use this section early on in the introduction with appropriate explanatory text as a way to present the organization of the guide. One aside is that the Appendix would have been more accurately entitled "Comparison of similar species of *Sebastes,*" as none of the thornyheads, scorpionfishes, or the authors' "one other fish" are included.

A useful addition would have been a photo of a fresh specimen on deck for each species. Most people, professional and lay, are identifying and working with these fishes after they have been caught, when their colors are at once less vibrant and generally more uniform. Although admittedly less appealing than the brilliant underwater photos the authors have gathered, providing even a small deck photo for all species would have made the guide much more useful to many more scientific workers and fishermen.

I found a few minor issues. Many photos are too tightly cropped, in some cases cutting off part of the fish unintentionally (e.g., pages 35, 149, and others). For *Sebastes reedi*, the illustrated range includes Kodiak to the north, while the text gives Sitka as the most northerly record, a difference of over 1000 km. I also disagree with at least one of the identifications, highlighting a problem with books of this nature, unsupported by collected voucher specimens. For example, the "juvenile dusky" on p. 24 has a posterior slant to the anal fin, in contrast to the perpendicular anal fin of *S. variabilis*, and has the color of *S. proriger* (compare p. 35). However, the authors freely discuss this challenge, having widely solicited opinions on many of the photos, and recognize this limitation. Some photos appear to be taken of preserved specimens (juvenile *S. babcocki*, p. 108), perimortem specimens (many rarer species), or live fish in small aquaria (juvenile *S. nigrocinctus*, p. 122; *S. rastrelliger*, p. 128; *S. atrovirens*, p. 132). These should be labeled appropriately.

All in all, this book is a great advance in our study of rockfishes and is well deserving of a place in the submersible, on the bookshelf, or on the coffee table of anyone interested in the fishes found from Alaska to Baja California, be they fishermen, fisheries biologists, naturalists, or ichthyologists.

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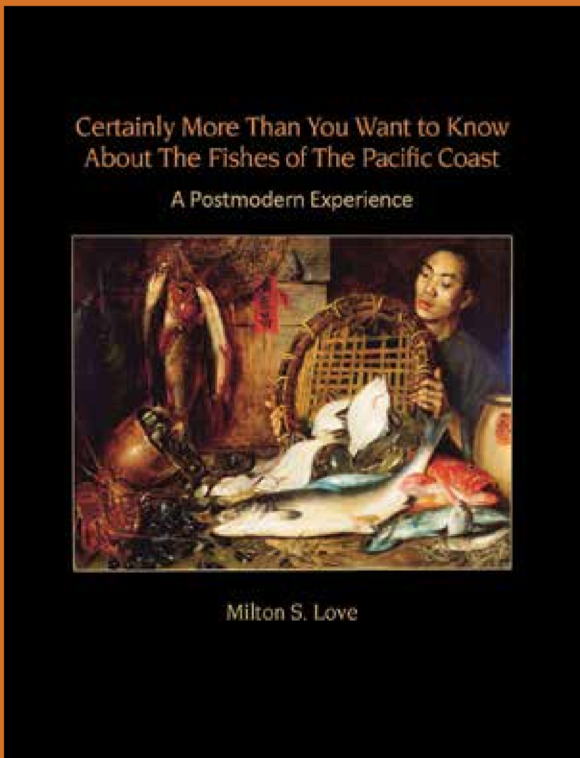
BOOK REVIEW



Certainly More Than You Want to Know About The Fishes of The Pacific Coast: A Postmodern Experience

Milton S. Love. Really Big Press. Santa Barbara, CA. 2011. 685 pages. US$29.95/CAD$29.95

Milton Love has produced a highly readable encyclopedia of Pacific Coast marine fishes that is packed with photographs, life history information, and anecdotes for just about any fish you can name. The life history information typically includes geographic range, maximum size, von Bertalanffy growth parameters, length–weight parameters, size and age at maturity, longevity, reproductive biology, diet, and predators. The anecdotes cover the history of the fishery for species of economic value and a wide range of (sometimes bizarre) facts that are often presented in a stream-of-consciousness style meant to entertain, amuse, and inform.

Some readers may be disappointed by the uneven manner in which source references are cited. Though Love has succeeded in maintaining a smooth flow throughout the book, the reader often has no way of knowing how the underlying information was obtained or of pursuing its reliability. Perhaps this was what postmodernism demanded. Nevertheless, the book reflects the quality, attention to detail, and accuracy that characterized Love et al.(2002)'s *The Rockfishes of the Northeast Pacific* and will appeal to naturalists, fishermen, and scientists from Mexico to Alaska.

Irreverent vignettes from the lives of our founding ichthyologists are interspersed with captivating photographs and fish-inspired art throughout the book, and these alone justify the modest ($29.95 on the Really Big Press website) price for this extensive (685-page) synthesis of information on Pacific Coast fishes. It is the perfect place to turn when somebody asks you how long a Grunt Sculpin *Rhamphocottus richardsonii* lives, how sharks have sex, what a Spiny Lumpsucker *Eumicrotremus orbis* eats, or what eats them. Put it on your coffee table and watch as visitors get drawn into it. Then when they leave, turn to it yourself whenever you have a few minutes and want to learn more about the amazing diversity of fishes that the Pacific Coast is blessed with.

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Love, M. S., M. Yoklavich, and L. K. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press, Berkeley.

AFS

Inaugural Inductees—Legends of Canadian Fisheries Science and Management

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Jack Imhof
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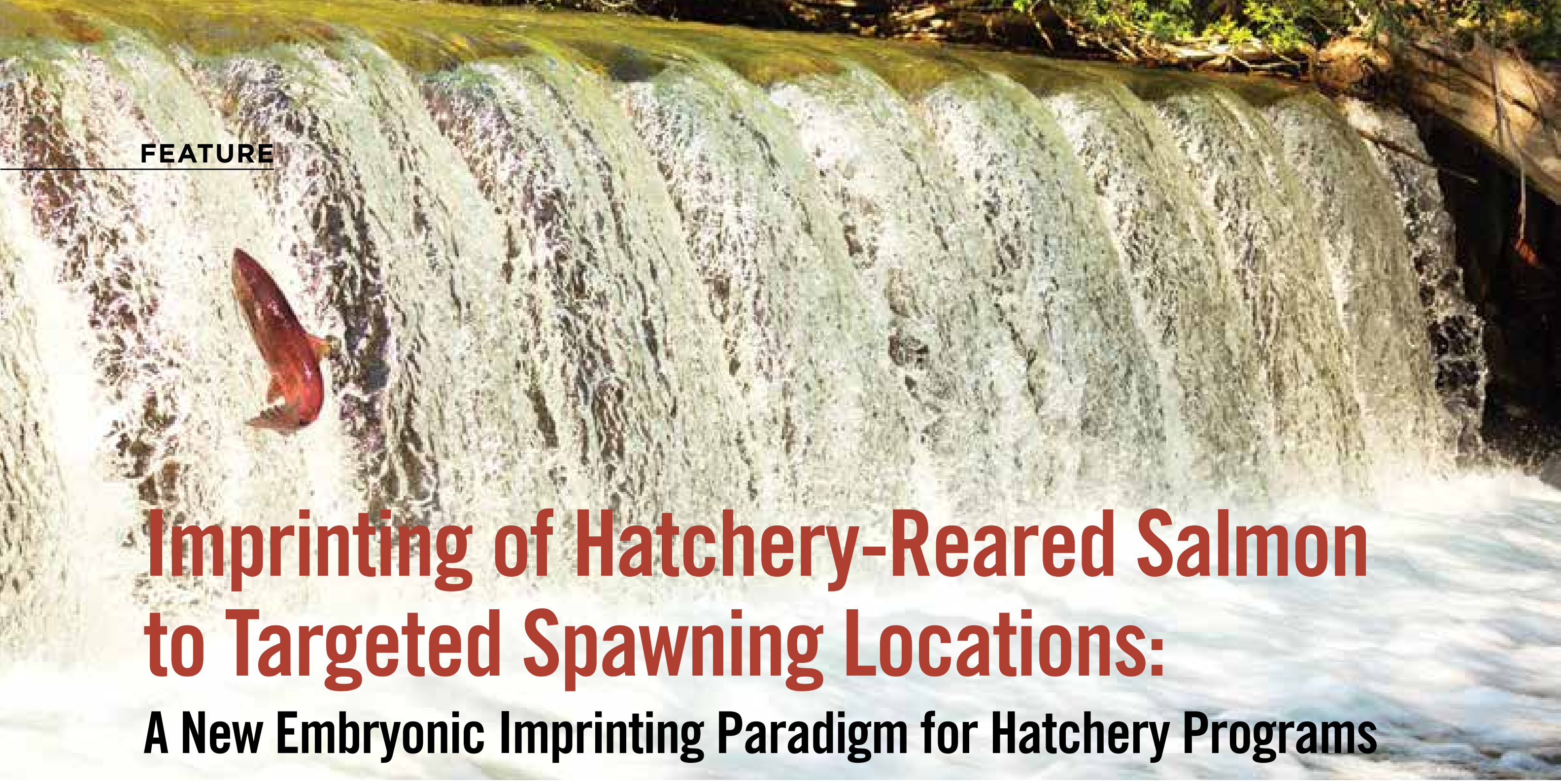
Canada has a long and illustrious history in fisheries science and management. Indeed, many scientific discoveries, assessment tools, and even contemporary management strategies can be attributed to Canadian fisheries professionals. The Canadian Aquatic Resources Section of the American Fisheries Society has launched a new recognition program called Legends of Canadian Fisheries Science and Management. The goal of the program is to recognize the accomplishments of fisheries professionals in Canada. Beyond the recognition to the individual, highlighting their accomplishments will ensure that the next generation of fisheries professionals remain connected to the past. "Legends" will typically have completed (i.e., be retired) or be near the end of their professional career. Legends can also be recognized posthumously. Our purpose is not to recognize achievements of early career scientists or singular accomplishments—it is truly to recognize legendary figures in Canadian fisheries science and management. There is no financial compensation associated with the award; however, those recognized will have their profiles added to a website maintained by the Canadian Aquatic Resources Section. For 2014, we received around 30 nominations for the inaugural competition and are pleased to recognize 15 remarkable legends—individuals that have made notable contributions to fisheries science and management in Canada and beyond. The nominations that were not successful will be carried forward for consideration in future years along with new nominations (an annual March 1st deadline). After the inaugural competition, we will induct up to five legends on an annual basis.

The 2014 inductees are as follows: Bev Scott (Deceased – University of Toronto [U of T]/Royal Ontario Museum [ROM]/ Department of Fisheries and Oceans [DFO]); Carl Walters (Retired – University of British Columbia [UBC]); Henry Regier (Retired – U of T); Casimir Lindsey (Retired – UBC); Zbigniew (Bob) Kabata (Deceased 2014 – DFO); Fred (F. E. J.) Fry (Deceased 1989 – U of T); Ed (E. J.) Crossman (Deceased 2003 – U of T/ROM); William Edwin (Bill) Ricker (Deceased 2001 – DFO); Joe Nelson (Deceased 2011 – University of Alberta); Ram Myers (Deceased 2007 – Dalhousie University); Wilfred Templeman (Deceased 1990 – DFO); Donald McAllister (Deceased 2001 – Canadian Museum of Nature); Archibald Gowanlock Huntsman (Deceased 1973 – U of T /DFO); Peter Larkin (Deceased 1996 – UBC); and Bill Hoar (Deceased 2006 – UBC). AFS

New AFS Director of Student and Professional Development: Beverly Pike

Many of you were able to meet Beverly Pike, our new Director of Student and Professional Development, in Québec. Pike brings over 13 years of e-learning experience to the American Fisheries Society (AFS) that includes both professional development and higher education. Previously, Pike was the Associate Director of Educational Initiatives at Gannett Healthcare Group, a healthcare multimedia company, in which she was responsible for high-profile online continuing education courses that served the nursing and allied health professions. Pike's background also includes online professional development in engineering and human resources. As a Professor of Communication Studies, Pike began designing and teaching online courses in 2003. As the new Director of Student and Professional Development, Pike will identify continuing education needs in the fisheries profession, establish and collaborate with public and private sector partnerships, and be responsible for the design and implementation of educational solutions that meet the learning and performance needs of the fisheries profession.

"I am very excited to be a part of AFS as well as the larger sphere of natural resource management and conservation," Pike says. "It is a dynamic time for natural resource management and conservation, and there are many opportunities to positively impact the fisheries profession, related professions, and the public. I look forward to working closely with AFS's leadership, committees, partners, and members to serve the educational needs of those involved in this amazing field as well as those of the public." AFS



Imprinting of Hatchery-Reared Salmon to Targeted Spawning Locations:

A New Embryonic Imprinting Paradigm for Hatchery Programs

Straying by hatchery-reared salmon is a major concern for conservation and recovery of many salmon populations. Fisheries managers have attempted to minimize negative ecological and genetic interactions between hatchery and wild fish by using parr-smolt acclimation facilities to ensure successful olfactory imprinting and homing fidelity. However, the effectiveness of offsite acclimation for returning adults to targeted locations has been mixed. Since laboratory and field studies indicate that the period of hatching and emergence from the natal gravel is a sensitive period for olfactory imprinting, we propose an alternative imprinting approach wherein salmon are exposed as embryos to targeted waters transferred to their rearing hatchery. To test the feasibility of this approach, we conducted a series of electrophysiological and behavioral experiments to determine whether water can be successfully transferred, stored, and treated for pathogens without jeopardizing its chemical integrity. Stream water could be frozen or stored for one week at 4° or 10° C without affecting the olfactory signature. Ultraviolet light treatment altered the responses of the olfactory epithelium to stream water; however, behavioral studies suggested that this treatment did not alter the attractiveness of this water. Finally, we describe several alternative approaches to embryonic imprinting using artificial odors.

Impronta en salmones cultivados para incidencia en sitios de desove: un nuevo paradigma embrionario de impronta en programas de cultivo

La fuga de salmones cultivados es un asunto considerable para la conservación y recuperación de muchas poblaciones naturales de salmón. Los manejadores de pesquerías han intentado minimizar las interacciones negativas de orden ecológico y genético entre los peces cultivados y los silvestres mediante el uso de instalaciones en las que se asegure una impronta olfatoria y una filopatría exitosas. Sin embargo, la efectividad de la aclimatación remota para que los adultos regresen a los sitios de desove, no ha sido contundente. En virtud de que los estudios de laboratorio y de campo indican que el periodo de cultivo y emergencia en el sitio de nacimiento es un lapso sensible para que se establezca la impronta olfatoria, en este trabajo se propone un enfoque alternativo de impronta en el que el salmón, siendo embrión, es expuesto a sitios seleccionados a los que se les traslada desde las áreas de cultivo. Con el fin de probar la efectividad de este enfoque, se realizaron una serie de experimentos electrofisiológicos y etológicos para determinar si el agua puede ser exitosamente transferida, almacenada y tratada contra patógenos sin comprometer su integridad química. El agua de río puede ser congelada y almacenada por una semana a 4º C o 10º C sin afectar su firma olfatoria. El tratamiento con rayos UV alteró las respuestas del epitelio olfatorio al agua de río; sin embargo, los estudios etológicos sugieren que este tratamiento no altera la atracción hacia este tipo de agua. Finalmente, se describen diversos enfoques alternativos a la impronta embrionaria utilizando olores artificiales.

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INTRODUCTION

Hundreds of millions of hatchery-reared salmon are released into waters of the United States annually (Rand et al. 2012). The hatchery programs that produce these fish are designed primarily to increase commercial, recreational, and tribal fishing opportunities, but increasingly they have become integral to recovery efforts designed to conserve native populations. The magnitude of these hatchery releases has raised concerns about potentially deleterious ecological and genetic interactions that may occur between wild and hatchery-reared salmon (Rand et al. 2012). One area of particular concern is that rearing and release practices used by many hatcheries may increase straying, the term for dispersal of individuals to nonnatal areas for reproduction, which can further increase undesirable interactions (Brenner et al. 2012). These concerns have led to calls for strict guidelines for hatchery programs to minimize straying to levels that will not impact native salmon populations. For example, a common guideline is that straying outside of the targeted area for a hatchery program should not exceed 5% or 10% (Paquet et al. 2011). Salmon are well known for their extraordinary homing migrations from the ocean to their natal stream for reproduction (Quinn 2005). Though some low level of dispersal from the natal site is normal in both wild and hatchery populations, some hatchery practices can dramatically increase the rate of straying (Pascual et al. 1995). Many hatchery rearing and release practices have been developed to increase survival and to optimize imprinting, but straying by hatchery fish remains a major concern for salmon managers. In particular, one of the most common approaches for imprinting fish to a specific location is to transfer and hold fish at sometimes expensive and logistically challenging acclimation facilities on the river or specific stream reaches that are targeted for homing. Here, we propose a new embryonic imprinting approach to improve successful imprinting and reduce straying by exposing embryonic salmon to waters collected from their targeted return location.

Homing is governed by olfactory discrimination of home-stream water, and exposure to the home stream during appropriate juvenile stages is critical for olfactory learning (imprinting) and successful completion of the adult homing migration (Dittman and Quinn 1996). Ensuring that juvenile salmon experience specific water sources during appropriate periods for imprinting can be a challenging problem for artificial production programs because logistical realities (e.g., access to ground water, ability to obtain construction permits, and financial cost) often require that salmon are incubated and reared at large centralized hatcheries that use water sources that are different than target waters. Furthermore, salmon are often transported between facilities and released off-site to supplement specific populations or fisheries. While most salmon will typically return as adults to their juvenile release site after transfer (Donaldson and Allen 1957), such transfers and off-site releases tend to increase the rate of straying from the targeted return site (Pascual et al. 1995; Hard and Heard 1999). To address this concern, many hatchery programs have developed specific acclimation and release facilities designed to optimize the imprinting process by allowing salmon to experience imprinting cues for an extended period prior to release during the parr-smolt transformation (PST), the developmental period characterized by endocrine, physiological, and behavioral changes that prepare salmon for life in the ocean (Hoar 1976).

PARR-SMOLT IMPRINTING AND ACCLIMATION

The PST acclimation strategy has been employed because the PST has been identified as a critical period for successful olfactory imprinting in both Pacific *Oncorhynchus* spp. (Hasler and Scholz 1983) and Atlantic *Salmo salar* (Morin et al. 1989) salmon. A long history of transport studies (Lister et al. 1981) and a series of experimental assessments of imprinting using artificial odors (Hasler and Scholz 1983; Morin et al. 1989; Dittman et al. 1996) have pointed to the PST as a sensitive period during which imprinting occurs. Subsequent laboratory studies have also demonstrated that the peripheral olfactory system is sensitized to imprinted odorants (Nevitt et al. 1994) and olfactory sensitivity increases during the PST (Morin and Doving 1992). Among the many endocrine changes that are associated with the PST is a distinct surge in the plasma levels of the hormone thyroxine (Dickhoff et al. 1978) that has been linked to successful olfactory imprinting (Hasler and Scholz 1983). This was demonstrated most clearly in experiments wherein Coho Salmon *O. kisutch* exposed to odors prior to the PST did not demonstrate long-term imprinting memories for these odors unless their thyroxine levels were also experimentally elevated (Hasler and Scholz 1983). Elevated thyroxine levels also stimulated proliferation of olfactory sensory neurons (Lema and Nevitt 2004) and have been linked to imprinting in other vertebrate species (Yamaguchi et al. 2012).

Though the PST is an important developmental period for imprinting, freshwater migratory patterns of wild juvenile salmon suggest that the process and timing of imprinting may be much more complex (Quinn 2005). The best example of this is Sockeye Salmon *O. nerka*, which typically spawn in streams flowing into lakes, and then, upon emergence from their natal sites, their offspring migrate to a nursery lake and rear 1–3 years before the PST and seaward migration. Upon returning from the ocean as adults, these fish spawn in their natal streams rather than the nursery lake they experienced during the PST. Complex and extensive migrations away from the natal site before PST are common for many salmon species (e.g., Daum and Flannery 2011), particularly in association with changing seasons, temperatures, flows, densities, and other ecological factors (Beckman et al. 2000), yet adults almost invariably return to their natal location to spawn. For example, Chinook Salmon *O. tshawytyscha* populations can migrate away from their natal site as either fry, parr, or smolts, and different populations have different proportions of migrants at different life stages (Healey 1991; Figure 1). These observations led us to hypothesize that the process of imprinting involves a complex interaction between developmentally regulated periods for imprinting, environmental stimuli (e.g., flow and temperature), and migration (Dittman and Quinn 1996). The diversity of juvenile migratory patterns coupled with extensive transport studies (reviewed in Lister et al. 1981) led Harden Jones (1968) and Brannon (1982) to propose a sequential imprinting hypothesis for salmon homing: salmon learn a series of olfactory waypoints, beginning at the natal site, as they migrate downstream to the ocean, and later retrace their path as returning adults using these waypoints to guide them (Figure 1). Under this scenario, returning salmon would be expected to return to their site of release and then, if available or detectable, seek an earlier imprinting signal until they reach their natal site (Figure 1).

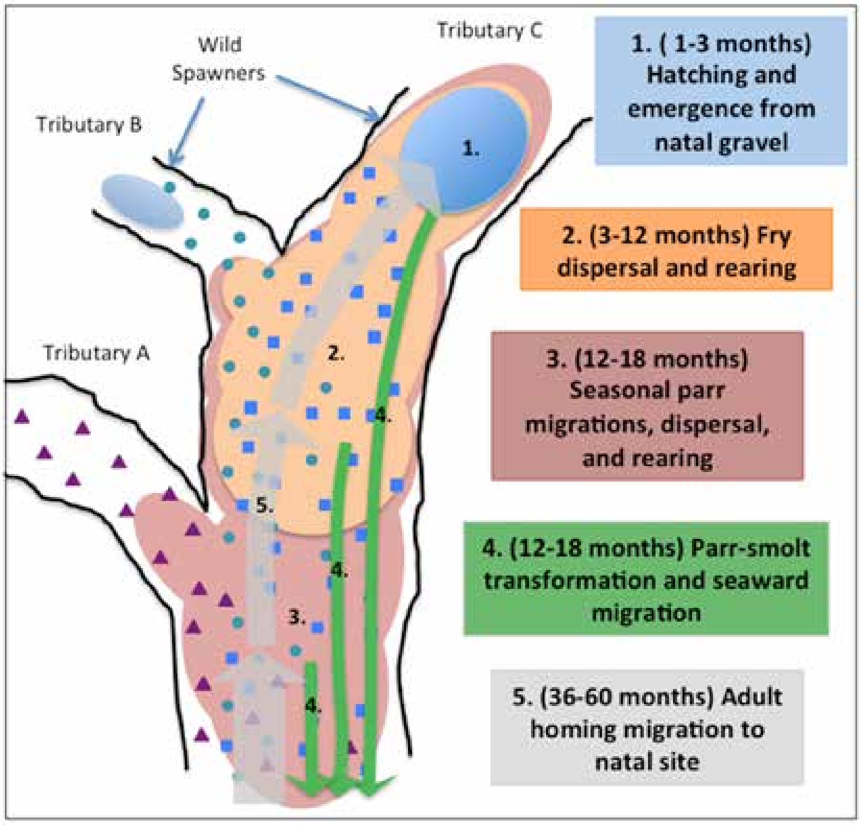

Figure 1. Example of sequential imprinting hypothesis for Chinook Salmon. In this scenario, spring Chinook Salmon learn a series of olfactory waypoints, beginning at hatching and emergence at the natal site and continuing as they disperse and make seasonal downstream migrations. Typically in their second spring, salmon initiate the parr-smolt transformation and migrate to the ocean. Later, adult salmon retrace their path using these waypoints to ultimately guide them back to their natal site.

The complexity of the imprinting process, combined with logistical realities of salmon artificial production programs, makes the management of salmon populations extremely challenging. The infrastructure required for large-scale artificial production (hatcheries, personnel, pumps, wells, etc.) essentially requires that fish are reared at large central facilities, whereas the population dynamics of these species require fine-scale outplants to ensure appropriate spatial and genetic segregation or integration of hatchery and wild fish, depending upon the program goals (Paquet et al. 2011). For segregated hatchery programs, designed to enhance harvest, the goal is typically to outplant salmon that will be captured in fisheries and also to ensure that those fish that avoid capture return to locations where broodstock can be collected or spawn when and where they will not interact with wild populations. On the other hand, the goal of integrated hatchery programs is to return hatchery-produced salmon to the same locations where wild fish spawn to enhance the wild population (Paquet et al. 2011). Finally, conservation hatchery programs are designed to reintroduce fish into historical or recovered habitat with the strategy of releasing fish that will imprint and ultimately return to these locations as adults.

All of these programs share a common dilemma: releasing salmon into the wild at earlier life stages provides a better opportunity for successful imprinting and homing, but releasing salmon at later life stages (i.e., larger sizes) provides a better opportunity for survival (Zabel and Achord 2004) and may reduce deleterious ecological interactions with other species (Pearsons and Temple 2010). These two competing concerns force managers of hatchery programs to weigh the likely tradeoffs of managing for natal homing versus managing for survival. In most cases, hatchery programs have adopted the smolt release strategy, taking advantage of the PST sensitive window for imprinting and the increased survival of larger fish reared through the PST in the hatchery. In many cases this strategy requires dedicated acclimation facilities, ranging from natural ponds to complete small-scale hatcheries, near the targeted site for returning adults (Figure 2). Most acclimation facilities are only operated during the spring prior to release, but some (e.g., Clarke et al. 2012) acclimate fish beginning in the winter prior to release. Parr-smolt acclimation and imprinting facilities have been developed or proposed as part of most hatchery supplementation programs in the Pacific Northwest, and hundreds of millions of dollars have been spent or proposed for construction, operation, and maintenance of these facilities.

For the most part, acclimation prior to release improves survival (e.g., Clarke et al. 2010, although see Kenaston et al. 2001), and most salmon tend to return to the vicinity of their release site (Garcia et al. 2004). However, offsite acclimation (i.e., moving parr from a central rearing hatchery to a smaller facility on a different stream prior to release) has not always been successful in providing adult returns to targeted locations (Dittman et al. 2010; Williamson et al. 2010). The major problem with acclimation sites is their locations relative to

Figure 2. Parr-smolt acclimation, imprinting, and release facilities. Parr-smolt acclimation is the primary tool for imprinting salmon to release locations. Acclimation sites range from (A) natural ponds and side channels, (B) net pens in lakes, and (C) temporary mobile acclimation tanks, (D) to complete small-scale hatcheries near the targeted site for returning adults (Photos A, B, C by T. Pearsons; Photo D by A. Dittman). Facilities costing hundreds of millions of dollars have been developed or proposed as part of most Pacific Northwest hatchery supplementation programs.

desired spawning locations for returning adults (Dittman et al. 2010; Williamson et al. 2010). If acclimation sites are located too close to initial rearing hatcheries, adults tend to return to hatchery locations rather than juvenile release sites (Lister et al. 1981; Dittman et al. 2010). Many acclimation sites were developed years ago before improvements in our understanding of the imprinting process and for different programmatic needs. Furthermore, siting of acclimation facilities is often driven by cost, site availability, environmental permitting, and physical access (e.g., roads and snow) issues rather than biology. This means that acclimation and release sites frequently must be located away from, and often downstream of, appropriate spawning habitat. It was hypothesized that salmon would return to their acclimation sites and then seek appropriate spawning habitat upstream, but in most cases studied, spawning was observed closer to acclimation sites rather than at locations farther upstream typically used by wild spawners (Dittman et al. 2010; Williamson et al. 2010). Thus, for parr-smolt acclimation and release strategies to successfully meet the needs of salmon management programs seeking to supplement spawning populations in specific tributaries or at even finer spatial scales, multiple expensive acclimation sites may be needed within each drainage system.

EMBRYONIC IMPRINTING

As an alternative, or complementary, approach to the use of parr-smolt acclimation facilities, we hypothesize that embryonic imprinting might be a useful management tool for achieving successful imprinting and homing fidelity to targeted spawning locations without moving fish from their central rearing hatchery prior to release. This new imprinting paradigm is based on the observation that while the PST is an important period for imprinting, salmon also imprint to their natal sites much earlier during development. In the wild, embryonic imprinting is evident from a range of studies that demonstrate very fine-scale homing to the natal site by multiple salmon species (Bentzen et al. 2001; Quinn et al. 2006). Furthermore, laboratory studies have demonstrated that embryonic salmon can distinguish and learn different natural waters based on chemosensory cues (Bodznick 1978), possibly even as early as prehatch eyed embryos (Courtenay 1989). This occurs during a sensitive window for imprinting during hatching and emergence from their natal gravel (Tilson et al. 1994; Figure 3). Using juvenile Sockeye Salmon, Tilson et al. (1994) demonstrated that these imprinting windows coincided with developmentally regulated surges in thyroid hormone levels as evidenced by strong attraction of maturing adult salmon to odors they were exposed

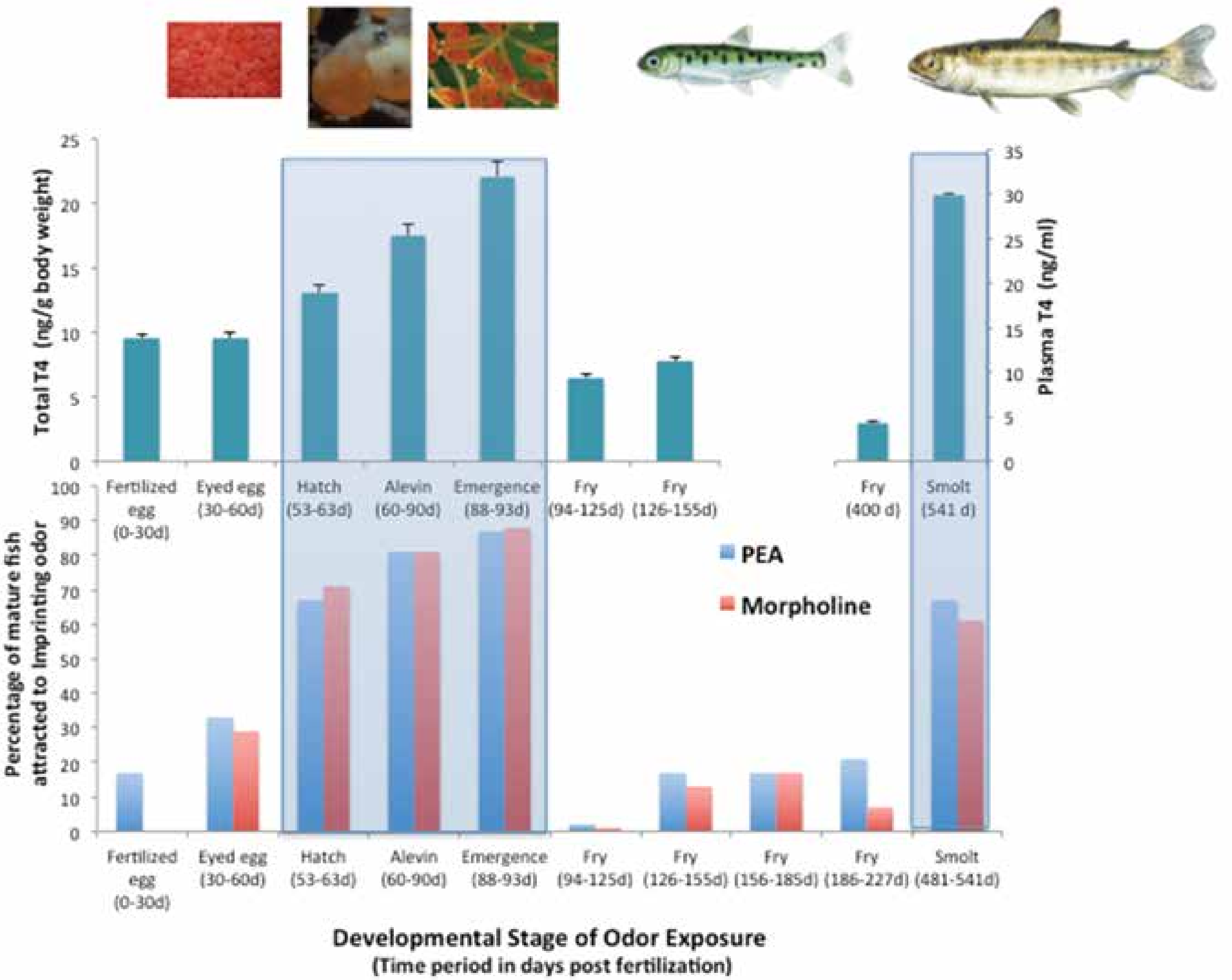

Figure 3. Salmon demonstrate a sensitive window for imprinting during hatching and emergence from their natal gravel in addition to a sensitive period for imprinting during PST (Tilson et al. 1994). Kokanee (lacustrine Sockeye Salmon), exposed to the artificial odorants, morpholine or phenylethyl alcohol, for short periods at hatching, as alevins, at emergence, and during PST showed successful imprinting as evidenced by attraction of these fish to these odorants as maturing adults (bottom panel). These sensitive windows for imprinting corresponded with surges in thyroxine (upper panel), which is associated with successful imprinting. Adapted from Tilson et al. (1994).

to at hatching and emergence (Figure 3). As suggested by the sequential imprinting hypothesis, it appears that wild adult salmon terminate their spawning migration upon reaching the area associated with olfactory cues learned in their natal redd. Therefore, we hypothesize that hatchery-reared salmon returning as adults will seek their earliest detectable imprinted olfactory waypoint as the appropriate location to terminate their spawning migration. Furthermore, if salmon are exposed as embryos to water derived from a targeted location upstream of their release site, they will, as adults, migrate past the release site and spawn at the targeted location.

We suggest that an alternative embryonic imprinting protocol may be useful for many hatchery programs. Using this protocol, hatchery salmon embryos would be exposed to natural waters from locations that managers want them to return to as adults (Figure 4). Rather than transport juvenile salmon from a central hatchery to desired spawning locations, we propose that water from these locations be collected and transported to a central hatchery for use during incubation and early rearing (Figure 4B). At these developmental stages, salmon embryos require relatively small volumes of water for incubation, so large numbers of embryos could be maintained in several small independent single-pass or recirculating systems within the hatchery. Upon emergence and ponding, salmon would be reared under normal hatchery protocols until release. Depending on the goals of the program and availability of parr-smolt acclimation facilities, juveniles would be directly released at locations downstream from the embryonic exposure sites or, ideally, acclimated at existing facilities downstream from the embryo water-exposure sites (Figure 4B). Fish from different upstream embryo-rearing sites could all be acclimated and released from a common site. We predict that returning adults would follow the sequence of odors they experienced as migrating juveniles to home to their release site. At that point, they would continue to migrate upstream to the source of the water they were exposed to as emergent embryos, where they would ultimately spawn (Figure 4C). We designed this protocol to facilitate reestablishment of sustainable natural populations of Pacific salmon in the Columbia River without the need for expensive, potentially environmentally harmful, and logistically challenging acclimation facilities, but we believe that this approach could be effective for all salmon species and locations.

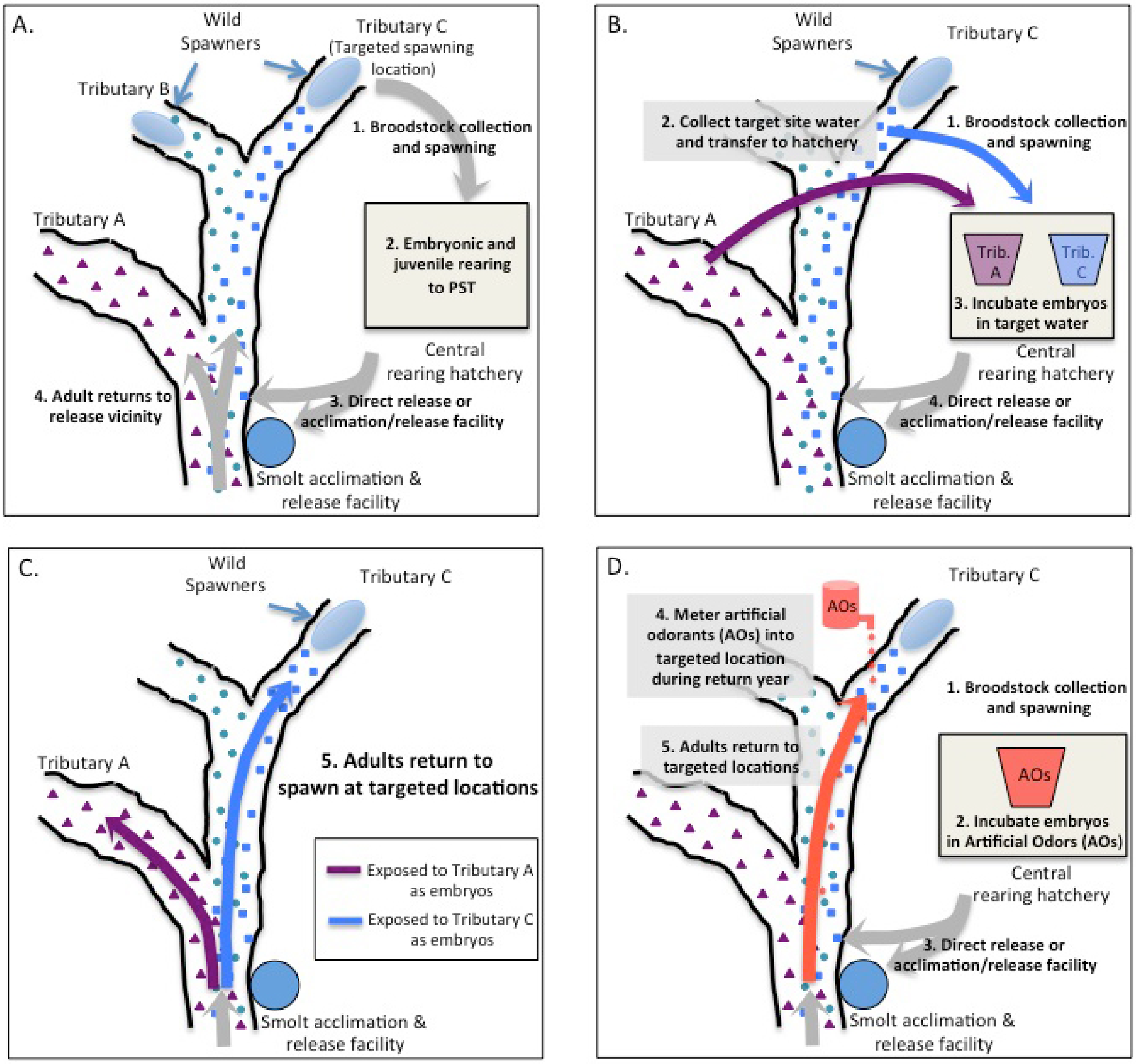

Figure 4. Schematic showing how embryonic imprinting could be applied to a supplementation hatchery program. (A) In a typical integrated hatchery program, wild adults are collected and spawned artificially, reared through the PST at a central hatchery, and then acclimated and released from dedicated acclimation sites. Upon return, adults often return to the vicinity of the release site rather than spawning at a targeted location upstream. (B) Using embryonic imprinting, fertilized embryos are exposed to stream waters collected and transported from targeted spawning sites. In this hypothetical case, water from Tributary A, which no longer has a spawning population, is used to imprint embryos and then to lure returning adults to Tributary A to help recolonize it. Water from Tributary C, which has a small wild spawning population, is used to imprint embryos and then lure returning adults to Tributary C to rehabilitate the wild spawning population. After embryo exposure, fish would be reared under normal protocols through the PST at the central hatchery and then acclimated and released directly or from dedicated acclimation sites. (C) We hypothesize that returning adults would follow the sequence of odors they learned as seaward migrating juveniles until they return to their release site. At that point, fish would seek an earlier imprinting cue, in this case the upstream water source (Tributary A or C) they learned as emergent embryos, and ultimately spawn in the vicinity of this "earliest" imprinting cue. (D) Under an alternative scenario, embryos could also be imprinted to artificial odors chosen by program managers. After normal rearing and release procedures, returning adults could be lured to targeted spawning sites they have never experienced by metering these artificial odorants into waters at the site.

PRACTICAL ISSUES

For embryonic imprinting to be useful and effective, several practical concerns must be addressed before widespread application. First, it is critical that water be collected and maintained in a manner that retains its odor qualities. Though the chemical nature of the odorant profile used by salmon to discern their natal stream is not known, it is hypothesized that these odors are a complex mixture of inorganic and organic chemicals from soil, plants, and aquatic organisms (Hasler and Scholz 1983). Recent work has demonstrated that different combinations of amino acids present in natural stream waters act as chemoattractants for homing salmon, and these compounds may represent part of the chemical signature salmon use to discriminate their homestream water (Shoji et al. 2003). Because organic compounds can be rapidly removed or altered by microbial consumers, care must be taken to ensure that the odor qualities of transported and stored water are retained during embryonic imprinting.

To explore this question, we collected water from a proposed spring Chinook Salmon acclimation site on the White River, Washington, a tributary of the Wenatchee River in the Columbia River Watershed. To test odor stability under different storage regimes, we used an electro-olfactogram (EOG) technique that measures the olfactory responses of the salmon's olfactory epithelium (Baldwin and Scholz 2005). Specifically, we used a technique termed "cross-adaptation" (Quinn and Hara 1986), wherein the epithelium is continuously exposed to the odors of freshly collected White River water (ambient temperature ~1°C) until the olfactory epithelium adapts and no longer responds to those odors. We then applied stored White River water. If storage alters the chemical nature of the water, then the olfactory epithelium will respond to these different chemicals and a response will be detected. A reciprocal test with each odor pair was also conducted. Using this technique, we found that White River water collected in January could be held for 7 days at either 4°C or 10°C or frozen (−20°C) for 7 days and thawed without altering the olfactory signature (Figure 5). This suggests that under the proper conditions, water can be collected, transferred, and stored for use in embryonic imprinting. However, more research needs to be conducted on different water sources, water collection and storage protocols, and water replacement procedures during imprinting. We also examined effects of using reconstituted White River water samples that had been freeze dried. For freeze drying, a known volume of water was frozen on dry ice–methanol and then lyophilized under vacuum until all water was removed. The freeze-dried residue was then reconstituted in deionized water to the same volume as the original water sample. The reconstituted water elicited a response from olfactory epithelium that had been adapted to White River water, so this storage method did alter odor qualities of the original water sample (Figure 5). Further study of this method may be warranted to determine whether olfactory cues from the original water source can be preserved.

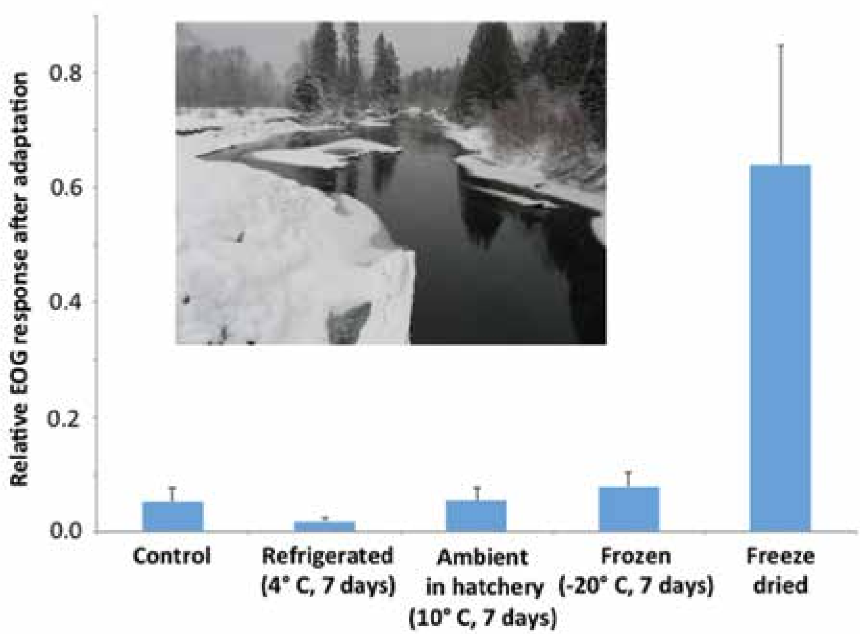

Figure 5. Cross-adaptation EOG studies to assess effects of storage on odor quality of stream water. Using a cross-adaptation technique, we found that natural stream water could be held for 7 days at 4°C or 10°C or frozen (−20°C) for 7 days and thawed without altering the olfactory signature of the water. However, freeze drying (water volume was measured, frozen on dry ice–methanol, and then lyophilized under vacuum until all water was removed) and reconstituting in an equal volume of deionized water did alter the odor qualities. Methods: Water was collected in January from the site of a proposed spring Chinook Salmon acclimation site on the White River, Washington, a tributary of the Wenatchee River in the Columbia River system (inset). To test the stability of water under different storage regimes, we utilized a technique termed cross-adaptation, wherein the olfactory epithelium of juvenile Coho Salmon was continuously exposed to the odors of fresh White River water until the olfactory epithelium adapted and no longer responded to those odors. We then applied a second water source. If the second water (e.g., stored White River water) had the same chemical constituents as fresh White River water, no response was elicited. If holding water altered the chemical nature of the water, the olfactory epithelium would respond to these different chemicals and a response would be detected. We also performed the reciprocal experiment with each odor pair. Data shown are EOG responses to each water source after adaptation to control White River water. Data are presented as responses relative to the response to a 10^{-4} M L-serine control (mean ± SEM; *N* = 4–6 fish per odor pair).

Additionally, because transferring natural stream water into a central hatchery for embryo imprinting has the potential to introduce pathogens, we were also interested in assessing whether treating the water to kill pathogens altered the water's olfactory signature. Embryonic salmon are often initially reared in pathogen-free well water, but where stream water is used, it is typically treated with ultraviolet (UV) light or ozone to kill pathogens. In many cases, transferring natural stream water into a hatchery for embryonic imprinting would be prohibited unless that water was treated to remove pathogens. This could alter the water's chemical composition and, therefore, the olfactory signature. To address this question, we again utilized the cross-adaptation technique using fresh White River water that was either treated with UV light to remove pathogens or left untreated. Interestingly, UV treatment apparently altered the chemical nature of White River water because UV-treated water elicited a different olfactory response than untreated water (Figure 6A). However, we wondered whether the overall odor qualities of the water were conserved enough to provide salmon with the chemical cues necessary to still allow them to distinguish this as White River water. To determine whether salmon could still recognize UV-treated water as equivalent to untreated river water, we conducted behavioral experiments on emergent fry, which tend to be attracted to water in which they were incubated (Bodznick 1978). For these experiments, we were unable to rear embryos in White River water, so we conducted a separate experiment using steelhead *O. mykiss* embryos incubated in Carnes Creek water at the Oregon Hatchery Research Center near Alsea, Oregon, and then tested fish for attraction to different waters at emergence. Emergent fry demonstrated a strong attraction to Carnes Creek water when given a choice of Carnes Creek water vs. well water in a two-choice maze. To assess the effect of UV treatment on the perception of Carnes Creek odor qualities, we tested whether emergent fry would choose untreated Carnes Creek water

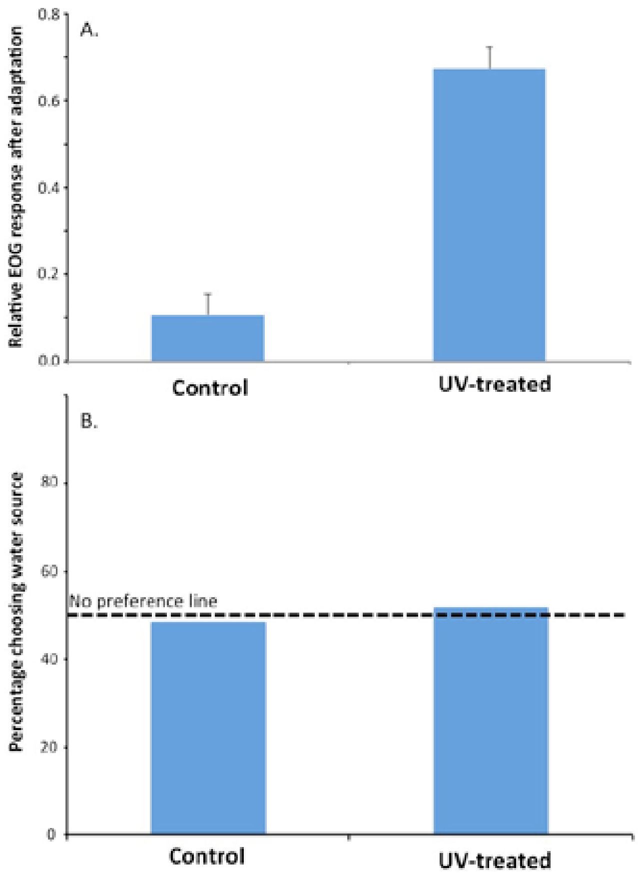

Figure 6. Effects of UV treatment on stream water odor qualities. (A) Cross-adaptation EOG analysis indicated that UV treatment may have altered the chemical nature of White River water. (B) We then tested whether chemical changes affected how salmon perceive UV-treated stream water relative to natural water (i.e., do they distinguish these waters behaviorally?). Recently emerged steelhead demonstrated no preference for untreated water vs. UV-treated water. Methods: (A) White River water was collected in January and either treated with UV light or maintained untreated at 4°C. The cross-adaptation technique described in Figure 5 was used to examine whether White River water was perceived differently by the salmon olfactory epithelium after UV treatment. Data shown are EOG responses to each water source after adaptation to control White River water. Data are presented as responses relative to the response to a 10^{-4} M L-serine control (mean ± SEM; N = 4 fish per odor pair). (B) Behavioral assessments were conducted at the Oregon Hatchery Research Center using recently emerged steelhead that had been incubated in Carnes Creek water. For these experiments, we tested whether emergent fish chose untreated Carnes Creek water over UV-treated Carnes Creek water in a two-choice maze. Data represent the responses of 200 fish tested in 20 trials (10 fish/trial).

over UV-treated Carnes Creek water in a two-choice maze. We predicted that more fish would choose the untreated arm of the maze, if UV treatment altered the attractive qualities of the water. However, we observed no difference in attraction to treated and untreated water (Figure 6B). Though these results do not show that UV treatment did not alter the odor qualities that allow fish to distinguish Carnes Creek water, they suggest that any changes to treated water that occurred did not influence its attractiveness. Further studies of the effects of UV treatment and other sterilization techniques on odor qualities are needed before embryonic imprinting is accepted for use as a salmon rehabilitation or enhancement tool.

ARTIFICIAL ODORS

In some circumstances, concerns about disease, water stability, water volume requirements, and other logistical challenges may make transporting stream water to a central hatchery for embryonic imprinting impractical. However, this does not preclude the use of embryonic imprinting as a management tool. One alternative that has been proposed is the use of artificial imprinting odors to lure returning adult salmon to desired locations. Much of our understanding about olfactory imprinting comes from a series of groundbreaking experiments by Arthur Hasler and his colleagues in the 1960–1970s, in which they exposed juvenile salmon to the artificial odors morpholine and phenylethyl alcohol during the PST and then lured these salmon years later as returning adults into unfamiliar streams scented with these chemicals (reviewed in Hasler and Scholz 1983). Based on these studies, it has been suggested that artificial odorants could be used by salmon managers to manipulate migratory patterns and promote increased homing fidelity (Hasler and Scholz 1983). Initial studies indicated that adding artificial odorants to hatchery outlet water had little effect on homing fidelity (e.g., Rehnberg et al. 1985). However, combining artificial odorants with embryonic imprinting may provide a useful tool for integrated hatchery and supplementation programs to direct salmon to specific tributaries or reaches for spawning. Under this scenario, salmon would be exposed to artificial odorants in the central rearing hatchery using the same embryonic exposure system described earlier. We hypothesize that salmon will imprint to these artificial odorants and use them during the final stages of their adult homing migration. Therefore, fish imprinted to artificial odorants and released at a downstream location or acclimation site could be lured to an upstream site they had never experienced by metering the artificial imprinted odorant(s) into the river at the target site (Figure 4D).

One obstacle to utilizing artificial odorants is the lack of safe, inexpensive, and effective odorants for these studies. Early imprinting studies successfully used morpholine and phenylethyl alcohol; however, a more stringent regulatory environment may make these chemicals inappropriate for large-volume releases into natural waters. To be effective as a management tool for homing manipulation, artificial odorants ideally will (1) be safe for release into natural waters, (2) not impact nontarget taxa, (3) be inexpensive and readily available, (4) be stable for storage and after release into natural waters, (5) be detected by the salmon olfactory epithelium at relatively low concentrations, (6) not elicit innate behavioral (attraction or avoidance) or physiological (e.g., endocrine) responses, (7) elicit a learned behavioral response by juvenile salmon, and (8) allow imprinting of juvenile salmon and prove to be an effective cue for adult homing. Further research to identify and test appropriate chemicals will be required before this approach can be utilized.

Finally, another alternative approach to transporting water from a targeted homing location to the central hatchery would be to identify the chemical signature of stream water present at the targeted location and artificially recreate it for use in embryonic imprinting at the hatchery. As indicated earlier, Hasler and Scholz (1983) hypothesized that the odors allowing salmon to discriminate between waters consist of complex mixtures of inorganic chemicals, organic chemicals from soil and plants, and aquatic organisms. Ueda (2012) proposed that the primary chemical cues utilized by homing salmon are amino acids present in natural stream waters, and Shoji et al. (2003) demonstrated that amino acids present in natural stream waters can act as chemoattractants for homing salmon. Therefore, by exposing embryos to an artificial solution of amino acids that matches the amino acid profile present in the targeted water, it may be possible to imprint hatchery fish to natural waters they have never experienced. Assuming the amino acid profile is sufficient as a homing cue, the natural amino acid signal present in the stream waters at the target location may attract homing adults to this location for spawning.

CONCLUSION

Whether managers use transported natural water, artificial odorants, or artificial natural waters, embryonic imprinting may provide an important new management tool for reducing negative interactions between hatchery and wild salmon populations, facilitating recovery of endangered populations and recolonization of recovered habitat, and increasing the homing precision of hatchery-reared fish. Furthermore, embryonic imprinting may significantly reduce costs associated with building and operating new acclimation sites, reduce mortality risks for cultured fish in harsh remote locations by keeping them in safe centralized locations longer, and lessen environmental degradation associated with construction and operation of acclimation facilities in targeted spawning areas. Each hatchery program is unique in terms of its program goals, infrastructure and logistic realities, and geographic complexities, so the use of embryonic imprinting and the specific application of these tools must be developed on a case-by-case basis. Embryonic imprinting is already being employed as part of a kokanee recovery program in Lake Sammamish Washington (Lake Sammamish Kokanee Work Group 2012) and could also be appropriate for a number of conservation and supplementation hatchery programs in the Northwest. The principles underlying this approach are well founded in our understanding of salmon biology and life history strategy, but full-scale tests of this approach within existing hatchery programs are required to confirm the utility of embryonic imprinting.

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FEATURE

A Comprehensive Approach for Habitat Restoration in the Columbia Basin

The Columbia Basin once supported a diversity of native fishes and large runs of anadromous salmonids that sustained substantial fisheries and cultural values. Extensive land conversion, watershed disruptions, and subsequent fishery declines have led to one of the most ambitious restoration programs in the world. Progress has been made, but restoration is expensive (exceeding US$300M/year), and it remains unclear whether habitat actions, in particular, can be successful. A comprehensive approach is needed to guide cost-effective habitat restoration. Four elements that must be addressed simultaneously are (1) a scientific foundation from landscape ecology and the concept of resilience, (2) broad public support, (3) governance for collaboration and integration, and (4) a capacity for learning and adaptation. Realizing these in the Columbia Basin will require actions to rebalance restoration goals to include diversity, strengthen linkages between science and management, increase public engagement, work across traditional ecological and social boundaries, and learn from experience.

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Un enfoque integral para restauración de hábitats en la cuenca de Columbia

La cuenca Columbia alguna vez albergó una gran diversidad de peces nativos y grandes corridas de salmones anádromos que sostuvieron importantes pesquerías y valores culturales. La conversión extensiva de la tierra, la interrupción de cuencas hidrológicas y la subsecuente disminución de las pesquerías han puesto en marcha uno de los programas más ambiciosos de restauración a nivel mundial. Se ha progresado, sin embargo la restauración ecológica es costosa (más de 300 millones de dólares al año) y aún no queda claro si, en lo particular, las acciones en pro del cuidado de los hábitats han sido exitosas. Se requiere un enfoque integral que sirva de guía para llevar a cabo una restauración de hábitats eficiente en términos de costos. Para ello es indispensable abordar de manera simultánea cuatro aspectos: 1) los fundamentos científicos de la ecología paisajística y el concepto de resiliencia; 2) apoyo público amplio; 3) gobernanza para la colaboración e integración; y 4) adaptabilidad y capacidad de aprendizaje. Lograr esto en la cuenca de Columbia demanda de acciones que tiendan a un balance en los objetivos de la restauración incluyendo la diversidad, el fortalecimiento de los lazos entre la ciencia y el manejo, un mayor compromiso social, trabajo a través de las fronteras de la ecología y la sociedad y el aprendizaje derivado de la experiencia.

INTRODUCTION

The native fish community in the Columbia Basin evolved in a landscape as diverse as any major river system in the world. That landscape supported more than 80 native species, including six anadromous salmonids *Oncorhynchus* spp. and a variety of other migratory and resident fishes. Although total species diversity was not remarkable for a large river basin, intraspecific diversity was, particularly for salmonids (Thurow et al. 1997). Moreover, annual adult returns of all anadromous salmon and steelhead *O. mykiss* were estimated to have exceeded 7.5 million before Euro-American development (Figure 1). Those fish populations have been dramatically altered through land conversion, hydropower development, water extraction, grazing, mining, logging, and road construction (Independent Science Advisory Board [ISAB] 2011b; Figure 2); proliferation of nonnative species and toxic chemicals; and a shift from natural to extensive artificial production of native (and nonnative) fishes (ISAB 2011a; Naiman et al. 2012). Remnant populations are fewer, smaller, less connected, and more restricted in spatial extent, and there is less diversity within and among populations than in the past (Thurow et al. 1997; Shepard et al. 2005; ISAB 2011b). McClure et al. (2003) concluded that 84% of remaining salmon and steelhead populations in the basin were not viable. Many populations will become increasingly vulnerable as environmental disruptions continue (Naiman et al. 2012; Naiman 2013).

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Northwest Power Act of 1980) created the Northwest Power and Conservation Council (NPCC) to protect, mitigate, and enhance fish and wildlife and their habitats affected by hydroelectric development. The program now guides a basin-wide fish restoration effort. In recent years, more than US$300M has been spent annually for research, monitoring, and evaluation; hatchery support of fisheries and failing populations; control of predators; and acquisition and restoration of habitat (Naiman et al. 2012). Although actions are diverse, the focus is on freshwater and estuarine habitat to support naturally productive populations (NPCC 2009). Habitat restoration throughout the basin is also seen as compensation for effects of the hydropower system and a key to formal recovery of federally listed wild salmon and steelhead. More than 13,000 habitat projects have been implemented since 1980 (NOAA 2015), representing about 40% of recent annual expenditures for restoration.

Despite the investment, many if not most native salmonid populations remain depressed (U.S. Fish and Wildlife Service 2008; Ford 2011). There is still little empirical evidence to show that tributary habitat actions have led to measurable improvements in abundance or survival of fish populations (Marmorek et al. 2004; Paulsen and Fisher 2005; ISAB 2013a; Figure 2). Some actions can certainly improve the quality and capacity of individual habitats (e.g., Bonneville Power Administration, Bureau of Reclamation 2013) and even the reexpression of life history diversity (Jones et al. 2014). But in the Columbia Basin, net habitat losses have been substantial, existing efforts are often piecemeal and limited in extent (Independent Scientific Review Panel [ISRP] 2013; Wiley et al. 2013), and environmental disruptions continue (ISAB 2011a, 2011b; Naiman et al. 2012). It simply is not clear that habitat restoration as currently practiced can be effective enough to be successful.

In this article, we outline a more comprehensive approach to habitat restoration drawing directly from a previous review of relevant science and management experience both in and outside the Columbia Basin (ISAB 2011b). In ISAB (2011b), we argued for a "landscape approach" not because we saw some critical scale for future work but because we saw landscape ecology and integration with the allied biophysical and social sciences as critical to success. We describe four elements that, taken together, comprise our view of comprehensive habitat restoration: (1) a scientific foundation in landscape ecology and the concept of resilience; (2) broad public support; (3) governance supporting collaboration and integration; and (4) a capacity for learning and adaptation. Although many habitat programs in the Columbia Basin have embraced several of the general concepts, we found no effort successful in all elements of a comprehensive approach. We identify five actions that are needed for progress in the Columbia Basin and conclude with suggestions for moving beyond the status quo. More detailed recommendations, a summary of case histories, examples, and other resources can be found in ISAB (2011b).

ELEMENTS OF A COMPREHENSIVE APPROACH

Landscape Ecology and Resilience

Landscape ecology and the conditions underpinning resilience provide the perspective required for comprehensive restoration. Landscape ecology emphasizes the importance of patterns in ecological elements and the physical, biological, and ecological processes that create and maintain those patterns (Turner et al. 2001; Hobbs et al. 2014). Few populations, for example, can persist in isolation and generally must be buffered from environmental variation and disturbances and supported by flows of energy, food, and genes, or other organisms from other places (Bisson et al. 2009; Wipfli and Baxter 2010; Anderson et al. 2014). Although landscapes have no fixed size or scale, they generally encompass areas larger than the local habitat units commonly considered in traditional restoration. Most fishes have adapted to a diverse set of habitats dispersed across encompassing landscapes or "riverscapes" (Fausch et al. 2002; Jones et al. 2014). For instance, salmon use interconnected habitats as they migrate from mountain tributaries to mainstem rivers, estuaries, into oceans, and back. Ultimately, they depend on the suitability of individual habitats as well as the size, juxtaposition, and connections among habitats required for complete life cycles, diverse life histories, and functioning metapopulations.

Resilience is the capacity to absorb and adapt to disturbance or change while maintaining essential functions (Walker and Salt 2006). It is enhanced by retaining diversity and redundancy of species, populations, and life histories (i.e., maintaining options) and by avoiding land use and management actions that reduce natural variability. Modularity (multiple distinct elements such as populations) and heterogeneity among elements (such as the genetic and life history diversity among populations) confer resilience in the larger ecosystem (Walker and Salt 2006; Bisson et al. 2009; Jones et al. 2014). For example, in the Columbia River estuary, at least 27 identifiable habitat types occur in repeatable patterns (Figure 3), all of which influence abundance, distribution, and life histories of aquatic and riparian organisms. The resulting mosaic of habitats imparts important resilience to the ecosystem in the face of environmental change. Human communities draw on resilience as well, through diversity in their landscapes, fisheries, and other natural resources, but also through experimentation and sharing of diverse ideas and information (Gunderson and Pritchard 2002; Berkes et al. 2003; Healey 2009).

A landscape perspective is required to conceive and guide effective restoration. That perspective will require analyses and planning across spatial scales matching the patterns and processes influencing the populations of interest. Actions should not focus just on the physical structure of habitats but on sources of degradation and the processes creating and maintaining habitats (e.g., Beechie et al. 2010, 2013). Goals and objectives should recognize biological diversity and the spatial structure of populations, as well as abundance and productivity (e.g., McElhany et al. 2000), as critical elements of long-term resilience.

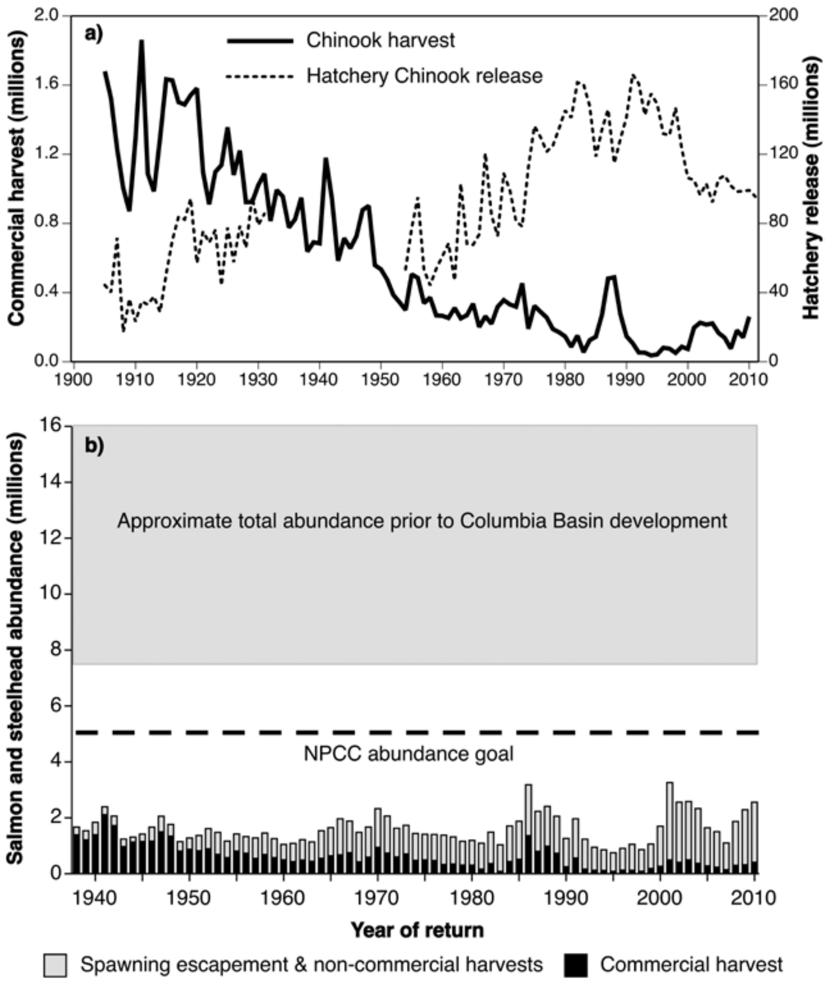

Figure 1. Abundance of Columbia Basin anadromous salmonids. (a) Estimated Columbia River commercial harvests and hatchery releases of Chinook Salmon since 1905. Hatchery numbers are shown 3 years postrelease to approximate the year of return. (b) Annual adult returns to the river and commercial harvest of all salmon and steelhead since 1938 after the first dams were built. Noncommercial harvests were not consistently estimated in the early years and are included in escapements. The range of estimated predevelopment returns is shown in the shaded bar. The current NPCC goal is total returns averaging 5 million fish by 2025 as a means to support tribal and nontribal harvests (NPCC 2009). Declining commercial harvests in recent years reflect, in part, the need to protect ESA-listed populations. Higher total numbers in recent years also have been linked to improved ocean conditions, hatchery releases, and some improvements in dam passage. Hatchery fish have contributed to larger returns of naturally spawning fish in some populations even though return per spawner is often less than replacement and wild populations may not be viable. (Primary data sources: Cobb 1931; Chapman 1986; Mahnken et al. 1998; Oregon Department of Fish and Wildlife and Washington Department of Fish and Wildlife 2002).

Broad Public Support

A comprehensive approach must integrate social and economic patterns and processes as well as the ecological ones (McKinney et al. 2010; Shultz 2011; Kareiva and Marvier 2012). That requires an understanding of the constraints and potentials that are imposed by both the landscapes and the people inhabiting them (e.g., Scarnecchia 1988; Lackey 2013; Lichatowich 2013). Too often social, economic, and cultural considerations remain outside, or occur too late in, planning and action (Nassauer 1997; Kareiva and Marvier 2012; Fremier et al. 2013; Menz et al. 2013). A comprehensive approach will engage the full spectrum of people who are interested in, and affected by, restoration (Hampton et al. 2013; Naiman 2013). Early and continuing public engagement is critical to define goals, consider alternatives, provide active education, and, especially, grow the support required to take action. Trust in those leading restoration is critical to engaging people in the discussion and the actions needed to conserve and restore habitats (ISAB 2011b). Action is easier to obtain when people understand the science and support the intended outcomes that are derived from it. Otherwise,

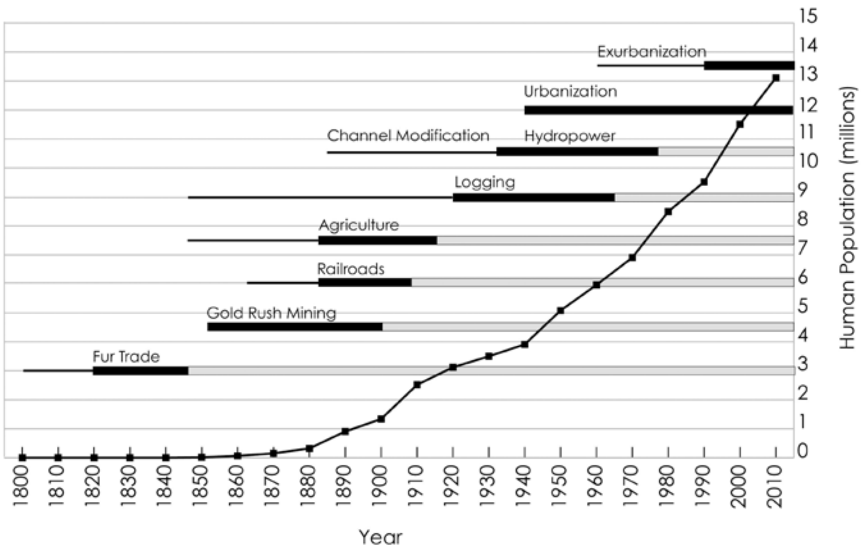

Figure 2. Sequential development driving landscape change in the U.S. portion of the Columbia Basin and concurrent changes in human population size. Wide dark bars indicate the period of peak development and rapid habitat conversion. Wide light bars indicate continued effects following the initial period of rapid change (from ISAB 2011b).

actions often end up delayed by policy and legal battles.

Broad engagement is achieved through a breadth of outreach activities. Efforts may include public meetings, print, radio, TV, social media, and web-based tools. Advisory groups, university extension, volunteer programs, citizen science, and experiential learning activities for youth and adults engage people and help them develop a deeper understanding of ecological conditions. Effective public engagement must begin early, encourage debate and discussion of alternatives, and include individuals and groups that will be positively and negatively affected.

Governance for Collaboration and Integration

Comprehensive restoration requires working across disciplines, landownerships, management responsibilities, and public and private interests (Gunderson and Holling 2002; McKinney et al. 2010; Tabor et al. 2014). That requires a supporting structure (Cosens and Williams 2012; Fremier et al. 2013), specifically, an intentional process or framework for governance that supports collaboration and integration of the work of multiple participants (Sabatier et al. 2005; Flitcroft et al. 2009; McKinney et al. 2010). The process needs to include mechanisms to share information, resolve differences, make decisions, and identify critical uncertainties.

Collaboration and integration emphasize working relationships and common goals among individuals and organizations, science and management disciplines, and the institutions or agencies needed to do the work (Rogers 2006; Kania and Kramer 2011). Success requires common or complementary visions, shared knowledge and conceptual models, and funding to support integrated planning as well as on-the-ground actions (Sabatier et al. 2005; Reeve et al. 2006; McKinney et al. 2010). Effective collaborations form only after considerable time and effort to understand one another, establish trust, and foster cooperation (Kenney 1999; Smith and Gilden 2002; Flitcroft et al. 2009).

Learning and Adaptation

Comprehensive restoration will require new and untried actions that must evolve with experience. Learning and using what is learned to modify future restoration actions are key. Adaptive management is a full-cycle process starting with the identification of quantitative objectives to fulfill agreements, policies, or laws. This is followed by an assessment of physical, biological, social, and economic conditions that need to be addressed to meet the objectives. Based on the assessment, actions are designed and implemented. Periodic monitoring and evaluation provide critical feedback (Reeve 2007; Runge 2011). The results are then used to gauge progress toward objectives and ultimately to support or modify actions.

Adaptive management ideally uses deliberate experiments to inform future decisions (Holling 1978; Lee 1993; McDonald et al. 2005; Armitage et al. 2008). It can still provide a useful path, however, where traditional scientific experimentation, replication, and intensive monitoring become difficult or impossible at very large scales (Runge 2011). For example, models can be used to explore restoration scenarios and help managers and the public visualize the response of complex systems (Holl et al. 2003). The models can be integrated in a structured approach to making decisions, and the results can be updated periodically to focus new work and limited financial resources (Runge 2011).

Ultimately, learning and adaptation require sharing experiences across watersheds, regions, and cultures so that each project becomes an observation for a larger collective evaluation of successes and failures. Active networking across groups with common interests must be part of the process.

A COURSE OF ACTION FOR THE COLUMBIA BASIN

Many of the ideas highlighted above have been recognized in guidance for Columbia Basin restoration for some time (e.g., McElhany et al. 2000; Williams 2006; NPCC 2009; Bottom et al. 2011). Despite that, success remains uncertain and implementation has been inconsistent (Lichatowich and Williams 2009; ISAB 2013a; ISRP 2013; Naiman 2013). Wild salmon stocks remain depressed; most are vulnerable to changing conditions, and hatchery programs continue to produce most of the fish (Paquet et al. 2011; Naiman et al. 2012). Societal constraints to progress in the basin have been linked to lifestyle choices and priorities, including the drive for economic efficiency, competition for natural resources and resulting scarcities (especially water), and accommodations for increasing numbers of people (Lackey et al. 2006; Lackey 2013). McKinney et al. (2010) argued that most restoration efforts lack landscape ecological information and analytical capacity, policy tools, and a realistic funding structure. Groups working in the same landscapes often have different conceptual models (Reeves and Duncan 2009; Rieman et al. 2010; Columbia River Inter-Tribal Fish Commission 2013). Institutional structures needed to support integration are often lacking (e.g., Samson and Knopf 2001), and political interference can impede the incorporation of science into management (Lichatowich and Williams 2009; Lichatowich 2013).

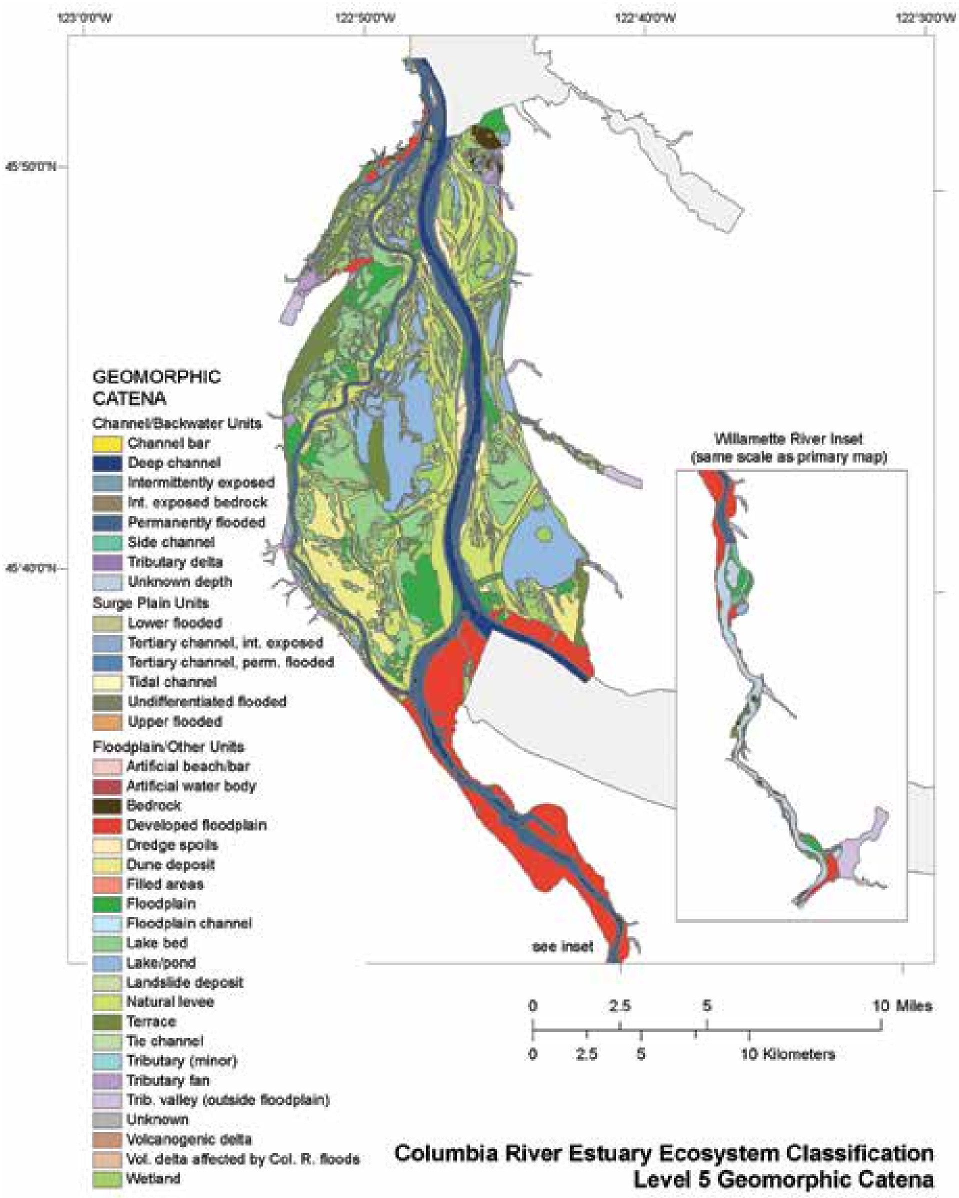

Figure 3. Geomorphic catenae described for a reach in the Columbia River estuary. There are at least 27 distinct habitat types present that affect the distribution and abundance of aquatic and riparian organisms (modified from Simenstad et al. 2011; ISAB 2011b).

Five actions are needed for more comprehensive habitat restoration in the Columbia Basin. To provide a strong science foundation, we must *rebalance the goals* for the program to include resilience and biological diversity, not just fish abundance. We must also *strengthen the linkages between science and management*. To gain broad public support for the program, we must *increase public engagement*. To provide governance for collaboration and integration, we must *work across traditional ecological and social boundaries*. And, to learn and adapt, we must fully commit to *learn from experience* at all levels of the program. We briefly consider these five actions below.

Rebalance the Goals

The Columbia River Basin Fish and Wildlife Program (NPCC 2009) speaks to a more comprehensive restoration effort, but vision, goals, and action remain at odds (Lichatowich and Williams 2009; ISAB 2013a). The program notes that biological diversity is important, but the specific objectives focus on abundance and in-river survival of salmon and steelhead and do not include species, genetic, life history, or habitat diversity or the number and spatial structure of populations. Abundance remains the focus of public discussion, and biological diversity and the ecological patterns and processes that underpin resilience are mostly limited to the technical literature (ISRP 2005; ISAB 2013a).

Reliance on hatcheries to produce large numbers of fish is an example of the narrow focus on abundance. Hatcheries now number about 200 (with new facilities being planned and built) and are influential enough to impede recovery of wild fish (ISRP 2005; Naiman et al. 2012; ISAB 2013a). Extensive artificial production also fosters a public expectation that hatchery technology can provide abundant salmon for harvest, irrespective of habitat conditions (Lichatowich 1999, 2013). Abundance is the commonly publicized measure of fish status. Clearly, increased abundance is an important and popular goal, but increasing hatchery production while ignoring the overall capacity of the ecosystem to support extensive diversity in wild populations is ill-advised (Naiman et al. 2012; and see Lindley et al. [2009] for a case in point).

Steps toward a more balanced vision can be taken with an intentional effort to engage the broader public on the importance of biological diversity and resilience. This requires communicating more than simple numbers of fish. Schindler et al. (2010), for example, found that the frequency of fishery closures could increase 10 times as multiple independent stocks were homogenized to a single population. Discussions like this can help the public (and managers) understand the benefits of diversity to fish populations and fishing opportunities. Recent research has focused on the influence of hatchery releases on fitness of both wild and hatchery stocks (Paquet et al. 2011); a similar focus is needed on the effects of hatcheries on concentrations of predators, disruption of food webs, and habitat capacity influencing wild populations (Naiman et al. 2012). Moreover, we do not know whether biological and habitat diversity is increasing or declining across the basin (ISAB 2013a). Rapidly changing science and technology (e.g., Miller et al. 2010; Campbell et al. 2012; Hess et al. 2014), synthesis of existing regional viability assessments (Ford 2011; ISAB 2011b), and refined analyses of new or existing information (e.g., Moore et al. 2010; Jones et al. 2014) could dramatically extend our collective understanding of the trends in biological diversity and the ability to communicate those to the stakeholders in the basin.

To provide a more comprehensive vision for habitat restoration basin, state and local policy makers, and project managers must:

- develop and communicate goals and measurable objectives for biological diversity that are held as equal priority to the goals and objectives for abundance;
- directly engage all stakeholders and the general public to broaden understanding of the critical value of biological diversity;
- develop indicators for monitoring that measure and communicate progress on abundance and biological diversity at multiple scales across the basin; and
- consider the implications of hatchery production for carrying capacity and diversity of wild fish as a basis for integrating hatchery production with habitat restoration.

Strengthen Linkages between Science and Management

Science provides information to help guide management. A comprehensive approach to habitat restoration requires the broad perspective that only landscape ecology and supporting disciplines can provide. Analytic and technological advances have dramatically extended our ability to describe broad habitat patterns (e.g., McKean et al. 2008; Isaak et al. 2010) and watershed and biological processes (e.g., Beechie et al. 2010; E. A. Steel et al. 2010; Campbell et al. 2012). But widespread application of new tools and analyses and the design of scientific experiments in the adaptive management process remain a challenge (e.g., McDonald et al. 2005). We still need the capacity to monitor not only the effectiveness of habitat restoration actions (e.g., Roni et al. 2008) but the cost-effectiveness of those actions measured as benefits in the status of entire populations. We need the help of sociologists, cultural anthropologists, and others to understand and communicate with the full range of stakeholders.

Too often, scientists have little incentive to collaborate with managers (e.g., Arlettaz et al. 2010), and managers often lack time, funding, or analytical expertise to effectively engage with scientists, use their tools, or guide the development of new ones. In many cases, managers do not use information that already exists because traditional funding mechanisms favor piecemeal, localized actions over extensive analysis and more comprehensive planning (McKinney et al. 2010).

Attempts to bridge these barriers in the Columbia Basin include the creation of technical recovery teams, application of life history and habitat models in decision analysis (e.g., E. A. Steel et al. 2008; Beechie et al. 2013; Peterson et al. 2013; Anderson et al. 2014), integrated population and habitat monitoring (Bennett et al. In Press), and work to visualize management alternatives and scenarios (Baker et al. 2004; Guzy et al. 2008; Hulse et al. 2008; Bolte 2013). A restoration extension service built on the model of agricultural extension and Sea Grant programs or "communities of practice" (Collay 2010) could further efforts like these to bridge the science–practice gap (Cabin et al. 2010). Although there has been consideration of dedicated technical support in the past, the commitment has not materialized. Scientific bodies such as the Columbia River Hatchery Scientific Review Group (Paquet et al. 2011), formed to deal with a growing concern over hatchery programs, could be formalized to provide continuing support for project and hatchery managers. Emerging habitat–life history modeling could help managers understand what, where, and how much habitat restoration is actually needed and whether it will be cost effective; however, dedicated support will be required to realize the potential (ISAB 2013b).

These examples show that science and management can engage effectively (Naiman 2013). Learning from these and other experiences (ISAB 2011b), and making sure that the scientific capacity to conduct effective large-scale assessments is available and used, is key.

To strengthen the science and application of science in restoration, program and project managers must:

- use landscape sciences and technology in assessment and restoration planning and support and expand common application of relevant research, monitoring, modeling, and analytical tools.

Program managers, funders, and policy makers must:

- create and support communities of practice and peer-learning networks that demonstrate science–management integration; highlight new tools and analyses that are innovative and promote those with real potential for success; and
- recommit to options for broadly based technical assistance to provide analytical support, constructive criticism, and feedback to proposed and ongoing projects.

Increase Public Engagement

Articulating a widely supported vision remains a problem. The Columbia Basin is socially and ecologically complex. Cultural and political histories lead to different values and intentions, constraining solutions that people will support (Malle et al. 2001). Conflict among stakeholders is time consuming and stressful, resulting in habitat actions attempted where conflict is least rather than where it is needed most.

Restoration strategies are commonly developed within the confines of individual resource uses (e.g., terrestrial or aquatic but rarely together). Managers for different resources or agencies frequently fail to communicate or work effectively with each other as well as the full spectrum of potentially competing stakeholders (e.g., Rogers 2006; Rieman et al. 2010; Cosens and Williams 2012). Public and planning meetings are held; plans are revealed but not necessarily debated or revised, and parties talk past one another. The public is often brought in after internal discussion, after planning options are chosen (Smith et al. 1998; Johnson et al. 1999), or after their input would be useful.

One approach to more effective public engagement is to foster discussion of ecological services such as clean water, mitigation of natural disturbances (such as wildfire and flooding), production of fish for harvested food and recreation, and resilience in the supply of fish with environmental change. Modeling and other assessment and communication tools can also help put restoration actions into a landscape and social context and help stakeholders visualize alternatives, contemplate different roles, and understand potential results or tradeoffs of any actions. Experience in the Willamette River Basin, outlined as a case history in ISAB (2011b), is a good example where these concepts have been explored in some detail. Helping the public recognize the problem as complex and related to other values has a real advantage because it looks at reality (Rogers 2006), making it, in the end, a broad-based consensus easier to achieve. In the case of the Columbia River, and for most other rivers ongoing large-scale restoration, efforts fall short of goals because the social aspects are neither well developed nor well integrated with the physical restoration efforts and therefore do little to create a public or scientific consensus (Naiman 2013).

To increase public engagement to achieve more comprehensive restoration, policy makers and program and project managers must:

- include education and outreach specialists as key players at the earliest stages of project development;
- engage people and organizations early through forums that encourage dialogue between managers, researchers, and stakeholders associated with a range of resource values;
- align ecological needs with social and economic incentives and consider benefits and costs to people and their communities;
- use a wide diversity of media and forums for public and community engagement; and
- make public involvement and active learning through citizen science in monitoring and research a central element in project implementation.

To support actions like these, basin, state, and local program managers and policy makers across must:

- recognize the social sciences as a critical element of scientific review and guidance and include social scientists as primary contributors to the advisory, review, and planning processes.

Work across Traditional Ecological and Social Boundaries

The Columbia Basin encompasses two countries and, within the U.S. portion, seven states, 15 Native American tribes, 11 ecological provinces, 62 subbasins, more than 100 counties, many more towns, and other entities representing diverse patterns of ownership, management, and regulatory jurisdiction (e.g., Forest Service and Bureau of Land Management districts, irrigation and water districts) as well as a wide range of ecosystems (Figure 4). Responsibilities for managing natural resources are scattered across agencies and jurisdictions with different missions, authorities, and scientific capacities (Samson and Knopf 2001; Reeves and Duncan 2009; Rieman et al. 2010). One result can be a bewildering array of plans, rules, and regulations. Regulatory complexity can be so daunting that landowners become suspicious of government and reluctant to participate in conservation and restoration programs. Still, private lands are critical to landscape structure, diversity, and connectivity (Dale et al. 2000; ISRP 2005).

A comprehensive approach should seek integration with cities and counties that control many mid-level land use actions (Smith 2002) as well as private landowners and other jurisdictions not well represented by traditional approaches (Cosens and Williams 2012). Private landowners will favor improved coordination among regulators and managers that simplifies and streamlines land and water use rules where appropriate and possible without compromising intent. This can also lead to increased public support for proposed restoration actions.

Although coordination across very large areas (such as the entire basin or large subbasins) is extremely challenging, important steps can certainly be made within smaller subbasins and watersheds that are important ecological components of the larger system. Familiarity can bring trust in the process (Smith and Gilden 2002; Sabatier et al. 2005; B. S. Steel et al. 2003). Extension and other outreach and programs, such as the watershed organizations, soil and water conservation districts, and the U.S. Department of Agriculture Farm Service Agency's Conservation Reserve Enhancement Program that exist in many Columbia Basin counties have already engaged farmers, ranchers, and other private property owners in a conservation discussion and could serve as a useful foundation (Flitcroft et al. 2009; Collay 2010). Nongovernmental organizations are playing an increasingly important role bringing nontraditional partners together as well (McKinney et al. 2010). One example is the Upper Salmon River Basin, Idaho, where multiple agencies, nongovernmental organizations, and some ranchers are working together to restore habitat and stream flows while also encouraging more landowners to conserve habitat as a means to improve quality of life (Upper Salmon Basin Watershed Program 2010). Other examples can be found in current experiments with "collective impact" (Kania and Kramer 2011), "networking governance," and "nested adaptation" (Tabor et al. 2014), where nontraditional partners in and across watersheds are supported through network organizations that share common goals (e.g., Wiley et al. 2013; RCC 2012; Russell Family Foundation 2013). Learning from nonconventional efforts like these, providing new incentives, and supporting alternative structures that work across traditional boundaries will be important.

More effective collaboration and integration across traditional boundaries will require efforts where program and project managers embrace governing structures that engage and support a broad diversity of stakeholders, communities, and interests in the planning and decision process.

To support that, program managers and those funding projects should:

- highlight and support experiments in governance for collaborations that bridge agency and intellectual groups, local and regional organizations, governments, landowners, and science–management disciplines and
- bring innovative and successful examples (including those from other resource and restoration disciplines) to others in the basin.

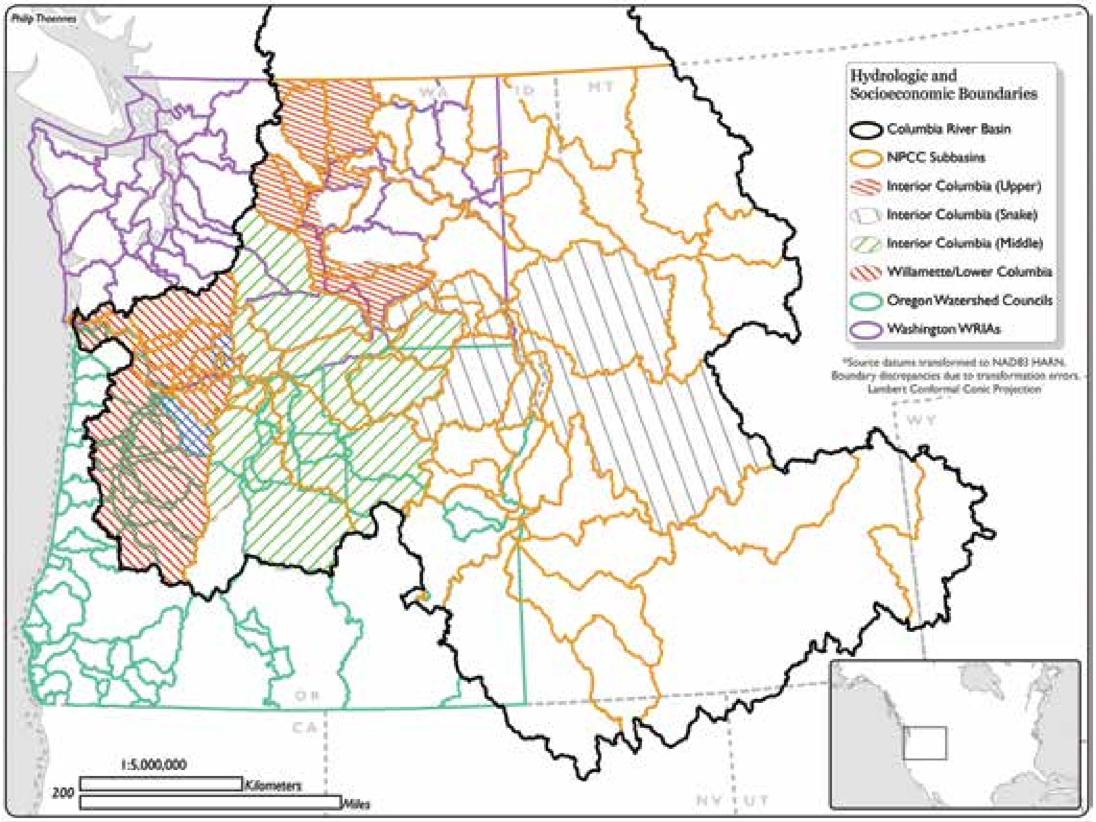

Figure 4. An example of organizational complexity and overlap in the Columbia Basin. The Northwest Power and Conservation Council subbasins are intermediate regions for planning used across the basin. Subbasins encompass multiple fourth field watersheds often used to consider hydrologic or large-scale ecological issues. Four Columbia Basin National Oceanic and Atmospheric Administration salmon and steelhead recovery domains (crosshatched areas), Oregon's Watershed Council planning areas and Washington's Water Resource Inventory Areas are shown as well. Not shown are the counties, national forests, tribal lands, state fish and game agency regions, or other districts used to organize activities that can influence watershed conditions as well as fisheries.

Learn from Experience

A commitment to learn from the experiences gained through the extensive restoration efforts already in progress across the Columbia Basin is critical. Adaptive management has been a central tenet of the Columbia Basin Fish and Wildlife Program since the 1980s (Lee 1993). Unfortunately, adaptive management has not always been practiced as originally intended (e.g., Smith et al. 1998; Stankey et al. 2005; Lichatowich and Williams 2009; Westgate et al. 2012), and application has often failed (Reeve 2007). Though project leaders routinely assert that adaptive management is used, many efforts have no measurable objectives, and very few have either an experimental design or conceptual model that could be used to revise management based on updated information. Often, projects continue even when monitoring indicates that biological objectives are unattainable. The reasons why adaptive management has failed are varied and complex (Walters 1997), but they can be summarized in the Columbia Basin as overconfidence in projected restoration outcomes, unwillingness to terminate unproductive activities, limited funding for monitoring, unwillingness to experiment, and lack of formal analysis, scientific guidance, or effective governance (Cosens and Williams 2012; ISAB 2013a; J. Shurts, NPCC, personal communication).

One suggestion for improved learning is to expand approaches such as structured decision making (SDM) and be guided by the precautionary principle to better implement and communicate an adaptive management cycle (ISAB 2013a). Structured decision making is a transdisciplinary approach that incorporates elements of adaptive management, quantitative modeling, social engagement, statistical rigor, and ecological understanding (Runge 2011; ISAB 2013a, 2013b). Broad implementation of SDM, which is being explored in the basin, will require additional commitment and facilitated guidance, but it may help both managers, and the public, visualize and formalize the process.

There are also opportunities to learn from other experiences with large-scale restoration. Worldwide, there are numerous ongoing attempts at restoring large rivers (e.g., ISAB 2011b; Naiman 2013; Murray-Darling Basin 2010). Admittedly, these are highly difficult undertakings and fraught with problems, but there is much to be learned from their successes as well as their failures. In general, two important attributes central to the successful aspects are setting clear ecological goals and encouraging public participation, both of which are important attributes proposed here.

Beyond renewed efforts to practice adaptive management, implement SDM, and learn from others around the world, restoration efforts with similar objectives and project actions within the Columbia Basin need to share information, innovations, successes, and failures continually. Learning from experience will require more rigorous application of adaptive management in addition to broad communication among restoration projects to learn from each other.

Demonstrated commitment to learn through experience must include efforts from project managers that:

- identify clear, quantitative objectives, including diversity objectives that form the baseline for the adaptive management cycle;
- implement intentional, science-based management experiments that promote learning about landscapes, cost-effective restoration actions, and understanding of their social–ecological implications;
- incorporate options for citizen science in monitoring and experiential programs that help reduce monitoring costs and promote broader understanding of the results; and
- use formal models to guide more structured decision making and to communicate a broader vision of the system and its critical uncertainties to all involved.

Program and project managers and funding authorities must include structures and forums to broadly share experiences, innovations, successes, and failures as a foundation for shared learning across projects.

MOVING FORWARD

We advocate an approach to restoration where all four elements outlined above are fully embraced in every project and the policy, planning, and management direction that make them possible. There are important examples of progress in the Columbia Basin, but few efforts have effectively incorporated all four elements. These are not new ideas or radically divergent hypotheses about how restoration can and should work; rather, they emerge directly from nearly two decades of guidance for salmon conservation (e.g., Stouder et al. 1997; McElhany et al. 2000), river and ecosystem management (e.g., Naiman and Bilby 1998; Bernhardt et al. 2005; Williams 2006), and landscape or riverscape ecology (e.g., Wiens 2002; Fausch et al. 2002). It is time to weave that guidance into a more comprehensive approach to habitat restoration.

Some will argue that costs will be prohibitive or that social and ecological complexity will become overwhelming with a broader context. There are formidable challenges, but a broader context will make the opportunity for efficiencies and tradeoffs more apparent and allow managers to focus limited resources more effectively (Noss et al. 2006; Hobbs et al. 2014). Cost-effective restoration can only be defined by the response of entire populations that depend on encompassing landscapes. Even so, a comprehensive approach does not mean working only at the largest scales. Instead, it means working at the scales relevant to the social and ecological patterns and processes driving the habitat networks and populations of concern. The approach we advocate can be adapted to many scales, with clear understanding that the needed perspective will change as we move across scales and that some process for nesting work across scales must also exist. Indeed, the modularity emphasized in resilience thinking implies building in a hierarchical fashion, securing fundamental pieces (e.g., local populations), and understanding the linkages among them that ultimately structure a larger system.

We have offered a series of elements, recommendations, and examples (with more detail in ISAB 2011a, 2011b, 2013a), but important steps are needed at the highest levels of the program as well to provide the incentive and direction for change. The ISAB (2013a) strongly recommended a revised series of scientific principles underpinning the Columbia Basin Fish and Wildlife Program based on the concepts outlined here (see text box). We urge policy makers to embrace those principles by establishing clear goals and quantifiable objectives for biological diversity and communicating the importance of resilience in the face of an uncertain future for the Basin. The ISAB (2011b) argued that the four elements outlined here should become criteria for review and funding of long-term projects. Continued funding for projects implemented within this context should demand commitment to the program's underlying principles and demonstrated progress toward those criteria.

Stronger leadership is needed. Those funding or providing the policy direction can provide leadership directly (e.g., setting the course and prescribing the process). Alternatively, they can foster and support leadership in other partners across the basin. These two options are not mutually exclusive, but the first requires an understanding of issues, actors, and environments and a level of control that may be virtually impossible. The second requires a capacity to recognize and champion local and regional efforts that are innovative and effective even though they may not follow a common or prescribed structure. That will require support for nontraditional models of governance and networking with new partners. It will require investment and technical support in social sciences, environmental education, and outreach, not just salmon ecology and watershed processes.

Some have argued that the challenges to progress in the basin are largely social and perhaps insurmountable (Lackey 2013). But, salmon and other species continue to be central components of the basin's cultures, and people can decide to conserve and restore what matters to them. People are tied to their landscapes—a living synthesis of ecology, people, and place that is vital to local and regional identity and social and economic well-being. Landscapes help define the self-image of a region, a sense of place, and structure social interactions (Kemmis 1990). Because human decisions and actions interact within landscapes to shape abundance, diversity, and resilience of Columbia Basin fishes and cultures, a more comprehensive approach to habitat restoration, a landscape approach, provides the best opportunity for success.

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The Evolution of Scientific Principles for the Columbia Basin Fish and Wildlife Program

In 2013, the ISAB reviewed the NPCC Fish and Wildlife Program's existing scientific principles (NPCC 2009) based on the elements of a landscape approach and subsequent work (ISAB 2011b; Naiman 2013). The ISAB (2013b) proposed that the eight principles be reduced to six that better reflect recent advances in scientific knowledge about complex adaptive systems and their patterns, processes, diversity, and resilience. The proposed principles focus guidance for management and restoration activities placing greater recognition on the importance of human influence and involvement. The original principles included one describing humans as an integral part of the ecosystem. The revised principles expand on this concept and emphasize that broad public engagement and cultural diversity are required for effective ecosystem management and restoration (see especially 3, 5, and 6 below). We expect the principles will continue to evolve with new insights into social–ecological dynamics and as restoration and management approaches are improved in the basin.

The proposed, revised principles were as follows:

1. The abundance, productivity, and diversity of organisms are sustained by complex and adaptive ecosystems.
2. Biological diversity allows ecosystems to persist in the face of environmental variability.
3. Human health and well-being are tied to ecosystem conditions.
4. Ecological management is adaptive and experimental.
5. Socioeconomic understanding and engagement is required to make management actions more sustainable.
6. Biological and cultural diversity provide the raw material for reorganization and adaptability during unexpected transitions to new ecosystem regimes.

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AFS 2015 Portland

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August 16th- 20th, 2015

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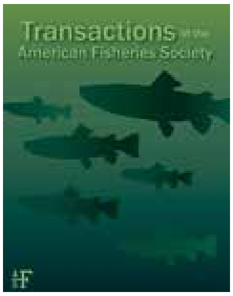

Journal Highlights

TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY
Volume 144, Number 1, January 2015

Otolith Chemistry to Determine Within-River Origins of Alabama Shad in the Apalachicola–Chattahoochee–Flint River Basin. *Jason J. Schaffler, Shawn P. Young, Steve Herrington, Travis Ingram, and Josh Tannehill 144:1-10.*

Predicting Brook Trout Occurrence in Stream Reaches throughout their Native Range in the Eastern United States. *Jefferson T. DeWeber and Tyler Wagner. 144:11-24.*

[Note] Poor Survival of Acoustically-Tagged Juvenile Chinook Salmon in the Strait of Georgia, British Columbia, Canada. *Chrys M. Neville, Richard J. Beamish, and Cedar M. Chittenden. 144:25-33.*

Comparison of Tributary Survival Estimates of Steelhead using Cormack–Jolly–Seber and Barker Models: Implications for Sampling Efforts and Designs. *Mary M. Conner, Stephen N. Bennett, W. Carl Saunders, and Nicolaas Bouwes. 144:34-47.*

[Note] Fall Spawning of Atlantic Sturgeon in the Roanoke River, North Carolina. *Joseph A. Smith, H. Jared Flowers, and Joseph E. Hightower. 144:48-54.*

Correspondence between Scale Morphometrics and Scale and Otolith Chemistry for Interpreting Juvenile Salmon Life Histories. *Lance A. Campbell, Daniel L. Bottom, Eric C. Volk, and Ian A. Fleming. 144:55-67.*

Changes in Relative Abundance of Several Minnesota Fishes from 1970 to 2013. *Bethany J. Bethke and David F. Staples. 144:68-80.*

[Note] Best Practices for Surgically Implanting Acoustic Transmitters in Spotted Seatrout. *Megan M. Reese Robillard, Laura M. Payne, Robert R. Vega, and Gregory W. Stunz. 144:81-88.*

[Note] Using Multimethod Occupancy Estimation Models to Quantify Gear Differences in Detection Probabilities: Is Backpack Electrofishing Missing Occurrences for a Species of Concern? *Kasey C. Pregler, Jason C. Vokoun, Timothy Jensen, and Neal Hagstrom. 144:89-95.*

Coastwide Otolith Signatures of Juvenile Atlantic Menhaden, 2009–2011. *Kristen A. Anstead, Jason J. Schaffler, and Cynthia M. Jones. 144:96-106.*

Coastal Distribution and Consequent Factors Influencing Production of Endangered Snake River Sockeye Salmon. *S. Tucker, M. E. Thiess, J. F. T. Morris, D. Mackas, W. T. Peterson, J. R. Candy, T. D. Beacham, E. M. Iwamoto, D. J. Teel, M. Peterson, and M. Trudel. 144:107-123.*

Deciphering Hatchery Stock Influences on Wild Populations of Vermont Lake Trout. *Shauna M. Baillie, Craig Blackie, Leonard Gerardi, and Paul Bentzen. 144:124-139.*

[Note] Importance of Resident and Seasonally Transient Prey to Largemouth Bass in the St. Johns River, Florida. *Nicholas A. Trippel, Micheal S. Allen, and Richard S. McBride. 144:140-149.*

Genetic Population Structure of Willamette River Steelhead and the Influence of Introduced Stocks. *Donald M. Van Doornik, Maureen A. Hess, Marc A. Johnson, David J. Teel, Thomas A. Friesen, and James M. Myers. 144:150-162.*

Early Emigration of Juvenile Coho Salmon: Implications for Population Monitoring. *Jennifer J. Rebenack, Seth Ricker, Colin Anderson, Michael Wallace, and Darren M. Ward. 144:163-172.*

[Note] Microchemical Signatures in Juvenile Winter Flounder Otoliths Provide Identification of Natal Nurseries. *David S. Bailey, Elizabeth A. Fairchild, and Linda H. Kalnejais. 144:173-183.*

Long-Term Increases in Trout Abundance following Channel Reconstruction, Instream Wood Placement, and Livestock Removal from a Spring Creek in the Blackfoot Basin, Montana. *Ron Pierce, Craig Podner, and Leslie Jones. 144:184-195.*

Varying Effects of Common Reed Invasion on Early Life History of Northern Pike. *M´elissa Larochelle, Pierre Dumont, Claude Lavoie, and Daniel Hatin. 144:196-210.*

Temporal Population Genetic Structure of Yellow Perch Spawning Groups in the Lower Great Lakes. *Timothy J. Sullivan and Carol A. Stepien. 144:211-226.*

[Erratum] High Diet Overlap between Native Small-Bodied Fishes and Nonnative Fathead Minnow in the Colorado River, Grand Canyon, Arizona. *Sarah E. Zahn Seegert, Emma J. Rosi-Marshall, Colden V. Baxter, Theodore A. Kennedy, Robert O. Hall Jr., and Wyatt F. Cross (volume 143:1072–1083)*

Guide for Authors

CALENDAR

To submit upcoming events for inclusion on the AFS website calendar, send event name, dates, city, state/province, web address, and contact information to sgilbertfox@fisheries.org. (If space is available, events will also be printed in *Fisheries* magazine.) More events listed at www.fisheries.org

March 25–27, 2015
AFS 2015 Mississippi Chapter Meeting | Tara Wildlife, Vicksburg, Mississippi | www.mississippiafs.org

April 28–30, 2015
FLOW 2015: Protecting Rivers and Lakes in the Face of Uncertainty | Portland, Oregon | www.instreamflowcouncil.org/flow-2015

May 17–19, 2015
NPAFC International Symposium on Pacific Salmon and Steelhead Production in a Changing Climate: Past, Present, and Future | Kobe, Japan | npafc.org

May 18–22, 2015
AFS AFS 2015 Piscicide Class | USU, Logan, Utah | fisheries.org

May 26–30, 2015
World Aquaculture 2015 | Jeju Island, Korea | was.org

May 28–29, 2015
AFS 2015 Louisiana Chapter Meeting | Baton Rouge, Louisiana | sdafs.org

June 22–24, 2015
Fish Passage 2015 | Groningen, Netherlands | fishpassageconference.com

July 12–17, 2015
39th Annual Larval Fish Conference | Vienna, Austria | larvalfishcon.org

July 26–31, 2015
World of Trout | Bozeman, Montana | Facebook > The World of Trout - 1st International Congress

August 16–20, 2015
AFS 145th Annual Meeting of the American Fisheries Society | Portland, Oregon | 2015.fisheries.org

November (TBA), 2015
5th International Symposium on Stock Enhancement and Sea Ranching | Sydney, Australia | www.searanching.org

February 22–26, 2016
Aquaculture 2016 | Las Vegas, Nevada | marevent.com

March 13–15, 2016
Muskie Symposium | Minneapolis, Minnesota | www.muskiesinc.org

September 19–22, 2016
OCEANS 2016 | Monterey, California | oceanicengineering.org

POLICY (continued from p. 96)

assistantship in academia. The position was announced in August and filled in October, and our first AFS Fishery Policy Fellow, Patrick Shirey, Ph.D., started last November. With his work nearing completion, we can offer some initial thoughts on how to bolster plans for future fellows.

The administrative aspects of this experiment were successful. Although the six-month window proved tight, Shirey stuck to his ambitious schedule and produced an updated background document that was sharpened by review by AFS units and the public. The entire process was virtual, with Roulson in Montana, Shirey in Indiana, mentor Bill Taylor in Michigan, and me in Maryland. The result was more than the RPC could have accomplished as a wholly volunteer committee. And Shirey's work on endangered and threatened species enabled the RPC to focus on its next priorities.

Now the real test is to use the policy to effect change, to convert the best-available science into policies that can influence management decisions. Great policies serve little good if they idle on desk shelves or thumb drives. We must share our fisheries knowledge with others and use that information to influence decisions. The AFS did that in 2013 with a letter to President Obama on climate change and with letters in 2014 to Environmental Protection Agency against Pebble Mine and in favor of wetland conservation under the Clean Water Act. Now we must do the same with the results of Shirey's toils. Only then will we know for certain that the AFS investment and our experiment have been successful.

One surprising aspect of this effort was the intense interest expressed by AFS members. Nearly 30 members expressed interest in the fellowship, with 23 submitting applications. Most were highly qualified, with at least one and sometimes three advanced degrees and experience ranging to 35 years. That cadre of "young professionals" and retirees proved to be the strongest candidates, but the applicants still in school attracted equal attention. It was surprising and refreshing to receive solid resumes from about a dozen of our youngest AFS members, and it was enlightening to recognize the untapped potential of those members in the science and policy arenas. Based on that showing, AFS is considering options for a second type of Policy Fellowship for those members still training for a career in science, resource management, and policy. Our first foray into that second type of position was in January 2015 when we arranged a winter break internship for Owen Mulvey-McFerron, a sophomore with a dual major in marine biology and environmental science from Stockton College in New Jersey. That ancillary experiment confirmed my commitment to consider a second type of fellowship for later this year.

I hope 2015 is witness to a replicate of our 2014 fellowship experiment, plus a new effort to provide meaningful opportunities for those AFS members who are even earlier in their career path. Both types of interns can help to position AFS to use the best science to develop policy that will influence fishery management decisions. After all, that's what it's all about! AFS

BACK PAGE

Living Fossil Fishes

Relative of the Senegal Bichir, the Congo Bichir *Polypterus endlicheri congicus.* Photo credit: Solomon David.

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Solomon David with a Great Lakes Basin Spotted Gar *Lepisosteus culatus* collected during a field survey at University of Michigan. Photo credit: Solomon David.

Solomon David lives and breathes for all things Bowfin *Amia calva*, sturgeon, lungfish, and especially gar. How fitting, since these relics of earth's geologic past are still living and breathing today. The curator of the website primitivefishes.com, and Twitter account @PrimitiveFishes, David's interest with ancient fishes started at childhood with a Ranger Rick article on Alligator Gar *Atractosteus spatula*. Now a postdoctoral associate at Shedd Aquarium and the University of Wisconsin, David is a researcher, conservationist, and advocate of these often misunderstood and underappreciated fishes.

One such fish is the bichir. Bichirs are now catching the attention of evolutionary scientists. Is it the multitude of *Stegosaurus*-like dorsal finlets running along a bichir's spine? Perhaps the pair of lungs and pectoral-fin-aided terrestrial "walking" are too curious not to investigate. This peculiar creature, that can be found swimming in rivers in African floodplains, appears to be adapted for life in water and on land. Similar to *Tiktaalik roseae*, bichirs appear to be part fish, part tetrapod. This bimodal life makes bichirs an excellent study model for exploring how our aquatic ancestors may have made the switch from water to land.

Emily Standen and colleagues saw this potential in bichirs. They raised juvenile Senegal Bichirs *Polypterus senegalus* in water and on land. Water-reared bichirs swam about in a filled 300-gallon aquarium. The aquarium of land-reared bichirs was designed for a terrestrial existence: a mere 2 mm of water, a carpet of pebbles, and grocery store lettuce misters to avoid desiccation. After only eight months under their respective conditions, biomechanical differences were striking between water- and land-reared bichirs. When water- and land-reared fish strutted their stuff on a runway, terrestrialized bichirs took quicker steps, hoisted their heads higher, and their fins slipped less frequently (Standen et al. 2014). The skeleton of land-reared fish also had changed. Bones in the pectoral girdle elongated and thinned, increasing strength and flexibility. Sturdier chest anatomy could help support upright posturing of land dwellers now subject to the force of gravity. More flexibility would facilitate the rotational requirements of pectoral fin movement on land. These changes within a generation of a living fossil fish may reflect changes in fossilized "fishapods" over evolutionary time, suggesting tetrapods emerged when a fish put its best fin forward.

REFERENCE

Standen, E. M., T. Y. Du, and H. C. E. Larsson. 2014. Developmental plasticity and the origin of tetrapods. Nature 513(7516):54–58.