Fisheries

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AFS

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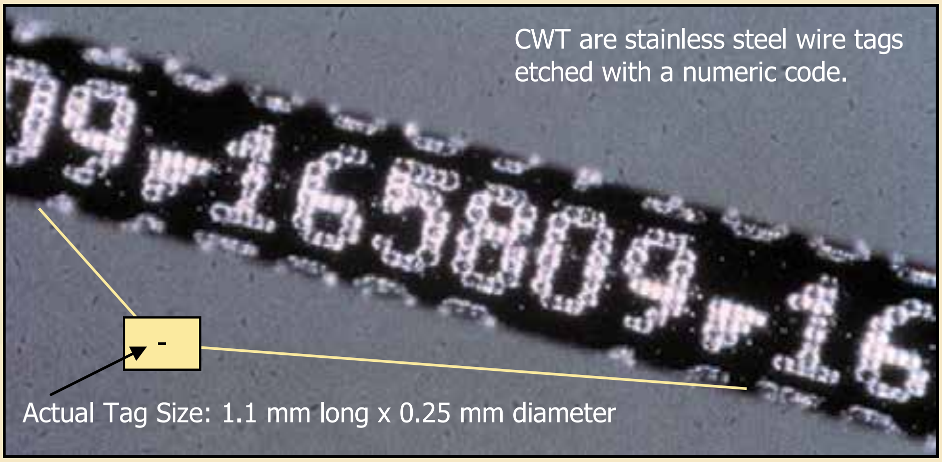
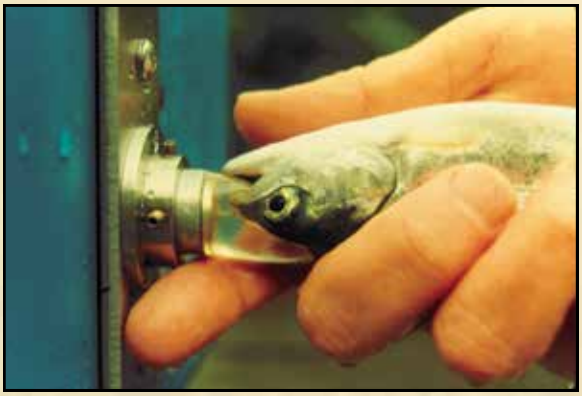
Coded Wire Tags™

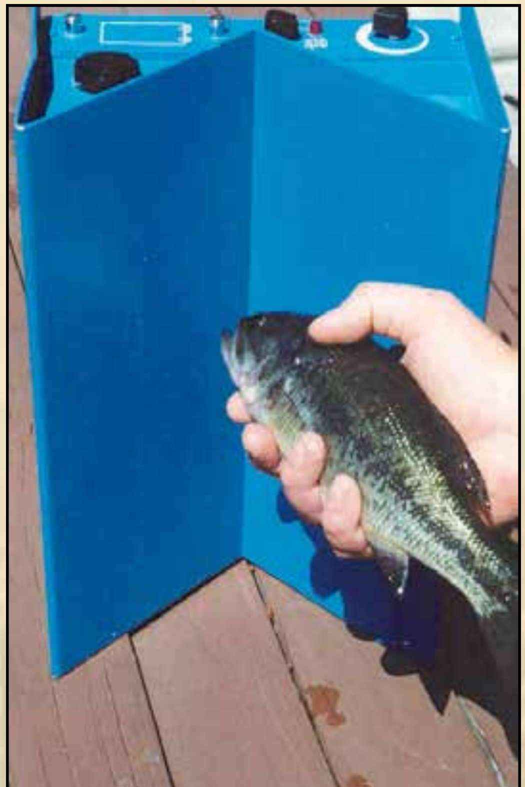


Billions of aquatic animals have been tagged with NMT's Coded Wire Tags™ (CWT) worldwide. CWTs are unique in their nearly universal high retention rates, even through molts and metamorphosis. Retention for the life of the animal is the norm, and tags have been recovered 25 years after release.



CWTs are implanted hypodermically (left). Because they are so small, CWTs have little effect on the host and can be used with life stages and species too small for other types of tags. Automated tagging makes it possible to quickly tag large batches of fish.

CWTs are detected electronically (right), then the code must be read under a microscope. Tags are usually removed from dead animals, (e.g. adult salmonids returning to spawn), but benign recovery is often possible.



There are numerous applications for CWTs. Examples are: evaluate how hatchery practices affect post release survival; identify the stock of origin and age; estimate population size; estimate fishery contributions of a particular stock over time; monitor habitat use; measure growth; evaluate whether stocked fish contribute to population recovery; learn about migration routes and straying between populations; evaluate the effects of climate change on Pacific salmon. Hundreds of publications describing their use are available on our website. Please contact us if we can help with your project.

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103 Dr. J Frances Allen and her first microscope. (Photo courtesy of Lochie Jo Allen)

Cover: Dr. J Frances Allen examining clams at the seafood processing laboratory. (Photo courtesy of Lochie Jo Allen)

Fisheries

American Fisheries Society • www.fisheries.org

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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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COLUMN
President's Hook

Replenishing the Fisheries Profession

John Boreman, President

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

Several factors led me to choose fisheries as a profession. I was in my senior year at the College of Forestry at Syracuse (now the SUNY College of Environmental Science and Forestry) when the environmental movement in the United States was just getting off the ground. President Nixon had just signed the National Environmental Policy Act into law, requiring environmental impact statements (or at least environmental assessments) for every federally licensed or permitted project. Furthermore, my undergraduate advisor, Bob Werner, had moved to Cornell, where he was heading up the newly established Finger Lakes Fisheries Investigation, and he was looking for a research assistant to study the population of Rainbow Trout in Cayuga Lake and its tributaries. It was the harmonic convergence of a new law that would likely be leading to increased employment in environmental sciences, a chance to work with a professor who served as my role model during my undergraduate years, and an opportunity to attend one of the premier fisheries graduate programs in the country studying my favorite fish—trout.

Probably very few of us decided to become fisheries professionals before entering college. Instead, we entered the fisheries profession due to a combination of coincidences, opportunities, situations, and circumstances, guided by the advice of teachers, mentors, peers, and friends. It is also likely that few of us even knew of the fisheries profession until we were well into our undergraduate degree programs.

In preparation for writing this column, I visited the American Fisheries Society (AFS) web site to look for any materials related to recruitment into the fisheries profession. Although our Strategic Plan clearly states that one of the roles of the AFS is to support "recruitment, training, and retention of fisheries professionals with a diverse array of technical skills to meet the needs for workforce continuity and adaptability" (http://fisheries.org/strategic-plan), nothing is mentioned in the plan about actively recruiting people into the profession. I hope that the next iteration of the plan that will cover the years 2015–2019 will address this deficiency.

The AFS web site also links to a *Public Visibility Plan* that the AFS published in the mid-1990s through the efforts of a special committee chaired by Phil Janik. The plan is still relevant today, although I have not seen any reference to it in the *Strategic Plan* or other society documents (including my own work plan). It encourages increasing the visibility and understanding of the fisheries profession and its importance, increasing the influence of fisheries science in decisions affecting resource management, promoting activities that further enhance the public perception of the AFS as a professional organization, and increasing public appreciation and understanding of the benefits resulting from scientifically managed fisheries. As with the *Strategic Plan*, however, one key area in which the *Public Visibility Plan* falls short is recruitment to the fisheries profession.

The AFS needs to take advantage of the opportunities afforded us through our outreach and education programs to convince the younger generations that fisheries is a way cool profession that is relevant and necessary for conservation and wise management of our planet's living resources. Thanks to the Hutton Program and the growing number of student subchapters, visibility of fisheries as a profession has been extending to younger ages, but we could be doing more. For example, many AFS members, especially those in our student subchapters, serve as judges for local science fairs. Why not use the interaction with students at the science fairs as a means to promote the pursuit of a career in fisheries? For relatively little cost, the student subchapters could build a traveling exhibit promoting the fisheries profession that could be displayed at science fairs and other local events in which youngsters and their families gather. Brochures that explain the fisheries profession and the associated educational track that is required could be developed and handed out to high school guidance counselors.

We should also take advantage of social media as a means of recruitment. Back in the early 1970s the AFS Northeastern Division produced a short subject film entitled *The Aquatic Ecologist.* Recently, Bill Fisher (AFS immediate past president) found a copy in the archives at Cornell University and had it transcribed to DVD format. Scripted by Dwight Webster and his fisheries colleagues at Cornell and Syracuse and narrated by Emmy Award winner Rod Serling (an avid lake trout fisherman who lived on Cayuga Lake just north of Cornell and did the narration *gratis*), the video reviews the types of jobs that fisheries biologists do, including involvement in fish tagging and stocking, construction and operation of fish passage facilities, and aquaculture. Today, these types of promotional videos can be loaded onto YouTube, Facebook, Twitter, etc., and, with any luck, may even go viral.

In the coming decade, we will be called upon to address increasingly complex problems facing conservation and management of the planet's fisheries resources. In order for us to keep pace with (and maybe even stay slightly ahead of) those problems, we must continually replenish our ranks with capable people. The AFS must take the lead in ensuring that our profession is doing enough to recruit the best and the brightest to help us prepare to meet the challenges that lie ahead.

CANDIDATE STATEMENTS
Second Vice President

Jim Bowker

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

I'm living a charmed life working as a fisheries professional by day and fly-fishing addict at all other times. Living in southwest Montana provides ample opportunities to chase trout, but I've also been fortunate to fish many other places throughout the country, often with fellow fisheries professionals. My passion for fishing piqued my interest in the many scientific disciplines that make up our profession, but my interactions with fisheries professionals galvanized my commitment to serving them, our profession, and the fisheries resources. I can think of no better way to serve than as American Fisheries Society (AFS) president, and I am humbled and honored to be nominated for the position of AFS second vice president. I'm currently the research program manager for the U.S. Fish and Wildlife Service's Aquatic Animal Drug Approval Partnership Program. I started my career nearly 30 years ago with a B.S. in aquatic biology from Eastern Michigan University and a series of temporary positions with the Great Lakes Sciences Center in Ann Arbor, Michigan. Along the way, I completed courses to qualify as a chemist and finished up my M.S. in biology (also from Eastern Michigan University). In 1994, I joined the U.S. Fish and Wildlife Service's newly established Aquatic Animal Drug Approval Partnership Program. As one of the program's charter employees, I helped transform it from "two guys in a trailer in Montana" into one of the premier fish drug approval programs in the country.

AFS INVOLVEMENT

Although my involvement with the AFS has a longer history, I've been a consistent dues-paying member since 2000. There are a variety of reasons that I became more engaged with AFS, mostly because I finally understood a primary value of AFS membership—the rewards of service. I am currently the president of the Fish Culture Section (FCS) and member of various FCS committees, including the Working Group on Aquaculture Drugs, Chemicals, and Biologics (cochair), Award of Excellence Committee (chair) established during my term, and am the AFS FCS rep for the Triennial World Aquaculture Conference. As FCS president, I serve on the society's governing board and Management Committee and am a member of the Resource Policy and Membership committees. I am also a member of the Fish Health and Fisheries Management sections and the Montana AFS chapter. I helped lead the group that developed the *AFS Resource Policy Statement on the Need for Immediate-Release Sedatives* and am helping to update the Guidelines for Use of Fishes in Research. I also serve as an associate editor for the *North American Journal of Aquaculture* and as a science editor for *Fisheries* and am a frequent contributor to these and other AFS publications.

VISION

For the past 142 years, our members have been building our reputation and legacy on a foundation of best-available science, effective communication, and empowering our membership. AFS has an excellent roadmap and, as leader, I'd focus my attention on how we can get closer to accomplishing the goals drawn up in our society's Strategic Plan.

Leading from Anywhere

AFS encourages "leading from anywhere"—an ambitious plan created by and carried out by our officers, unit leaders, and members at large. One way we lead is through our annual meetings. Wherever they might be, our units host them at a great cost—both fiscally and physically. Working with a professional meeting planner is an idea worth pursuing, knowing full well that it would come at a cost, but that cost would be offset by lightening the load on our members and allowing them to focus on what they do best—creating a dynamic and informative program that leads our society wherever the meetings take place. As well, we must build on the quality of our publications, on- and offline, as our published science provide the world with an in-depth glance at our leadership.

Policy

The society is in the enviable position to meet with any entity with an interest in fisheries, including nongovernmental organizations, agency leaders, fisheries-related business owners, and congressional staffers. We need to be more proactive in taking advantage of these opportunities, to showcase our science and provide information that might help shape decisions and policies that ultimately affect the fisheries resources. Congressional briefings are one example of how we can engage with many stakeholders and decision makers, and the AFS staff is anxious to schedule these to help strengthen the position and presence of our broad constituency.

Membership

Membership in AFS, particularly in a leadership role, is a key that unlocks many doors. We can do a better job of communicating this core door-opening value of AFS membership to younger generations. This is one of the numerous beneficial outcomes of the governing board mentor/mentee program. The enthusiasm exhibited by the first mentor–mentee cohort was palpable, and we need to do what we can to ensure that programs such as this thrive.

Networking

Networking is one of the values of membership paramount to success. AFS members are provided that opportunity, most often at the unit level. Unit leadership is one of the society's many strengths—it's where things get done. The society needs to maintain its connectivity with all of the units and to reach out beyond AFS, since we globally represent the fisheries disciplines and all fisheries professionals.

We can play to our strengths as a society and protect our legacy of sound science, effective communication, and empowered members—but there are many other considerations that demand our continued attention, such as keeping our fiscal house in order, better utilizing technology to cut travel costs and increase participation, and continuing to strive to be a global leader in fisheries. What I will bring to the table is a well-used pair of work gloves, my "doer" mentality, and a commitment to devote my time and effort to building the value and strength of our society. I am deeply humbled and honored to have an opportunity to serve the society—the professional organization that has helped bring greater meaning to my career—at the highest level and will do everything in my power to live up to the legacy that is known as AFS.

Joe Margraf

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BACKGROUND

Over my career I have had the very good fortune to work in fisheries around the United States. In 1970, after receiving my B.S. degree in fisheries from Cornell, I went to work in New Jersey for an ecological consulting company. After a few years, I became keenly aware that I needed more education and training. After completing my M.S. and Ph.D. in fisheries at Texas A&M, I again went into ecological consulting in Texas. In 1980, I joined the Cooperative Fishery Research Unit at Ohio State. I moved to West Virginia in 1987 to start a new co-op unit at West Virginia University. From there I started another new co-op unit on the eastern shore of Maryland in 1995. In 1999 I made the big jump to the wilds of Alaska with the co-op unit in Fairbanks. Since 2010 I have been the supervisor of western co-op units in Denver. Moving around my entire career has given me the opportunity to work in aquatic systems including streams, rivers, reservoirs, lakes, estuaries, and oceans. This has forced me to think of biological systems in a broad context, to search for commonalities, and to think outside the parochial box. It also has given me the opportunity to work with some of the most incredible people in and out of our profession.

AFS INVOLVEMENT

In 1970, I had been on my first job only a couple of months when I had the opportunity to go to my first AFS meeting in New York City—the centennial meeting. I was agog at the presence of some of the biggest names in fisheries; yet, they were all human and accepting of a neophyte biologist—something I still find to be true. I joined AFS in 1972 and became a life member in 1984. Almost from the beginning I became an active member. I was first elected president of the Texas A&M chapter and, after moving to Ohio, was elected chapter secretary–treasurer and then president. I started the West Virginia chapter soon after moving there: getting the necessary petition signatures, writing the chapter's bylaws, and serving as the first president. In 1993–1994 I did my first stint on the governing board as president of the Education Section. I then served as the AFS constitutional consultant from 1996 to 2002, chairing the committee that rewrote the AFS Constitution and Rules and receiving the 2001 Distinguished Service Award for this effort. I again served on the governing board as president of the Western Division in 2004–2006. After moving to Alaska, I became more interested in fish habitat—particularly the difficulties in discerning habitat in a large, remote place. I reached out to the habitat community within AFS for help, only to discover that habitat issues were spread over a number of sections in the society. So in 2007 I began efforts to form the Fish Habitat Section. The section had its first annual meeting in 2009 and I again found myself on the governing board for a 2-year stint. In addition to elected offices, I have served on, or chaired, more committees at every society level than I can recall. In 2009 I received the Meritorious Service Award for lifelong involvement with AFS.

VISION

The AFS has been the conduit for much of the scientific information I've relied upon to do my job. It is the source of opportunity to develop a network of professional friends necessary for career enlightenment and satisfaction. It is the venue through which to translate the importance of what we do. I've seen AFS through young eyes, middle-aged eyes, and now old eyes. I still like what I see. AFS continues to provide world-class scientific information; guidance to decision makers through policy statements; and opportunities for our members to network through local, regional, and North American meetings. We have evolved in our delivery by taking advantage of technological advances while retaining the personal connectedness to our members. However, there is always room for improvement.

Our publications are among the best in the world. However, our journals' impacts often do not live up to their quality. Our highest impact journal is our monthly magazine, Fisheries—largely because of its broad circulation. Perhaps it is time to investigate different strategies for our publications. While this effort has already begun, it's important to continue if our status as a world-class provider of information is to advance. Because of the large importance of publications to our budgetary well-being, we also must evaluate the financial consequences of changes.

Over the past few years, AFS has been actively evaluating and updating our Policy Statements to remain relevant to policy makers. However, AFS has lost some relevancy to many of our natural resource management and scientific agencies at all levels. With shrinking budgets and competing needs, AFS needs to be a "go to" source of information and support when decisions are being made. Many of our members work for these agencies and cannot speak out as individuals. AFS must serve the role of spokesperson for fisheries issues.

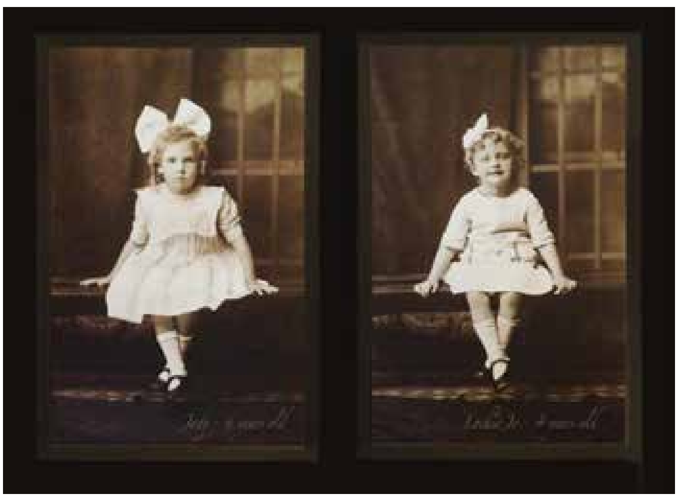
Networking has been an extremely important aspect of AFS. Our meetings at all levels are a very large part of who we are and what we do as a society. As an "old-timer," my view of networking is usually face to face, and this is what I personally prefer. However, to younger generations and many busy professionals, face-to-face meetings are passé or simply too expensive and time consuming. For AFS to remain relevant to its members, we must consider alternatives to our present meeting structure. Our meetings have become too large for many venues and the cost and complexity of putting them on exceeds the capabilities of local chapters. Major changes in our meeting paradigm need to be explored.

I am most honored to run for the highest office in AFS. If elected I will do my best to serve the best interests of AFS members and the organization that has been so important to me throughout my career.

Dr. J Frances Allen: Pioneer of Women in Fisheries

Gwen White, Julie Claussen, Christine Moffitt, Brenda Norcross, and Donna Parrish

J Frances Allen, known as Jady to those who knew her. (Photo courtesy of Lochie Jo Allen)



Jady and Lochie Jo as young children. (Photo courtesy of Lochie Jo Allen)

Dr. J Frances Allen—Jady to those who knew and loved her—a pioneer of women's involvement in the field of fisheries, passed away on February 11, 2011. The combined talents of Jady and her sister, Lochie Jo Allen (of Front Royal, Virginia), significantly influenced the development of scientific publications and women's participation in the American Fisheries Society (AFS). However, many of us may know little about how these pioneering women came to excel in the field of fisheries at a time when few women were taken seriously. Here is the story of Jady and the women she touched—through her life and her scholarship.

Jady—a combination/derivation of her first name, J, combined with the endearment *Dear*—was born April 14, 1916, in New York. From the beginning, she was an outdoor adventurer. Two events helped formulate her career. She had a beautiful singing voice and thought of music performance, but a bout with pneumonia changed her voice and caused her to consider other interests, including the sciences. While attending junior high, she and Lochie Jo lost their father; however, their mother had a strong influence, so when she took her daughters hiking or to stop and sit at the edge of a stream to eat lunch, they fell in love with the natural world.

Jady and her first microscope. (Photo courtesy of Lochie Jo Allen)

Jady studying Striped Bass. (Photo courtesy of Lochie Jo Allen)

Jady taking her students out on the Chesapeake. (Photo courtesy of Lochie Jo Allen)

Lochie Jo (left), co-founder and first editor of *Fisheries* magazine, with older sister Jady (right). (Photo courtesy of Lochie Jo Allen)

As a young student at the State Teachers College in Virginia (now Radford University), Jady's research paper on snails was written so well that her instructors strongly encouraged her to pursue science and provided access to fieldwork. Thus, she began a lifelong interest in marine systems at the Chesapeake Biological Laboratory, Solomons Island, Maryland, during the summer of 1937 and continued with a DuPont Scholarship in the summer of 1938 at the Mountain Lake Biological Station of the University of Virginia.

Jady received her B.S. degree (1938) from the State Teachers College and her M.S. and Ph.D. degrees in zoology (1948 and 1952, respectively) from the University of Maryland. Before graduate school she taught secondary school science in Virginia, West Virginia, and New York and was assistant professor of science at Radford College during the summers of the mid-1940s. At the time Radford was a women's college, except in the summer when some coed classes were offered.

While teaching in Virginia, Jady became one of the founders of the Virginia Junior Academy of Science. She was a graduate assistant at the University of Maryland (1947–1948), then an instructor, and, following that, she became assistant professor of zoology of the University of Maryland, where she taught, among other courses, fisheries biology and management, shellfisheries, animal ecology, and marine zoology.

Jady never let being a woman dissuade her from participating in professional societies or conducting her own fieldwork. As a professor at the University of Maryland, she led her students on many scientific cruises into the Chesapeake Bay to study molluscs (clams, oysters, snails), blue crab, fish (Striped Bass), and prawns.

She felt very strongly about the community of scientists and truly enjoyed associating with her colleagues and supporting her students. She was reportedly the second woman to attend the annual meetings of the AFS. At her first event, she remembered meeting Dr. Emmeline Moore, who was an active member and—for many years—the only woman in a leadership position, having been elected as AFS president in 1927 (only 7 years after women were granted the right to vote in the United States. It was more than 55 years before the AFS installed another female president, in 1983.) For 9 years she was editor of the AFS retiree's newsletter, *Homopiscis rusticus*.

Her sister, Lochie Jo, was a pioneer in her own right. In fact, she started *Fisheries* magazine. At the time, her title was associate editor (1976–1983), although she truly was the first

Jady was often the only woman present during business meetings. (Photo courtesy of Lochie Jo Allen)

was a man's name. Interestingly—yet not surprising—one of Jady's biggest fans was a young man she taught. His mother wrote to Jady to tell how she would always remember how happy her son was when Jady asked him to take a class on lobster fishing. He then went on to pursue a career in the fisheries profession.

The J Frances Allen Scholarship was set up in 1987. Before she retired to New York, two of her colleagues told Jady that they had started the scholarship for women Ph.D. in fisheries, complete with a committee to review applications.

Dr. J Frances Allen of Front Royal, and formerly of Roxbury, New York, died Friday, February 11, 2011, at her home at The Southerlands. She is survived by her devoted sister, Lochie Jo Allen, of Front Royal, Virginia.

editor of the AFS flagship magazine (later the board changed the name of the position to managing editor). Needless to say, both sisters were accomplished, independent women whose complementary efforts supported the early scientific and publication mechanisms of the AFS.

In 1948, Jady joined the Systematic Biology Program of the National Science Foundation in Washington, D.C. In 1967 she left her position as associate program director to become chief of the Water Quality Requirements Branch, later named the U.S. Environmental Protection Agency. At the time of her retirement in 1982 she was staff scientist–ecology for the Science Advisory Board, Office of the Administrator, U.S. Environmental Protection Agency.

Jady lectured in 47 states and was the U.S. representative to the Organisation for Economic Cooperation and Development World Conference on Water Quality in Paris, France, in 1973. Unlike many who went overseas to deliver a report written by others, Jady actually wrote the report she delivered. As successful as she was professionally, she was often met with curiosity and even disbelief over the fact that she was a woman. One summer lecture at a university, the hosts assumed that "Dr. Allen" was a man, so they reserved a room in the men's dormitory. When Jady appeared, they had to send for a custodian to open the women's dormitory, which had been closed for the summer. Clerks at some hotels refused to provide a room key, unconvinced that a "Dr. Allen" could be the woman standing in front of them. She had to produce a male scientist who could vouch for her, as she said with some exasperation, "Would you please tell this lady who I am?" Misidentification through her name led to other well-deserved recognitions before such recognition was typical for a woman. At a time when women were not considered for listing, Jady's biography appeared in the *American Men of Science*, because they mistakenly thought Frances

Jady will be missed by all who knew her—and for those who were not lucky enough to know her, they will have missed being in the presence of a true pioneer. Thankfully, her impact will live on through the J Frances Allen Scholarship.

The AFS would also like to thank Lochie Jo Allen for continuing to make her own impact with continued funding into her sister's scholarship—as well as for her very own important work as the first editor of Fisheries*. For those who would like to know more about Jady, please send mail to:*

Lochie Jo Allen
c/o The Southerland
600 Mount View Street
Front Royal, VA 22630

CREATION OF A SCHOLARSHIP TO ENCOURAGE WOMEN IN FISHERIES PROFESSIONS

Twenty-five years ago, the J Frances Allen Scholarship was created in honor of this remarkable woman pioneer. The award recognizes the highest levels of academic achievement and is intended to encourage women to become fisheries scientists. A sportfishing company provided the initial $10,000 to endow the scholarship. At the 1986 meeting, the first and only Fisheries Women's Caucus was convened, with Brenda Norcross, now Second Vice President Donna Parrish, and other important women fisheries professionals as organizers and/or participants. Led by Julie Claussen (the group developed the EOS in the next few years), the meeting began with a bit of tension, because there were rumors that some men would be showing up to protest (on the grounds that any money should go to men or women alike), but in the end the crowd (made up of both sexes) was supportive and the first AFS scholarship just for women was inaugurated.

The qualified applicant for the J Frances Allen Scholarship must be a female Ph.D. student who is a member of the AFS. The applicant must be conducting aquatic research in line with AFS objectives in some aspect of fisheries science, including but not limited to aquatic biology, engineering, fish culture, limnology, oceanography, and sociology. Award recipients are evaluated on (1) promise as a fisheries scientist, (2) the potential to complete their proposed work, and (3) the significance of the proposed research to the advancement of fisheries science.

Many of those serving on the scholarship review committee indicate that it is a true pleasure to serve, because the applicants are women who are avidly pursuing research interests that range widely and focus intensively on science needs in fisheries management and related disciplines.

The idea for the scholarship was spawned by a number of AFS members concerned with the lack of diversity in the professional society. Recently, a similar scholarship in honor of Dr. Allen was established by the Institute of Malacology.

Scholarships Provide a Boost to Young Professionals

Testimonies from J Frances Allen scholars reveal the great significance that such an award can have in the young professional lives of the recipients. Funds provided through the J Frances Allen Scholarship played a significant role for many of the recipients, often building on resources from their programs to expand the horizons of their work to allow them to pursue fieldwork, obtain equipment, finance publications, stretch personal finances to meet demands on time from family and school, and attend scientific meetings.

In addition to the financial resources, recipients frequently cited the encouragement that came with knowing that others valued their professional accomplishments and future potential, encouraging their participation in research and in leadership positions within the AFS at a time when women continue to be underrepresented in the fisheries disciplines. The scholarship is positioned at a key time in the professional development of many women who are nearing completion of their doctorate and may need added resources to meet the many demands of their family and scholarly lives.

J Frances Allen Scholarship Recipients

1987 Elizabeth Marschall
1988 Deborah A. Bodolus
1989 Susan Sogard
1990 Lisa L. Williams
1991 Nancy A. Auer
1992 Susan C. Sponaugle
1993 Gwen White
1994 Jodee Hunt
1995 Dorothy E. Medeiros-Bergen
1996 Sandra Diamond
1997 Karen Mumford
1998 Tracy Galarowicz
1999 Lisa A. Eby
2000 Kimberly Howland
2001 Cynthia Kolar
2002 Amy Schrank
2003 Maureen Walsh
2004 Julie Kay Henry Zimmerman
2005 Stephanie Carlson
2006 Virginia Shervette
2007 Anne M. Cooper
2008 Melissa Wuellner
2009 Karen Murchie
2010 Marie-Ange Gravel
2011 Neala W. Kendall
2012 Brooke Penaluna

THE STORIES BEHIND THE J FRANCES ALLEN SCHOLARSHIP AWARDS

Elizabeth “Libby” A. Marschall (1987)
Professor in Evolution, Ecology, and Organismal Biology at the Ohio State University

This is the 25th anniversary of the J Frances Allen Scholarship that I was awarded at the 117th Annual Meeting of the American Fisheries Society in Winston–Salem, North Carolina. As I thought about this recently, I reread the proposal I submitted as part of my application. That proposal, on “The Early Life History of Brook Trout: Population Consequences of Interactions with Rainbow Trout,” was a bit far afield from the coastal marine systems I had moved to North Carolina State University to study with my advisors Larry Crowder and Leslie Real. Despite having their full intellectual support for my research pursuits, I was proposing work in a system in which neither of them could provide significant financial or logistical support. The J Frances Allen Award provided funding for my first field season, including travel to the mountains of Virginia, the site of my research. The results of that field season provided the basis for future successful proposals for funding that ultimately allowed me to complete my dissertation research. Receiving the J Frances Allen award early in my career did not just fund a field season; being selected to receive the award also provided a needed statement to me that my behavior- and ecology-based fisheries research was acceptable in the eyes of a panel of fisheries experts. And I received a beautiful, complimentary letter from Dr. Allen herself (which I still have) that made me take even greater pride in this award.

Susan Sogard (1989)
National Marine Fisheries Service

Receiving the award was very helpful for me in covering field expenses for the final stage of my dissertation research at Rutgers University. I am currently the ecology branch chief for the Santa Cruz Laboratory of the Southwest Fisheries Science Center of the National Marine Fisheries Service. I supervise other researchers and lead the Early Life History Team, which conducts research on the ecology of larval and juvenile stages of marine (primarily rockfishes) and anadromous fish (primarily Steelhead and Coho Salmon). We study life history strategies, oceanographic/climate effects on reproductive ecology, habitat requirements, and restoration effectiveness and maternal and epigenetic effects on early life stage traits. I have been actively involved in the AFS's Early Life History Section throughout my career and served as secretary from 2000 to 2002 and president of the section from 2010 to 2012.

Nancy A. Auer (1991)
Associate Professor, MTCWS Advisory Committee, Michigan Technological University

I received the J Frances Allen Scholarship in 1991. This was a critical stage in my career and the award was a much-appreciated boost. I obtained a B.A. in biology in 1973 at the University of Minnesota–Duluth. I immediately went to the University of Michigan for an M.S. degree in 1977 in resource ecology. After that I worked for many years at the Great Lakes Research Division Zooplankton and Fishery laboratories until my husband graduated with a Ph.D. and secured a job at Michigan Technological University in 1981. In the early 1980s little attention was paid to spousal accommodation, so I held various adjunct, soft money, and part-time posts. When we moved to Houghton we actually carried pedigree dwarf rabbits for show breeding in the back of the truck, because I thought I would be out of work and out in the woods. The latter proved true—I was out in the woods, but I could not quell my desire for science. In 1987 I began my lifelong relationship with Lake Sturgeon by acquiring several small nongame wildlife grants the state provided. Because I was doing research and I had some grant money for a few years, I started a Ph.D. program. The money I received from the J Frances Allen scholarship gave me two things: (1) confirmation from other women that I could do worthwhile research even though I could not work full time and (2) a buffer of money that I squirreled away for manuscript publication costs. I actually entered the sum into our checking account but never incorporated it into the balance so it remained unspent until needed. The money allowed me to publish three papers from my thesis, for which I am forever grateful. I feel tremendously blessed, even though it was a struggle at many times, and I am totally enjoying my career in academia and my work contributing to fisheries.

Susan (Su) C. Sponaugle (1992)
Professor and Chair, Marine Biology & Fisheries, University of Miami

I received the J Frances Allen Scholarship in 1992 about halfway through my Ph.D. dissertation research. The financial support was immediately valuable because it allowed me to purchase a computer; however, it was the professional recognition more than anything that was beneficial to my career. Receiving the scholarship was a huge vote of confidence and helped propel me through the low points to complete my doctorate. I likely will never know how the listing of the award on my curriculum vitae may have helped me obtain my first academic position, but I am now professor and chair of the Division of Marine Biology and Fisheries at the Rosenstiel School of Marine and Atmospheric Science at the University of Miami. For the past 8 years I have also served as the editor-in-chief of the international scientific journal *Bulletin of Marine Science*. My overarching area of research has evolved from my dissertation research and is primarily focused on the population replenishment of coral reef fishes. My students and I examine the microstructure of the otoliths of young fishes to investigate the relationship between environmental parameters, oceanographic features, and larval growth and survival. By investigating the biological and physical processes critical to the growth and survival of early life stages, we hope to better quantify the degree to which different local populations of fishes are ecologically connected. Our interdisciplinary studies of population connectivity have basic ecological and applied relevance to the management and conservation of coral reefs and the fishes that inhabit them.

Gwen White (1993)
Science Coordinator, Eastern Tallgrass Prairie and Big Rivers Landscape Conservation Cooperative

The J Frances Allen scholarship was instrumental in connecting me to the AFS community and facilitating a complicated shift in my research topic from forested streams in Rwanda to land use planning in Indianapolis. I purchased a backpack shocker that I needed to determine the impacts of urban construction on stream fish assemblages and for which I had no other source of funds. At the time, I was also shopping around for a professional society to which I could commit myself, having attended a number of meetings hosted by several other societies related to aquatic resources and land use policy. In combination with a Skinner Travel Award, the scholarship motivated me to attend my first AFS meeting that year in Portland, Oregon. Many will remember a challenging conversation about management of salmon at that business meeting where we received our awards. How those strong differences of opinion were handled convinced me that the AFS was truly an association of people who took their mission seriously and were able to productively debate critical issues with each other. At a time when I was often the only woman in the room at many meetings, the awards sent a message that the society valued the participation of female students. The support fostered my desire to serve in leadership positions at many levels in the AFS, including president of the Equal Opportunities Section (EOS), AFS constitutional consultant, and North Central Division president. Recognizing the role that this award played in my career, I have worked hard to "pay it forward" by soliciting funding for the student travel awards in the EOS. With assistance from many other AFS units and external sources, the EOS raised over $30,000 during the past 10 years to support annual meeting attendance of over 60 female and minority students from 42 institutions. I will always be very thankful for a scholarship that not only gave me the physical tools to carry me along an amazing career trail but also ushered me into a community of lifelong friends and colleagues.

Jodee Hunt (1994)
Professor, Biology Department, Grand Valley State University

I completed a Ph.D. in systematics and ecology at the University of Kansas in 1995 after being awarded the J Frances Allen Scholarship. My dissertation research took a nontraditional approach to Largemouth Bass reproductive ecology, focused on parental behavior, and the J Frances Allen Scholarship award money supported critical captive experiments that yielded insights about effects of spawning habitat on parental behavior. Following graduation, I began a tenure-track position at Grand Valley State University (GVSU) near Grand Rapids, Michigan, continuing my research on Largemouth Bass but primarily teaching courses in ecology, environmental science, animal behavior, fish ecology, and environmental ethics. I have coauthored articles in a variety of AFS publications, including *Black Bass 2000*, and have remained active in AFS activities, including reviewing J Frances Allen Scholarship applications, judging student presentations, reviewing journal submissions, and serving on the steering committee of the 2005 Midwest Fish and Wildlife Conference. I love working at GVSU, a growing, vibrant regional university, and was promoted to professor in 2008, received an Outstanding Faculty Mentor Award from our Graduate and Professional Student Association in 2010, and was named to the Faculty of Distinction by our Omicron Delta Kappa Honor Society Circle in 2012. Recently, I have focused on molecular-based research, investigating horizontal transmission of microbes via parental care in *Amatitlania nigrofasciata*, as well as interdisciplinary work in Nicaragua with colleagues from GVSU and Universidad Nacional Autónoma de Nicaragua (UNAN) Estelí. My favorite work, however, is mentoring students and helping them identify and pursue their dreams. None of these accomplishments would have been possible without the support I received from the J Frances Allen Scholarship award, the AFS, and other AFS members.

Sandra Diamond (1996)
Senior Lecturer, School of Science and Health, University of Western Sydney

Receiving the J Frances Allen award was an extremely important event in my life. It came at a very tumultuous time and helped me to stay in graduate school and continue in my fisheries career. At the time I received the award, I was about midway through my Ph.D. at North Carolina State University, but as a returning older student (38 years old at the time), I was married and had a 3-year-old daughter. My husband, who is also an academic, had gotten a job offer in Texas, so I was facing the decision to quit my degree to move or to try to continue my education long distance. Receiving the award made me feel good about what I was doing and helped me decide to, indeed, continue long distance. Completing my degree was very difficult because of the isolation and lack of resources away from my home institution, but every time I needed a boost in spirit, I looked at that award certificate and went back to work. I have now been a professor for 12 years, and I spend half the year at Texas Tech University and the other half at the University of Western Sydney in Australia. I am still an AFS member, and until I moved to Australia I rarely missed the annual AFS meeting. Based on my life and what I see of the lives of my female graduate students and fellow professors, women still face more difficult career decisions and pathways than men. The recognition of hard work and excellence represented by the J Frances Allen award helps women to validate these difficult life choices and encourages women to continue to pursue their dreams of working in fisheries. I have never regretted my decision to continue in fisheries science, and will always be grateful to the AFS for giving me the J Frances Allen award.

Tracy Galarowicz (1998)
Department of Biology, Central Michigan University

Receiving the J Frances Allen Scholarship was an honor at the time, but the award has had longer term effects on my career and involvement in the AFS than I would have ever imagined. As a professor at Central Michigan University, I work with talented undergraduate and graduate students. The award has influenced my mentorship style. I am grateful for the support I received from the award as a graduate student, and I actively seek opportunities to recognize the talents of the students in my lab and classes as a result. After receiving the scholarship, I volunteered to serve on—and then chair—the scholarship committee for several years, which had many rewards in itself. I connected with professionals in the EOS and throughout AFS while learning about the fascinating research conducted by the applicants. I still pay extra attention to the work done by the award winners.

Amy Schrank (2002)
Adjunct Assistant Professor at Michigan Technological University, Lecturer at the University of Michigan Biological Station

Both the J Frances Allen scholarship and the AFS had strong impacts on my early career in aquatic ecology. I was involved with the AFS while a doctoral student, as the treasurer and then president of the University of Wyoming student subunit of the Colorado–Wyoming Chapter of the AFS. I was awarded the J Frances Allen scholarship in 2002 and it helped me to complete my dissertation research on movement patterns of Inland Cutthroat Trout. Attending, giving talks, and meeting colleagues at Colorado–Wyoming and Western Division AFS meetings was formative for me and was where I learned valuable lessons about fisheries biology, public speaking, and professionalism. I am currently an adjunct assistant professor at Michigan Technological University in Houghton and a lecturer at the University of Michigan Biological Station in Pellston. I am focused on drawing undergraduate students into research in aquatic science.

Maureen Walsh (2003)
Research Fishery Biologist, U.S. Geological Survey Lake Ontario Biological Station

The J Frances Allen Scholarship increases visibility and awareness of the achievements of female students within the AFS, and I was so honored to receive this award in 2003 to support my dissertation work at Oklahoma State University. Since 2005 I have been a research fishery biologist with the U.S. Geological Survey Great Lakes Science Center's Lake Ontario Biological Station in central New York. My research focuses on forage fish population dynamics and invasive species in Great Lakes ecosystems, and I still get out in the field often on our 65-ft. research vessel. Although I had been active in the AFS as a student, receiving the J Frances Allen Scholarship really piqued my interest in pursuing leadership opportunities at the society level, and so I volunteered on the program committee for the 2006 AFS meeting in Lake Placid and became more active in sections (including the EOS) and other AFS committees. I chaired the Membership Concerns Committee (2008–2011) and currently chair the Meetings Oversight Committee. I have really gotten a lot out of these service roles in the AFS. The demographics within fisheries have changed a lot—even in the course of my career—and I am encouraged to see more and more female students at meetings each year. As a new mom, working to balance my career and my family, I am thankful to J Frances Allen—and to so many of the other women in the past who helped pave the way to change attitudes about women in this profession. I hope that someday my daughter will find a career that she loves as much as I do mine.

Virginia Shervette (2006)
Department of Biology and Geology, University of South Carolina Aiken

The J Frances Allen Scholarship meant the world to me. I received the award in my final year as a doctoral student, when I was wrapping up my fieldwork in coastal Mississippi and Alabama. I had just given birth to my son Rali and my family was picking up the pieces from Hurricane Katrina. A chunk of my research specimens perished in freezers that lost power for over a week, and field equipment stored at our Mississippi field site was carried away in the flood waters. J Frances Allen funds enabled me to purchase new equipment and finish up my research, pushing me over that last hump so I could write up the final chapter in my dissertation, defend it, and graduate. The scholarship also made it so I could focus in the end and get through the writing worry-free concerning what I had lost. I published every single research chapter in my dissertation (five peer-reviewed papers). Now I am in a tenure-track position at the University of South Carolina Aiken as director of the Fish/Fisheries Conservation Lab. I have research in the United States, Costa Rica, and Ecuador encompassing freshwater, estuarine, and marine fisheries species. I am also a member of the South Carolina AFS chapter, where my students and I regularly participate in the meetings. We are looking forward to the Southern Division Spring meeting in 2014 in Charleston, South Carolina. For me, the J Frances Allen Scholarship accomplished the goals it was set up to do: it encouraged and enabled me to become an active fisheries professional.

Anne M. Cooper (2007)
Professional Officer for Advisory Services, International Council for the Exploration of the Sea, Copenhagen

I was awarded the J Frances Allen scholarship in 2007 while I was finishing my Ph.D. in conservation biology at the University of Minnesota. Trained in fisheries ecology, population genetics, and risk assessment, my diverse scientific background and interests in federal policy led me to Washington, D.C., where I worked with the U.S. Senate Commerce, Science and Transportation Committee on international fisheries and protected species policy, the Science Committee in the U.S. House of Representatives to develop oceans and climate policy, and the undersecretary's office at the National Oceanic and Atmospheric Administration. Today I work with the International Council for the Exploration of the Sea in Copenhagen, Denmark, where I guide the development and implementation of methods to assess data limited fish stocks in the North Atlantic as well as to identify potential marine protected areas in the Baltic Sea. As a student, I often felt caught between the two worlds of conservation and fisheries science. Receiving the J Frances Allen Scholarship revealed to me that my work is accepted by an accomplished and diverse community of fisheries professionals who have made their own valuable and unique contributions in the field of fisheries science. This award was an honor for me as a student, but now that I am a professional this award is a responsibility that I take seriously. My career goal is to be a leader in shaping sustainable fishery policies and practices in the international arena. My motivation is a deep commitment to improving people's lives and the health of aquatic ecosystems. As a J Frances Allen awardee, I work to support sustainable commercial fisheries, healthy oceans, and vibrant coastal communities the world over.

Melissa Wuellner (2008)
Assistant Professor and Distance Education Coordinator, Department of Natural Resource Management, South Dakota State University

Reviewing the list of previous and more recent winners and honorable mentions of the J Frances Allen Scholarship humbles me. The women who have received this award are awe-inspiring, and I am beyond thrilled to be included in that list. I believe that one of the factors that helped in the decision to give me the award was the mention of my service to the AFS on my application. The Student Subsection and the Dakota Chapter provided excellent leadership opportunities, and I had no shortage of great ideas and driven colleagues to help put initiatives in place. The award encouraged me to continue pursuing service opportunities at all levels of the AFS, and I have been privileged to have been given new chances to serve the society that has already given so much to me. Though the scholarship did not directly affect my graduate education, it has influenced my education and development as a young professional. I have mentored several graduate students as they applied for (and sometimes won) the J Frances Allen Scholarship, the Skinner Memorial Award, and the Janice Fenske Memorial Award (among others), which allows me to develop my skills as an advisor and educator of undergraduate and graduate students. I hope to continue honoring the memory of a pioneer as inspiring as J Frances Allen throughout my career, through my work as an educator, and as a member of the AFS.

Karen Murchie (2009)
Assistant Professor, School of Chemistry, Environmental & Life Sciences, College of the Bahamas

I was a runner-up for the J Frances Allen Scholarship in 2008 and the winner of the scholarship in 2009. Receiving the award in Nashville at the annual AFS conference in front of so many esteemed fisheries scientists strengthened my commitment to the AFS. I have since continued to serve on the executive committee for the Canadian Aquatic Resources Section of the AFS and have been a judge for the J Frances Allen Scholarship (2010–2012). The money from the scholarship is extremely helpful, but the biggest impact comes from seeing in your peers' eyes that you have potential as a fisheries scientist and that you are committed to striving for excellence. That boost of confidence is overwhelmingly important—especially for young scientists. It propelled me to a joint postdoc position with the Great Lakes Fishery Commission and Carleton University (June 2010–July 2011) and then to an assistant professor position at the College of The Bahamas (August 2011–current). I am very grateful for the legacy that J Frances Allen has left behind and hope that I can follow in her footsteps to foster the love of fisheries science with all those with whom I interact.

Neala W. Kendall (2011)
National Research Council Postdoctoral Research Associate, National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center

I received the scholarship in 2011, the year I defended my Ph.D. I used the money to buy a laptop computer. It was essential for me to have access to a powerful computer as I transitioned from my doctorate to my postdoc and completed the writing and publication of my dissertation. Because of the new computer, I was able to submit for publication the third and fourth chapters of my dissertation at the end of my doctorate, which helped me to secure a great postdoc that has set me on my way in the professional world. Along with receiving the J Frances Allen Scholarship, I served as student activities chairperson at the AFS annual meeting in Seattle in 2011. Being honored with this position and this award helped me to understand the importance and benefits of AFS. Through AFS I have met a number of great colleagues and friends, have had the opportunity to network for career information and research ideas, and have been able to further my education and professional development through scholarships, mentorship, and advice. I will continue to be involved in the AFS and hope to be able to give back to younger scientists as I progress in my career.

For those who would like information on how to contribute to the J Frances Allen Scholarship Fund, please contact AFS coordinator Eva Przygodzki at eprzygod@fisheries.org or call (301) 897-8616 ext. 203. The findings and conclusions in this article are those of the author(s) and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Linking Climate Change and Fish Conservation Efforts Using Spatially Explicit Decision Support Tools

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ABSTRACT: *Fisheries professionals are increasingly tasked with incorporating climate change projections into their decisions. Here we demonstrate how a structured decision framework, coupled with analytical tools and spatial data sets, can help integrate climate and biological information to evaluate management alternatives. We present examples that link downscaled climate change scenarios to fish populations for two common types of problems: (1) strategic spatial prioritization of limited conservation resources and (2) deciding whether removing migration barriers would benefit a native fish also threatened with invasion by a nonnative competitor. We used Bayesian networks (BNs) to translate each decision problem into a quantitative tool and implemented these models under historical and future climate projections. The spatial prioritization BN predicted a substantial loss of habitat for the target species by the 2080s and provided a means to map habitats and populations most likely to persist under future climate projections. The barrier BN applied to three streams predicted that barrier removal decisions—previously made assuming a stationary climate—were likely robust under the climate scenario considered. The examples demonstrate the benefit of structuring the decision-making process to clarify management objectives, formalize assumptions, synthesize current understanding about climate effects on fish populations, and identify key uncertainties requiring further investigation.*

Acoplamiento entre el Cambio Climático y la Conservación de Peces mediante Herramientas de Decisión Espacialmente Explícitas

RESUMEN: *los profesionales de las pesquerías están siendo presionados para incorporar proyecciones de cambio climático en sus decisiones. En este trabajo se demuestra cómo un marco de decisiones bien estructurado, acoplado con herramientas analíticas y bases de datos espaciales, puede ayudar a integrar información climática y biológica para evaluar alternativas de manejo. Se presentan ejemplos que relacionan escenarios de cambio climático con poblaciones de peces, con el fin de abordar dos tipos comunes de problemas: (1) priorización espacial estratégica de recursos limitados para la conservación y (2) decidir si la remoción de barreras migratorias beneficiaría a los peces nativos, los cuales también están amenazados por la introducción de competidores foráneos. Se utilizaron redes Bayesianas (RBs) para traducir cada problema de decisión en una herramienta cuantitativa y se implementaron estos modelos bajo proyecciones climáticas históricas y hacia el futuro. La priorización espacial por medio de RB predijo una pérdida sustancial de hábitat de las especies objetivo para el año 2080, y proveyó medios para mapear tanto los hábitats como las poblaciones que más posibilidades tienen de persistir considerando los distintos escenarios climáticos en el futuro. La simulación de barreras mediante RB aplicadas a tres ríos predijo que las decisiones que implicaban una remoción–previamente hechas asumiendo un clima constante–serían, muy posiblemente, robustas bajo el escenario climático considerado. Estos ejemplos demuestran los beneficios de estructurar el proceso de toma de decisiones con la finalidad de clarificar objetivos de manejo, formalizar las suposiciones de los modelos, sintetizar el entendimiento que hasta la fecha se tiene acerca del efecto del clima en las poblaciones de peces e identificar piezas clave de incertidumbre que requieren de investigación ulterior.*

INTRODUCTION

Climate is changing in ways that may profoundly affect aquatic systems (O'Reilly et al. 2003; Winder and Schindler 2004; Parmesan 2006). Trends in climate-influenced abiotic factors, such as water temperature and streamflow, are already apparent in North America (Stewart et al. 2005; Kaushal et al. 2010; Isaak et al. 2011), as well as worldwide (Moatar and Gailhard 2006; Webb and Nobilis 2007; Schneider and Hook 2010). These changes have already been associated with fish population declines in Europe (Hari et al. 2006; Winfield et al. 2010; Almodóvar et al. 2012) and extirpations in populations of other aquatic species (Pounds et al. 2006; Durance and Ormerod 2010) and are predicted to alter coldwater fish distributions across Western North America (Keleher and Rahel 1996; Rieman et al. 2007; Wenger et al. 2011b). As a consequence, biologists are beginning to consider climate trends in planning and assessment, and resource management agencies are adopting climate change policies (U.S. Forest Service 2008, 2011; U.S.

Fish and Wildlife Service 2010). Managers need tractable approaches to assess the vulnerability of populations and habitats and to guide the prioritization of limited management resources.

The amount of climate science information available to conservation professionals is rapidly expanding (Overpeck et al. 2011; Porter et al. 2012). However, the sheer volume of data can be overwhelming and compound an already complicated decision context that may include other non-climate stressors, such as consumptive water use, habitat fragmentation, and invasive species. Initiatives to integrate climate data are helping bring that science into application, but challenges remain. For example, climate assessments for freshwater salmonids have utilized qualitative indices based on expert opinion or rules (Williams et al. 2009) or statistical relationships expressed in bioclimatic models (Flebbe et al. 2006; Rieman et al. 2007; Wenger et al. 2011b) to predict effects or "risks." These approaches are useful, but greater utility could be achieved by explicitly linking these models to the decision process and management objectives. One approach is to develop and apply integrative decision support tools that formalize known or potential linkages between climate and fish population biology. These tools help structure the decision and also identify mechanisms, refine critical management questions, and make it possible to explore model assumptions. In an increasing number of instances, data can be derived from spatially explicit stream habitat models representing climate scenarios, which permits evaluation of choices in real-world coordinates.

Our objectives are to present two examples of a decision process and explore the utility of decision support tools that link climate change to fish population responses. A number of general frameworks have been proposed to assess the effect of climate change on aquatic systems (e.g., Johnson and Weaver 2009) or fisheries (e.g., Chin et al. 2010; Johnson and Welch 2010); these examples draw extensively on risk assessment or structured decision making. Our approach is grounded in these methods. This article describes the three steps we followed to adapt a decision support tool for two fishery management problems: (1) clearly defining essential problem elements (e.g., Johnson and Weaver 2009; National Research Council [NRC] 2009); (2) building conceptual models linking climate drivers to focal species; and (3) converting the conceptual model to an analytical decision support tool parameterized with relevant ecological data and driven by future climate projections. Our objective was not to build the most comprehensive models possible but to illustrate the process through case studies of two decision problems from the Northern Rocky Mountains of the Western United States (Figure 1). We demonstrate how the models could provide a conduit between the growing amount of climate information for streams and the decision-making process (NRC 2009).

The first decision problem involves spatial prioritization. The goal is to rank a number of streams, watersheds, or populations for conservation, restoration, or some other purpose that requires a strategic allocation of limited management resources. Our example here focuses on habitat potential related to climate

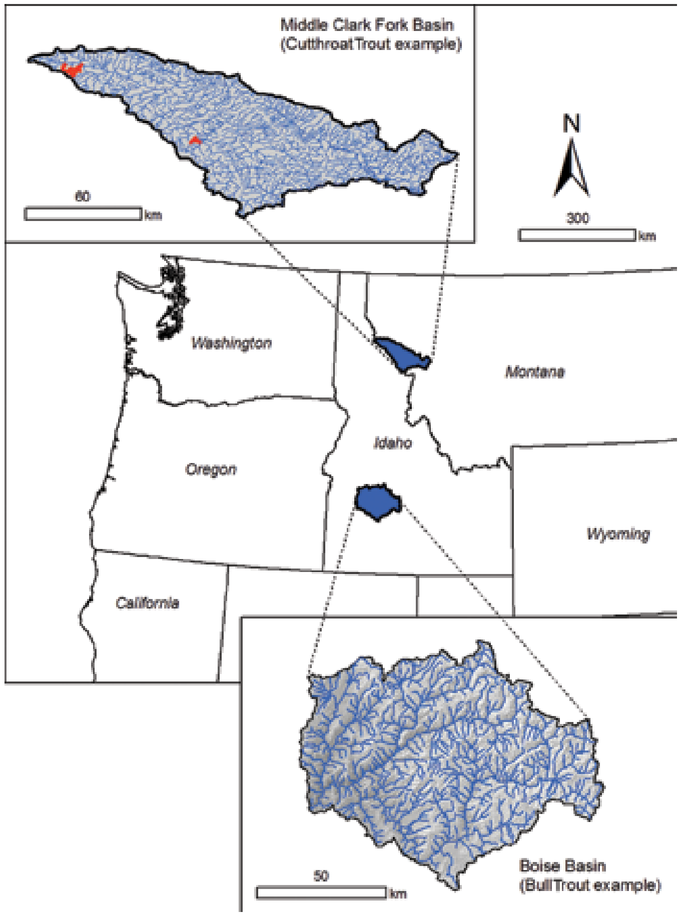

Figure 1. Location of two case studies used to illustrate application of spatially explicit decision support tools to evaluate management decisions for aquatic species under climate change.

change scenarios for Bull Trout (*Salvelinus confluentus*) populations across a river network. The second problem illustrates a yes-or-no decision about a specific management action among streams. This example focuses on removing or maintaining fish barriers in streams containing isolated populations of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) threatened by invading Brook Trout (*Salvelinus fontinalis*) and whether this decision changes in the context of future climate conditions.

APPROACH AND METHODS

A Generalizable Approach to the Decision Process

To help organize our thinking, we structured our analytical process around a logical sequence of steps; here we describe the sequence in general terms. In subsequent paragraphs we build and apply decision support models for the two examples.

1. *Define the essential elements of the problem.* The first step in decision analysis is to identify the essential elements of the problem, including (a) values and objectives; (b) the decision to make; (c) uncertainty; and (d) consequences (Clemen 1996). This process may sound obvious but can be surprisingly difficult in decisions related to how climate affects species. Often management agencies are given vague mandates to incorporate climate projections into

their management activities or to conduct a climate vulnerability or climate sensitivity analysis. This needs to be translated into a clear decision problem or series of decision problems.

2. *Build a conceptual model linking climate drivers to focal species.* A conceptual model can be represented initially as a box-and-arrow diagram: boxes represent variables or conditions integral to the decision and arrows depict causal relationships. The conceptual model synthesizes the most plausible hypotheses, experimental data, observational data, statistical or empirical relationships, and expert opinion. Constructing this model helps formalize understanding and assumptions; this focuses discussion, refines logic, and identifies uncertainties. Overall, the conceptual model provides a template to structure thinking about the problem (Marcot et al. 2001, 2006; Uusitalo 2007). The models can be as detailed or simple as information and knowledge allow, but in general they should be no more complex than necessary to represent the problem at hand. Additional detail can always be added if it becomes clear that it is needed.

3. *Convert the conceptual model to a decision support model.* The next step is to quantify the relationships in the conceptual model so that it can be used to make predictions and evaluate management alternatives. There are different tools available for creating such a parameterized decision support model. We used Bayesian networks (BNs) in both examples. Bayesian networks are graphical models that represent probabilistic relationships among a set of variables or nodes and support consistent reasoning based on existing knowledge and uncertainty (Jensen 1996; Marcot et al. 2001; Newton et al. 2007). Causal relationships among nodes are represented by directed arrows called "links." Bayesian networks are graphical, so there is a natural connection between the conceptual model and the quantitative tool. Parameterization is accomplished by quantifying the conditional relationships represented by the nodes and their links. For each node, a discrete set of states representing possible conditions or values is defined based on that node's meaning. A node's conditional probability table quantifies the probability of any state given the conditions in the contributing nodes, including any interactions among them. Bayesian networks have some recognized limitations. For one, they are not able to directly represent cycles or feedback loops (Borsuk et al. 2006). Other decision support constructs, such as decision trees (Clemen and Reilly 2001), structural equation models (Pearl 2009), or fuzzy sets (Zadeh 1988), can be used in similar ways. We chose BNs because of their previous application to climate modeling (Amstrup et al. 2010; Jay et al. 2011) and our familiarity with development and application of these models in fisheries management (Rieman et al. 2001; Peterson et al. 2008) Bayesian networks are well suited for climate modeling because they are transparent, can integrate different classes of information, and are good for exploring uncertainty and competing hypotheses.

   The information used to parameterize and implement the model can come from many sources: field data, empirical relationships from external studies, expert opinion, output from other process-based physical models (e.g., climate models), or stochastic life history models (e.g., Lee and Rieman 1997). In Bayesian networks, nodes that do not have arrows pointing to them are called "root nodes," and they require some form of external input data to drive the model. We used climate variables to initiate the root nodes and drive the BNs in our examples, and a variety of climate data are available to model aquatic species (Appendix A, see http://fisheries.org/appendices). The probabilities for all other nodes, which have one or more arrows pointing to them, are calculated based on the relationships defined in the probability tables. The probability tables can be developed using the same suite of information described above.

Application of the Decision Process to the Examples

Here we show how we organized the decision analyses and built analytical tools for the two real-world examples. We then link climate projections to the tools to help with prioritization at the basin scale (Bull Trout) or evaluate management decisions with barriers (Cutthroat Trout).

Example 1. Prioritization of Bull Trout in the Boise River Basin

Study Area and Context

Bull Trout is listed as threatened under the U.S. Endangered Species Act (USFWS 1999) and is the focus of active management efforts by state and federal agencies. The species' temperature sensitivity (Selong et al. 2001) has prompted concerns that climate change could lead to substantial range contractions (Rieman et al. 1997, 2007). Our focal area in the Boise River basin (BRB) of central Idaho is near the southern limit of the species' range (Figure 1) and is characterized by high seasonal and spatial variability in temperature and precipitation. Bull Trout spawn and juveniles rear in the coldest headwater streams, so natal habitats are often patchy across river networks. The BRB contains 22 habitat patches occupied by Bull Trout (Dunham and Rieman 1999; Whiteley et al. 2006), where a "patch" is defined as a continuous network of thermally suitable habitat (Rieman and McIntyre 1995; Dunham and Rieman 1999). Habitat conditions appear to be changing in the BRB, and thermally suitable and high-quality habitats have been lost in recent decades (Isaak et al. 2010).

Problem Definition

We assume that a land management agency or another entity has been directed to consider climate change in its management plans. We assume also that the biologists involved focus on Bull Trout and their ultimate objective is to maintain a healthy, self-sustaining Bull Trout metapopulation by creating or maintaining suitable spawning habitats and connectivity over the next 70 years. A specific decision is where to focus conservation efforts, such as habitat protection or restoration. A key issue to consider will be the size and distribution of suitable spawning habitats, which are constrained, in part, by climatic conditions (Dunham and Rieman 1999; Rieman et al. 2007). Consequences of the decision include which populations are supported, as well as financial costs associated with implementing conservation efforts, whether additional Bull Trout management activities are needed, and what effects will occur for other species. A common conservation approach is to build from existing strengths. The idea here is to focus on populations with the best chance to persist or habitats most likely to support Bull Trout in the future and invest where the greatest benefits can be achieved for the least cost. A different objective might entail different decision logic. If the objective were to maximize among-population genetic diversity or distinct traits that reside within specific populations, then so-called peripheral populations may be of greater importance (Lesica and Allendorf 1995). For simplicity, we focus on building from existing strengths.

Conceptual Model

Our goal was to estimate the occurrence probability of Bull Trout for many individual stream segments, and the conceptual model represents the key processes that we think likely to influence those probabilities (Figure 2A). We constructed the conceptual model from first principles, and it resembles a simplified version of one described in Rieman and Isaak (2010).

Habitat potential for Bull Trout is determined by stream size, temperature, flow regime, and channel gradient. We assumed that nonnative Brook Trout would interact competitively with juvenile Bull Trout, and the strength of that interaction might vary with climate (Rieman et al. 2006; McMahon et al. 2007; Rodtka and Volpe 2007). We did not consider habitat degradation because the objective was simply to determine which stream segments would most likely support Bull Trout based on intrinsic factors and biotic interactions with Brook Trout. We assumed that extrinsic factors associated with degradation could later be mitigated through restoration actions where it made sense to do so. For convenience the decision is not formally represented in the diagram, because it involves comparisons across all stream segments or groups of segments after the predictions are made.

Bayesian Network

The BN model captured the key physical and ecological processes that we believe, given existing knowledge, will influence the occurrence of Bull Trout in response to climate change (Table 1, Figure 2B).We sought to keep the model relatively simple because it is easier to track the logic and implement conditional probability tables for nodes with three or fewer links (Marcot et al. 2006)—though that is not a constraint of the approach. The model can be revised as new information and questions emerge.

The parameterized BN predicts the occurrence of Bull Trout as a function of habitat suitability, occurrence of Brook Trout, and their interactions mediated by climate—in this case streamflows and temperature. Node states represent potential conditions or thresholds important for the characteristic or relationship of interest. For example, Bull Trout and Brook Trout have different thermal optima, with Brook Trout more tolerant of higher water temperatures (McMahon et al. 2007; Isaak et al. 2009). Rearing areas for Bull Trout are generally associated with colder stream reaches. We used five states for mean summer water temperature to depict these preferences. Thermal influences for Bull Trout were modeled as a logistic-type relationship across the five states, with the species preferring mean water temperatures <10°C (e.g., Dunham et al. 2003; Isaak et al. 2010) and preference declining rapidly as temperature increases (e.g., Wenger et al. 2011a). In contrast, thermal influences for Brook Trout were portrayed as a dome-shaped curve with preferred temperatures between 10°C to 15°C (e.g., Isaak et al. 2009; Wenger et al. 2011a). Synthesis of relevant information and a similar logic process was used to define states of the other nodes (Appendix B, see http://fisheries.org/appendices).

Climate Data

We used a single climate scenario (A1B) with downscaled projections of temperature and hydrology consistent with the Parallel Climate Model, Version 1 (PCM1) general circulation model (GCM) to provide representative climate projections for the 2040s and 2080s. The A1B scenario is considered a "mid-range" scenario for greenhouse gas accumulation that assumes a world of rapid economic growth, a global population that peaks in mid-century, and rapid introduction of new technologies balanced between fossil-intensive and non-fossil-intensive energy resources (Intergovernmental Panel on Climate Change 2007). The PCM1 GCM projects less warming and more summer precipitation across the interior Western United States compared to other GCMs (Littell et al. 2010). Projections based on scenario A1B and the PCM1 model have been used to model changes in trout distributions in the Northern Rockies (e.g., Wenger et al. 2011b).

There are a variety of statistical methods and data sources available to generate temperature and hydrologic projections (Appendix A, see http://fisheries.org/appendices). For the Bull Trout example, historical and future summer air temperatures were translated to stream temperatures in the BRB using the temperature model developed in Isaak et al. (2010). Historic conditions were based on averages of recent air temperatures and flows observed at climate stations in the basin. The future stream temperature scenarios were based on rates of air temperature increases of 0.44°C per decade and flow declines of 5% per decade. These rates approximate that of the PCM1 GCM used to force a hydrologic model and derive stream flows for individual National Hydrography Dataset Plus (NHD+) segments (Wenger et al. 2010, 2011b).

Strategic Prioritization

The probability of occupancy of Bull Trout within a stream segment was calculated during historical and future

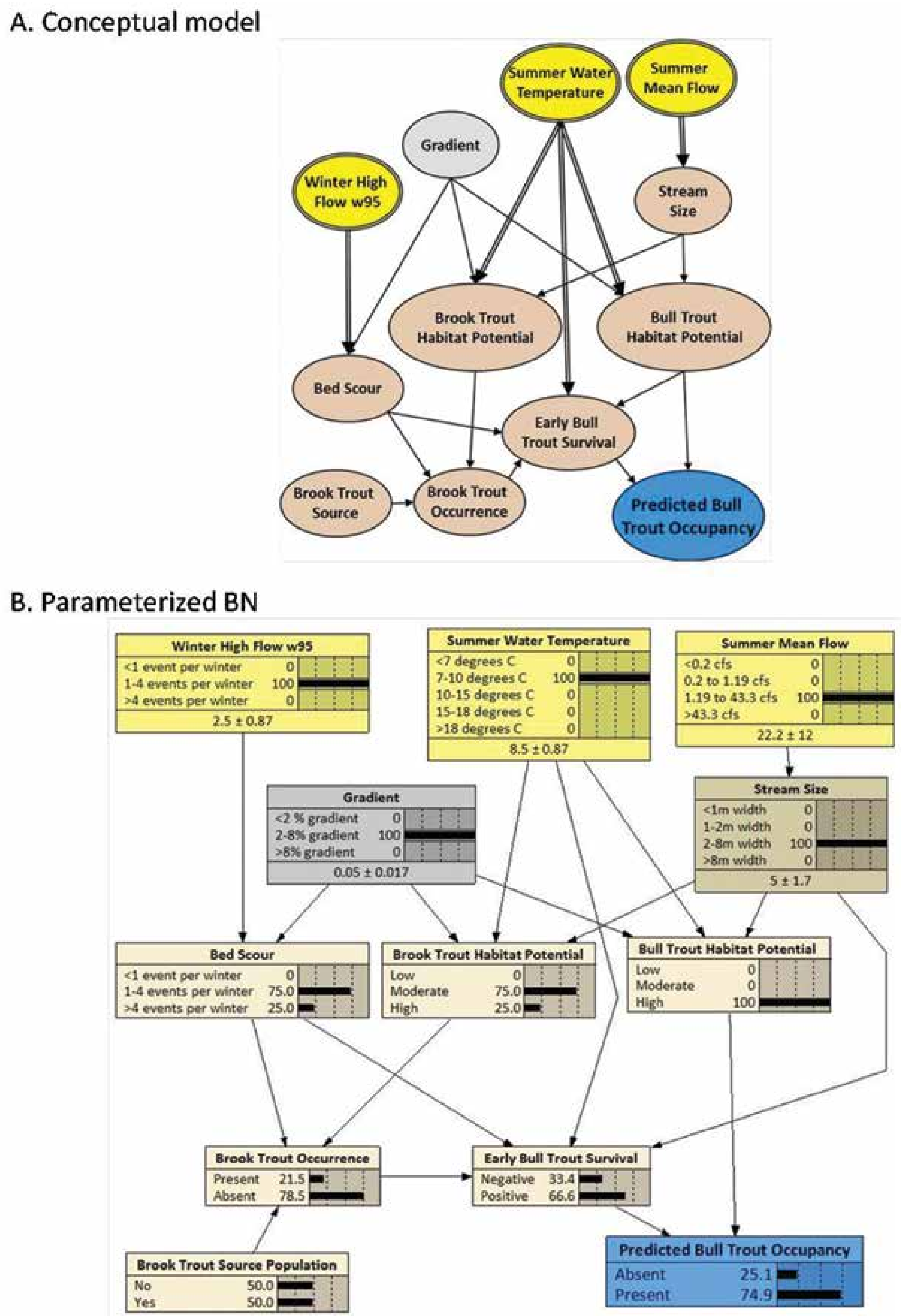

Figure 2. (A) Conceptual model and (B) resulting Bayesian network used for the spatial prioritization exercise with Bull Trout in the Boise River basin. Arrows indicate functional or cause-and-effect relationships between connected variables or nodes. The BN estimates the probability that Bull Trout will occur in a steam segment (blue box) as a function of climatically controlled variables (yellow boxes) that affect habitat or survival, channel gradient, and presence of a nonnative competitor. The probability that a node will be in a particular state is indicated by the value of the bar next to each state name. For example, panel B depicts a case where the mean summer water temperature is known (100% probability 7–10 °C) but the presence of Brook Trout source population is unknown (50% yes, 50% no).

Table 1. Node (variable) and state definitions for Bull Trout Bayesian network (BN).

Node	Definition	States
Winter high flow w95[a]	The number of days in the winter (December 1–February 28) in which flows are among the highest 5% for the year	<1 event per winter, 1–4 events per winter, and >4 events per winter
Summer water temperature[a]	Mean water temperature from mid-July through mid-September	<7°C, 7–10°C, 10–15°C, 15–18°C, and >18°C
Summer mean flow[a]	Mean surface water flow in cubic feet per second (cfs) during the summer, defined as the first day after June 1 when flows fell below the mean annual value through September 30	<0.2 cfs, 0.2–1.19 cfs, 1.19–43.3 cfs, and >43.3 cfs
Gradient	Channel gradient in the stream segment	<2%, 2–8%, and 8%
Stream size	Mean wetted width during summer base flow	<1 m, 1–2 m, 2–8 m, and >8 m
Bed scour	Frequency of winter scour, which can cause direct mortality of developing embryos and newly emerged fry of fall-spawning Brook Trout and Bull Trout	<1 event per winter, 1–4 events per winter, and >4 events per winter
Brook Trout habitat potential	Intrinsic potential for stream segment to support Brook Trout (natal habitat) at a given density, assuming that the habitat is fully seeded and constrained only by channel gradient, water temperature, and stream size	Low: Brook Trout absent or rare; moderate: Brook Trout present at low-moderate density; and high: Brook Trout present at high density
Brook Trout source population	Presence of a Brook Trout population in a connected stream network that is capable of producing immigrants that invade a stream segment during a given time horizon	No, yes
Brook Trout occurrence	Potential occurrence of Brook Trout in a segment is constrained by the presence of a source population, bed scour, and habitat potential	Present, absent
Bull Trout habitat potential	Intrinsic potential for stream segment to support Bull Trout spawning and early rearing (natal habitat) constrained only by channel gradient, water temperature, and stream size	Low: Bull Trout absent or rare; moderate: Bull Trout present at low-moderate density; and high: Bull Trout present at high density
Early Bull Trout survival	Potential population growth rate as a function of survival from embryo deposition to age 2 as mediated by interactions between scour, stream size, and competitive interactions with nonnative Brook Trout. This stage-specific survival rate is assumed to be the only constraint on population growth	Positive: survival rate sufficient for positive population growth; negative: survival rate not sufficient for positive population growth
Predicted Bull Trout occupancy	Probability that Bull Trout occur in a segment depends on the natal habitat potential and whether survival has the potential to confer a stable or positive population growth rate. In effect, this represents the habitat's realized potential to support Bull Trout	Present, absent

[a] Climatically driven nodes that are equivalent to the same nodes in the Cutthroat Trout BN (see Figure 4) but have different state or threshold values

scenarios and with or without Brook Trout. The historical period represents contemporary conditions based on recent stream temperature and flow and provides a baseline for comparison of future climate projections. The "with Brook Trout" case assumes that Brook Trout could occur anywhere in the stream network where the habitat can support the species and with no condition on its current distribution. We used the modeling program Netica (Norsys 2010) to implement the BN and generated predictions for each of the 1,847 NHD+ stream segments in the BRB by inputting a data file containing temperature and flow projections for each time period. To provide a model output that was also amenable to population-level interpretation, we aggregated segment predictions into continuous networks or patches of habitat (sensu Dunham et al. 2002; Rieman et al. 2007). Each patch consisted of all stream segments above and including stream segments where mean summer temperatures were 10°C or lower (Isaak et al. 2010). Thus, patches here delineate stream networks judged to have high habitat potential based strictly on the current thermal regime. Patches of this sort have been used previously to approximate local populations of Bull Trout that may compose larger metapopulations (Rieman and McIntyre 1995; Dunham and Rieman 1999; Whiteley et al. 2006). Patch size is also believed to be an important constraint on the resilience of populations (U.S. Fish and Wildlife Service 2008) that may be influenced by climate change (Rieman et al. 1997, 2007; Dunham et al. 2003). For each segment, we multiplied the predicted probability of occurrence by segment length to provide an estimated length of occupancy. For example, a 10-km segment with occurrence probability 0.6 yielded an estimated occupancy length of 6 km. We summed the predicted occupancy length across segments within a patch to provide a patch-level estimate for occupancy. Patches were then mapped in one of five categories based on occupancy lengths, with categories selected to approximate those used previously for describing a range of Bull Trout occupancy probabilities from high to low (Rieman and McIntyre 1995; Isaak et al. 2010).

Example 2. Barrier Decision for Cutthroat Trout in the Middle Clark Fork Basin

Study Area and Context

Cutthroat Trout are native to much of the interior West and the West Coast of the United States. The number of healthy populations has declined and local abundances have decreased substantially due to habitat alteration and the introduction of nonnative species (Young et al. 1995 and references therein). In many regions, artificial barriers have been used to isolate local populations from invasive fishes, particularly Brook Trout and Rainbow Trout (*Oncorhynchus mykiss*). Although this practice is often effective in its main purpose, it limits migration and genetic exchange among Cutthroat Trout populations. Thus, the question of whether isolation is a benefit or threat has been the subject of research and debate and is generally believed to be context dependent (Fausch et al. 2009). It is possible that climate change could alter the decision regarding barrier removal at a given location because warming could have differential effects on Cutthroat Trout and nonnative competitors such as Brook Trout (Wenger et al. 2011b).

In the Cutthroat Trout example, we reassess the results of a previous study of this problem (Peterson et al. 2008) by incorporating climate change projections. The focus area covers three small watersheds in the Middle Clark Fork basin in western Montana: Deep, Dominion, and Silver creeks. Each stream contains a resident population of Westslope Cutthroat Trout fragmented by one (Silver), two (Dominion), or three culvert barriers (Deep). The streams would presumably support migratory individuals if some or all of these barriers were removed. The barriers isolate very small (<3 km) stream networks in Deep and Dominion creeks and a much larger one (>10 km) in Silver Creek. Habitat conditions have been degraded by land use in Deep Creek. For all streams, Brook Trout are present in and likely to invade from adjacent main-stem habitats and tributaries or may already be present in lower reaches (Dominion).

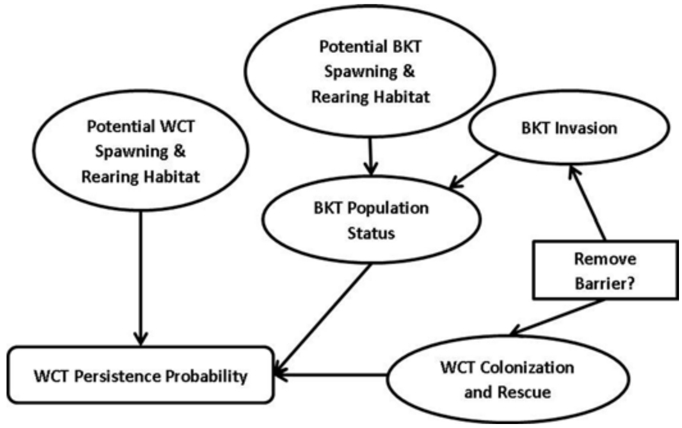

Figure 3. Simple conceptual model representing the decision context for the Cutthroat Trout barrier removal example.

Problem Definition

The decision is whether to keep or remove barriers isolating local populations of Cutthroat Trout. The ultimate objectives are to maximize the probability of persistence for individual populations and focus resources available for barrier management in the most effective way. Uncertainties involve whether Brook Trout will invade, whether this invasion will displace Cutthroat Trout, and whether the connectivity with other Cutthroat Trout populations or the expression of migratory life histories will offset the effects of invasion by Brook Trout or hybridization with Rainbow Trout. Each of these may be influenced by future climate. The consequences are the future probabilities of persistence for the Cutthroat Trout populations and the relative benefits that can be anticipated for the costs of barrier removal or alternative management actions, such as habitat restoration or removal of nonnative trout species.

Conceptual Model

The objective expressed in the simple conceptual model is to maximize the probability of persistence of Cutthroat Trout; the decision is whether to remove a barrier that prevents Brook Trout invasion but also prevents connections with other Cutthroat Trout populations (Figure 3). Persistence of Cutthroat Trout depends on the habitat constraints on population growth rate, population size, and demographic support from other populations (see Peterson et al. [2008] for supporting discussion). Cutthroat Trout population growth rate will be influenced by interaction with Brook Trout, which in turn depend on their own habitat potentials and strength of source populations.

This simple model is a good start but may not be sufficient because we know that habitat potential for both species varies from location to location. If the additional detail is important, this variability can be measured through field surveys or estimated from other information, such as geographic information system (GIS) layers, remote sensing data, or model outputs. We assume that habitat potential for both species varies along a continuum of stream size, temperature, flow regime, channel gradient, and perhaps other variables that are intrinsic to the watershed and streams of interest (Wenger et al. 2011a). We added some of these additional variables to express spatial variation in habitat potential. The notion of species-specific habitat potential used here represents the association between fish use and persistent stream attributes (equivalent to intrinsic potential; sensu Burnett et al. 2007). Realized habitat conditions depend on how that potential is modified by extrinsic factors, such as habitat degradation. Ultimately the presence and size of the population in any stream will be some function of the realized habitat conditions and the outcome of inter- and intraspecific biotic interactions. Competition between the two species is central to the decision problem, so this mechanism must be considered in the model. Of particular importance is the potential for reduced survival of juvenile Cutthroat Trout when Brook Trout are present (Peterson et al. 2004).These and other ideas are incorporated into an expanded version of the conceptual model based on a previous study of the invasion or isolation problem (Peterson et al. 2008). In the expanded model (Figure 4), yellow ovals represent the variables directly or indirectly influenced by climate that could change in the future.

Bayesian Network

To evaluate potential climate effects on barrier management decisions, we modified an existing BN by adding links to streamflow and temperature variables that are influenced by climate (Figure 4). Briefly, the existing BN considers the environmental factors influencing Westslope Cutthroat Trout and nonnative Brook Trout habitat, the species' interactions, and how placement or removal of invasion barriers may affect persistence of a local Cutthroat Trout population (Peterson et al. 2008). To revise the model to consider climate, we simply added three new nodes—summer air temperature, summer mean flow, and winter high flow w95—that were derived from downscaled climate projections (Wenger et al. 2011b). These new nodes were then linked to existing nodes for water temperature, stream width, and flow regime. Formally, these linkages were defined by the conditional probability tables that translate one variable into another. For example, the conditional probability table for stream width was based on a regression relationship between stream width and summer mean flow derived in the interior Columbia River basin (Appendix C, see http://fisheries.org/appendices).

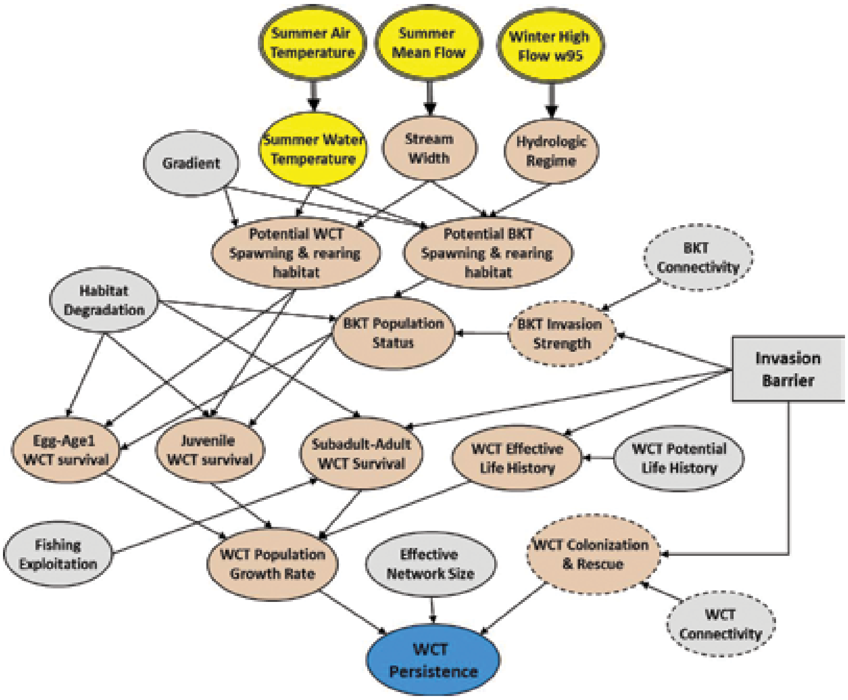

Figure 4. Detailed conceptual model depicting how climatically driven changes in stream temperature and hydrology influence persistence of Westslope Cutthroat Trout when managers are balancing trade-offs between intentional isolation by barrier versus potential invasion by nonnative Brook Trout. The conceptual model was based on Peterson et al. (2008), with the addition of three variables (double outline) that link thermal and hydrologic changes to habitat suitability for both species. Climatically controlled variables are shown in yellow.

This highlights the relative ease with which BNs can be modified to integrate new knowledge (Marcot et al. 2006). This flexibility is advantageous when biologists and managers have neither the time nor resources to develop a new model or tool. Moreover, we were interested in the implications of climate change for a decision framework that already had considerable investment and support in the ongoing discussion regarding barrier management (Fausch et al. 2006, 2009; Peterson et al. 2008). The modified BN retains the parameterization of the original model, and the new nodes allow the user to evaluate how climate might alter interactions between barriers, Brook Trout, and Cutthroat Trout in the future.

Climate Data

Hydrologic variables for the middle Clark Fork were based on Variable Infiltration Capacity hydrologic model (VIC) output forced by climate data from the PCM1 GCM under an A1B emissions scenario. Mean summer air temperatures were based on the same gridded air temperature values used to force the VIC hydrologic model (Wenger et al. 2011a). To translate from air to water temperature, we assumed that mean summer water temperature was ~0.8 times the mean summer air temperature (Wenger et al. 2011a). To generate water temperature values for the 2040s, we assumed air warming rates of 0.6°C per decade and that stream temperatures warmed at 60% of this rate.

Barrier Decisions

We used the BN to evaluate a range of possible decisions in these streams under historical and future conditions (2040s), given the number and location of barriers and any additional threats (Peterson et al. 2008). In Silver Creek, the only decision was whether or not to remove the barrier at the creek mouth. In Dominion Creek, potential actions were to (1) remove the upper barrier, (2) remove the lower barrier, (3) remove both barriers, (4) eradicate Brook Trout between the barriers, and (5) combine actions 1 and 4. In Deep Creek, the two upper barriers were very close together and were considered jointly. Options in Deep Creek were to (1) remove the lower barrier, (2) remove the upper barriers, (3) remove all barriers, and (4) restore degraded habitat alone or in conjunction with barrier removal scenarios 1–3. In each stream we applied the Cutthroat Trout BN under these different combinations of barrier removal and habitat rehabilitation.

RESULTS

Prioritization of Bull Trout in the BRB

Under historical conditions, the BN predicted moderate to high probability (>0.4) of Bull Trout occupancy in 28.6% of the total segment length (TSL) in the BRB and that there were 12 of 22 patches with at least 10 km of stream likely to be occupied by Bull Trout (Table 2). The extent and size of stream segments and patches capable of supporting Bull Trout in the future were predicted to shrink dramatically (Table 2; Figure 5). By the 2040s, the aggregate length of moderate-to-high probability segments and number of patches were predicted to decline to 10.8% of TSL and to 7 patches where at least 10 km of stream could be occupied by Bull Trout; by the 2080s, these lengths shrank to 1.4% of TSL and there were only 4 patches where at least 10 km of stream could be occupied. Reductions in the probability of occupancy of Bull Trout were most evident at lower elevations and were attributed to temperature increases, but summer flow reductions at the upper extent of the stream network also reduced the probability of occurrence.

The presence of Brook Trout within a stream segment was predicted to have small effects on the probability of occupancy of Bull Trout compared to changes in climatic factors, especially by the 2080s (Table 2). Brook Trout had little effect in segments where the probability of Bull Trout occurrence was relatively high (>0.6) but larger effects in segments initially having a moderate probability of occupancy (0.4–0.6). Within patches, occupied stream length tended to decrease when Brook Trout were present but, again, these changes were small compared to climate effects. In the future scenarios, Brook Trout did not dramatically alter the distribution and relative position of habitats likely to be occupied by Bull Trout, which were increasingly constrained to headwater reaches.

There are different ways in which a manager could use these results to prioritize populations for conservation and restoration. The future warming trajectory of the Earth is uncertain, so a conservative approach might focus conservation efforts on the patches most likely to support Bull Trout in the future and that also meet a minimum size criterion (i.e., build from existing strengths). Three patches contain greater than 40 km of habitat predicted to be occupied under recent historical conditions (shown in dark green in Figure 5A) and are projected to still have greater than 20 km of habitat occupied by the 2080s if Brook Trout are not present (Appendix B, see http://fisheries.org/appendices). These three might be viewed as "key patches" (Verboom et al. 2001) or "strongholds" (Haak and Williams 2012) that form the core of a conservation strategy, and management efforts might focus on maximizing the quality of these habitats and removal of any internal migration barriers. If resources permit, a lower patch size criterion could be used and conservation efforts extended to additional patches that would be ranked based on spatial representation and connectivity to larger patches or climate-resistant patches (e.g., Vos et al. 2008). A manager might also choose to conduct targeted monitoring to confirm the effects of predicted habitat declines. For example, Bull Trout populations should be lost first from small, isolated patches or the warmest stream segments at the downstream extents of patches, and monitoring designs could target these areas specifically (Rieman et al. 2006; Isaak et al. 2009).

Table 2. Summary of probability of occurrence and predicted occupancy of Bull Trout by NHD+ segment and patch, respectively, in the Boise River basin (BRB). The analysis encompassed 1,846 NDH+ segments totaling 3,256.2 km habitat and 22 patches.

	Total segment length (km)				
	Predicted probability of occupancy				
Situation	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0
Historical—no Brook Trout	1,776.2	547.7	485.2	228.0	219.2
Historical—with Brook Trout	1,809.8	973.1	26.0	228.0	219.2
2040s—no Brook Trout	2,168.7	736.8	213.1	127.3	10.2
2040s—with Brook Trout	2,168.7	883.9	66.0	127.3	10.2
2080s—no Brook Trout	2,465.9	743.0	18.7	28.4	0
2080s—with Brook Trout	2,465.9	749.8	12.0	28.4	0
	Number of patches				
	Occupied stream length within patch				
	<5 km	5–10 km	10–20 km	20–40 km	>40 km
Historical—no Brook Trout	8	2	6	3	3
Historical—with Brook Trout	9	3	5	2	3
2040s—no Brook Trout	10	5	4	1	2
2040s—with Brook Trout	11	5	3	1	2
2080s—no Brook Trout	14	4	1	3	0
2080s—with Brook Trout	15	4	1	2	0

Barrier Decisions for Cutthroat Trout in the Middle Clark Fork Basin

Mean summer air temperature near the three streams was projected to increase ~2°C by the 2040s, which shifted water temperatures from optimal (10–15°C) to high (15–18°C; Table 3). In Dominion and Deep creeks, winter flood frequencies were predicted to increase from 0.65–0.80 to 2.65–3.85 times per winter as the hydrologic regimes shifted from snowmelt to mixed rain and snowmelt (Table 3). Silver Creek was predicted to experience more than a twofold increase in winter flood frequency. This had no biological effect in the model relative to the historical conditions, because the hydrologic regime did not change and was already in the mixed rain and snowmelt category. Declines in summer mean flow were projected for all streams, but a shift in stream width categories was predicted only for Dominion Creek (Table 3).

In all three streams, the decision with the highest probability of Cutthroat Trout persistence was similar whether the climate was assumed stationary (Peterson et al. 2008) or changing (this study). This suggests that the decision was largely robust to the climate scenario considered. We focus here on Deep Creek (see Figure 6) and Dominion Creek as representative examples (see Appendix C for Silver Creek results).

In Deep Creek, removing all barriers and letting Brook Trout invade, instead of removing just the upper two and preventing invasion, would result in a larger increase in persistence under climate change (0.11 to 0.53, a 3.7-fold relative increase) relative to historical environmental conditions (0.15 to 0.59, 3.0-fold relative increase; Figure 6). Restoring degraded habitat provides an even greater relative benefit under climate change (persistence = 0.73, a 5.5-fold increase) than under historical conditions (0.77, a 4.2-fold increase), and habitat restoration appears even more important if Brook Trout are likely to invade.

In Dominion Creek there was no difference between the 2040s time periods for any barrier removal scenario. Changes in temperature and stream flow (Table 3) had a counteracting effect on Cutthroat Trout, with the net result that the probability of persistence did not change (Appendix C, see http://fisheries.org/appendices).

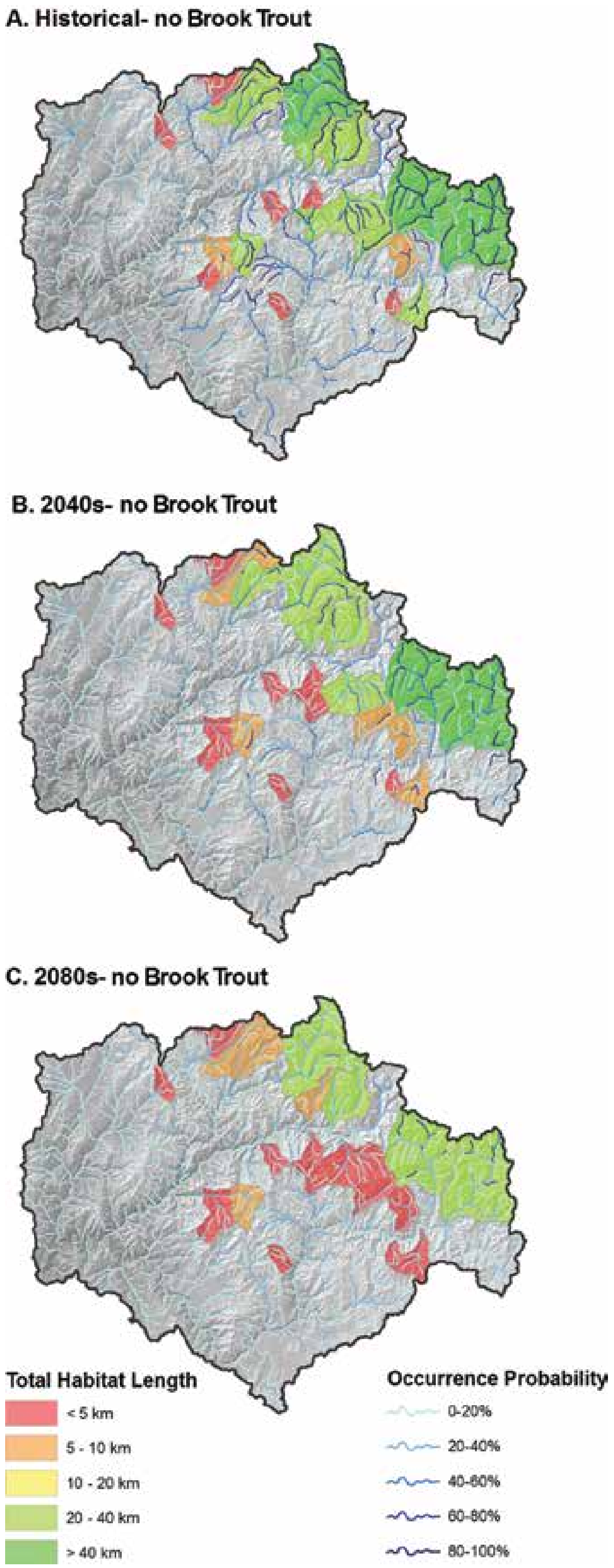

Figure 5. Probability for occurrence and predicted occupancy of Bull Trout in the Boise River basin in the absence of Brook Trout. The individual panels show the probability of occurrence for each segment estimated by the BN under (A) historical or (B) and (C) future environmental conditions. Shaded areas within each panel indicate the estimated length of occupancy within each patch (see text for additional details).

DISCUSSION

We have argued that formal decision models help structure our understanding of climate effects on fish populations. We demonstrated this approach with two real-world examples and found that climate change did not always lead to a radically different outcome. For Bull Trout in the BRB, those habitat patches that are currently the largest and have the highest probability of occurrence are predicted to remain so in the future. Managers and scientists came to similar conclusions in a 2011 workshop (Text Box 1). Application of the Cutthroat Trout BN for three streams indicated that the optimal decision—in terms of maximizing persistence in the presence of Brook Trout—was generally robust to climate change; climate simply reinforced the importance of barrier removal and reestablishing connectivity (e.g., Figure 6). From a manager's perspective, the models may make them more confident that they are proceeding correctly. In the Bull Trout example, the BN model output created a stronger consensus regarding which habitat patches to prioritize (Text Box 1), which could counter the practice of trying to save everything everywhere (Rieman and Isaak 2010). Conservation resources are limited, so choices must be made about where to prioritize; climate change simply adds urgency to these decisions.

The Bull Trout model projected that future occupancy would be strongly influenced by water temperature and that patches with higher probability of occupancy would be distributed further upstream in the BRB in the 2040s and especially in the 2080s. Declines in the probability of occupancy within patches might proceed in two directions simultaneously (range collapse; sensu Moritz et al. 2008): upstream, presumably driven by anticipated increases in water temperature (Rieman et al. 2007; Isaak et al. 2010), and downstream, caused by seasonal dewatering of very small headwater streams. These results notwithstanding, we caution against making irreversible commitment of conservation resources or reprioritizing before decision models and predicted climate effects are adequately validated. The ability to accurately project hydrologic conditions at the fine scale using macroscale models is limited (Wenger et al. 2010). Therefore, short-term management priorities might include (1) biological monitoring to determine whether and how fast distributions are actually shifting, (2) development of better hydrologic estimates through additional empirical monitoring and finer-scale modeling, and (3) establishment of stream temperature monitoring sites (Isaak et al. 2012).

The models can sometimes generate counterintuitive results that suggest the need to revisit current understanding or open new lines of inquiry. In Dominion Creek, the Cutthroat Trout BN predicted no difference in the probability of persistence under the A1B climate scenario compared to recent historical conditions. This cancellation of effect was unexpected. Given projected increases in stream temperatures and decreases in summer base flow, we would have hypothesized that the probability of persistence would decrease. We cannot discount that this could be a modeling artifact influenced by the choice of state values within the BN. However, it will be

Table 3. State and point estimates of climate and surrogate variables (nodes) for three streams used in the invasion barrier Bayesian network (BN) analysis for Westslope Cutthroat Trout under recent historical and future conditions (2040s). Future conditions were based on the A1B emissions scenario and the PCM1 global circulation model, and were used to generate the downscaled estimates for the BN analysis.

	Most probable state (point estimate)					
	Silver Creek		Dominion Creek		Deep Creek	
Node	Historical	2040s	Historical	2040s	Historical	2040s
Water temperature (°C)[a,b]	10–15 (air = 17.2)	15–18 (air = 19.3)	10–15 (air = 17.7)	15–18 (air = 19.7)	10–15 (air = 17.8)	15–18 (air = 19.8)
Winter high flow w95[a,c]	>2 events per winter (3.45)	>2 events per winter (7.35)	<2 events per winter (0.65)	>2 events per winter (3.85)	<2 events per winter (0.8)	>2 events per winter (2.65)
Hydrologic regime[d]	Mixed	Mixed	Snowmelt	Mixed	Snowmelt	Mixed
Summer mean flow (cfs)[a]	1.19–43.3 (7.63)	1.19–43.3 (5.42)	1.19–43.3 (4.29)	1.19–43.3 (2.99)	1.19–43.3 (5.31)	1.19–43.3 (4.22)
Stream width (m)[e]	3–10 (4.09)	3–10 (3.59)	3–10 (3.28)	<3 (2.85)	3–10 (3.56)	3–10 (3.26)

[a]Node definition and/or states are listed in Table 1.
[b]Values in parentheses are mean summer air temperatures (mean air temperature) estimated for the watershed (wtemp; Wenger et al. 2011b). We generated air temperature categories corresponding to those water temperature states by examining the relationship between Brook Trout occurrence and the mean summer air temperature at a point (ptemp; Wenger et al. 2011b). Additional details are found in Appendix C (see http://fisheries.org/appendices) .
[c]A threshold value of two events per winter delineated hydrologic regimes as either predominantly snowmelt (less than two) or mixed rain-on-snow and snowmelt (more than two). The threshold value was based on ad hoc interpretation of the geographic distribution of modeled winter high flow frequencies across the Pacific Northwest and Intermountain West United States. Similar approaches have been used to approximate transition points between so-called hydrologic regimes (e.g., Mantua et al. 2010).
[d]"Hydrologic regime" is defined as the seasonal pattern of runoff and flooding that might influence bed scour and subsequent incubation or emergence success of fall spawning salmonids like Brook Trout. Hydrologic regime has two states: Snowmelt and mixed rain-on-snow and snowmelt. See Peterson et al. (2008) for additional details.
[e]"Stream width" is defined as mean wetted width over the stream network during base flow. Stream width has three states: <3 m (small), 3–10 m (medium), and >10 m (large). See Peterson et al. (2008) for additional details.

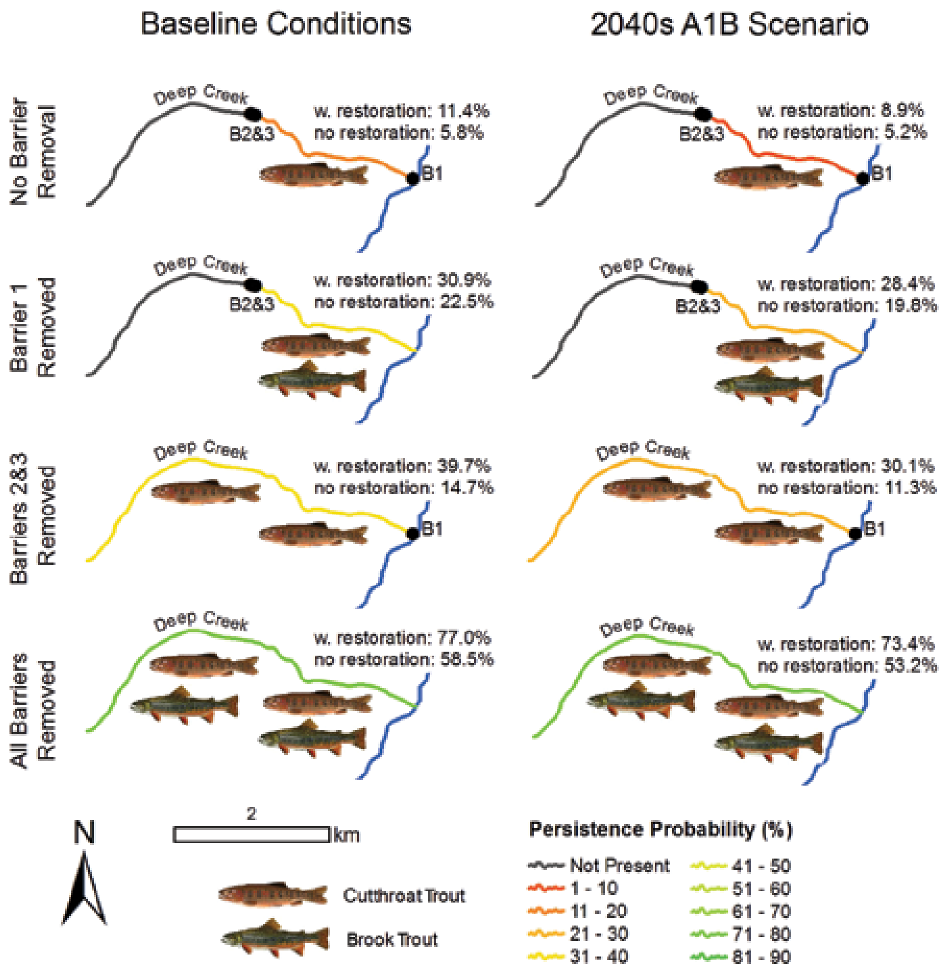

Figure 6. Decision analysis for barrier removal in Deep Creek, Montana, under current and future climate conditions. Colored lines represent the probability of persistence for Westslope Cutthroat Trout in that stream fragment under different combinations of barrier removals (rows) and climatic conditions (columns) assuming that habitat has been restored from its current condition. Actual probability values assuming habitat has been restored (w. restoration), or not restored (no restoration), are above each fragment. Black circles (•) denote existing migration barriers, and fish icons represent species with access to that stream fragment.

TEXT BOX 1. A WORKSHOP APPLICATION OF THE BULL TROUT DECISION SUPPORT TOOL

Application of the Bull Trout decision support tool was explored with a diverse group of 60 scientists and managers from 16 different state, federal, and private resource organizations during a 2-day workshop held in Boise, Idaho, in 2011. The objective was to see whether detailed climate projections and a formal decision tool could support a more refined or objective spatial prioritization process within a specific river network. Essentially, we asked whether the additional information provided by downscaled climate projections—filtered through a spatially explicit model of Bull Trout climate vulnerability—would affect the decisions people made.

On day 1, workshop participants were given a short primer on climate change and the anticipated effects on stream environments and fish populations (presentations archived online at the U.S. Forest Service Climate Change Resource Center: http://www.fs.fed.us/ccrc/video/boise-aquatics.shtml). Participants were then split into groups of four to six individuals and provided GIS layers summarizing topography, hydrography, and land ownership within a river network in central Idaho. Spatially explicit information on Bull Trout populations and potential threats to these populations—for example, road networks, movement barriers, wildfire, invasive Brook Trout—was provided, as well as GIS layers of stream temperatures (Isaak et al. 2010) and hydrologic regimes (Wenger et al. 2010, 2011a) representing recent historic conditions.

Each group was asked to prioritize 5 populations (of 22 total) where limited conservation resources should be directed to conserve Bull Trout and maximize their chances of persistence pending future climate change. There was general agreement that the largest habitat networks for existing populations should be less vulnerable to climate change and should be priorities for conservation while the smallest, most isolated populations or habitats should not be. There was less agreement on populations of intermediate size and connectivity, with diverse actions and rationales offered to support choices based on existing tenets of conservation biology (e.g., increase spatial diversity, spreading risk from catastrophic events).

On day 2, participants were given future climate scenarios showing predicted stream temperature and hydrologic conditions for 2046 and 2086. The decision support tool was introduced with a brief demonstration and participants were asked to reconsider their prioritization using the tool. Concordance among the groups was more consistent on day 2 and the number of populations receiving votes declined from 15 to 12. Priority populations were again those that were largest, and several small populations that had received votes on day 1 were not voted for on day 2. The number of populations in an intermediate "maybe" category dropped by half.

We made several observations from this exercise. First, consistent, spatially explicit information served as a useful means of focusing people from diverse backgrounds on a common problem. Despite the length and intensity of the workshop, participants remained fully engaged in examining the data and discussing alternatives. Second, basic principles of conservation biology strongly influenced initial priorities. Third, the decision support tool and climate projections did not result in wholesale changes, but they did bring clarity to the discussions and confidence to participants that many of their initial choices were supported by the available science. The example also served as a sobering reminder of how much habitat might be lost this century for Bull Trout. One participant remarked that their most powerful insight was how difficult it would be to save every population, which is a departure from what many biologists and managers have attempted to do in the past. Interested readers can access the decision support tool and spatial data layers used in this example at the workshop website: http://www.fs.fed.us/rm/boise/AWAE/workshops/climate_aquatics_decision_support.shtml.

important to understand whether such interactions are real. Managers could consider monitoring invaded Cutthroat Trout streams to identify whether there are threshold values for temperature or flows that mediate co-occurrence with Brook Trout.

The two examples presented here do not encompass the full range of environmental conditions or decision contexts that a biologist or manager may encounter. A more pessimistic emissions scenario may have dramatically altered the invasion dynamics of Brook Trout and reduced the potential benefits of barrier removal for Cutthroat Trout. Use of the Bull Trout BN to conduct a similar prioritization exercise elsewhere in the species range may reveal more dramatic or unexpected patterns. Managers still need to make decisions despite the uncertainties inherent in climate change analysis (Johnson and Weaver 2009). The process we described—a stepwise approach and use of decision support tools, like BNs, that link climate to biology—facilitates decisions, makes the scientific learning process explicit (Uusitalo 2007), and promotes "maturity in reasoning" on a management problem (Hamilton et al. 2005; Johnson et al. 2012).

Decision support systems have been developed to assist natural resource managers, but BNs generally have been underutilized in ecological and environmental disciplines (Aguilera et al. 2011). That is changing quickly with the recognition that they can be useful in climate vulnerability assessment and adaptation planning (e.g., Catenacci and Giupponi 2010). Bayesian networks recently have been used to predict effects of sea level rise (Gutierrez et al. 2011), determine whether extreme hydrologic events can be attributed to climate change (Hall et al. 2005), evaluate how greenhouse gas mitigation can influence loss of sea ice (Amstrup et al. 2010), and model vegetation response to climate warming (Dlamini 2011). The Bull Trout BN in our example is admittedly simple and the Cutthroat Trout BN directly addresses only a single type of management decision, but they can be thought of as individual modules or plug-ins to address pieces of a larger, more complex ecological problem (Johnson and Mengersen 2012). Indeed, individual BNs provide a natural way to decompose seemingly intractable problems into lower-dimensional subproblems (Uusitalo 2007; Johnson and Mengersen 2012) and create building blocks to handle multi-objective or multi-criteria decision analysis.

We have demonstrated how these models can be used for spatially explicit prioritization and passage barrier decisions. Other modeling platforms could, in theory, accomplish similar tasks. For example, Marxan is a software package designed for conservation reserve planning (Ball et al. 2009) and is being used to identify so-called salmon strongholds in California (Wild Salmon Center 2010). The interactive tool NetMap (Benda et al. 2007) contains an expanding suite of data layers relevant to watershed analysis and planning—geomorphic attributes, hydrology, road networks, and land use—that could facilitate habitat prioritization and evaluation of management actions under climate change. The EAGLES modeling platform can be used for landscape- and regional-level geospatial analysis and decision support (Crabtree and Sheldon 2012); it incorporates species distribution and habitat selection models and therefore can be used to identify critical habitats or migration corridors under climate change (Crabtree et al. 2011). Additional decision support models are available for biologists conducting climate change analyses, and off-the-shelf options are appealing as resource management agencies face shrinking budgets and decreased staffing levels. A potential drawback here is that readily available models might constrain articulation of the management problem and objectives. We argue that the more robust process proceeds in the opposite direction, where the tools are developed after the management problem and objectives are specified. A biologist with sufficient time and resources can coordinate this process and help develop a conceptual model and decision analysis tool for their particular management issue. This should not be a solo effort; the process typically involves a small working group that collaborates closely with additional stakeholders and domain experts—biologists, scientists, decision makers—who contribute knowledge and peer reviews (Marcot et al. 2001, 2006). Model building can be done through a well-organized series of workshops or panel sessions designed to ensure scientific rigor and elicit expert judgment (Johnson and Weaver 2009; Marcot et al. 2012). Biologists without previous experience can consult with decision analysis experts for guidance on how to structure these workshops or find suitable decision analysis methods.

Process can be important. A quantitative decision support tool can be helpful, but following a sequence of steps to define and analyze a problem, which we refer to as the "decision process," can also make a tangible contribution to conservation planning (NRC 2009; Pollinio and Henderson 2010). Our examples included three steps—problem definition, conceptual model development, and process-based model construction. There are at least two advantages to following these steps. First, it facilitates acceptance of the conceptual model and decision support tools by biologists and their administrators, because the biological mechanisms are largely transparent and the biologists or administrators may have participated in the model-building process. Second, the process can identify information gaps and motivate important research that might be overlooked or is suggested by counterintuitive results. In fact, completion of just the first two steps, or even just the first step, offers potential benefits. Consider that agency biologists are sometimes forced to proceed under a strongly worded, yet ambiguous, directive to "consider climate change" in their planning and management activities. This is virtually meaningless if the conservation objectives are not clearly defined and important uncertainties in domain knowledge are not acknowledged. The process of defining the problem and building a conceptual model is not always easy when many stakeholders are involved and can be humbling when it forces a critical evaluation of purpose and knowledge. However, it is beneficial if it leads to a clearly articulated decision problem that sets the stage for consistent and transparent decision making.

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The NAS Alert System: A Look at the First Eight Years

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ABSTRACT: *The U.S. Geological Survey's Nonindigenous Aquatic Species (NAS) database program (http://nas.er.usgs.gov) tracks the distribution of introduced aquatic organisms across the United States. Awareness of, and timely response to, novel species introductions by those involved in nonindigenous aquatic species management and research requires a framework for rapid dissemination of occurrence data as it is incorporated into the NAS database. In May 2004, the NAS program developed an alert system to notify registered users of new introductions as part of a national early detection/rapid response system. This article summarizes information on system users and dispatched alerts from the system's inception through the end of 2011. The NAS alert system has registered over 1,700 users, with approximately 800 current subscribers. A total of 1,189 alerts had been transmitted through 2011. More alerts were sent for Florida (134 alerts) than for any other state. Fishes comprise the largest taxonomic group of alerts (440), with mollusks, plants, and crustaceans each containing over 100 alerts. Most alerts were for organisms that were intentionally released (414 alerts), with shipping, escape from captivity, and hitchhiking also representing major vectors. To explore the archive of sent alerts and to register, the search and sign-up page for the alert system can be found online at http://nas.er.usgs.gov/AlertSystem/default.aspx.*

El Sistema de Alertas EAN: una Mirada a los Ocho Primeros Años

RESUMEN: *la base de datos de Especies Acuáticas No-indígenas (EAN) perteneciente al Sondeo Geológico de los Estados Unidos de Norteamérica (http://nas.er.usgs.gov) rastrea la distribución de organismos acuáticos introducidos a lo largo de los EEUU. La concientización de, y la respuesta oportuna a la introducción de especies foráneas que brindan los involucrados en el manejo e investigación de especies acuáticas no-indígenas, requiere un andamiaje que permita una rápida diseminación de datos de ocurrencia a medida que se incorporan a la base de datos de EAN. En mayo del 2004, como parte de un sistema nacional de detección rápida/temprana, el programa EAN desarrolló un sistema de alerta para notificar a los usuarios registrados de nuevas introducciones. En esta contribución se resume la información de los usuarios del sistema y las alertas despachadas desde la creación del sistema hasta finales del 2011. En el sistema de alertas EAN se han registrado más de 1,700 usuarios, con aproximadamente 800 suscriptores hasta el momento. Un total de 1,189 alertas se han transmitido durante 2011. En comparación a cualquier otro estado, la mayor parte de las alertas se enviaron a Florida (134). Los peces representan el grupo taxonómico más grande (440) de las alertas, seguidos de los moluscos, plantas y crustáceos, con más de 100 alertas cada uno. La mayoría de las alertas se trataban de organismos que fueron liberados intencionalmente (414 alertas), siendo los principales vectores las embarcaciones, fuga de cautiverios y el transporte involuntario. Para explorar los archivos de alertas enviadas y registrarse en línea, se puede acceder a la página http://nas.er.usgs.gov/AlertSystem/default.aspx.*

INTRODUCTION

The Nonindigenous Aquatic Species (NAS) database (http://nas.er.usgs.gov) functions as a repository and clearinghouse for occurrence information on nonindigenous aquatic species from across the United States. It contains locality information on more than 1,100 species of vertebrates, invertebrates, and vascular plants introduced since 1850 (Fuller et al. 1999). Taxa include foreign species as well as those native to North America that have been transported outside of their natural range. The NAS web site provides immediate access to new occurrence records through a real-time interface with the NAS database. Visitors to the web site can use a set of predefined queries to obtain lists of species according to state or hydrologic basin of interest. Fact sheets, distribution maps, and information on new occurrences are continually posted and updated. Dynamically generated species distribution maps show the spatial accuracy of the locations reported, population status, and the points are linked to the full specimen record containing all information about that report. Individual specimen records also have a map showing their location for the user's reference.

Data from the NAS database have been used in conducting risk analyses (Jenkins et al. 2007; Whittier et al. 2008; Zajicek et al. 2009), preparing field guides for early detection (Schofield et al. 2009), for predictive modeling (Drake and Lodge 2006; Mercado-Silva et al. 2006; Bossenbroek et al. 2007; Chen et al. 2007; DeVaney et al. 2009; Poulos et al. 2012), in state aquatic nuisance species management plans (California Department of

Fish and Game 2007; Idaho Invasive Species Council Technical Committee 2007; South Carolina Aquatic Invasive Species Task Force and South Carolina Department of Natural Resources 2007), in species-specific management plans (Western Regional Panel on Aquatic Nuisance Species 2010), in regional management (Rodgers et al. 2010), in congressional testimony (Thayer 2010), for national assessments (Rahel 2000; Heinz Center 2002, 2008; Stohlgren et al. 2006), to document species invasion (Schofield 2009), for hazard analysis and critical control point planning (Gunderson and Kinnunen 2004), and for national policy making (Silver Carp [*Hypophthalmichthys molitrix*] listing on the Lacey Act; U.S. Fish and Wildlife Service 2007). Additionally, the U.S. Army Corps of Engineers has used the NAS database to determine the presence and distribution of exotic species in the Great Lakes and Mississippi River basins near hydrologic connections between the two as part of the Great Lakes and Mississippi River Interbasin Study (U.S. Army Corps of Engineers 2011). These distributional data are combined with information on species' biology to determine the likelihood of these species traversing the drainage divide. In addition, the study has analyzed options and technologies to prevent or reduce the risk of those particular species moving between the basins through aquatic vectors. The NAS database is referenced in the National Invasive Species Management Plan (National Invasive Species Council 2008) and the Aquatic Nuisance Species Task Force Strategic Plan (Aquatic Nuisance Species Task Force 2007). Specific management applications include use by the Forest Service to determine contaminated waters to avoid as water sources when fighting fires; by the Pennsylvania Fish and Boat Commission to determine risk of water sources used for hydraulic fracturing; and by The Nature Conservancy to determine the risk of invasive species movement when removing dams, as well as to determine risk to endangered species they are trying to conserve on protected lands.

Numerous discussions were held among federal agencies in the late 1990s and early 2000s to discuss the need for an alert system as part of a national early detection and rapid response (EDRR) plan. Scientists and managers identified a need for interdisciplinary and international cooperation and collaboration on sharing data to strengthen strategies and responses to invasions and occurrences. It was recognized that due to ineffective collaboration among the invasive species networks, limits were placed on EDRR because of a lack of technical experience, data accessibility, and interoperability (Simpson et al. 2009). One of the components of the EDRR plan was an alert mechanism to notify managers of a new invasion in their area or nearby so that they could determine whether management actions needed to be implemented or whether they should begin monitoring for the new species. Timely generation of alerts represents an important component of EDRR plans to resource managers so that monitoring strategies can be prioritized and management plans can be initiated, including the potential of eradication. Identification of drainages where a species has been reported can assist in the prediction of regions that may be susceptible to future expansion and can be invaluable in the protection of these areas or prioritizing monitoring areas for the detection of the first arrivals. Managers need to know what is new to their area, or new to a nearby area, in order to respond quickly. In addition, managers are encouraged to report these new occurrences to the NAS database so the information can be disseminated to other managers, researchers, the public, and the press.

In response to these efforts, the NAS program launched its NAS Alert System in May 2004. The NAS Alert System provides a searchable database of new and notable NAS introductions. Users can interact with the alert system in two ways: they can search the alert system archive through a web interface using a number of defined queries or they can register to receive notifications of new occurrences based on their desired categories of interest, including regional ("state watches") and/or organismal (taxonomic "group watches" or "species watches" for select high-profile species) groupings. Originally the alert system was only implemented for aquatic animals. Aquatic plants were added in December 2006 through a cooperative agreement with Portland State University. Mississippi State University took over this role in early 2010. Tracking of aquatic plants has recently been discontinued and the database will be refocused on nonindigenous freshwater animals and marine fish. Plant distributional data will be transferred to other databases (e.g., EDDMapS, http://eddmaps.org) so that they are not lost.

The objectives of this article are to (1) provide a brief overview of the NAS database and alert system, including data sources and quality control procedures, and (2) summarize how the alert system has been used in the eight years since its creation.

THE NAS DATABASE AND ALERT SYSTEM

Overview of the NAS Database

The NAS database obtains data from many sources, including literature; state, federal, and local monitoring programs; museum accessions; online databases; news feeds; web sites; professional communications; and online reporting forms. Before being included in the database, records are reviewed to ensure accuracy and are geographically referenced. Our quality assurance process varies with the source of the report, the species reported, and the degree of expectation at the reported location. Specifically, scientific publications are accepted with little to no review, unless it is an extremely old publication and the taxonomy has changed or the species was previously misidentified (e.g., African Jewelfish *Hemichromis letourneuxi* was originally identified as *H. bimaculatus*; W. Smith-Vaniz, personal communication). News releases are generally accepted for most species. However, sometimes we contact local biologists or try to obtain photographs, particularly with species that are difficult to identify or can be mistaken with native species (e.g., Piranha *Pygocentris* or *Serrasalmus* spp. are morphologically similar to Pacu *Colossoma* or *Piaractus* spp.; Snakeheads *Channa* spp. can be confused with Bowfin *Amia calva*). The extent of web site review is dependent upon site authorship, with scientifically focused web sites (those containing detailed information on taxonomy and locality, including sites from natural resource agencies, museum collection databases, and nongovernment conservation groups) generally taken as accurate, whereas informal web sites (those that might contain less rigorous taxonomic or geographic information, including personal web sites or discussion forums) are given more scrutiny. When personal communications or our online data entry forms are utilized, the reporter and the species are considered: detailed, complete reports (generally from individuals trained in scientific data collection or familiar with nonindigenous aquatic species and those including photographs and careful locality descriptions) are routinely accepted with the exception of commonly misidentified species (e.g., Snakeheads), and reports of a common species known to be in the area are generally believed. When something significant to a new area is reported, we request photographs or specimens to verify the report before publishing in the database. If we are uncertain of a species' identification, we request assistance from ichthyologists and fish biologists from federal and state agencies, museums, and universities. We also utilize the "Experts Database" compiled by the Aquatic Nuisance Species Task Force (http://anstaskforce.gov/experts). The database is designed so that the public is first directed to the state ANS coordinator, who is familiar with common and introduced species within that state and can decide whether a report warrants management action. If the coordinator cannot identify the species, he or she has access to a second tier of contacts more experienced in taxonomy of various groups. The database contains a listing of state Aquatic Nuisance Species contacts and taxonomic experts across the country willing to assist in identification. Lastly, our database users are constantly reviewing the data and are quick to inform us if there is a problem or concern. For very unusual species or sightings, we encourage specimen deposition in a museum to permit future verification or taxonomic work.

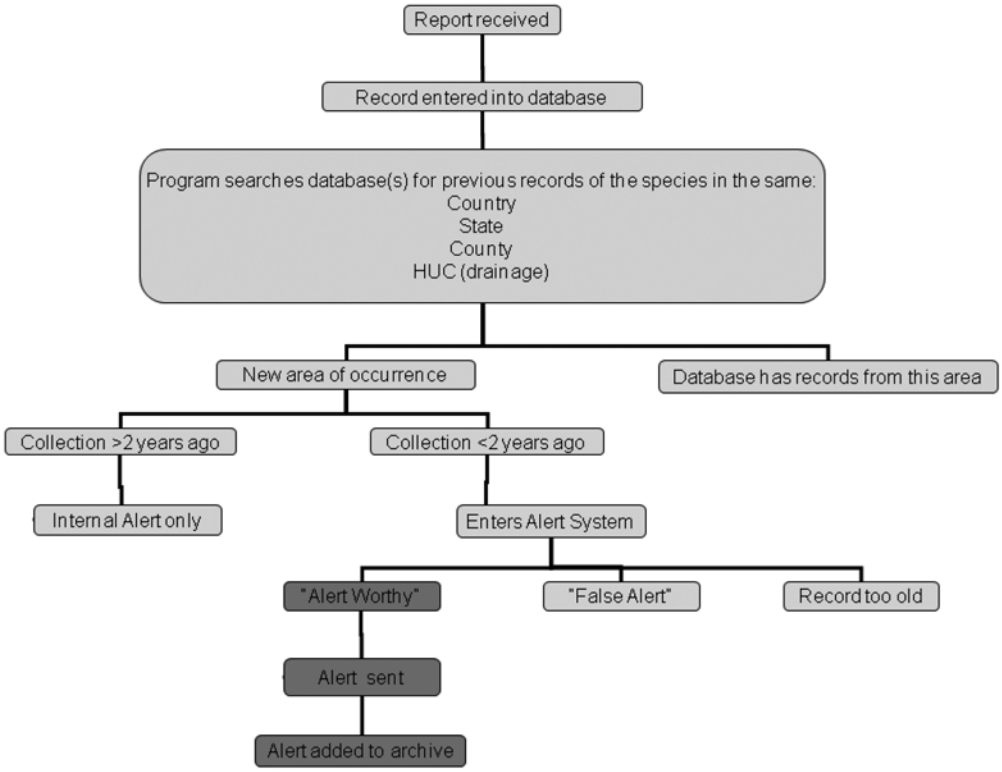

Figure 1. Flowchart of how the NAS Alert System works.

Once verified, the reports are entered into the NAS database. Each report is georeferenced using reported geographic coordinates and/or locality description and categorized at several hierarchical levels—nation, state, county, and hydrologic unit code (HUC). Because the accuracy of location reporting varies, locations are designated as accurate (reasonably close to collection location; e.g., mouth of Smith Creek), approximate (in the general vicinity of the collection; e.g., a pond in Gainesville), or centroid (center of a polygon; e.g., Alachua County or Potomac drainage).

Overview of the NAS Alert System

The NAS Alert System is designed with a hierarchical approach. As new observations are submitted to the NAS database, they are compared to current database records to determine whether that particular species has been previously reported at the national, state, county, or HUC level (Figure 1). If the species has been found at all four corresponding levels, no alert is generated and the record is added to the NAS database. If the report represents a novel occurrence anywhere in the geographic hierarchy, the system will generate an alert at each appropriate level. A national alert is issued for the initial introduction of a species into national waters (e.g., first occurrences of Round Goby *Neogobius melanostomus* and Tubenose Goby *Proterorhinus semilunaris* in the St. Clair River in 1990; Jude et al. 1992). Additional alerts are also generated at lower levels in the geographic hierarchy (i.e., all state alerts will also produce county alerts). If the record is more than 2 years old, an internal alert is issued to NAS personnel as a reminder to update the current distribution on the species fact sheet. If the report is from the current or previous year, it goes into a holding area for internal review to determine whether it is "alert-worthy" or not. Generally, alerts are issued for collections within the past 6 months. If the record is determined to no longer be newsworthy because of its age, the alert is not distributed and is deleted from the holding area. County-level alerts must be examined to determine whether the particular alert truly represents a new area. Often our records are at drainage levels. Our record may indicate that the species is present "throughout the ABC drainage," but because we never had a record specifically from a particular county, it generates a "false alert"; these often occur in large water bodies such as the Great Lakes or Mississippi River. The only time county-level alerts are determined to be alert-worthy is when they represent range expansion into a new area of that drainage. For example, county alerts are valid for Asian Carp migrating farther upstream in the Mississippi River or for a Great Lakes species moving eastward in Lake Ontario. Once an alert has met all the criteria, it is sent to users signed up for that taxonomic group, species, or state.

Periodically, significant reports occur for species that may not be new to an area and hence would not trigger a normal alert. These bonus alerts include things such as newly found evidence of reproduction and establishment, eradication, a subsequent collection of an important species from the same area (e.g., Snakeheads in the Potomac), or collection of a species from an area where it has not been reported for many years. Although these occurrences are not new, they represent important information because they could trigger management action. To cover these cases, we added a category called "Bonus Alerts" in November 2005. When a record does not automatically generate an alert because it has already been recorded from an area, we have the option of overriding the system and designating it as a bonus alert. When a record is designated as a bonus alert, a comment is included to explain the significance of the report.

Each record (species at a geographic location on a specific date) that generated an alert is examined for the vector responsible for a species' introduction to that location. Mack (2004) defined a "transport vector" as the manner in which species are carried along a pathway and a "pathway" as the route between the source region of a nonnative species and its location of release. Some species vectors have been documented (e.g., ballast tanks of shipping vessels), and some are fairly easy to deduce. Often a vector is assigned based on our best judgment of how a species arrived at its new location due to its biology and dispersal capabilities. Areas in which the species have newly spread are assigned the vector responsible for their original introduction to that particular region. Species introduced to multiple regions of the country may have different vectors in each region or even in different locations within the same region.

Interested users may get alerts in one of three ways: via e-mail, Really Simple Syndication or Rich Site Summary (RSS) feed, or, most recently, Twitter. The NAS Alert System employs Common Alerting Protocol, which uses Extensible Markup Language technology to create a standard message format for disseminating alerts and notifications across a variety of alert reporting systems and is the technology behind the U.S. Geological Survey (USGS) Earthquake Hazards Program (http://earthquake.usgs.gov/earthquakes/feed/), the National Weather Service weather advisory alerts (http://alerts.weather.gov/cap/us.php?x=1), and a variety of public and private alert notification systems. Our alerts are available via RSS and can be posted automatically on an agency's web page or used in a news reader. Alerts are now available on Twitter (twitter.com) by following @USGS_NAS. Regardless of the method chosen, alerts are sent indicating the species and area to which it is new (country, state, county, drainage). The alert includes links to the full specimen record in the database and, for e-mails, a link to the fact sheet for that species. The location of each occurrence is shown on a map displayed by the linked specimen record for each alert.

HISTORIC USE PATTERNS OF THE NAS ALERT SYSTEM

To examine the utility of the NAS Alert System, we summarized basic demographic information for registered users, as well as alert production. The analyses that follow have some associated biases, including differential reporting by regions; our decisions to send or not send an alert; the presence of surveys, which will artificially increase alerts from an area; and the arrival of new publications, such as state fish books, which can artificially boost alerts for a given state for that year. There are also habitat and, hence, taxonomic biases. We formerly tracked many marine species, but more recently we are sending those data to our partners at the Smithsonian Environmental Research Center, which maintains a similar database for marine and estuarine species (http://invasions.si.edu/nemesis). Although the database does contain some marine data on groups such as jellyfish and tunicates, among others, data in the NAS database focus primarily on freshwater species and largely on fishes. In addition, the database has begun incorporating records from outside U.S. territorial boundaries to track and monitor spread of Lionfish (*Pterois miles* and *P. volitans*) throughout the Caribbean and Atlantic. However, despite these biases, the data provide some interesting information.

Who Uses the System and What Do They Want?

Over the lifetime of the system there have been 1,765 registered users. During the past 2½ years (the time period during which the users have been tracked), the system continues to maintain approximately 811 users (as of September 2012). User statistics are posted on the web site: http://nas.er.usgs.gov/Alertsystem/AlertsStats.aspx. Of those who have unsubscribed, many were unsubscribed due to nondeliverable e-mails because of address changes. Most of those people resubscribed with their new address. The largest aggregate group of users of the alert system is government employees (primarily including state, federal, and military but also some municipality; e-mail address domains .gov, .us, and .mil; Figure 2). As part of their varied missions, these organizations are all responsible for managing natural resources at their respective levels. Many of these people are likely to be the ones who would initiate management actions for their areas such as new monitoring programs, containment, control, inspections of incoming equipment, or area closures. The second largest group comprises users with .com (commercial but unrestricted and used for general-purpose e-mail accounts such as AOL, Yahoo, and Google) and .net (also unrestricted; originally designed for use by network providers) address domains. The interest of users with .com and .net addresses in the NAS Alert System is unclear, and it is not possible to determine why these users are accessing the database. At least one state agency (Florida Fish and Wildlife Conservation Commission) uses a .com address. Other users with these addresses could represent members of the public interested in

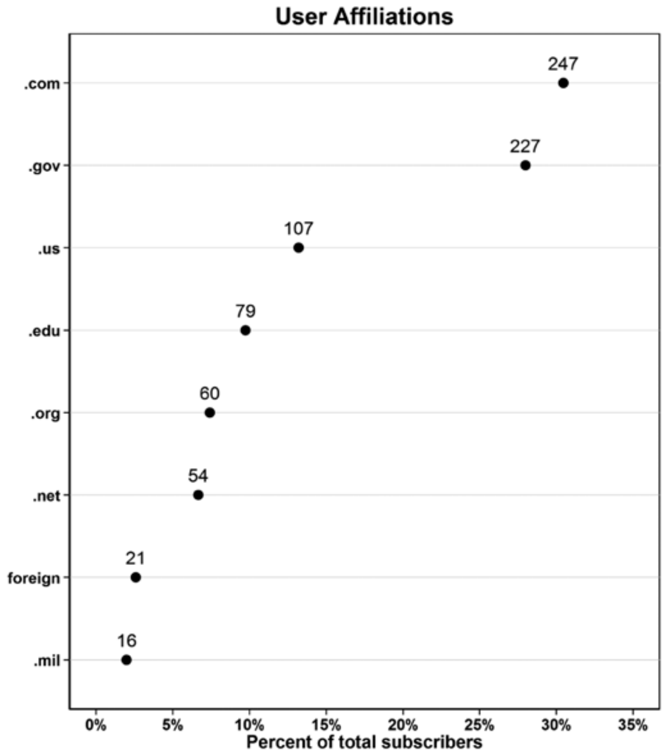

Figure 2. Demography of alerts system subscribers by e-mail domain suffix. Numbers indicate total number of subscribers for each suffix.

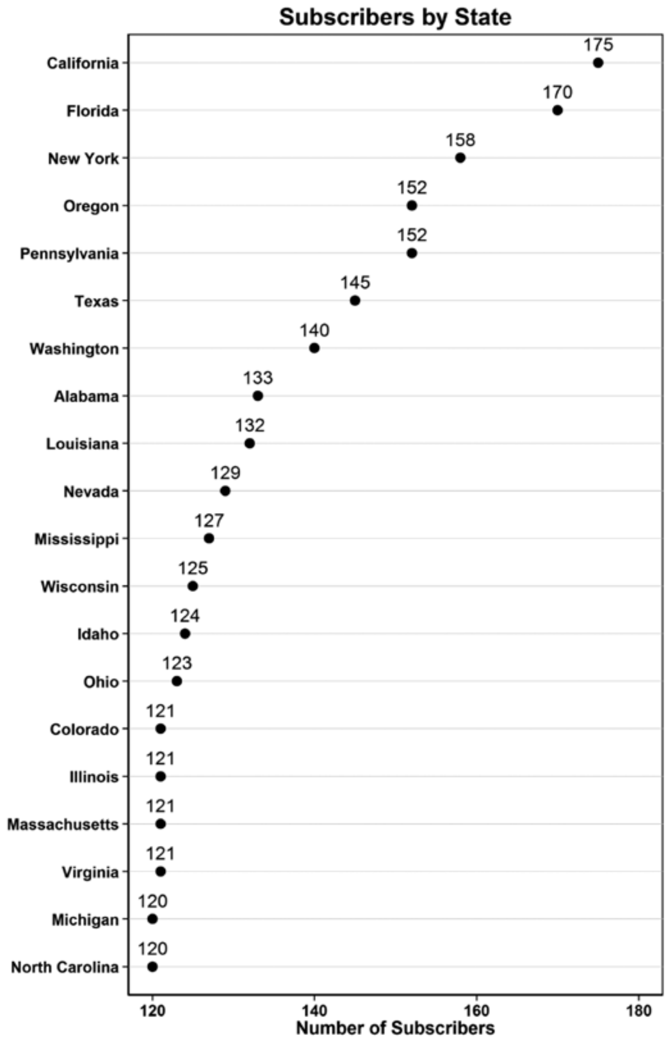

Figure 3. Number of subscribers to the top 20 states.

species introduction to their local areas. The last major group includes users from educational institutions (.edu) or other noncommercial entities (.org) and likely are university personnel or environmental nonprofit groups that are involved in invasive species research, educational programs, and public outreach. Additionally, there are 22 foreign users from Australia, Barbados, Canada, China, Colombia, Cuba, Finland, France, Norway, Russia, Spain, Sri Lanka, Slovenia, and the United Kingdom. Although we do not know their exact reasons, it could be that managers from those countries want to monitor spread of certain organisms or areas from which they might receive goods via trade or to use areas of successful introduction in the United States in predictive models of habitat suitability and establishment probability (e.g., Australia's Climatch; http://adl.brs.gov.au:8080/Climatch/climatch.jsp). This would allow them to be aware of new species that may cross their borders or enable new inspection procedures.

More users were registered for California than any other state, followed by Florida, New York, Oregon, and Pennsylvania (Figure 3). The number of users registered for a state cannot be directly attributed to subscribers residing in those states because many users subscribe to surrounding states as well as their own. Some people subscribe to all states in order to receive all alerts. However, four of these states (i.e., California, New York, Florida, and Pennsylvania) represent some of the most populous states in the nation.

More users are registered to receive fish alerts than any other taxonomic group (Figure 4), followed by bivalves, crayfish, gastropods, and frogs. Even the least requested group (nebaliaceans) has more than 90 subscribers. Of the nine species offered as species-specific alerts, most users registered for zebra mussel alerts (Figure 5).The fewest registered for Lionfish and quagga mussel alerts; however, those are new offerings and are not widely publicized. Of the 811 users, 642 (79%) subscribe to receive bonus alerts.

Characteristics of Generated Alerts

A total of 1,189 alerts were sent over the past 8 years. More alerts were generated in 2007 than in any of the other years (Figure 6). Over the last 8 years, country-level alerts (i.e., the initial introduction of a species to the United States) were the least frequent type of alert (39 alerts; 3.3% of all sent alerts). If we include our recent endeavors (beginning in 2008) to track the spread of Lionfish in the Caribbean, another 30 country-level alerts would be included. In addition, approximately equal numbers of state-level (227) and county-level (229) alerts have been generated since the alert system's inception (each class ~19% of total alerts; Figure 6). Puerto Rico has had the most state-level alerts (15). The high number of recent detections is probably due to some recent fish surveys conducted by the commonwealth. Previously, little data were available for Puerto Rico and it is likely that some of these species may have been there longer but were only recently discovered (Kwak et al. 2007).

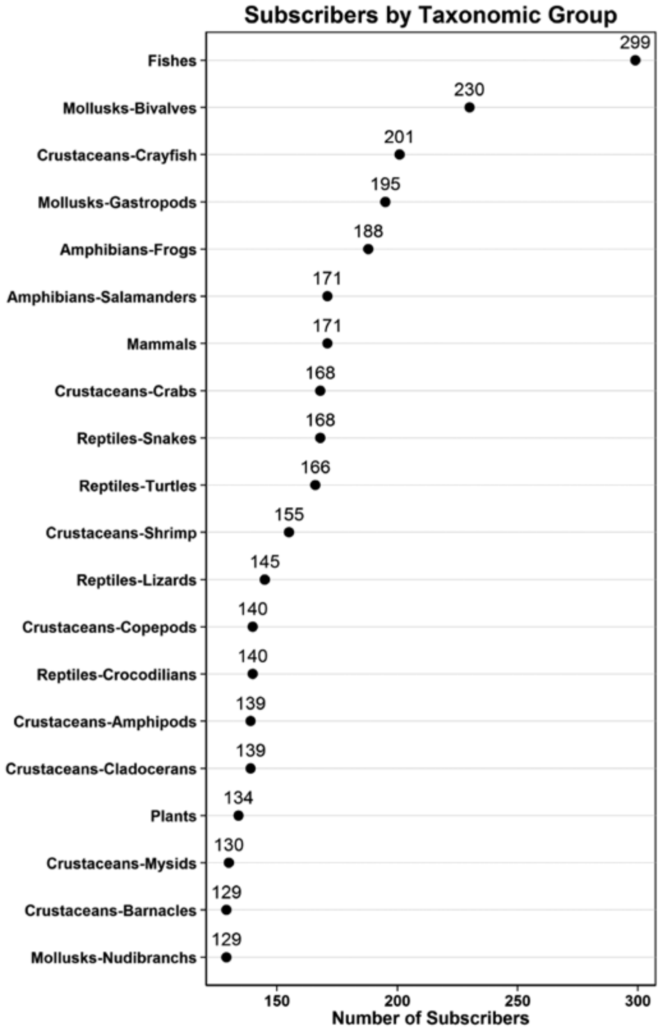

Figure 4. Number of users registered to receive alerts by taxonomic group for the top 20 groups are shown.

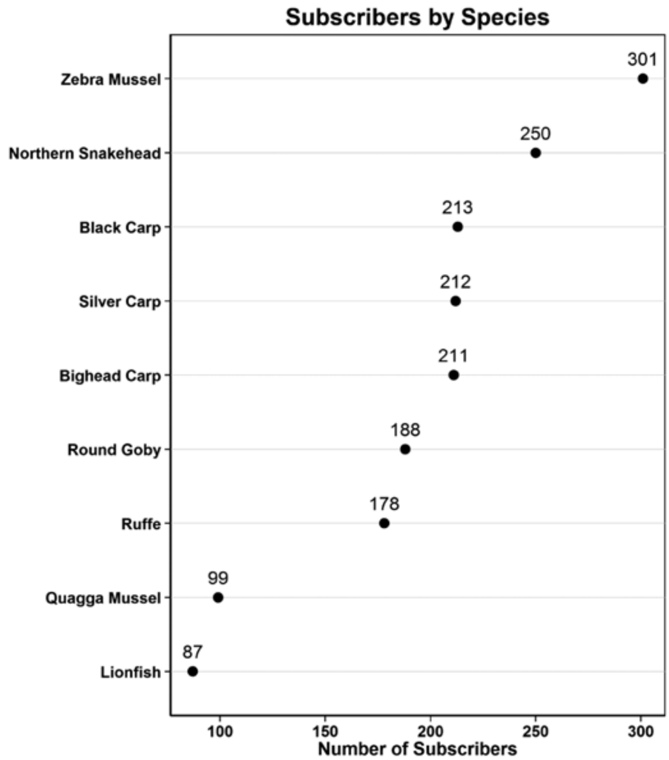

Figure 5. Number of users registered to receive species-specific alerts.

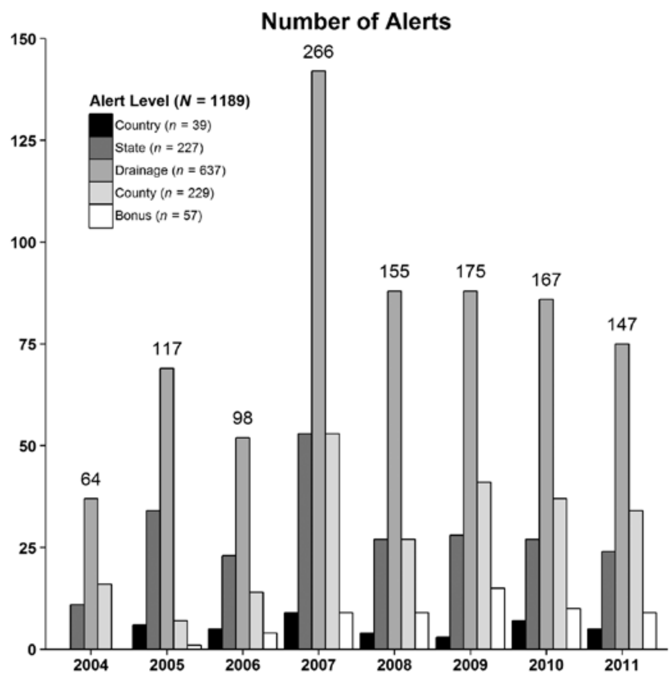

Figure 6. Number of alerts sent per year at each hierarchical level. Numbers above bars indicate total number of alerts sent per year across all alert levels. Note: 2004 is from May through December. Large spike in number of alerts in 2007 represents addition of plant data to NAS database.

Eleven new species were reported for Louisiana, 10 new species for Colorado, and 9 new species were reported in both Florida and North Carolina since 2004. Drainage alerts, documenting species' first occurrence in new drainages, accounted for the majority of the alerts sent out in any given year (Figure 6) and comprised the largest fraction of all sent alerts (54%; Figure 6). Most drainage alerts (138) occurred in the South Atlantic–Gulf Region (HUC 03), with the Pacific Northwest Region (HUC 17; 75 alerts), New England Region (HUC 02; 57 alerts), and Great Lakes Region (HUC 04; 50 alerts) each containing a large number of alerts.

More alerts were generated for fishes than for any other taxonomic group, followed by mollusks and plants (Figure 7). These three categories accounted for 76% of the alerts issued. Fishes showed the highest variability in number of alerts sent per year, ranging from 21% to 62% of alerts sent in a given year. Most other taxa showed a relatively consistent number of alerts across years. Plant alerts were added in December 2006, partially accounting for the large spike in alerts seen in 2007 (Figure 6). The state of Florida had the largest number of total alerts sent, almost double the next state (New York; Figure 8). Many of these alerts include the expansion of several high-profile species (e.g., Asian tiger shrimp *Penaeus monodon*, Lionfish *Pterois miles* and *P. volitans*). Recent fish surveys in Puerto Rico likely account for the high number of alerts for the commonwealth, because these are some of the first recent assessments of its freshwater fish fauna (Kwak et al. 2007).

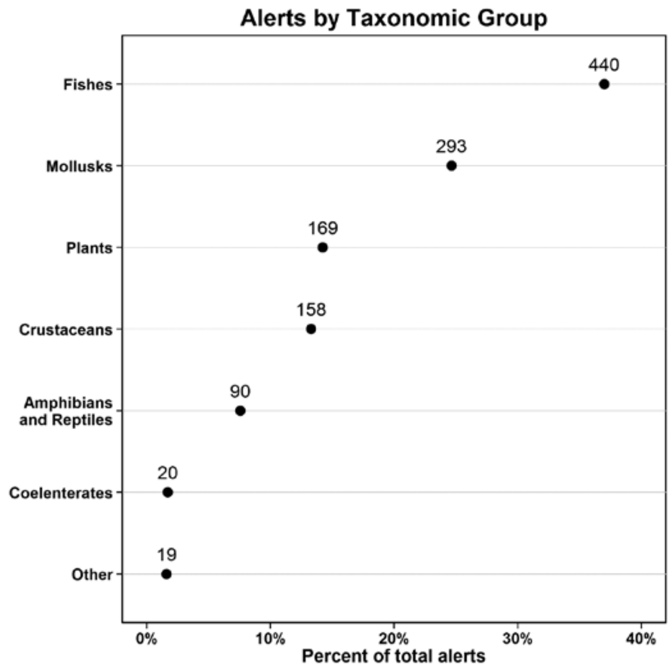

Figure 7. Proportion of alerts sent by taxonomic group. Numbers indicate total number of alerts sent for each group. "Other" includes annelids, bryozoans, tunicates, and mammals.

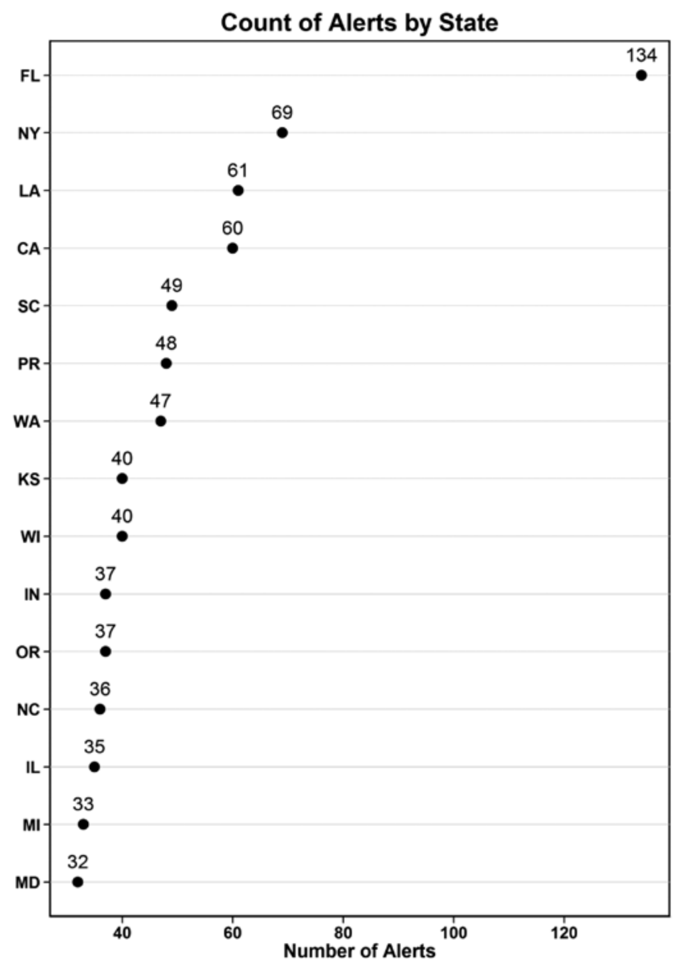

Figure 8. Number of alerts sent out by state. This graph shows the top 15 states.

Dispersal Vectors for Generated Alerts

The vectors most responsible for moving species to new areas were release (35%), which includes aquarium and pet release, bait release, and release of organisms sold as food; shipping (17%), including both ballast water discharge and hull fouling; hitchhikers (i.e., species inadvertently transported with other species; 12%); and escape from captivity, including escapees from aquaculture, fur, or other farms (11%; Figure 9). Of the releases, the primary method was aquarium release (including fish, gastropods, and plants). In fact, of all new introductions, aquarium releases were the single largest source. Aquarium releases accounted for 273 or 23% of all the introductions and for 47% of all fish alerts generated. Introductions with an unknown dispersal vector also comprised a large number of all sent alerts (185; 16%), and represented a sizeable portion of all sent alerts for crayfish (22/38; 58%), bivalves (44/168; 26%), gastropods (41/123; 33%), shrimp (23/60; 38%), and plants (25/169; 15%).

Information Source of Generated Alerts

The majority of records that generated alerts (743; 63%) were derived from personal communications (Figure 10).Of these, less than 3% came directly from the public, with the remaining reports derived from state, federal, or university contacts. However, many of the state agency reports originate from the public and are sent to us secondhand. Of the 25% that came from literature (all published sources; includes journal articles, books, book chapters, technical reports, and news), more than half (62%) of those came directly from news sources (i.e., news article was the primary information source for specimen record).

DISCUSSION

Alerts: Species and Vectors

The USGS Nonindigenous Aquatic Species Database represents the most comprehensive repository of information on aquatic species introductions in the United States, with the NAS Alert System providing rapid dissemination of novel occurrences to interested stakeholders (U.S. Geological Survey 2013). Fishes are the taxonomic group most commonly moved to new areas, comprising the largest fraction of all sent alerts through the NAS alert system as well as the largest taxonomic group in NAS specimen database. Of the 440 alerts for fish, 47% were generated by aquarium releases. Although many of these are species released in areas where they will not survive, aquarium or pet releases represent a large vector transporting species to new areas (Fuller 2003). Compared to other high-profile introduction vectors (i.e., ballast water), organisms in the aquarium trade are generally larger (i.e., adults) and more likely to survive until reproduction (Padilla and Williams 2004). Due to advances in husbandry and rearing technology, methodology, and increases in the speed of travel, a rise in the number of species being imported to the United States for the use of home aquaria and pets has increased the likelihood of survival of many species. The diversity of species present in the aquarium and ornamental trade is vast, with estimates of between 1,200

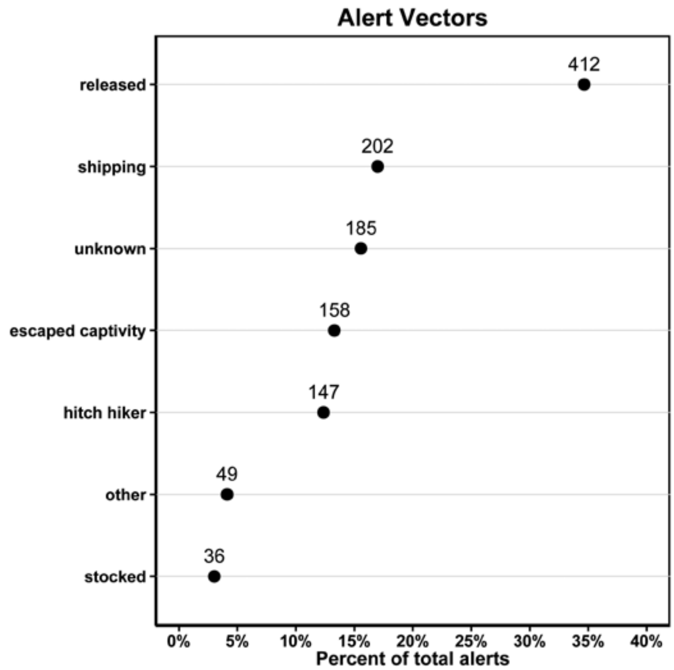

Figure 9. Vectors responsible for NAS specimen records (i.e., a species at a specific location at a specific time) generating an alert. Species introduced to multiple geographic locations can have different vectors for each introduction (e.g., Red Swamp Crayfish *Procambarus clarkii* were introduced to some states through bait bucket release but were deliberately stocked for food and forage in Hawaii).

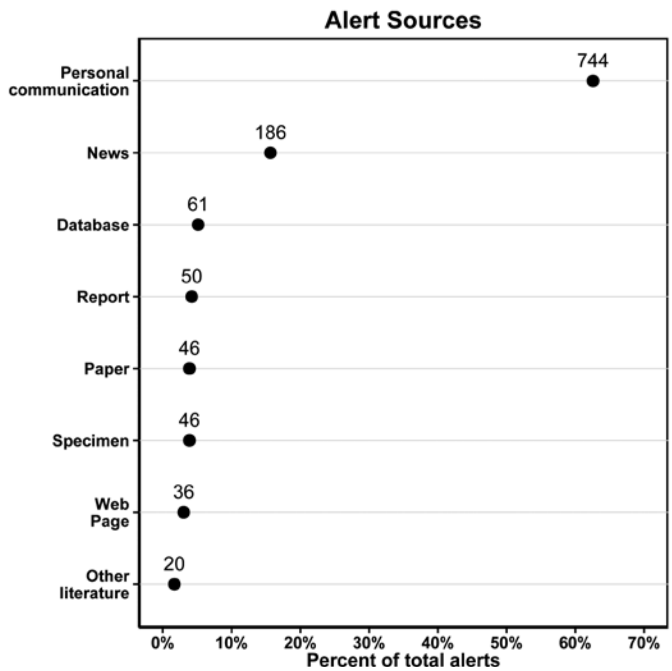

Figure 10. Sources of specimen records generating an NAS alert. "News" includes all articles (print and online) published by news organizations; "database" includes online state occurrence/sighting databases, as well as files containing multiple collections records provided by individual researchers; "report" includes technical and project reports from federal and state agencies; "paper" indicates articles from primary scientific literature; "specimen" indicates museum collection lots; "web page" includes all other online sources that do not fall into the "news" or "database" categories (e.g., state agency press releases, state fishing report sites); "other" includes books, book chapters, and sources that do not fall into any other category.

and 1,800 species of fishes and millions of individuals regularly imported to the United States for the aquarium trade (Radonski et al. 1984; Chapman et al. 1997; Rhyne et al. 2012), although this is dominated by a few highly abundant, popular species (Rhyne et al. 2012). Recent publications (e.g., Lintermans 2004; Rixon et al. 2005; Duggan et al. 2006; Cohen et al. 2007) suggest that invasions of nonnative species are not occurring due to accidental escapes from wholesalers or importers (perhaps as in the past) but because pet owners and the ornamental plant trade are serving as the dominant vector for range expansions due to intentional releases. Gertzen et al. (2008) and Strecker et al. (2011) used retail store inventories and customer behavior surveys as propagule pressure model inputs to estimate releases of ornamental fishes in the St. Lawrence Seaway and the Pacific Northwest, respectively, and found that direct releases of ornamental fishes likely represent a significant introduction vector, with thousands of fish estimated to be released annually in each region.

The USGS NAS database has documented 157 alien freshwater aquarium fishes caught in the wild, including 89 species with reproducing populations (U.S. Geological Survey 2013). Many of these are tropical or subtropical species and, due to physiological restrictions imposed by climate, most of the established populations are limited to Hawaii and Florida. However, as new temperate species are imported and become popular in the aquarium trade (e.g., White Cloud Mountain Minnow *Tanichthys albonubes*; Gertzen et al. 2008), the probability of establishment across a wider geographic range could increase. The majority of the aquarium fish species reported from new areas are those that quickly become too large, aggressive, or destructive to keep, such as Pacu (*Colossoma* and *Piaractus* spp.), Oscar (*Astronotus ocellatus*), "Algae Eaters"/"Plecos" Sailfin Catfish (*Pterygoplichthys*, *Hypostomus*, and other loricariid genera), other catfishes (several families), and cichlids (several genera). Providing consumers with adequate information on the biology (e.g., maximum size, interactions with other species, reproductive behavior) of species in trade, as well as mechanisms for relieving owners of unwanted pets, may prevent the release of large, aggressive, and destructive species into the environment. Educating owners about the problems associated with releasing unwanted pets or plants into the environment is the major thrust of the Habitattitude campaign (Habitat Campaign 2013), whose logo and message can now be seen on aquariums and fish bags in some of the major pet retailers. Another approach has been taken by the Florida Fish and Wildlife Conservation Commission, which organizes "Amnesty Day" events where pet owners can turn in unwanted pets (Florida Fish and Wildlife Conservation Commission 2012). The state matches the unwanted animals to new prescreened owners, placing the animals into new homes with responsible and knowledgeable owners. The intent of this program is to give people a legal option to get rid of their pets without turning them loose or having them euthanized. Currently there are only between two and four amnesty events held each year; the state's intent is to help other agencies and organizations host their own Florida Fish and Wildlife Conservation Commission–sanctioned amnesty events. More amnesty events will give people additional opportunities to relinquish problem pets and will be located in more parts of the state to make them accessible to a larger number of people.

After fishes, the group that generated the second most alerts, mollusks, did so because of recent range expansions of zebra (*Dreissena polymorpha*), and quagga (*D. rostriformis bugensis*) mussels and, to a lesser extent, Asian clams (*Corbicula fluminea*), mysterysnails (*Cipangopaludina* spp.), New Zealand mudsnails (*Potamopyrgus antipodarum*), and applesnails (*Pomacea* spp.). Dreissenid mussels are primarily being transported on recreational boats. Many states, especially in the West, require boat inspections before launching into uninfested waterways to prevent further range expansion (Western Regional Panel on Aquatic Nuisance Species 2010). Mysterysnails and applesnails, two genera common in the aquarium and water garden trade, are likely releases/escapes from aquariums and outdoor ponds (Mills et al. 1993; Rixon et al. 2005). The Pet Industry Joint Advisory Council is drafting best management practices to discourage water garden designers and owners from using nonnative species (M. Meyers, personal communication). New Zealand mudsnails, rock snot (*Didymosphenia geminata*), as well as other aquatic nuisance species can be dispersed on anglers' felt-soled waders and other equipment (California Department of Fish and Game 2005; Bothwell et al. 2009; Gates et al. 2009). Some states no longer allow felt-soled waders, hoping to reduce this occurrence (Center for Aquatic Nuisance Species 2012), or these states offer specific guidelines for disinfection (California Department of Fish and Game 2005; New Zealand Mudsnail Management and Control Plan Working Group 2007), and some retailers (e.g., Orvis, L.L. Bean, Simms) no longer offer products with felt soles.

One of the more disconcerting results seen in our analysis of the alert system data is the large number of records (208) with an unknown introduction vector; indeed, records of this type comprised the second largest group of all introduction vectors. This pattern echoes that of the entire NAS database, where unknown introduction vectors comprise the largest introduction vector. Although much effort is put into assigning probable vectors to an introduction based on a species' biology, prior introduction history, and its utility/uses by human society, in many cases it is a difficult task and highlights the need for more research into potential and probable means of transport for both current and future introductions.

Several countries have expressed the need to develop and implement aggressive and thorough risk analysis frameworks for alien species in an effort to implement prevention and control strategies for target species (McNeely et al. 2001). Risk analysis frameworks, including models for predicting potential invaders (Kolar and Lodge 2002), site invisibility and propagule pressure (Leung and Mandrak 2007), and bioeconomics of control and prevention strategies (Leung et al. 2002), are important components of controlling the spread of aquatic invasive species. Equally important are EDRR frameworks for identifying new invasions as they occur and expediting management efforts (National Invasive Species Council 2008). The NAS Database and Alert System assists with both of these goals by providing distributional data for risk analysis and modeling efforts, as well as rapid dissemination of new introductions to natural resource managers and other stakeholders as part of the national EDRR system.

Alert System

There are vast amounts of very good but fragmented data on the distribution on nonindigenous species (e.g., personal observations/collections, museum holdings, survey data from natural resource agencies) that are difficult to use in large-scale analysis. The NAS program aims to act as a centralized repository for distributional data on introduced aquatic species and is involved in various partnerships with other agencies and groups to try to bring together disparate data sets. Some of our partners include the National Oceanic and Atmospheric Administration Great Lakes Environmental Research Laboratory, Florida Fish and Wildlife Conservation Commission, Smithsonian Environmental Research Center (SERC), the state of Washington, and the 100th Meridian Initiative Columbia River Basin Team. Our partners contribute their data to the NAS database so that it can be part of an integrated national approach to tracking aquatic species introductions. For some, we generate in return a region- or state-specific "filtered view" of the NAS data for their use, such as the National Oceanic and Atmospheric Administration's Great Lakes Aquatic Nuisance Species Information System (NOAA 2013).

We have worked with SERC's Marine Invasions Lab for many years, which maintains a parallel database for marine and estuarine data: the National Exotic Marine and Estuarine Species Information System. We are working to develop a joint alert system with SERC, which has been very active in tracking high-profile species as they expand their range, such as green crab (*Carcinus maenas*) and Chinese mitten crab (*Eriocheir chinensis*). Together, these two databases cover most introduced aquatic species in the United States. When completed, there will be a single place to register for new alerts on all aquatic species. The two databases combined will assist natural resource managers by compiling existing data and literature describing life histories, previous expansion patterns, and previous attempts at eradication, which will enable managers to predict and prioritize specific areas for monitoring and quarantine of certain areas, construct barriers, and develop EDRR programs as well as allow the use of scale as a tool for detection.

We encourage all biologists and the public to participate and submit reports to the NAS database in order to help provide an accurate picture of the distribution of introduced aquatic organisms nationwide. The public is very important for finding and reporting introductions. As pointed out above, 63% of the records that generated alerts were a result of personal communication. The database contains approximately 13,000 reports from personal communications, nearly 12% of the records. Some of these are directly from the public and others are from state or federal agencies whose source was the public. Reports should be sent to http://nas.er.usgs.gov/SightingReport.aspx. This reporting site allows for photos to be uploaded. We strongly encourage people to include photographs when possible so that we can verify identification. Photographs are posted on the web site so they can be seen and verified by others and provide overall confidence in the record. This integrated system provides the ability for users to report nonindigenous and invasive aquatic species they observe, automatically receive alerts, and/or perform searches on aquatic species on a nationwide scale.

Analysis of data from the NAS Alert System suggests that species are being introduced into new areas at an alarming rate. Overall, 1,189 alerts in 7.5 years is an average of 159 alerts per year, or an introduction to a new area (as defined here, not just a new water body) every 2.3 days. Our analysis does not include introductions to new waters within the same county or drainage (i.e., movement among individual streams within a HUC8-level watershed); inclusion of these would likely increase the total number of introductions. There also may be many introductions of which we are not aware or remain unknown (i.e., discovery of an introduction is separate from the introduction process; Solow and Costello 2004), indicating that the NAS database and alert system represents a conservative minimum record of the introduction and spread of aquatic species nationwide.

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AFS 2013 Little Rock: Preparing for the Challenges Ahead

The William J. Clinton Presidential Center and Park will be the site of the Farewell Social on Thursday, September 12. The William J. Clinton Presidential Center and Park is a short half-mile walk or trolley ride from the Peabody Hotel and State House Convention Center. The social will be held at the LEED certified Clinton Library in downtown Little Rock along the banks of the Arkansas River. The reception will be hosted in the Great Hall, which boasts 40-foot ceilings, bamboo floors, and glass walls that offer you a spectacular and unforgettable panoramic view of downtown Little Rock. In addition, you will have access to the outside Scholars Garden that showcases native flora. Tours of the Clinton Library will be included during the first two hours of the reception. The library houses the largest archival collection in American presidential history. Attendees will be treated to a relaxing event, complete with music, food, and beverages.

Forty Two, the Clinton Library restaurant, will cater the social, which will feature local fare and drinks from Arkansas, as well as introduce you to Canadian cuisine and drinks to help get you in the mood for the 2014 AFS annual meeting in Quebec City. The chef at *Forty Two* practices the "farm to table" movement, so the menu is sure to be filled with an array of fresh produce and all-natural proteins.

(Much of the information in this article is from the Center website: clintonpresidentialcenter.org)

Hatcheries and Management of Aquatic Resources (HaMAR) Group Focuses Attention on Issues Surrounding Hatcheries and Hatchery-Origin Fish and Shellfish

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For the past several decades, AFS has coordinated and helped to sponsor a forum to collectively discuss the role of hatcheries and hatchery-origin fish in natural resources management. Conducted at approximately 10-year intervals, these forums generally include a state-of-art science symposium and survey addressing the interactions between hatcheries and key management issues. The symposium is followed by a facilitated workshop to distill these issues into a summary publication that includes recommendations regarding the use of hatchery-origin fish. Previous forums, respectively entitled, "Roles of Fish Culture in Fisheries Management" (1983), "Uses and Effects of Cultured Fishes in Aquatic Ecosystems" (1993), and most recently "Propagated Fishes in Resource management" (PFIRM; 2003) each addressed the evolving concerns surrounding hatcheries, such as the value of hatcheries as management tools, and how to optimize the ability of hatcheries to support management objectives. These efforts brought together a cross section of North American fisheries professionals to discuss and debate contentious management issues for reconciliation. The last cycle produced "Considerations for the Use of Propagated Fishes in Resource Management," the first comprehensive publication that tied science-based information with political realities of aquatic resource management, and offered decision-makers a set of consensus-guiding principles for the use of hatchery-origin fish and shellfish.

In response to changes that have occurred, newly available information, and issues that have arisen since the previous cycle, then AFS President, Bill Fisher, established an ad-hoc committee, Hatcheries and Management of Aquatic Resources (HaMAR), to reengage AFS in addressing current issues related to hatchery operation and the role of hatchery-origin fish and shellfish in aquatic resource management. Representing interested AFS Sections and state and federal agencies, Committee members Jesse Trushenski (co-chair), Don MacKinlay (co-chair), Doug Bradley, Tom Flagg, Kurt Gamperl, Jeff Hill, Christine Moffitt, Vince Mudrak, George Nardi, Kim Scribner, Scott Stuewe, John Sweka, Gary Whelan, and Connie Young-Dubovsky, have been working to develop, organize, and implement the HaMAR process.

The HaMAR committee's work began with a scoping survey to give voice to a diverse cross-section of fisheries professionals in identifying contemporary issues of concern. Nearly 450 AFS members and other fisheries professionals responded to this survey. Collectively, they highlighted a number of critical issues related to hatcheries, hatchery-origin fish, and fisheries management (Figure 1). The Committee is currently planning fact-finding symposia around these topical areas, to bring these challenging aquatic resource management issues before a body of scientists and resource managers spanning a wide range of scientific disciplines, and representing different professional perspectives. A small initial symposium will be held at AQUACULTURE 2013 in Nashville, Tennessee (February 21–25), and a larger core symposium is currently being coordinated for AFS 2013 in Little Rock, Arkansas (September 8–12). Both forums will be held at locations in the central U.S. and will draw a large numbers of fisheries professionals for a frank and engaging dialogue. The content of these symposia and the associated discourse will be used to frame the next set of guiding principles.

Science-based resource management and research findings continue to provide new information to strengthen the decision-making of regulatory agencies, and new challenges continue to emerge. The timing is right to assess the effects of hatchery reform, the increasing importance of imperiled species restoration, as well as a number of other emerging issues in hatchery operation and the uses of hatchery-origin aquatic animals in fisheries management. By calling upon the shared expertise of AFS, HaMAR is well-positioned to lead fisheries professionals in assessing and advocating for effective uses of hatchery-origin fish in aquatic resource management.

Top Ten Topics Identified by Scoping Survey
Nearly 40 topics ranked from 0 (not important) to 5 (extremely important)

Topic	Rank
Habitat restoration and management efforts as companions to stocking	4.2
Monitoring and adaptive management of stocking programs	4.1
Development of propagation techniques that results in genetically appropriate, healthy hatchery-origin fish	4.1
Fish health and access to disease management tools	4.0
Understanding the limitations of hatchery-origin fish and stocking programs	4.0
Biological interactions between wild and hatchery fish	3.9
Defining appropriate uses for hatchery-origin fish, defining expectations and understanding the limitations of hatchery-origin fish and stocking programs	3.9
Culture of imperiled species and conservation hatcheries	3.8
Risk assessment and decision-making	3.8
Genetic integrity of hatchery-origin fish	3.7

Figure 1. Most important hatchery topics as identified by scoping survey.

The Fish Culture Section's Perspective on HaMAR

Jim Bowker, Section President

The Society is in a truly unique position to address issues like hatcheries and management of aquatic resources due to its structure and the diversity of members' expertise. Reaching out and establishing leadership groups with wide-ranging expertise in the scientific disciplines is readily done in a society like AFS. Belonging to AFS opens doors, allowing individuals and the Society as a whole to work collaboratively and, through science-based processes like HaMAR, identify solutions to complex challenges. The Society's structure, with its various Sections, provides access to leading experts in the many disciplines of fisheries science related to the proper use of hatchery-origin aquatic animals in natural resources management. An approach such as HaMAR leverages our collective wisdom, ensures that all perspectives on such issues will be heard, and increases the likelihood that decisions and recommendations related to hatcheries and hatchery fish will be predicated on one of the cornerstones of AFS: sound science. I commend those in our Society willing to engage in this forum and address these issues, and am confident that this collaborative effort will result in scientifically justifiable, up-to-date recommendations regarding hatcheries and management of aquatic resources.

JOURNAL HIGHLIGHTS

North American Journal of Aquaculture
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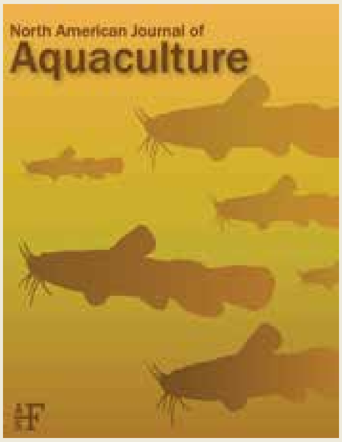

OPEN POSITION

State Program Administrative Manager Sr – Fisheries Habitat Program Manager
MN Department of Natural Resources – Division of Fish and Wildlife in St. Paul

Responsibilities: Direct, plan, develop, administer and evaluate the Fisheries Habitat program for lake and streams, and their watersheds throughout MN. Assist the Fisheries Section Chief with administrative, supervisory and legislative responsibilities so Division programs and policies are effectively funded and delivered.

Qualifications: BS in Fisheries Management or a related field. Applicants must meet MN DNR Fisheries minimum course work requirements or be certified by AFS. Three years of managerial or advanced supervisory experience or 5 years of advanced professional-level experience required.

Salary: $62,911–$90,515

Ad Closing Date: March 29, 2013

Contact: Dirk Peterson, 651.259.5229 or dirk.peterson@state.mn.us

Weblink: https://statejobs.doer.state.mn.us/JobPosting (for complete job posting: search on the job title)

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CALENDAR
Fisheries Events

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

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

More events listed at www.fisheries.org

DATE	EVENT	LOCATION	WEBSITE
March 17–22, 2013	9th International Conference on Molluscan Shellfish Safety	Sydney, Australia	www.icmss2013.com
March 19–20, 2013	2013 IAFS, ISAF, & TWS Spring Conference	Lafayette, IN	www.indianaafs.org
March 21–23, 2013	The Tidewater Chapter Annual Meeting	Solomons, MD	www.sdafs.org/tidewater/AFSTidewater/Home.html
March 26–29, 2013	2013 Utah Chapter of the American Fisheries Society Meeting	Page, AZ	http://utahafs.org/wp-content/uploads/2011/12/Draft-Agenda-2.8.13.pdf
April 4–6, 2013	47th Annual Cal-Neva Conference	Davis, CA	www.afs-calneva.org/annual_meeting.php
April 8–12, 2013	7th International Fisheries Observer and Monitoring Conference (7th IFOMC)	Viña del Mar, Chile	IFOMC.com
April 15–18, 2013	Western Division Annual Meeting	Boise, ID	www.idahoafs.org/2013AnnualMeeting
April 22–24, 2013	Sustainable Ocean Summit (SOS) 2013 - World Ocean Council	Washington, DC	www.oceancouncil.org/site/summit_2013
April 25–26, 2013	NPAFC 3rd International Workshop on Migration and Survival Mechanisms of Juvenile Salmon and Steelhead in Ocean Ecosystems	Honolulu, HI	npafc.org/new/index.html
May 7–9, 2013	The 3rd Managing Our Nation's Fisheries Conference	Washington, DC	www.cvent.com/events/managing-our-nation-s-fisheries-3/event-summary-94ddf325198f4501996ccc62aa396aa2.aspx
May 11–19, 2013	Fisheries Awareness Week	Ireland	www.faw.ie
May 20–24, 2013	AFS Piscicide Class - Planning and Executing Successful Rotenone and Antimycin Projects	Logan, UT	fisheriessociety.org/rotenone; Contact: Brian Finlayson at briankarefinlayson@att.net


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