Fisheries

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NOVEMBER 2009

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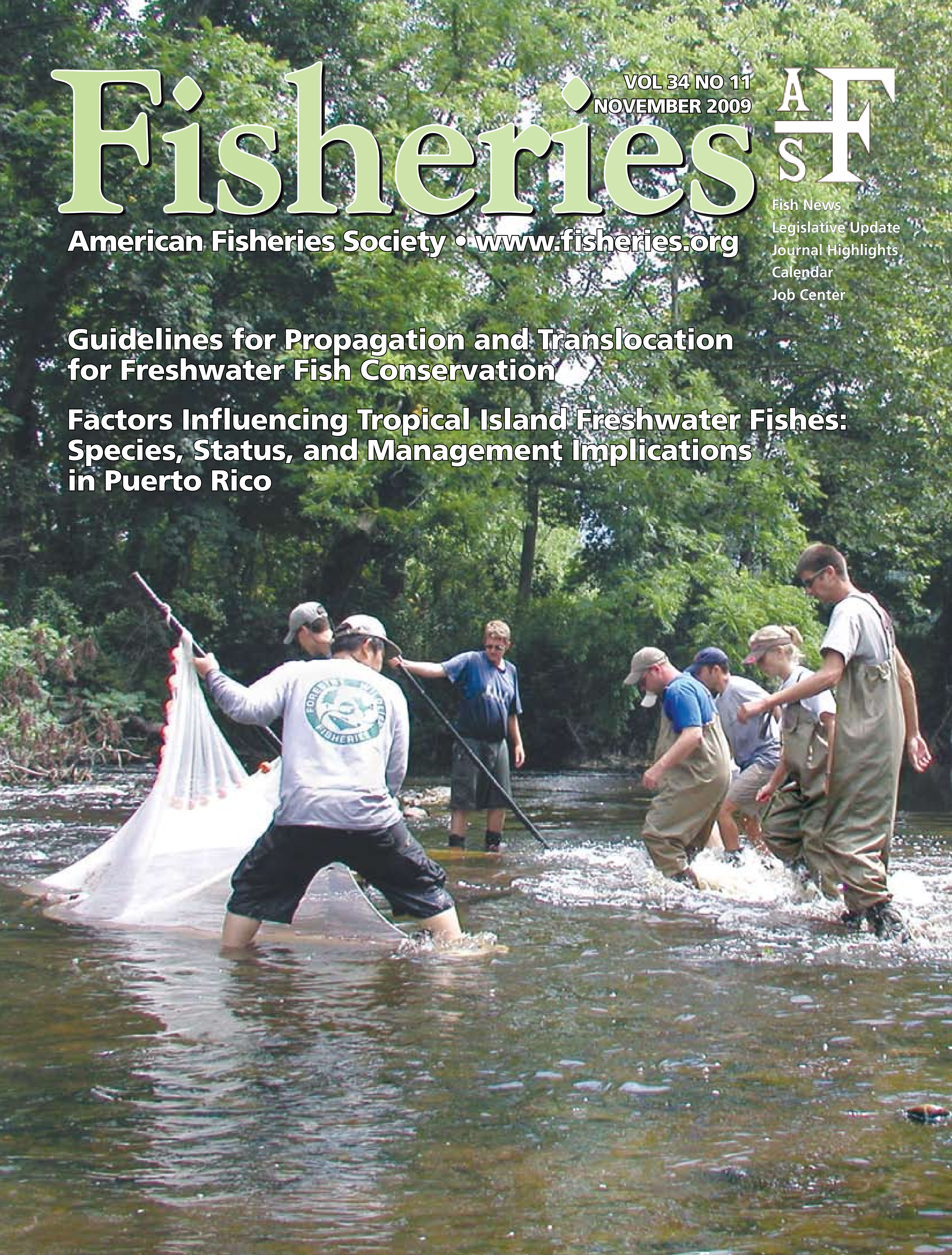

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The American Fisheries Society (AFS), founded in 1870, is the oldest and largest professional society representing fisheries scientists. The AFS promotes scientific research and enlightened management of aquatic resources for optimum use and enjoyment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

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COVER: Annual assessments indicate that several native species are successfully reproducing after translocation into the Pigeon River, a tributary of the French Broad River in the Tennessee River drainage.

CREDIT: Joyce Coombs

COLUMN:
PRESIDENT'S HOOK

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Building Bridges for Community Development among Natural Resources Organizations

Scientists are real sticklers when it comes to detail, precision, and efficiency. We are prone to tease things apart and then develop and use specific terms to define our discoveries, formulate our concepts, and express our perspectives. As scientific disciplines and associated concepts have evolved, so have their respective languages. Accordingly, college curricula are to a large degree dedicated to teaching and learning discipline-specific vocabulary and, through exposure to fundamental concepts, providing students with opportunity to communicate with these terms. In the more progressive curricula, considerable attention also is given to cross referencing the language and concepts of the chosen major with those of other fields. This cross referencing is particularly important for students in the natural resources majors because of the diversity of interactive components in our professions.

In reality, cross referencing continues throughout our careers in fisheries and as scientists. We recognize that by adopting language and concepts from other fields, we enhance precision in thought and communication in our own. We also discover that doing this affords us greater opportunity to build cross-disciplinary bridges which, in turn, expose us to new methodologies, technologies, and perspectives. Our worlds become larger and more interactive. We find commonality of purpose. We learn that we are not alone in the quest for synergistic relationships. Stated in ecological terms, opportunity emerges for transforming assemblages into communities.

One need only look within the organizational framework of the American Fisheries Society to understand that we have taken this evolutionary process very seriously. Take, for example, AFS Sections. They range from an emphasis on basic sciences to fisheries law and engineering, and from biological and ecological arenas to fisheries management and the humanities. We come together professionally as an integrated society, and transcend discipline specificity in order to address common denominators related to fisheries. We understand the power and efficiency of organized, collective endeavors. We also are tempered by the reality that as an organization, as a professional scientific society, AFS cannot function effectively (and perhaps cannot survive) in isolation. We are not an end unto ourselves. We are part of a greater movement addressing understanding and stewardship of natural resources.

The players in this movement are many and diverse. Some are governmental. Many are not. Some are profit motivated while others are non-profit. Some (like AFS) are professional scientific organizations. Others are primarily citizen conservation organizations that are attractive to a broader spectrum of membership. There are AFS members who are members of other professional organizations and there are AFS members who are members of citizen conservation organizations. This mix is a very good thing because even though we find ourselves caught up in the same currents, different groups play different roles and express different emphasis and perspectives. All are needed.

Within the realm of professional scientific organizations, AFS currently is working to develop a coalition of societies that clearly deal with similar issues in similar ways. The societies engaged in this dialogue are The Wildlife Society, the Society for Range Management, and the Society of American Foresters. If we are successful in coming together as a coalition, we will be able to command more attention and likely have more influence in dealing with government and legislative processes. We will be able to work together more efficiently to establish and maintain programs and communication initiatives (e.g., topic oriented meetings) of mutual interest, and jointly develop outreach materials. Eventually we might even be able to increase our efficiencies and perhaps even our effectiveness by sharing resources and opportunities. This is all a budding concept and we are moving slowly and cautiously, testing the waters as we go. We want to be sure that this synergism can occur without loss of our distinct identities.

To help advance this initiative, it was my privilege to attend The Wildlife Society's (TWS) recent annual meeting in Monterey, California. As AFS president, I was invited to participate in their Council meeting (equivalent to the AFS Governing Board). The Council's structure and dynamics differ from those of our Governing Board, but the purposes were clearly the same. I recognized many common denominators between governance of AFS and TWS. During the Council meeting, I was encouraged to ask questions and seek clarification. On occasion I was asked to provide opinion. There was, fundamentally, a very clear and strong desire expressed by TWS leadership during the Council meeting and beyond to work ever more closely with AFS.

The current president of TWS, Bruce Leopold, is a longtime colleague of mine on the faculty of Mississippi State University. This is the first time in history that presidents from both societies are from the same university. The situation provides AFS and TWS with a unique opportunity to strengthen relationships between the two societies in very tangible ways. Incidentally, next year both presidents will be from Wyoming.

Not only do Bruce and I share resources at our university, we share fundamental professional values and perspectives as they relate to scientific

Continued on page 565

NEWS: FISHERIES

Berkeley Fellowship Deadline Now Earlier

The Steven Berkeley Marine Conservation Fellowship was created by AFS in 2007 to honor the memory of Steven Berkeley, a dedicated fisheries scientist with a passionate interest in integrating the fields of marine ecology, conservation biology, and fisheries science to improve fisheries management. Berkeley was a long-time member of AFS and a member of the first Board of Directors of the Fisheries Conservation Foundation. The fellowship comprises a competitively based $10,000 award to a graduate student actively engaged in thesis research relevant to marine conservation. Research topics may address any aspect of conservation; a focus on fisheries issues is not required.

REQUIREMENTS FOR APPLICATION:

1. The applicant must be a student officially accepted or currently enrolled in a M.S. or Ph.D. program.
2. The student must be actively engaged in thesis research related to some aspect of marine conservation; the intent of the award is to support ongoing research costs.
3. The student must be a member of AFS in good standing; membership can be obtained at the time of application submission.

APPLICATION PACKAGE:

1. Cover letter, including a statement of how the award will be used and how the student's research aligns with Berkeley's scientific interests and conservation philosophy.
2. Resume, including the following:
   - o Educational history: degrees, relevant courses completed, grade point averages.
   - o Professional experience: positions held with description of responsibilities, including any volunteer activities

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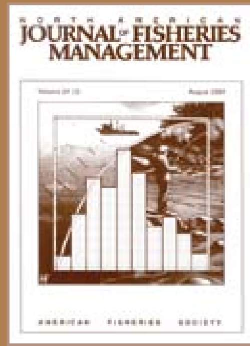

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A Seabass Revival

Mike Shane leads HSWRI's seabass assessment research. Above, he shows the displays used to encourage sport fishers to return heads from captured seabass. Below, he works with commercial fishers to recover CWTs. The smaller fish was released at 23 cm and recovered 144 mi from the release site at age 6. The larger fish was released at 25 cm and recovered 65 mi from the release site at age 9.

CWTs are pieces of stainless steel wire 1.1 mm long and 0.25 mm in diameter etched with a numeric code (magnified, left).

Once a rare catch, the white seabass (*Atractoscion nobilis*) is resurging from severe depletion with the help of a unique program at Hubbs-SeaWorld Research Institute (HSWRI) in California, USA. In 1983, the Ocean Resources Enhancement and Hatchery Program began with the goal of raising white seabass for ocean release, and is one of only a few marine finfish stock enhancement programs in the world.

HSWRI scientists first learned to spawn the fish in captivity and rear the delicate larvae. This process is highly successful—production is 350,000 juveniles annually, with plans for 1 million. A combination of direct and net pen year -round releases are used after about 3 months of hatchery rearing. For net pen releases, the juveniles are transferred to 13 saltwater grow out facilities along the coast. They are released several months later at about 20 cm long.

Before release, each fish is tagged in the cheek with a Coded Wire Tag (CWT). The CWT is used to distinguish hatchery-reared from wild fish after release, evaluate hatchery rearing practices, and monitor how well the fish are surviving in the wild. To help HSWRI retrieve the tags, fishers are asked to save the heads of white seabass caught off the California coast and to deposit them at various drop-off locations. More than 1,800 tagged fish have been recovered since the start of the program with anglers recovering some fish 13 years after release.

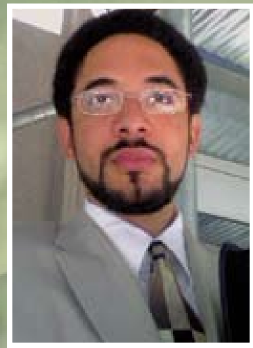
The CWT program provides much information that benefits seabass enhancement. For example, tag recoveries showed that releasing juveniles from net pens is more effective than direct releases. The hatchery is reorganizing production and release strategies to maximize survival and subsequent recruitment to the fisheries.

NMT is proud to be part of this project and hundreds of others around the world. Please contact us if we can help with yours.

UPDATE: LEGISLATION AND POLICY

Elden Hawkes, Jr.

AFS Policy Coordinator Hawkes can be contacted at ehawkes@fisheries.org.



National Fish Habitat Board Meeting

On 7–8 October, the National Fish Habitat Board met in Arlington, Virginia. The issues discussed included climate change, potential new partnerships, and pending congressional legislation.

The board approved the applications of five candidate Fish Habitat Partnerships for full recognition during the meeting. The newly approved partnerships are: Atlantic Coastal Fish Habitat Partnership, Ohio River Basin Fish Habitat Partnership, Reservoir Fisheries Habitat Partnership, Great Lakes Basin Fish Habitat Partnership, and the Great Plains Fish Habitat Partnership. Applications from two candidate partnerships were deferred pending additional information: the Kenai Peninsula Fish Habitat Partnership and the California Fish Passage Forum. This increases the total number of recognized partnerships to 14.

A presentation on climate change and NFHAP was also given to the board as part of the meeting. During this presentation it was stated that the National Climate Change and Wildlife Science Center (of the U.S. Geological Survey [USGS]) has been renamed the National Center for Climate Change Response. This was done to reflect Interior Secretary Salazar's desire for the center to encompass all of the Department of Interior's endpoints for climate change. The center will be comprised of eight regional response centers that report to a central headquarters. The center will work with the partnerships to sustain fish and wildlife communities in natural systems.

Other agencies like the U.S. Fish and Wildlife are trying to understand the societal response to climate change. It is felt that a synergy needs to be built across all aspects of climate change response including forecasting, mitigation, and adaptation to adequately address the problem. In contrast, many states are still trying to figure out where they stand on climate change. Many are unsure as to what actions they are going to take, especially regarding mitigation and adaptation. States' response is also hampered both budgetary and personnel limitations.

NFHAP legislation: Bills have been introduced in both the House and Senate. The House's Natural Resources Subcommittee on Insular Affairs, Oceans, and Wildlife held a hearing on 16 June 2009, while a hearing in the Senate committee on Environment and Public Works is tentatively planned for November. It was reported that the Senate bill (S 1214) has strong bipartisan support and that it may be moved as part of a package of wildlife bills, while the House bill (HR 2565) has very little bipartisan support.

NFHAP data: The board voted to accept the offer of the USGS National Biological Information Infrastructure (NBII) to house the NFHAP Data System. The board also approved the Standard Operating Procedures for Data Management proposed by the Data Subcommittee and approved the white paper on the NFHAP Assessment and Decision Support System for review by the fish habitat partnerships and other interested parties.

U.S. supports CITES listing for Atlantic bluefin tuna

Tom Strickland, Assistant Secretary of the Interior for Fish and Wildlife and Parks, announced that the United States supports a proposal submitted by the principality of Monaco to list Atlantic bluefin tuna in Appendix I of the Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES). This action affords stringent protection and prohibits all international commercial trade. The fifteenth regular meeting of the CITES parties (CoP15) is scheduled for 13–24 March 2010 in Doha, Qatar. Strickland will lead the U.S. government delegation to CoP15.

The Atlantic bluefin tuna is a long-lived species, found in the entire extent of the North Atlantic Ocean and its adjacent seas, particularly the Mediterranean Sea. The fishery is managed as two separate stocks separated by the 45°W meridian: the Eastern Atlantic and Mediterranean stock, and the Western Atlantic stock. The separation between the stocks is based on separate spawning grounds, genetic differentiation, differing ages for reaching sexual maturity, and the apparent absence of spawning in the middle of the North Atlantic.

The eastern stock of the Atlantic bluefin tuna has declined precipitously in the last 10 years. It is estimated that the stock has decreased by 60% in that period. The western Atlantic spawning stock has declined by 82.4% since 1970. However, this stock has been stabilized at a very low population level. Many believe that this is due to stronger management and compliance measures adopted for that stock.

The management of the bluefin tuna is regulated by the International Commission for the Conservation of Atlantic Tunas (ICCAT). ICCAT is an inter-governmental, regional fishery management organization responsible for the conservation of tunas and tuna-like species in the Atlantic Ocean and its adjacent seas.

Guidelines for Propagation and Translocation for Freshwater Fish Conservation

Anna L. George, Bernard R. Kuhajda, James D. Williams, Mark A. Cantrell, Patrick L. Rakes, and J. R. Shute

George is director of the Tennessee Aquarium Conservation Institute, Chattanooga.
Kuhajda is collections manager at the Department of Biological Sciences, University of Alabama, Tuscaloosa.
Williams is a research associate at Florida Museum of Natural History, Gainesville.
Cantrell is a fish and wildlife biologist at the U.S. Fish and Wildlife Service, Asheville, North Carolina.
Rakes is co-director of Conservation Fisheries, Inc., Knoxville, Tennessee.
Shute is co-director of Conservation Fisheries, Inc., Knoxville, Tennessee.

ABSTRACT: Reestablishment of locally extinct populations and augmentation of declining populations are management activities used with increasing frequency in the conservation of imperiled fishes in the United States. Unfortunately, these options were not always carefully or appropriately used in past cases, partly owing to a lack of guidelines that address scientifically-based protocols for propagation, translocation, reintroduction, and augmentation (PTRA). PTRA programs are an important management tool for the recovery of imperiled fishes when undertaken with careful planning, including everything from determining that PTRA is necessary to incorporating knowledge of life history and genetics into the PTRA plan. In addition, PTRA programs must also assemble advisory groups, obtain funding and permitting, construct and maintain propagation facilities, and raise community awareness of the program. Because such diverse skills are needed, successful PTRA programs should prepare for long-term partnerships to achieve the goal of recovery.

Guía de propagación y trasladación para la conservación de peces de agua dulce

RESUMEN: En los Estados Unidos de Norteamérica, el restablecimiento de poblaciones localmente extintas y la recuperación de poblaciones en descenso son actividades de manejo utilizadas cada vez con más frecuencia en la conservación de peces en peligro o amenazados. Infortunadamente, en el pasado dichas opciones no siempre fueron usadas de forma apropiada ni cuidadosa, debido en parte a la falta de guías científicas sobre los protocolos de propagación, trasladación, reintroducción y recuperación (PTRR). Los programas de PTRR son importantes herramientas de manejo para recuperar las especies de peces que se encuentran en peligro o amenazadas cuando son planeadas con el debido cuidado, incluyendo desde determinar si el PTRR es necesario, hasta la incorporación de conocimientos acerca de ciclos de vida y aspectos genéticos al cuerpo del programa. Adicionalmente, los programas PTRR deben reunir distintos grupos de asesores, recabar fondos y permisos; construir y mantener la infraestructura necesaria para actividades de propagación así como también despertar la conciencia de la comunidad con respecto al programa. En virtud de que todas estas tareas son indispensables, aquellos programas PTRR que resulten exitosos debieran estar dispuestos a establecer sociedades de largo plazo si el objetivo es alcanzar la recuperación de los peces en peligro.

THE NEED FOR PTRA GUIDELINES

Over the past 20 years, the number of imperiled freshwater fishes in the United States has almost doubled (Jelks et al. 2008). Habitat destruction has been a major contributing factor to the steady decline of fish populations (Etnier 1997; Jelks et al. 2008). Though conservation actions have restored some freshwater habitats, fragmentation or isolation may limit recolonization by fishes and prevent full recovery of the community (Detenbeck et al. 1992; Lonzarich et al. 1998; Morita and Yamamoto 2002). In these scenarios, recovery of the target species and complete restoration of the system may depend on PTRA: propagation or translocation for reintroduction or augmentation. Propagation is the production of individuals within a captive environment for the purpose of reintroduction to the wild. We define translocation as the movement of wild-caught fishes from one place to another within their known range. We consider relocations of fishes outside of their native range as introductions. An augmentation is the addition of individuals to an existing wild population. A reintroduction is a release of fishes within their historic range where a population no longer exists. Augmentations and reintroductions can be accomplished through the release of propagated or translocated fishes. When implemented with a scientific foundation, PTRA can be a powerful tool in the recovery of imperiled fishes.

Short-term goals of PTRA projects are often to prevent the extinction or population loss of imperiled fishes (Johnson and Jensen 1991; USFWS 2000; Shute et al. 2005). In some drastic situations, propagation and maintenance of an ark population is necessary to prevent extinction of an entire species when all suitable wild habitat has been lost (Miller and Pister 1971; Flagg et al. 2004). PTRA projects are often an integral part of Endangered Species Act (ESA) recovery plans because establishment of additional populations are typically a criterion for down-listing or even delisting (USFWS 2000; Paragamian and Beamesderfer 2004). With foresight, PTRA projects can also be used as a tool to prevent listings by halting a downward spiral of decline and ultimately stabilizing populations (Goldsworthy and Bettoli 2006). Our objectives are to provide guidelines and precautionary rules for planning, executing, and monitoring PTRA programs for freshwater fishes in order to improve their likelihood of success and aid the recovery of aquatic ecosystems.

GUIDING PRINCIPLE: DO NO HARM

The first priority for the recovery of a species is to improve the status of wild populations in their natural habitat (USFWS 2000). PTRA should not be a substitute for addressing the factors that resulted in the decline of the species in the wild (Snyder et al. 1996). PTRA activities should only be undertaken if other recovery options addressing the current limiting factors are not likely to be effective in the foreseeable future (Philippart 1995; USFWS 2000). The threat of losing a species or population if no PTRA action is taken must be assessed and contrasted with the difficulties involved with PTRA. Sometimes, it may be better to do nothing than to risk activities that might cause even more harm to an imperiled species or ecosystem (Snyder et al. 1996; Ford 2002; Metcalf et al. 2007; Walker et al. 2008). However, if wild populations do not appear to be sustainable without action, then a PTRA program can be an effective, and sometimes essential, recovery tool, so long as this guiding principle is followed (Box 1).

Box 1.
Best Case Scenario: Abrams Creek Restoration

Abrams Creek in the Great Smoky Mountains National Park was poisoned with rotenone in 1957 to improve fishing for the nonindigenous rainbow trout (*Oncorhynchus mykiss*), causing the loss of many native fishes, though the habitat remained pristine. A multi-agency captive propagation project was initiated in 1986 to restore several federally-protected fishes to this stream (Shute et al. 2005). Conservation Fisheries, Inc. (CFI) of Knoxville, Tennessee, has managed the captive propagation and is the lead in monitoring both source and target populations. Because a project using captive propagated non-game fishes had never been undertaken, this program has been a learning process that will serve as a template for future restoration projects.

Captive propagation initially focused on the federally-endangered smoky madtom (*Noturus baileyi*) and the federally-threatened yellowfin madtom (*N. flavipinnis*). In 1993, the federally-endangered Citico darter (*Etheostoma sitikuense*) was included in the species being restored to Abrams Creek. Over the 20-year span, more than 3,000 smoky madtoms, 1,600 yellowfin madtoms, and 3,500 Citico darters have been released. These three species have been reproducing, recruiting, and dispersing into suitable habitats in Abrams Creek, where numbers of fishes now often rival those seen in the source population in nearby Citico Creek.

Attempts were also made to establish the federally-threatened spotfin chub (*Erimonax monachus*) in Abrams Creek. After several failed translocation efforts, captive propagation was undertaken. A total of 12,000 spotfin chubs were released into Abrams Creek, but efforts to restore this species have now ceased because no significant recruitment was ever documented.

Although progress on this project was often impacted by inadequate funding, it has been a great success overall with three of the four imperiled species now thriving in at least some sections of Abrams Creek. The most important lesson from this project has been patience—evidence of success took many years to materialize. Nearly 5 years passed before any released fish were recaptured in Abrams Creek, and 10 years before in-stream recruitment was documented. Those undertaking PTRA projects must be persistent to increase the chances of eventual success.

—PLR & JRS

Abrams Creek, site of a multi-agency captive propagation project to restore several federally-protected fishes that were lost from a rotenone application during the 1950s (Shute et al. 2005).

Photo: Conservation Fisheries, Inc.

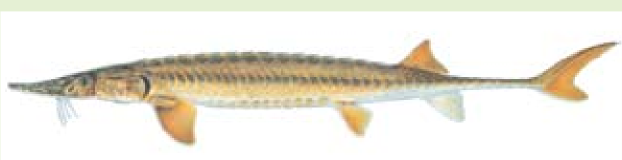
RULE 1: DETERMINE THAT PTRA IS NECESSARY

The decision to incorporate captive propagation or translocation involves several important considerations and must be evaluated on a case-by-case basis. First, an evaluation of the viability of a wild population must be conducted to determine its current status in terms of occurrence and abundance. This may be particularly difficult with rare fishes, when failure to detect the presence of the species does not necessarily imply its absence (Box 2; Gu and Swihart 2004). In these cases, greater sampling effort, multiple survey techniques and equipment, and estimating detection probabilities are necessary to increase confidence in the assessment of abundance (Yoccoz et al. 2001; Royle et al. 2005; Albanese et al. 2007). Repeated surveys using different sampling methods need to be conducted as fishes may differ in their habitat use seasonally or throughout their life cycle (Bayley and Peterson 2001; Royle and Nichols 2003; MacKenzie and Royle 2005). Even if individuals are detected, augmentation may be determined to be necessary if the long-term prognosis for recovery does not appear feasible or recruitment is failing (Philippart 1995).

Box 2.
Beyond Detectability: The Alabama Sturgeon

The Alabama sturgeon (*Scaphirhynchus suttkusi*) is a federally-endangered species restricted to large-river habitat in the Mobile Basin in Alabama and, historically, northeast Mississippi. It was proposed for listing as endangered in 1993. A coalition of businesses in Alabama opposed its listing, suggesting it was extinct since none had been collected in eight years. Collecting efforts in the Alabama River by the USFWS produced a single specimen later that year, but the USFWS withdrew the proposal to list the Alabama sturgeon in 1994 because there was "insufficient information to justify listing a species that may no longer exist" (USFWS 1994). Over the next five years, six specimens were collected by commercial fishers, the USFWS, and the Alabama Division of Wildlife and Freshwater Fisheries (ADWFF), demonstrating that this species was not extinct. These data plus the threat of a lawsuit prompted the USFWS to list the Alabama sturgeon in 2000, but additional efforts, including 30,400 survey hours from 2000 to 2005, failed to produce any specimens with the last verified sighting by a fisher in 2000 (Rider and Hartfield 2007). While sampling for paddlefish, ADWFF personnel captured an Alabama sturgeon in the Alabama River in April 2007, seven years after the last confirmed catch. Clearly, large-river fishes can go undetected for many years, even with efforts directed at their capture. Any hypotheses of population loss or extinction based on negative sampling data are valid only if directed efforts using correct fishing gear in appropriate habitat are employed over years or even decades.

—*BRK*



The Alabama sturgeon, an endangered species that persists even though it goes undetected for years despite targeted collecting efforts.
Illustration: Joe Tomelleri.

Second, the decision to begin PTRA activities must be based upon the need for action within the historical range of the species (IUCN 1987). Knowledge of the historical range should be based on locality data from scientific literature and museum records. Introductions should never be made outside of the historical range of a species, regardless of its imperilment, because it may have unintended negative impacts on the native species assemblage present at the introduction site (Box 3).

Box 3.
Do No Harm

The watercress darter (*Etheostoma nuchale*) is a federally-endangered fish native to only four springs in the Black Warrior River drainage of the Mobile Basin in Jefferson County, Alabama. These sites are in the greater Birmingham metropolitan area, where development threatens these springs with groundwater pollution and reduced flows due to extensive impervious surfaces. In response to these threats, the USFWS and local biologists established an additional population of watercress darters in 1988 by translocating 200 individuals from Roebuck Spring (Village Creek watershed) to Tapawingo Spring (Turkey Creek watershed), outside of the native range of the species. The translocation was successful; watercress darters are now found by the thousands throughout Tapawingo Spring and the surrounding wetland area.

However, this tale does not have a happy ending, at least not for another imperiled fish, the rush darter (*Etheostoma phytophilum*), which was not described as a distinct species until 1999 (Bart and Taylor 1999.) This darter also lives in springs and spring-fed streams and is a candidate species for federal listing with a distribution in the Black Warrior River drainage in three isolated populations, including the Turkey Creek watershed and Tapawingo Spring. As the nonnative watercress darters grew in numbers, rush darters became rarer at this site, with the last rush darter collected in 2001. It appears that rush darters can not co-exist with watercress darters in Tapawingo Spring, presumably due to competition for resources. Rush darters are still found at two other locations in the Turkey Creek watershed, but these sites have faced major habitat degradation. One site is a series of small spring seeps that almost dried up in the recent drought, and a building was constructed on the site of the other spring, leaving only a spring run that is precariously located along a state highway. The moral of this story is to never move a species, even one that is endangered, outside of its current or historical range because you never know what negative impacts it can have on the native fauna.

—*BRK*

Tapawingo Spring, site of the local extinction of rush darters (right).

Photos:
Bernard Kuhajda

Third, the suitability of the habitat in the historical range should be considered. A variety of factors must be considered, including water quantity and quality, substrate, spawning sites, nursery areas, and food supply (Shute et al. 2005). If habitat is not present in the quantity or quality necessary for all life stages, then any PTRA project is doomed to fail in the longterm. Consideration should also be given to the long-term sustainability of the habitat in the face of any future threats such as development that could cause degradation (Carroll et al. 2003). If habitat restoration is needed, that should be completed prior to any PTRA activities (Kauffman et al. 1997; Jones et al. 2006). Through habitat improvement alone, fishes may be able to reestablish self-sustaining populations by immigration or by increasing from a formerly undetectable level, making PTRA unnecessary (Lonzarich et al. 1998; Irwin and Freeman 2002; Bednarek and Hart 2005). However, if a species or population is under immediate threat of extinction or loss, consideration should be given to the establishment of an ark population.

At the conclusion of these evaluations, PTRA may be determined to be unwarranted for the survival of the species. Preliminary propagation without releases may still be advisable, as it will allow hatchery staff to gain the technical skills necessary for propagation in case it becomes necessary for recovery at a later date. If preliminary propagation is undertaken, the PTRA program should follow all of the same guidelines as those with releases.

RULE 2: GET APPROVAL AND ADVICE

After determination that PTRA is necessary, an advisory committee needs to be assembled if a recovery team or group does not already exist. The advisory committee should include biologists with research experience with the species, state agency scientists from wildlife and environmental agencies, federal agency scientists, as well as local stakeholders that may include private landowners, local and/or tribal governmental officials, members of the zoning board, and representatives from nongovernmental organizations (Runstrom et al. 2002). The role of the advisory committee is to provide guidance to the program at every step, as well as to help coordinate the program with other recovery activities for the species.

Environmental laws, regulations, and policies governing augmentation and reintroduction of imperiled fishes are complex and based on issues such as resource use, suitability, and security of transplant sites (Box 4). PTRA efforts must be conducted with approval from the agency(s) with authority and responsibility for the species and the habitat. Well-meaning but unauthorized PTRA activities could compromise wild populations of imperiled fishes.

If the fish is federally listed as endangered or threatened, or is a candidate for listing, a recovery plan may have already been drafted and approved. Many recovery plans have already prioritized PTRA activities as part of the strategy for conserving and recovering the species. If there is no recovery plan or if PTRA is not identified as a recovery strategy, PTRA activities can only

Box 4.
Fish Restoration by Translocation in the Pigeon River, North Carolina

The Pigeon River, a tributary of the French Broad River in the Tennessee River drainage, was severely polluted by paper mill effluent for nearly a century. Several fish populations were lost from the affected reach or from the entire Pigeon drainage and had no route to recolonize naturally from the nearby extant populations due to dams blocking dispersal. Ongoing efforts since the early 1990s have made great improvements to water quality and fish habitat, creating an opportunity for a PTRA project.

Though recovery of habitat has been substantial, the Pigeon River is still degraded from both point and non-point pollution. Therefore relatively common fishes believed to be tolerant of existing habitat conditions were utilized for translocation. Source populations were chosen from upstream of the impacted reach, tributaries, or other streams in the upper French Broad River system within the same Blue Ridge physiographic province.

Translocations have included mirror shiners (*Notropis spectrunculus*), saffron shiners (*N. rubricroceous*), silver shiners (*N. photogenis)*, telescope shiners (*N. telescopus*), Tennessee shiners (*N. leuciodus*), and gilt darters (*Percina evides*). Translocations began in spring 2003 for all species except gilt darters (spring 2005) and Tennessee shiners (spring 2007). As of 2007, 5,317 mirror, 2,533 telescope, 1,674 silver, and 670 Tennessee shiners, and 323 gilt darters have been released.

Successful translocation appears to depend heavily on the details of the technique. Native cyprinids are notoriously fragile, therefore minimal and careful handling of shiners during capture, preparation for transport, and release is essential. Fishes are translocated in April just prior to spawning and in October when young of the year are easily captured and air and water temperatures are favorable. Translocations in August when air and water temperatures were high resulted in unacceptable levels of mortality.

Annual assessment of survival in the Pigeon River indicates that silver and telescope shiners have done well, are recruiting, and have dispersed up to eight river miles from release sites with silver shiners re-established over at least 10 miles of the targeted reach. Mirror shiners are also surviving and appear to be recruiting, but are at lower densities and with less expansion. After only one translocation effort, Tennessee shiners appear to be doing well. Saffron shiners proved to be too uncommon for capture in effective numbers and habitat in the targeted restoration reach was marginal at best, so efforts were terminated after the first year. Gilt darters have been more difficult to recapture and assess their status because only one tagged adult and one untagged sub-adult have been recaptured, but these limited data may still indicate successful reproduction and recruitment in the Pigeon River in North Carolina.

—Steve Fraley, North Carolina Wildlife Resources Commission, and Joyce Coombs, University of Tennessee, Knoxville

Gilt darters are tagged under their second dorsal fin with visible implant elastomer prior to release into the Pigeon River. Tags can be used to determine the survival of released fish or to detect reproduction by the capture of untagged fish.

Collecting fish for the Pigeon River reintroduction program. Different collecting methods or different collecting times, daily or seasonally, can be used to minimize stress on fishes.

Photos: Joyce Coombs

be undertaken if approved by the U.S. Fish and Wildlife Service (USFWS) regional director and/or state nongame or fisheries director (USFWS 2000). If the fish is state-listed or a species of conservation concern, the state agency tasked with its management may have adopted a recovery plan. If a fish is not federally listed or a candidate species, state or regional peer groups (state nongame wildlife panels or various ichthyological societies) should be consulted for advice on PTRA activities and/or as a source for members of an advisory committee.

Biologists involved in PTRA activities for fishes must be knowledgeable of regulations and obtain necessary federal, state, and local permits for proposed actions. Most PTRA activities with fishes involve capture of wild individuals for translocation or captive propagation and require protected species permits from the state and USFWS.

Federal permits. The ESA requires individuals to acquire Section 10 recovery permits in order to collect, propagate, or conduct research on federally-listed species. The activities authorized by permits differ depending on endangered or threatened status. Applications for native endangered and threatened species permits can be found on the USFWS website (www.fws.gov/endangered/permits/index.html) or by contacting the regional office. A fee may be required for a permit or to amend an existing permit. For information on ESA permits issued by NOAA Fisheries (e.g., marine and anadromous species), visit their permit web page (www.nmfs.noaa.gov/pr/permits/). Applicants should allow at least 180 days for processing of the application.

State permits. States require permits prior to collecting native species or conducting PTRA activities. Regulations vary between states, so special consideration should be given to work involving a single species found in multiple states. Contacts for state permits are available from state fish and wildlife agencies via their websites.

Special use permits. Land management agencies often require special use permits prior to collecting on their lands or conducting PTRA activities, especially whenever PTRA activities involve collection or release of fishes from national forests, parks, or wildlife refuges. State parks, forests, or wildlife management areas also have rules or coordination steps dealing with the collection or release of fishes within their boundaries. Native American tribes may require separate permits for collection and/or release of fishes on their reservations.

Institutional Animal Care and Use Committee. U.S. federal law dictates that institutions which use laboratory animals for federally-funded research or instructional purposes must establish an Institutional Animal Care and Use Committee (IACUC) to oversee and evaluate such programs. Animal welfare at all stages of a PTRA program should have protocols approved by IACUC committees, including the capture of broodstock, transportation, husbandry techniques, and euthanasia. At this stage, a veterinarian with fish experience should also be identified to consult on minimizing stress, disease prevention and treatment, and euthanasia. Numerous guidelines on the use of fish in research or aquaculture are available to help draft these protocols (e.g., OLAW 2002; AFS 2004; CCAC 2005)

Plan Ahead. If fishes will be transferred across jurisdictional boundaries during any PTRA activities, permits will likely be required from each entity. In all instances, permits (federal, state, tribal or land manager) should be requested well in advance (several months) of proposed PTRA activities. In some cases, permits may require more than a year for processing and approval.

RULE 3: CHOOSE THE SOURCE WISELY

Two options are available to managers wishing to implement PTRA activities. If individuals are highly abundant in the source population(s), translocation will typically be the best recovery tool. Translocation allows for natural recruitment of the newly established population and eliminates or minimizes most problems associated with propagation facilities, such as transmission of disease, contact with exotic species, domestication, or artificial selection. If the source population is not robust enough to support translocation, a captive propagation program may be the better alternative. Captive propagation programs can vary from rearing eggs or young collected from wild populations to holding broodstock at propagation facilities for repeated spawning. However the PTRA program is carried out, the intent should be to replicate natural patterns of diversity and to allow the natural environment to drive the adaptation and fitness of the target population.

Determining which population will be used as the source for propagation or translocation is one of the most important decisions. With augmentation programs, a prior genetic and/or morphological study in an evolutionary framework must be conducted to identify a source population or populations that are most closely related to the target population. Unfortunately, since the target population for reintroduction programs is presumed to be locally extinct, a comprehensive genetic study of the target species is not possible, and morphological studies may not resolve evolutionary relationships to the population level. In these situations, a genetic study of other species with a similar distribution may help to determine if there are replicated patterns of biogeography where populations in one geographic area are always closely related to populations at the target site. These repeated patterns would indicate which population is the best source from an evolutionary standpoint, providing the greatest likelihood of restoring the ecosystem to its pre-disturbance state (Box 5).

In some cases, multiple populations may be identified as good candidates for a source population based on the genetic data. The next consideration is how to maximize the natural levels of genetic diversity captured from the source. Higher genetic diversity is not only necessary for the species to adapt to environmental change but is also positively correlated with population fitness (Reed and Frankham 2003). Though high abundance or larger range size could be used as proxies for genetic studies, as each are positively correlated with genetic diversity (Blackburn et al. 1997; Franklin and Frankham 1998; Pyron 1999; Boessenkool et al. 2007), a genetic study examining the variation in each source is the best option. Genetic studies may also reveal alleles that are naturally absent in a target population, and therefore prevent accidental introduction through a PTRA program. For example, a study of blotchside logperch (*Percina burtoni*) in the upper Tennessee River suggested that populations in the Clinch and Holston rivers had genes unique to each. However, both sets of genes are present in a population in the Hiwassee River, downstream from both the Clinch and Holston rivers (George et al. 2006). In this scenario, using individuals from the Hiwassee River as a source population would be unwise because genetic variation not naturally present could be introduced in the other populations. Although the

Box 5.
Replicated Patterns of Biogeography

The spotfin chub (*Erimonax monachus*) is a widespread federally-threatened species currently extant in four river systems in Tennessee, Virginia, and North Carolina, but locally extinct from several areas across its range. In 2004, various agencies considered reintroducing spotfin chubs into Shoal Creek in the middle Tennessee River drainage in Alabama and Tennessee, and the initial consideration for a source population was the nearby Buffalo River in Tennessee, a tributary to the Duck River of the lower Tennessee River drainage. This population was considered because of its close proximity in air miles to Shoal Creek and because they are both in the Highland Rim upland physiographic province. But these two systems are separated by over 400 river kilometers and the Coastal Plain, a lowland physiographic province that potentially acts as a barrier for upland fishes. Another potential connection between the Buffalo River and Shoal Creek is headwater stream capture, but this is an unlikely route for spotfin chubs because they are large-stream fishes.

But biogeographic patterns of other fish relationships in the Tennessee River drainage based on molecular phylogenies suggest an alternative choice for a source population. The boulder darter (*Etheostoma wapiti*) was historically found in Shoal Creek and is still found in the adjacent Elk River. It is more closely related to the wounded darter (*Etheostoma vulneratum*) from the upper Tennessee River drainage than to the coppercheek darter (*Etheostoma aquali*), which is endemic to the Duck and Buffalo rivers (Wood 1996). The Tennessee darter (*Etheostoma tennesseense*) is found throughout the middle and upper Tennessee River drainage, including Shoal Creek, and is more closely related to the snubnose darter (*Etheostoma simoterum*) from the extreme upper Tennessee River drainage, than it is to the Duck darter (*Etheostoma planasaxatile*), which is endemic to the Duck and Buffalo rivers (Powers and Mayden 2007). Lastly, blotchside logperch (*Percina burtoni*) in Shoal Creek are closely related to other middle and upper Tennessee River drainage populations, whereas populations in the Duck and Buffalo rivers (and one lower Tennessee River stream) represent a new undescribed species (George et al. 2006). Based on these replicated biogeographic patterns, spotfin chubs from the Emory River located further upstream in the Tennessee River drainage were considered the appropriate stock for reintroduction of this species into Shoal Creek. Even though Shoal Creek and the Emory River are not in close proximity and are in different physiographic provinces (Highland Rim versus Cumberland Plateau), other fish species with similar distributions show more recent gene flow between these two upland habitats than across the Coastal Plain between Shoal Creek and the Duck River system.

—*BRK*

Spotfin chub. Replicated patterns of biogeography of other fishes were useful in determining the source population for spotfin chubs that were reintroduced into Shoal Creek in the middle Tennessee River.

Illustration: Joe Tomelleri

Shoal Creek, reintroduction site for spotfin chubs.
Photo: Bernard Kuhajda

Emory River, source site for spotfin chubs based on replicated patterns of biogeography.
Photo: Anna George

Box 6.
The Consequences of the Founder Effect

The striped bass (*Morone saxatilis*) had been reduced to small remnant populations in a few Gulf of Mexico tributaries due in part to numerous impoundments that altered riverine habitat. The largest population was in the Apalachicola-Chattahoochee-Flint (ACF) river drainage in Alabama, Georgia, and Florida. To recover this population, the Striped Bass Technical Task Force (SBTTF), a group of state, federal and university personnel, established a series of captive populations that serve as striped bass broodstock repositories. In an effort to assess founder effects, a sub-sample of the striped bass broodstock repository in Lewis Smith Lake, Alabama, was screened using 11 microsatellite markers to determine if it had maintained similar levels of genetic variation when compared to striped bass from throughout the ACF.

The Lewis Smith Lake broodstock appears to have significantly less genetic diversity than that of the wild populations. This is probably due to a founder effect where too few individuals were used to establish and maintain this repository, though the exact cause of this difference is difficult to discern. Correcting the discrepancy requires supplementing Lewis Smith Lake broodstock with individuals from a broader sampling of striped bass in the ACF basin. Nonetheless, it is important to highlight that only after baseline genetic data were collected could this perceived threat be quantitatively evaluated.

—Greg Moyer, USFWS

goal is to maximize diversity in the target population, this should not come at the expense of maintaining natural patterns of diversity.

PTRA projects must also be carefully planned to prevent loss of genetic variation in captive populations, which may decrease the overall fitness of the wild population upon reintroduction (Hindar et al. 1991; Busack and Currens 1995). Numerous studies demonstrate that genetic diversity can be reduced in propagation facilities (Vuorinen 1984; Sekino et al. 2002; Osborne et al. 2006) and in translocation projects (Stockwell et al. 1996). Founder effect, the loss of variability due to a restricted number of individuals colonizing a new location, can occur if a limited number of broodstock are used for translocation or to establish a captive population (Box 6). Another risk is artificial selection, which can lead to unpredictable and rapid changes in critical life-history traits that differ from those in the wild population (Ford 2002; Frankham 2008). Artificial selection can negatively impact the reproduction of wild populations. Studies of various salmonids indicate that hatchery-reared fish are up to 40% less successful per generation in reproduction when reintroduced (Araki et al. 2007). This reduction may be due to altered morphological and behavioral characters that are used in breeding competitions (Fleming and Gross 1993; Berejikian et al. 2001) or by producing smaller eggs than those from wild individuals (Heath et al. 2003). Therefore, the PTRA plan must carefully set

Box 7.
Fish on the Edge: Extreme Life Histories

Fishes can have extremely different life-history strategies with varying body sizes, time to maturation, number of eggs produced, parental care, dispersal abilities, and life span. Where a species occurs on this spectrum of life-history strategies plays an important part in the development of a plan for PTRA.

Two imperiled species that reflect extremes in life-history traits are the spring pygmy sunfish (*Elassoma alabamae*) and the pallid sturgeon (*Scaphirhynchus albus*). Historically, spring pygmy sunfish were known from three different spring systems in the Tennessee River drainage in northern Alabama, but only one native population exists. Movement for an individual is restricted due in part to a maximum size of 25 mm. They spawn at one year of age and most die shortly thereafter with the female producing 60–65 eggs in a clutch (Warren 2004). In contrast, pallid sturgeon are capable of moving several hundred kilometers in the main stem of the Missouri, Mississippi, and Atchafalaya rivers where they are distributed from Montana to Louisiana. They attain lengths of over 1.5 m and live for over 30 years. Males do not spawn until the age of 3–9 years, females not until 5–15 years with 2–7 years between spawning. Females can produce 170,000 mature eggs in a spawning season (USFWS 1993; Mayden and Kuhajda 1997).

These extreme differences in life histories greatly impact the basic plan for any PTRA project. A spring pygmy sunfish propagation program could be successful at only one facility with a few aquaria due to its small size, few offspring per female, and the need for fewer stockings of progeny. Pallid sturgeon require multiple fish hatcheries due to their large size, long lives, and the large number of eggs produced by each female. Because of their large geographic range and long life span, tens of thousands of progeny must be stocked annually over multiple years. However, because one female pallid sturgeon can produce so many offspring, care must be given to prevent swamping of the gene pool with large numbers of progeny from predominately one or a few females. The length of time broodstock and progeny are held in captivity is also different depending on life history. Pallid sturgeon broodstock, barring any disease, are always returned to the river after captive spawning because (1) it will be years before they are ready to spawn again and (2) they are long-lived and will likely spawn in the future. Spring pygmy sunfish broodstock would not be released because they would likely not contribute any more progeny in the wild. Spring pygmy sunfish progeny could be held in captivity for only a short time (months), compared to perhaps 1–2 years for pallid sturgeon, which need a longer time to reach a size that can likely survive in the wild. A basic knowledge of the life history is important for planning a successful PTRA project.

—BRK & ALG

The life-history strategies of the spring pygmy sunfish and pallid sturgeon greatly impact the needs of each species' PTRA program. Spring pygmy sunfish are short-lived, native to a single creek system, and a program could be undertaken with a few aquaria in a single facility. Pallid sturgeon, a very long-lived and wide-ranging species, require a long-term PTRA program coordinated with multiple agencies, hatcheries, and conservation groups.
Illustrations: Joe Tomelleri

guidelines for minimizing artificial selection or loss of natural diversity in the offspring or translocated fishes. Throughout all of these decisions, detailed knowledge of the life history of the specific species is critical (Box 7).

The mating design for the program should be structured to minimize the risk of artificial selection. Variables that can be manipulated, such as the total number of males and females, number of partners for each, and the number of times broodstock are spawned, must be considered in the context of life-history traits, such as courtship and sexual selection, length of spawning season, the number of eggs produced, and viability of gametes. Free mate choice is preferred to minimize domestication, but if not feasible, protocols must be in place to minimize the impact of artificial selection through multiple randomly-selected pairings (Wedekind 2002; Fraser 2008). New broodstock should also be introduced frequently, preferably every breeding season (Harada et al. 1998; Iguchi and Mogi 2007). PTRA plans must set guidelines for an appropriate number of age classes of broodstock and whether to mix pairings between generations. Stocking equal numbers of offspring from each family group is expected to remove some effects of artificial selection, especially in highly fecund species (Allendorf 1993; Frankham et al. 2000). Stockings may continue for up to 20 years, particularly for longer-lived fish, which require multiple age classes of broodstock or multiple collections from the source population to increase genetic diversity or reduce the rate of genetic adaptation to captivity (Lynch and O'Hely 2001; Ford 2002; Drauch and Rhodes 2007). Whenever possible, genetic screenings of the broodstock and offspring should be conducted to ensure genetic diversity is being captured and inbreeding is minimized (Kozfkay et al. 2008).

Random genetic screenings are also essential to ensure that species identifications are correct. Although this concern may seem to only apply to smaller-bodied cryptic fishes that may be confused without the help of a taxonomist, even popular game species have proven difficult to identify (Box 8). The best results in the world will not save a PTRA project from a miserable failure if the wrong species is propagated or translocated.

Finally, do no harm to the source population. Although it is important to use enough individuals to ensure healthy and natural levels of diversity in the target population, the removal of the broodstock or individuals for translocation should not significantly impact the source population. It may be wise to establish some protective measures for the source population over the planned course of the PTRA project to ensure healthy stability of that population. Such measures could range from monitoring the source population to temporary regulatory protection. Failure to protect source populations could result in failure of some PTRA projects. Thus, an often overlooked, but essential part of PTRA projects is monitoring the source population, prior to and following the collection of the broodstock, to make certain that it remains healthy (Jones et al. 2006).

Box 8.
Oops: The Story of the Greenback Cutthroat Trout

As popular game fishes, trout and char have been moved between drainages for hundreds of years. In the western United States, trouts were widely propagated and stocked outside of their native range, starting in the late 1800s. These introductions were often in streams that contain other species of native trout, leading to competition and hybridization with close relatives. For example, Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) were moved from west of the Continental Divide into streams east of the divide, where it was mixed with a distinct subspecies, the greenback cutthroat trout (*O. c. stomias*).

The greenback cutthroat trout did not fare well when faced with the combined effects of competition with nonindigenous Colorado River cutthroat, mining, pollution, and fishing pressure, and the subspecies was considered extinct in 1937. A few "pure" populations were discovered in the 1950s, though by the end of the twentieth century, greenback cutthroat trout were found in only 0.5% of their historical range (Young and Harig 2001). Conservation programs strived to increase the number of self-sustaining populations from 9 to 20 through captive propagation and reintroduction, and the recovery of the species appeared on track as a success story for the ESA.

However, with the advent of new genetic techniques, researchers found that greenback cutthroat trout were not being recovered; the nonnative Colorado River cutthroat trout were instead being propagated and established (Metcalf et al. 2007). Analysis of variable DNA markers indicated that only four recovered populations were pure greenback cutthroat trout, and the species inhabited less than 13 kilometers of streams. Because populations of the two closely related subspecies had been repeatedly moved across the Continental Divide from the 1890s to the 1930s, broodstock for the greenback cutthroat trout were misidentified non-native Colorado River cutthroat trout on the east side of the divide.

Despite this severe setback to recovery, it is not all bad news for the greenback cutthroat trout. The discovery of a genetically pure population on the west side of the Continental Divide suggests that other populations may persist outside of its native range, preserving genetic diversity that did not survive elsewhere. However, the loss of two decades of recovery work reinforces the point that proper identification of broodstock using an array of techniques, including genetic screening, is a vital part of every PTRA project.

—*ALG*

Greenback cutthroat trout, a species that has had its recovery hampered by the propagation and introduction of misidentified Colorado River cutthroat trout into its range.
Illustration: Joe Tomelleri

RULE 4: PROPAGATE NATURALLY AND CAREFULLY

Propagation facilities devoted to spawning and/or rearing of fishes will vary in size and design, largely based on the requirements of the propagated species. Common to all, though, is the need to make every reasonable effort to minimize risks associated with captive propagation. The first goal is to naturalize the captive environment as much as possible to reduce artificial selection and maximize survival of released fishes (Maynard et al. 1995; Miller and Kapuscinski 2003; Fraser 2008). In addition, captive propagation facilities should prevent harm to the target community by preventing the export of diseases or parasites with the propagated fishes. Finally, protocols need to be developed that reduce security and equipment failure risks and replicate programs at multiple facilities where appropriate.

Incorporating knowledge of natural habitat preferences and behaviors will often improve fish health, both in captivity and upon reintroduction. Appropriate flow regimes, which may vary widely for different life stages, can be critical. Substrates and cover objects may be important, but bare tank bottoms might be preferable for feeding and waste removal, particularly at early life stages. Providing options, from woody debris to artificial cover, is often the best solution until observations guide refinement. Foods not only must be nutritionally appropriate but should stimulate natural feeding behavior. Food selection is a major challenge for rearing smaller non-game stream fishes, which are often sight feeders that prey primarily on live, moving aquatic insect larvae. Larval and juvenile fish usually have vastly different dietary needs from adults. Providing natural wild prey items is difficult but important so that fish learn natural feeding behaviors. Exposure to artificial predator stimuli may prevent behaviors that might reduce fish survival in the wild (Brown and Laland 2005).

Propagation of fish in artificial conditions, particularly in closed systems, can greatly increase the risk and rate of transmission and export of disease and parasites, requiring precautions to minimize risks. Standard protocols should be in place for quarantine procedures, water treatment, contamination control, and recognition and treatment of disease (see USFWS 2003). Open systems utilizing surface waters for supply and discharge are at less risk for disease but require redundant precautionary pre- and post-use water treatment protocols to prevent escape of propagated fishes, introduction of exotic species and disease organisms, or changes in local water chemistry. Closed systems using treated drinking water and sewage systems offer far less risk of escape but should never be considered risk-free. Propagation facilities should have access to fish health specialists and/or veterinarians for disease diagnosis and treatment. Culture systems should be constructed to allow for isolation of all or portions of captive populations for quarantine and therapeutic treatments.

Unauthorized human access should be controlled with perimeter fencing or screens and motion-detecting lights if fish are held outdoors. Monitored security systems for indoor facilities should be installed to detect criminal trespass, vandalism, fire, floods, and heating or cooling system failures. Culture systems should be designed with multiple redundancies to ensure life support, such as a back-up power system for power outages. Tanks and systems should be designed to prevent unnecessary handling of fish or unwanted mixing of stocks. Protocols should be established to deal with escapees of uncertain origin, such as permanent isolation or

Rush darters in yarn, an artificial substrate for spawning and hiding.
Photo: Conservation Fisheries, Inc.

euthanasia. Euthanasia protocols must be humane (AFS 2004) and should be appropriate for post-mortem preservation of specimens for subsequent genetic or other research. At a minimum, all mortalities should be catalogued and frozen prior to transfer and archiving at a research museum or repository. Along with mortalities, all individuals contributing to the propagation effort should be fin clipped for genetic analysis. Propagation projects should allot funding for genetic sampling for a randomly selected subset of the released fish in order to screen for genetic diversity and check against the existence of hybrids or incorrectly identified fish. Protocol manuals should be developed to document standard operating procedures.

Redundancy in systems by replicating programs at multiple facilities can greatly benefit PTRA programs and safeguard critically imperiled species. Maintaining the total population as an effectively single random mating population by regular translocation of animals among institutions will lower the risks of artificial selection (Frankham 2008). This also minimizes the chances of losing entire captive populations due to system failure or disease at one facility.

RULE 5: PREPARE FOR RELEASE!

Prior to Release. Before propagated or translocated individuals can be released, appropriate habitat, natural or restored, must be present (USFWS 2000; Jones et al. 2006). In some cases, such as the loss of a population due to a catastrophic event (Box 1) or by acute point-source pollution that has been mitigated (Box 4), additional habitat restoration may not be necessary. Other scenarios generally involve recovery through improved land use practices that lead to conditions favorable for restoring the native fauna. Reintroducing small numbers of individuals (pilot population) can determine if habitat restoration is sufficient for survival of the species and a continuation of reintroduction efforts, but only if habitat improvement is evident.

Tagging is one method to assess the success of the PTRA project by demonstrating survival, movement, or in-stream reproduction through detection of untagged progeny. Several options exist for tagging that vary widely in cost, time, and invasiveness (Guy et al. 1996; Jepsen et al. 2002; Gibbons and Andrews 2004). If tagging is used as part of the PTRA monitoring protocol, it likely needs to be completed prior to release. Disease screening of a subset of the captive individuals should also be conducted prior to release or whenever fish are moved from one facility to another (USFWS 2003). Screening fishes for a translocation project is nearly impossible without a mobile fish lab, but a randomly selected sample from the source population can be assessed a few weeks prior to translocation to help prevent transfer of unusual parasites or diseases to other native fishes at the release site. In general, fish should be fasted for at least 48 hours prior to transportation for the release, which minimizes mortality or stress with less fouling of the water during transport (Piper et al. 1982).

When to release. Determining the size and/or age at which fish should be released depends on a number of factors. Returning offspring to the wild at the earliest possible life stage reduces costs to the propagation facility, frees up space for the grow-out of other fishes and reduces the threat of domestication (Jones et al. 2006). However, survival may be higher when fish are stocked at a larger size (Szendrey and Wahl 1996). A short-lived fish, especially an annual species, under ideal conditions will grow quickly and can often be released within the same year they are spawned. Fishes that live for several to many years must be evaluated on a species by species basis. A combined approach, where randomly selected groups are either released early or left to grow longer in the propagation facility, may also be considered (Donovan et al. 1997). The life-history traits and post-release monitoring will reveal which stocking approach is most appropriate.

In addition to size(s) at release, the season and time of day when fishes are stocked may affect their survival. Available food items, growth, and activity increase in the warmer waters of spring/summer, often providing fishes with more resources to succeed (Garvey et al. 1998; Sutton and Ney 2001). Reproductive considerations may also determine release timing. Little is known of the "imprinting" of non-game species and this may be important to fishes that participate in runs as a part of their reproductive strategy (e.g., some catostomids). Night releases may be important for nocturnal fishes, but may be even more beneficial for small fishes (e.g., minnows) to avoid diurnal predators. Time should be allotted for acclimating fishes prior to release.

Release site considerations. The best habitats for reintroduction or restoration are protected public lands or private sites with limited public access. Establishing good relationships with managing agency personnel and/or landowners is essential to long-term recovery projects. Both should be made aware that species recovery projects can be long-term and usually require periodic return visits to assess the success of the project. Access to private lands is a privilege requiring consideration of and effective communication with the landowner.

Many factors come into play when considering how many individuals to release at a particular site. A delicate balance exists between releasing enough individuals to sustain a population without overstocking a particular site, reducing genetic variability, stressing donor populations, or exceeding carrying capacity of a site (Kelly-Quinn and Bracken 1989; Flagg et al. 1995). Fishes that are poor dispersers (e.g., darters, madtoms) will likely not travel far from the release site if appropriate habitat is available. Therefore, releasing smaller numbers in adjacent sites will likely populate suitable habitat across a larger area. On the other extreme, strong dispersers (e.g., darters with larval or juvenile drift, most minnows) may require larger numbers of individuals at a single site to compensate for the probability that most will disperse over a larger area.

Disposition of excess broodstock and progeny. Following propagation, excess broodstock or progeny should be disposed of following guidelines set in the PTRA plan. Because of the risk of harming the source population, returning broodstock to the wild population is rarely appropriate. Other options include use in toxicity studies, euthanasia and archival for future research, accessioning into teaching collections, or donation to zoos, aquariums, and nature centers for public displays. Euthanasia protocols must be approved by an IACUC committee (OLAW 2002; AFS 2004). Some of these same options are available for propagated individuals. Though a typical goal of propagation is to maximize numbers of progeny, the total number of released individuals must be controlled to maintain genetic diversity, which can result in surplus progeny. Institutions that maintain ark populations may also be burdened with too many offspring. Although it is tempting to reintroduce surplus progeny, particularly with extremely imperiled species, releases should be limited to the numbers recommended by the PTRA plan and approved by the advisory committee.

Acclimation of spotfin chubs in the Tellico River prior to release. The use of plastic bags lets water temperature slowly adjust to the river temperatures, reducing stress on fish.
Photo: Conservation Fisheries, Inc.

RULE 6: EVALUATE AND ADAPT

Monitoring of a reintroduced or augmented population is critical for evaluating the success of a PTRA project (Box 9; Lowe et al. 2008). PTRA protocols should be adaptive with improvement or changes based in part on feedback from regular monitoring of the population (Armstrong et al. 2007). Evaluation of PTRA populations should consist of more than just noting the presence of or an increase in the numbers of the target species at the site (Ostermann et al. 2001). Other useful data include growth and condition, movement of tagged individuals (especially for species that migrate), and the genetic diversity of surviving individuals. As with sampling efforts prior to PTRA projects, long-term monitoring includes consideration of detection probability, surveys for evidence of recruitment, range extension from stocking sites into distant suitable habitats, and any positive (or negative) changes in the aquatic community at and near the reintroduction site (Shute et al. 2005). For long-lived species, monitoring could last for more than a decade.

PTRA is not intended to be a continuous effort but rather a tool to reestablish a self-sustaining population represented by spawning-age adults and younger age classes at appropriate densities over a prescribed area (USFWS 2000). Specific milestones, set by the advisory committee, assist in determining when a PTRA program should cease (Armstrong and Seddon 2008). Even after the completion of a PTRA project, some long-term monitoring of the target population's status should be performed.

RULE 7: THE PUBLIC NEEDS TO KNOW

The impacts of PTRA programs can reach beyond the target species if the public is informed of projects and how they can be beneficial. This is accomplished by raising awareness of the program in the affected community through outreach (Box 10; Newton 2001). Formal and informal education programs in primary and secondary schools are obvious choices for outreach; students can visit a propagation facility, assist in releases, and learn more about their watersheds. Scout troops are excellent targets for outreach as their service projects can become a resource for PTRA programs. Educational opportunities for the general public should also be considered. Many nature centers, zoos, and aquariums display imperiled fishes, inform members and visitors about the ongoing conservation projects in their communities, and hold programs that include presentations by experts. Finally, live streaming video of fish behaviors uploaded to educational Internet sites can provide unique insights into the invisible underwater lives of fish.

Outreach efforts to key stakeholders affected by PTRA programs are also crucial if the species resides largely on private lands. One important element of cooperation with landowners is a conservation easement, a legal agreement between a landowner and a land trust or government agency that permanently limits certain uses of land in order to protect its conservation values (Rissman et al. 2007). Easements can be flexible, but landowners essentially forfeit some land rights in exchange for tax benefits. Conservation easements are an important tool in helping to preserve critical habitat for PTRA programs.

Both commercial and recreational anglers can be strong allies in PTRA programs and aid monitoring by reporting catches (Cowx and Gerdeaux 2004). Anglers can be made aware of PTRA programs by including information on the

Box 9.
How Are The Fish Doing Now?

One of the most common questions asked about a PTRA project is, "How are the fish doing now?" One answer comes from the food chain; a desiccated sturgeon skull was found below an osprey nest, indicating that at least one individual successfully entered the "circle of life" from stocking efforts by the Tennessee Lake Sturgeon Restoration Working Group (TLSRWG), a multi-agency partnership led by the Tennessee Aquarium in the Tennessee River drainage. Monitoring efforts, a necessity for any PTRA project, should include regular status surveys, tracking of reintroduced individuals, and impact on the human community, which can all be used to evaluate the success of the program.

Status surveys should be conducted at every stage of a PTRA project, rigorously testing the current hypotheses concerning the status of a population. In addition, any source populations should be surveyed to ensure that the removal of individuals is not negatively impacting its persistence. Status surveys may require very different equipment and techniques depending upon the species and habitat.

A variety of tagging options exists, and different combinations may be incorporated into the program where appropriate. For example, all lake sturgeon (*Acipenser fulvescens*) released in Tennessee as young-of-year are tagged by a system of scute removal. Fish that are held more than a year are tagged with a passive integrated transponder (PIT) tag as well, but both of these methods require recapture. A smaller subset of these have been implanted with either radio or sonic transmitters for more detailed studies on their movement in the river and habitat use, which can be conducted by boat or stationary receivers.

Not all monitoring efforts have to be done by biologists; both commercial and recreational anglers have aided the TLSRWG in monitoring. Commercial partners with the TLSRWG have been given PIT tag scanners, PIT tags to implant in untagged sturgeon, and vials for fin clips from each fish caught. Recreational anglers have been encouraged to report sturgeon catches to the state agency. Monitoring programs are not only useful for determining the status of the species in the wild, they can also increase community awareness and help determine the extent of public involvement in the PTRA project.

—ALG


Monitoring efforts for PTRA species may need to incorporate a variety of tagging options to evaluate the program. Selected lake sturgeon released into the Tennessee River drainage have both sonic and PIT tags for monitoring both instream and upon recapture.
Photo: Phil Bettoli

Box 10.
Saving the Sturgeon: Educating Those Who Use the River

Since 1998, the Tennessee River Lake Sturgeon Working Group has worked to restore a wild breeding population of lake sturgeon (*Acipenser fulvescens*). In 8 years of releases, over 60,000 lake sturgeon have been reintroduced to the upper Tennessee River drainage. The most significant public impact of the Saving the Sturgeon program, however, has been to educate the regional community about the overall health of their ecosystem and how their actions impact imperiled aquatic species like the lake sturgeon. Public outreach has been accomplished through classroom education, raising awareness among anglers, and displays at the Tennessee Aquarium. Inviting the media to attend major events helps the message reach beyond the specific audience targeted by the program.

The classroom education component takes place at an elementary school located three miles from the release site on the French Broad River. The fifth-grade students participate in a range of activities, including research projects, interactive lessons in river ecology, raising a lake sturgeon in their classroom, and visiting the Tennessee Aquarium. This culminates with the class participating in a release of lake sturgeon into the French Broad River at the Seven Islands Wildlife Refuge. Sturgeon Preservation Cards are distributed with fishing licenses throughout the east Tennessee region where the lake sturgeon release program occurs to raise angler awareness. The wallet-size cards depict a lake sturgeon, and include instructions on what to do if one is caught (i.e., release and notify the state agency) and what other steps anglers may take to help preserve the species and its habitat. The Tennessee Valley Authority has also posted signs about lake sturgeon at boat ramps in the upper Tennessee River drainage.

Finally, a lake sturgeon touch tank at the Tennessee Aquarium ensures that every visitor has the chance to interact with a sturgeon, talk to docents about the program, and learn about conservation in their backyard. One family was so excited about what they had learned at the sturgeon touch tank that they attended a summer release to get involved with the program. Now, their Girl Scout troop is developing a coloring book on lake sturgeon that will be distributed to kindergarten through second-grade students across Knoxville. A multi-faceted outreach plan can engage the entire community, encouraging them to protect their river.

—*ALG*

Lake sturgeon are released into the French Broad River with the assistance of fifth grade students from nearby Gap Creek Elementary School. The sturgeon release is part of a year-long immersive program about watershed conservation led by educators from the Tennessee Aquarium.

Photo: Julia Gregory.

species in fishing regulations, posting information at nearby boat docks, or setting up phone lines for reporting catches.

The last group of key stakeholders includes elected and non-elected officials. Informing elected officials of the conservation activities in their constituencies helps promote environmental awareness in the government, increasing the likelihood of further habitat improvement. Including public utilities and other resource managers in these educational efforts may help minimize their impacts on PTRA species.

Throughout PTRA programs, the media can be used to build general awareness of imperiled species and their conservation needs, especially in conjunction with outreach efforts that raise attention (Allen 2001). A simple event, such as staging a fish release with schoolchildren, can spread a remarkably strong conservation message to a wider community. However, some recovery projects can be controversial and undue attention to the project may be problematic. If a species' locality information is sensitive, some federal agencies may have non-disclosure clauses included in their contracts. In these cases, written permission from that agency would be necessary before media notification or the agency would have to make the media contacts. But in general, public recognition of the plight and recovery efforts of these imperiled species usually works to their benefit.

RULE 8: RECORD IT AND SHARE IT

A critical need in captive propagation and translocation projects is the maintenance of detailed records of the activity, beginning with broodstock collection and ending with evaluation of the program. During the past four decades there have been numerous reintroductions, augmentations, and even a case of introduction using both translocated and propagated imperiled fishes by state and federal agencies and non-governmental organizations. Though there is some documentation of these early movements of imperiled fishes, too often records are almost impossible to locate, are of variable quality, or simply do not exist (Seddon et al. 2007).

In the past 15 years progress has been made in documenting the release of propagated and translocated imperiled fishes. Reporting requirements associated with permits and contracts require much of the data needed for thorough documentation of these projects. Publications of PTRA projects in the scientific literature have also increased (Seddon et al. 2007). An example of this improvement can be seen in projects conducted by Conservation Fisheries, Inc., in Knoxville, Tennessee, which have maintained records of their PTRA activities via contractual reports, website updates, and some publications (Rakes et al. 1999; Shute et al. 2005).

However, there is still no single repository for data and documentation of captive propagation and translocation of imperiled fishes for reintroduction or augmentation. There is also no mechanism to retrieve and standardize these data and make them available for planning future projects or informing researchers. Written documentation of the rationale and sites selected for broodstock and release, as well as methods used in transportation and captive settings, makes this work replicable. Without these data, it is impossible for resource managers and scientists to understand changes in the population dynamics, infer population genetics results, or properly manage the recovery of a species or a system. These data are needed not only for current and future projects, but also for past projects, which will require a considerable effort on the part of those involved in PTRA activities. A critical need is a standardized database to capture information on captive propagation and translocation projects involving imperiled fishes. We suggest that the appropriate agency to manage this database is the USFWS. This effort needs to be initiated immediately as information is being lost as agency and university biologists involved in some of the early projects retire. Scientific publications of large projects and results are also essential to documenting successes and failures of PTRA projects.

As the number of imperiled fishes continues to climb (Jelks et al. 2008), PTRA will likely continue to be an integral part of their recovery. Having the results of previous propagation and translocation efforts available would provide valuable insights to partners planning similar projects and would allow researchers studying genetics, morphology, and biogeography of fishes to know where fish distribution patterns have been artificially altered. Documentation of the outcome of captive propagation and translocation efforts will also permit agencies and PTRA managers to better evaluate the outcome of these projects and identify areas for improvement.

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Factors Influencing Tropical Island Freshwater Fishes: Species, Status, and Management Implications in Puerto Rico

ABSTRACT: Anthropogenic effects including river regulation, watershed development, contamination, and fish introductions have substantially affected the majority of freshwater habitats in Europe and North America. This pattern of resource development and degradation is widespread in the tropics, and often little is known about the resources before they are lost. This article describes the freshwater resources of Puerto Rico and identifies factors that threaten conservation of native fishes. The fishes found in freshwater habitats of Puerto Rico represent a moderately diverse assemblage composed of 14 orders, 29 families, and 82 species. There are fewer than 10 species of native peripherally-freshwater fish that require a link to marine systems. Introductions of nonindigenous species have greatly expanded fish diversity in freshwater systems, and native estuarine and marine species (18 families) also commonly enter lowland rivers and brackish lagoons. Environmental alterations, including land use and development, stream channelization, pollution, and the impoundment of rivers, combined with nonnative species introductions threaten the health and sustainability of aquatic resources in Puerto Rico. Six principal areas for attention that are important influences on the current and future status of the freshwater fish resources of Puerto Rico are identified and discussed.

Factores que influencian a los peces tropicales de agua dulce: especies, estado actual e implicaciones para el manejo en Puerto Rico

RESUMEN: Las actividades de origen humano como la regulación de los ríos, desarrollos en cuencas hidrológicas, contaminación e introducción de peces, han afectado sustancialmente la mayoría de los hábitats de agua dulce en Europa y Norteamérica. Este patrón de desarrollo y degradación de recursos se extiende a lo largo de los trópicos, y a veces se alcanza a conocer muy poco acerca de los recursos antes de que éstos desaparezcan. En este artículo se describen los recursos de agua dulce de Puerto Rico y se identifican los factores que amenazan la conservación de los peces nativos. Los peces que se encuentran en los hábitats dulceacuícolas de Puerto Rico representan asociaciones de moderada diversidad, compuestos por 14 órdenes, 29 familias y 82 especies. Existen menos de 10 especies nativas periféricas-dulceacuícolas que poseen un componente marino. Las introducciones de especies foráneas han incrementado grandemente la diversidad íctica en los sistemas de agua dulce, y las especies nativas marinas y estuarinas (18 familias) comúnmente también ingresan a los ríos y lagunas salobres. Las alteraciones del ambiente, que incluyen uso de suelo y desarrollos, canalización, contaminación y represamiento de rios, combinadas con la introducción de especies exóticas, amenazan la salud y sustentabilidad de los recursos acuáticos de Puerto Rico. Se identificaron seis áreas principales de atención y se discute su influencia en la evaluación del estado actual y futuro de los recursos de agua dulce de Puerto Rico.

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Freshwater systems are dynamic environments, both ecologically and geomorphologically, but they are especially vulnerable to human influences. Multiple anthropogenic pressures including water extractions; industrial, agricultural, and domestic effluents; nonindigenous species; altered hydrology; habitat degradation; and overexploitation threaten ecosystem integrity in these environments (Allan and Castillo 2007; Jelks et al. 2008). These pressures have been particularly evident in developed countries in the Northern Hemisphere, but are becoming increasingly prevalent worldwide. Resource degradation is a major issue in the tropics, and often little is known about the resources before they are lost. In Puerto Rico, there have been few published accounts of the freshwater fish species, and these accounts either focused primarily on introduced fishes (Erdman 1984; Neal et al. 2004), or were reports with limited circulation (e.g., Bunkley-Williams and Williams 1994). There have been no attempts to summarize threats to the freshwater systems of Puerto Rico in the primary literature.

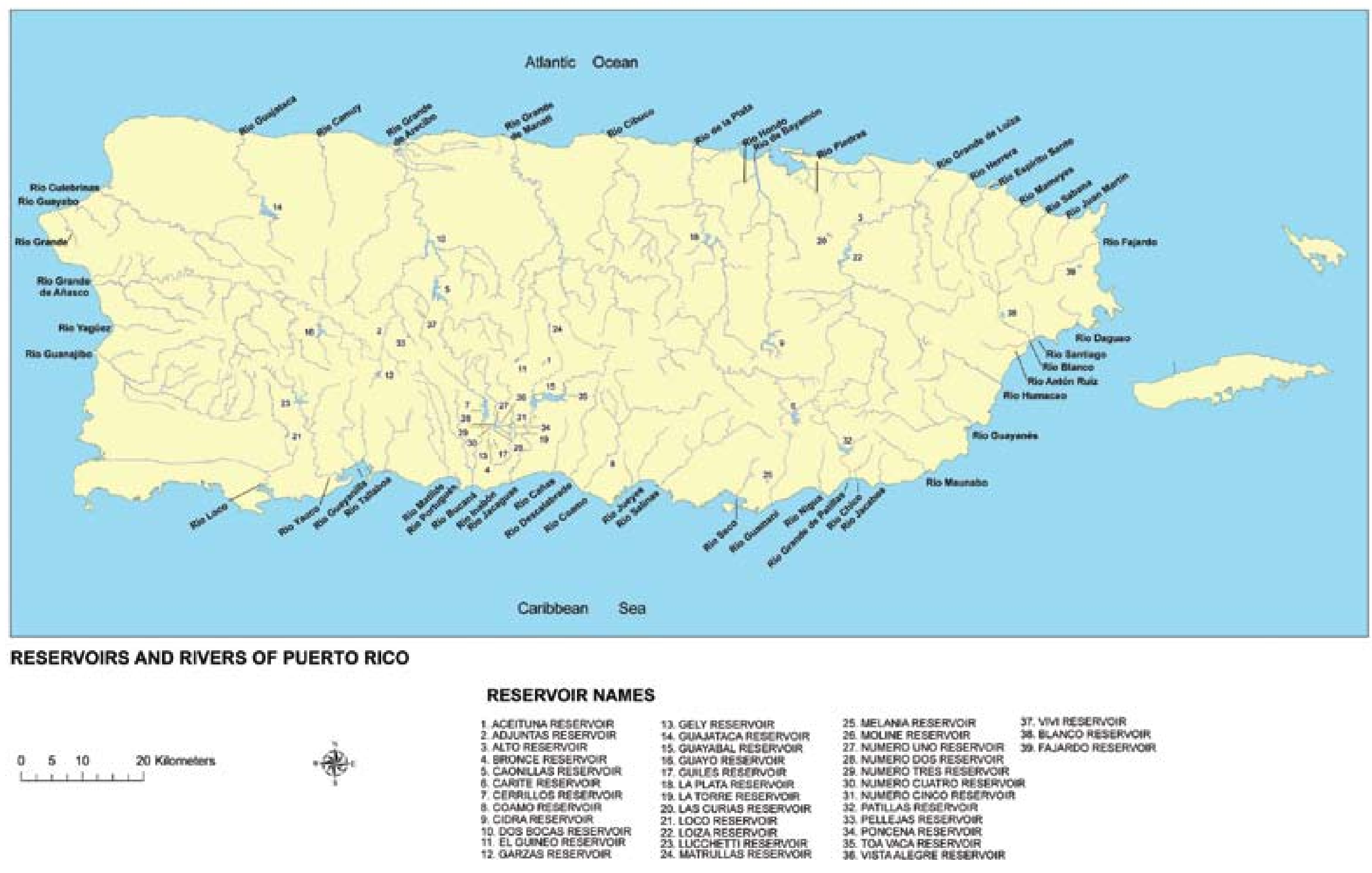
The island of Puerto Rico is not known for a high diversity of freshwater fishes and habitats. Due to its young age and volcanic origin, coupled with its relative isolation from potential sources of colonizing species, no truly freshwater fish species are native to the island (Erdman 1984). Instead, a handful of peripherally-freshwater species that require a link to marine systems have colonized its rivers. Intentional and unintentional introductions of nonindigenous species have greatly expanded fish diversity in freshwater systems on the island, with both positive and negative effects. This article describes the freshwater resources and fish species of Puerto Rico and identifies factors that threaten their conservation. The ecological and management environments that we review for Puerto Rico represent a microcosm of similar conditions that are less well studied and understood in other Caribbean and tropical island communities.

AQUATIC RESOURCES OF PUERTO RICO

The smallest of the Greater Antilles, Puerto Rico is a tropical island of mainly volcanic origin, measuring 175 km long by approximately 62 km wide at its widest points, with a human population of nearly 4,000,000 inhabitants (429/km^2). The capital city of San Juan and other major urban centers, such as Ponce on the south coast and Mayagüez on the west coast, are located on coastal lowlands. The interior of the island consists of an east-west running mountain chain (La Cordillera Central), and more than 50 rivers originate in this rugged terrain (Figure 1). Rivers on the north, east, and west slopes tend to be longer than those on the southern slopes of the central mountain range. The longest river (64 km) in Puerto Rico is the Río Grande de Añasco, which flows to the west coast. Streams in Puerto Rico are typically small and flashy, with rocky substrates that vary from gravel to house-sized boulders. The conductivity of Puerto Rico stream and reservoir water is moderate (50-1,000 µS/cm, with most waters 200–500 µS/cm; Díaz et al. 2005; Kwak et al. 2007), which is optimal for sampling with typical electrofishing gears (Reynolds 1996). Another primary physiographic feature is the karst region in the north, a limestone formation that covers about one-fifth of the island extending from the city of Aguadilla in the west to Loíza in the east. The hydrogeology of rivers in the karst region differs from that of rivers flowing through volcanic geology, owing to springs, subterranean channels, and permeability. Groundwater and surface waters are naturally linked in this region (Giusti 1978).

The Tortuguero Lagoon represented one of only two natural freshwater lentic systems in Puerto Rico. However, a constructed channel to the sea has converted this freshwater system to estuarine conditions, and as a result, a diversity of species ranging from native snook (*Centropomus* spp.) and tarpon (*Megalops atlanticus*) to stocked largemouth bass (*Micropterus salmoides*) and sunfish (*Lepomis* spp.) can be found there. The very shallow Cartagena Lagoon, in southwest Puerto Rico, depends on rainfall as a freshwater source, and is dominated by cattails (*Typha domingensis*). Previously, this lagoon provided important waterfowl habitat, though severe anthropogenic impacts have degraded the quality of the habitat in recent years (USFWS 2002). Many of the island's rivers have been impounded for various purposes, including irrigation, flood control, hydroelec-

Figure 1. Map of the water resources in Puerto Rico, including all primary river systems and reservoirs. Map modified and reprinted with permission of the Puerto Rico Department of Natural and Environmental Resources.



tric power generation, and drinking-water supplies. Consequently, Puerto Rico has 13 reservoirs over 100 ha in area and numerous smaller impoundments.

The deepest reservoir (84 m) is the recently constructed (1992) Cerrillos Reservoir. Many of the older reservoirs have lost storage capacity due to sedimentation originating from upstream areas of the drainage basins. For example, recent bathymetric mapping in Dos Bocas Reservoir has indicated sedimentation rates up to 1.4 m/yr (Soler-López 2001), and Lucchetti Reservoir has lost more than 60% of its maximum depth since impoundment in 1952 (Neal et al. 1999). Generally, Puerto Rico reservoirs are mesotrophic to eutrophic, and anoxic below approximately 3 m depth. Surface water temperature averages around 27°C, though this varies somewhat with altitude and season. Reservoir water levels can be highly variable, with annual fluctuations of 18 m or more for some systems (Neal et al. 2001). These extremes in variability are generally related to water-level management for flood control more so than variability in seasonal rainfall, which does not follow exaggerated seasonal patterns observed in many tropical climates.

Freshwater resources of Puerto Rico are not intensively developed with respect to freshwater fishing, boating, and recreational access and facilities. Of the major reservoirs, five have well-developed access and recreational and fishing facilities (La Plata, Guajataca, Lucchetti, Cerrillos, and Dos Bocas reservoirs), including a resident biologist or enforcement personnel, public boat ramps, sanitary and picnic amenities, and other facilities. The typical Puerto Rico reservoir may provide unpaved, improvised access facilities, or access is limited to private fishing club facilities.

Puerto Rico's streams have potential as recreational resources, yet stream angling is not a common practice in Puerto Rico. Most fishing involves artisanal capture of *Atya* or *Macrobrachium* shrimp, freshwater crab (*Epilobocera sinuatifrons*), or estuarine species found near river mouths. Nevertheless, several abundant native fish species inhabit the lotic systems and could support recreational fisheries if they were developed. Development of access, promotion, and additional efforts to control the point and nonpoint sources of contamination are actions that could enhance and facilitate public interest in recreational fisheries. Concern of schistosomiasis historically discouraged wading and swimming in streams, but these concerns seem to have dissipated in recent years as shrimping and swimming are common. Although Tsang et al. (1997) found relatively high seroprevalence rates of the parasite (*Schistosoma mansoni*) in the municipalities of Naguabo and Jayuya, recent localized studies point to decreasing prevalence of this parasitic disease over the past decades (Hillyer and Soler de Galanes 1999).

The freshwater resources on the island have received substantial chemical and nutrient pollution from a variety of sources (Hazen 1988; Hunter and Arbona 1995; Stallard 2001; Warne et al. 2005). With the high human population density of Puerto Rico and the fact that roughly 57% of all households rely on water supplied from reservoirs by the Aqueduct and Sewer Authority, water quality in reservoirs is a valid concern (Barbosa 2005). Floating litter, especially after storm events, is common along the shorelines and coves in many systems, and while litter is primarily aesthetically unsightly, it may indicate contamination by other more influential chemical substances and nutrients from domestic, municipal, industrial, and depositional sources (Hazen 1988; Hunter and Arbona 1995; Stallard 2001; Warne et al. 2005).

Freshwater shrimp (*Macrobrachium heterochirus*) collected during stream electrofishing assessment in Puerto Rico. Shrimp are an important component of the riverine food web and a human food source, and are impacted by the same factors that influence fish communities.

Photo: Patrick B. Cooney.

FRESHWATER FISH SPECIES

While the marine fishes of Puerto Rico have received substantial attention by scientists, the freshwater and estuarine fish fauna is much more poorly understood. Biologists from a number of commonwealth and federal natural resource agencies, public water utilities, and universities in Puerto Rico and the United States have sampled freshwater fishes or conducted surveys in Puerto Rico, but a comprehensive sampling program or monitoring for this fauna has yet to be established. The work on freshwater fishes by former commonwealth biologist Donald Erdman is most noteworthy (Erdman 1972, 1984, and references cited therein), as well as recent extensive, quantitative stream fish surveys by Kwak et al. (2007). However, most previous sampling efforts have been directed at specific research or management objectives, and island-wide fish distributions and community dynamics are not well documented or understood.

In this contribution, we compiled fish species lists using published reports and manuscripts (cited within) and unpublished agency and university data and technical reports. The fishes currently or previously found in freshwater habitats of Puerto Rico represent a moderately diverse assemblage composed of 14 orders, 29 families, and 82 species. These species range from primarily freshwater (Table 1), including many nonnative freshwater species (7 families) and a few diadromous native species (4 families), to native estuarine and marine species (18 families; Table 2) that commonly enter lowland rivers and brackish lagoons. Additional species are occasionally collected or have been previously reported in Puerto Rico (Table 3), likely as a result of unauthorized releases or isolated distributions. Rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) were imported and stocked in island rivers between 1934 and 1942, but did not establish (Erdman 1972; Neal et al. 2004). Two more species (warmouth *Lepomis gulosus* and bobo mullet *Joturus pichardi*) have been reported in historical records, but these species were not

Table 1. Freshwater fish species found in reservoirs and rivers in Puerto Rico. Note: the sirajo goby *Sicydium plumieri* has been split into four *Sicydium* species (*S. buscki, S. gilberti, S. plumieri,* and *S. punctatum*; Watson 2000); it is not clear which are present in Puerto Rico.

Family	Species	Common Name	Origin	Status
Anguillidae	*Anguilla rostrata*	American eel	Native	Widespread
Centrarchidae	*Lepomis auritus*	redbreast sunfish	Introduced	Widespread
	Lepomis macrochirus	bluegill	Introduced	Widespread
	Lepomis microlophus	redear sunfish	Introduced	Widespread
	Micropterus coosae	redeye bass	Introduced	Restricted to Maricao River
	Micropterus salmoides	largemouth bass	Introduced	Widespread
Cichlidae	*Astronotus ocellatus*	oscar	Introduced	Loíza Reservoir and expanding
	Cichla ocellaris	butterfly peacock bass	Introduced	Widespread
	Cichlasoma labiatum	red devil cichlid	Introduced	Expanding
	Cichlasoma managuense	jaguar guapote	Introduced	Expanding
	Oreochromis aureus	blue tilapia	Introduced	Widespread
	Oreochromis mossambicus	Mozambique tilapia	Introduced	Widespread
	Tilapia rendalli	redbreast tilapia	Introduced	Widespread
Clupeidae	*Dorosoma petenense*	threadfin shad	Introduced	Widespread
Cyprinidae	*Puntius conchonius*	rosy barb	Introduced	Locally abundant in a few systems
Eleotridae	*Dormitator maculatus*	fat sleeper	Native	Widespread
	Eleotris perniger	smallscaled spinycheek sleeper	Native	Widespread
	Gobiomorus dormitor	bigmouth sleeper	Native	Widespread
Gobiidae	*Awaous banana*	river goby	Native	Widespread
	Sicydium plumieri	sirajo goby	Native	Widespread
Ictaluridae	*Ameiurus nebulosus*	brown bullhead	Introduced	Widespread
	Ameiurus catus	white catfish	Introduced	Widespread
	Ictalurus punctatus	channel catfish	Introduced	Widespread
Loricariidae	*Pterygoplichthys pardalis*	Amazon sailfin catfish	Introduced	Expanding
Mugilidae	*Agonostomus monticola*	mountain mullet	Native	Widespread
Poeciliidae	*Gambusia affinis*	western mosquitofish	Introduced	Widespread

vouchered, remain unconfirmed, and their occurrence is questionable (Table 3).

Introduced fishes and a handful of diadromous native species comprise the majority of species collected in upland rivers and reservoirs. The number of freshwater exotic fish species and ratio of exotic-to-native freshwater fishes in Puerto Rico is among the highest for island faunas where these data are known (Tables 1–3; Erdman 1984; Vitousek et al. 1997). Only seven native species are routinely collected in freshwater systems, and all are reliant on a connection to estuarine or marine systems for at least some portion of their lives. The American eel (*Anguilla rostrata,* Anguillidae) is the only truly catadromous species in Puerto Rico, as it lives in freshwater and returns to the open ocean to spawn. The bigmouth sleeper (*Gobiomorus dormitor*), fat sleeper (*Dormitator maculatus*), and smallscaled spinycheek sleeper (*Eleotris perniger,* Eleotridae); river goby (*Awaous banana*) and sirajo goby (*Sicydium plumieri,* Gobiidae; recently split into four distinct species; Watson 2000); and mountain mullet (*Agonostomus monticola*, Mugilidae) found in freshwater rivers in Puerto Rico are believed to be amphidromous, although little has been documented on their life histories. In amphidromy, adults spawn in the rivers and the larvae migrate or are passively transported to marine environments. After a period of growth, post-larvae re-enter streams, metamorphose into juveniles, and migrate upstream (Erdman 1984). The sole exception among these native fishes is the bigmouth sleeper, which although typically amphidromous, appears to maintain a self-sustaining population in Carite Reservoir (Bacheler et al. 2004). A small population appears to inhabit Patillas Reservoir (PRDNER, unpublished data), although the size structure of the population (predominantly large individuals) and the presence of amphidromous shrimp in this water body suggest episodic connectivity with the marine environment.

The presence of dams excludes most native species from the resulting reservoirs or upstream river reaches (Holmquist et al. 1998; Kwak et al. 2007). As a consequence, management practices in Puerto Rico reservoirs have resulted in fish communities that are primarily a mixture of exotic species introduced to the island from various continents. These include black bass and sunfishes (Centrarchidae), catfishes (Ictaluridae), and threadfin shad (*Dorosoma petenense,* Clupeidae) of North American origin; African tilapia (Cichlidae); and South American butterfly peacock bass (*Cichla ocellaris,*Cichlidae). Fish introductions began during the 1910s when the first wave of reservoir construction began in the eastern part of the island. Biologists of local and federal government agencies endorsed these introductions, which were common practice at the time, before the potential for negative ecological interactions between exotic and native fishes had been addressed by the scientific community (Kohler and Courtenay 1986;

Select freshwater fishes common in Puerto Rico:

(A) Amazon sailfin catfish (introduced),

(B) butterfly peacock bass (introduced),

(C) red devil cichlid (introduced),

(D) bigmouth sleeper (native),

(E) sirajo goby (native), and

(F) mountain mullet (native).

Photos A, B, & C: Craig G. Lilyestrom
Photo D: J. Wesley Neal and
Photos E & F: Patrick B. Cooney.

Table 2. Primarily marine and estuarine fish species collected in coastal freshwater rivers of Puerto Rico.

Family	Species	Common Name
Achiridae	*Achirus lineatus*	lined sole
	Trinectes inscriptus	scrawled sole
Belonidae	*Strongylura timucu*	timucu
Bothidae	*Citharichthys spilopterus*	bay whiff
Carangidae	*Caranx hippos*	crevalle jack
	Caranx latus	horse-eye jack
	Oligoplites saurus	leatherjack
	Trachinotus falcatus	permit
Carcharhinidae	*Carcharhinus leucas*	bull shark
Centropomidae	*Centropomus ensiferus*	swordspine snook
	Centropomus parallelus	smallscale fat snook
	Centropomus pectinatus	tarpon snook
	Centropomus undecimalis	common snook
Clupeidae	*Harengula jaguana*	scaled sardine
	Opisthonema oglinum	Atlantic thread herring
Elopidae	*Elops saurus*	ladyfish
Engraulidae	*Anchoa parva*	little anchovy
Gerreidae	*Eucinostomus argenteus*	spotfin mojarra
	Eucinostomus melanopterus	flagfin mojarra
	Eugerres plumieri	striped mojarra
	Gerres cinereus	yellowfin mojarra
Gobiidae	*Ctenogobius boleosoma*	darter goby
	Evorthodus lyricus	lyre goby
	Gobiodes broussonetii	violet goby
	Gobionellus oceanicus	highfin goby
Haemulidae	*Pomadasys crocro*	burro grunt
Lutjanidae	*Lutjanus apodus*	schoolmaster
	Lutjanus griseus	gray snapper
	Lutjanus jocu	dog snapper
Megalopidae	*Megalops atlanticus*	tarpon
Mugilidae	*Mugil curema*	white mullet
	Mugil liza	liza
	Mugil trichodon	fantail mullet
Polynemidae	*Polydactylus virginicus*	barbu
Syngnathidae	*Microphis brachyurus*	opposum pipefish
Tetraodontidae	*Sphoeroides spengleri*	bandtail puffer
	Sphoeroides testudineus	checkered puffer

Bunkley-Williams et al. 1994). The flourish of fish species introductions ended in the late 1960s (Erdman 1984), when it was perceived that all ecological niches in reservoirs had been filled. Although intentional introductions have been curtailed, maintenance stocking of sport fish species (e.g., largemouth bass, redear sunfish *Lepomis microlophus*) continues to be a primary management technique of the Puerto Rico Department of Natural and Environmental Resources (Neal et al. 2004).

The establishment of a few new exotic fish species has been documented for Puerto Rico freshwater habitats since 1970 (Tables 1-3; Erdman 1984; Bunkley-Williams et al. 1994; Kwak et al. 2007; USGS 2007). Recent introductions have been attributed to the aquaculture industry, aquarium releases, and anglers (Erdman 1984; USGS 2007). The growing list includes the Amazon sailfin catfish (*Pterygoplichthys pardalis*, Loricariidae), which continues to reproduce and proliferate in reservoirs (Bunkley-Williams et al. 1994), and several members of the family Poeciliidae, which are common and expanding in range. Recently, several species of cichlids have begun to appear in reservoir electrofishing and creel surveys, including the jaguar guapote (*Cichlasoma managuense*), red devil cichlid (*Cichlasoma labiatum*), convict cichlid (*Cichlasoma nigrofasciatum*), and Rio Grande cichlid (*Cichlasoma cyanoguttatus*). Introductions of these aggressive cichlids are of concern due to expanding populations, and they are known to impact native fishes in other freshwaters (Fuller et al. 1999; PRDNER 2006, 2007). The most recent fish introduction documented in Puerto Rico freshwaters is a population of the Chinese algae-eater (*Gyrinocheilus aymonieri*) established in the Río Grande de Loíza (Kwak et al. 2007).

FACTORS THREATENING NATIVE FISHES

Environmental Alterations

Puerto Rico's aquatic resources face many of the same anthropogenic burdens as elsewhere, but the effects are exacerbated by the spa-

Table 3. Occasionally or rarely collected fish species that result from bait, aquaculture, or aquarium releases, and species of limited or questionable record.

Family	Species	Common Name	Status
Anabantidae	*Helostoma temmincki*	kissing gourami	Occasionally collected
Centrarchidae	*Lepomis gulosus*	warmouth	Questionable record
Cichlidae	*Cichlasoma cyanoguttatum*	Rio Grande cichlid	Occasionally collected
	Cichlasoma nigrofasciatum	convict cichlid	Occasionally collected
	Oreochromis niloticus	Nile tilapia	Aquaculture species
	Oreochromis urolepis hornorum	Wami tilapia	Aquaculture species
	Oreochromis urolepis urolepis	Rufigi tilapia	Aquaculture species
Cyprinidae	*Carassius auratus*	goldfish	Occasionally collected
	Ctenopharyngodon idella	grass carp	Stocked for weed control
	Hypophthalmichthys molitrix	silver carp	Likely extirpated
	Pimephales promelas	fathead minnow	Likely extirpated
Gyrinocheilidae	*Gyrinocheilus aymonieri*	Chinese algae-eater	Occasionally collected
Mugilidae	*Joturus pichardi*	bobo mullet	Questionable record
Poeciliidae	*Poecilia orri*	mangrove molly	Common in isolated habitats
	Poecilia reticulata	guppy	Common in isolated habitats
	Xiphophorus hellerii	green swordtail	Common in isolated habitats
	Xiphophorus maculatus	southern platyfish	Common in isolated habitats
Salmonidae	*Oncorhynchus mykiss*	rainbow trout	Extirpated
	Salmo trutta	brown trout	Extirpated

tial concentration of the human population and the rapidly changing landscape. The human population of Puerto Rico has increased 72% in the last 50 years, and with the current population density of 429 inhabitants per km^2, Puerto Rico's aquatic resources are subject to increasing demand and degradation (López and Villanueva 2006). Over 2.27 billion L/d (598 million gal/d) of freshwater are dedicated to domestic use, which represents 80% of the total domestic, agricultural, industrial, and hydroelectric water usage.

The most prominent alterations to the landscape which affect aquatic resources include agricultural practices, deforestation, stream channelization, industrial and municipal pollution, land development, and the impoundment of rivers. Industrial and agricultural withdrawals of water from streams have depleted stream flows in some systems (Erdman 1984), due to the application of "minimum flow" criteria rather than "instream flow" criteria (sensu Annear et al. 2004) and removal of land cover for agriculture has increased runoff, erosion, and sedimentation rates (Clark and Wilcock 2000; Soler-López 2001). The abundance of freshwater shrimp in streams is directly related to flow (Scatena and Johnson 2001), and similar relationships likely exist for stream fishes.

Impaired water quality resulted in 51% of Puerto Rico river reaches assessed in 1988-89 to be considered moderately or severely contaminated, and 49% were inadvisable for swimming or fishing (Hunter and Arbona 1995). Bioaccumulation of heavy metals and pesticides in Puerto Rico fishes has been reported, with certain systems exceeding limits for human consumption for some species (Rodríguez and Gonzalez 1981; Olmeda Marrero 2000). Fish kills resulting from agricultural discharges and municipal sewage effluents have been documented, and salinity changes, bacterial or viral episodes, agricultural chemicals, or the loss of water from diversions also may impact aquatic resources (Hunter and Arbona 1995). However, scientists generally concur that the single greatest limiting factor to native fishes in Puerto Rico has been the presence and operation of the 26 major dams, none of which have fish passage structures (Holmquist et al. 1998; March et al. 2003; Greathouse et al. 2006).

The topography of Puerto Rico and the abundance of flowing surface water have led to the construction of many reservoirs, primarily in upland areas. These reservoirs provide a number of benefits to humans, including flood control, hydroelectric power, water supply, and creation of reservoir fisheries and associated recreational opportunities. However, the impoundment of a free-flowing stream is not without negative impact on ecological function and native fish populations (Ward and Stanford 1983). Because all native freshwater fish species and many native shrimp species in Puerto Rico are diadromous, and because few fish passage structures have been developed and implemented for these species (and none on large dams), the design and incidence of dams inhibits longitudinal instream migration and movement of these species between upland streams and marine systems. Thus, impounding streams eliminates most native freshwater fish and shrimp from above the dam structure, resulting in reduced biodiversity and impaired food webs and ecological function (Holmquist et al. 1998; Greathouse et al. 2006; Kwak et al. 2007). Furthermore, dams can alter the hydrology and ecology of the system both downstream and upstream, with impacts on native species from the headwater reaches to the marine environment that are difficult to measure and variable among regions (Pringle 1997; Pringle et al. 2000; Warne et al. 2005; Greathouse et al. 2006).

Nonnative Species

Intentional introductions of nonnative fishes to create reservoir fisheries have been occurring in Puerto Rico for nearly a century (Neal et al. 2004). While the negative ecological and economic impacts of many exotic fish introductions are clearly documented (Pimentel et al. 2000; Courtenay 2007), little is known about the relationship between the exotic and native fish faunas in Puerto Rico. Erdman (1984) reported that "With the possible exception of tilapia, there is little evidence of harmful impacts of exotic fishes on native Puerto

Rican fishes." This conclusion reflected the current understanding at the time, but since then, additional research suggests ecological effects on native species by exotics. For instance, Holmquist et al. (1998) found a negative correlation between the number of exotic fishes and the number of native fishes in a river reach in Puerto Rico; native species richness (of fish and shrimp) was also inversely correlated with exotic fish abundance.

The occurrence of centrarchids and ictalurids downstream of reservoirs is localized, affecting native fish populations only on a spatially-restricted scale. Although tilapia are most abundant in reservoirs, they are collected in significant numbers downstream and tolerate the brackish salinities of estuaries and lagoons (Stickney 1986). Tilapia may compete for spawning areas, food, and space resources with native fish, demonstrate aggressive behavior toward other species, alter aquatic vegetation, often thrive in altered conditions where natives cannot, and have been implicated in the decline of native fish and mussel populations elsewhere (Fuller et al. 1999). In fact, biologists in some tropical regions are calling for the eradication of nonnative tilapias due to serious impacts on native fishes (Eldredge 2000). Erdman (1984) suggested that other potential predators and increased fishing effort are needed to help keep tilapia populations in check in Puerto Rico, although this may require additional introductions. However, in a survey of tilapia species in a Puerto Rico estuary, Smith et al. (2008) did not detect an increase in their numbers in the Espiritu Santo River estuary between 1977 and 2004, suggesting that populations have stabilized.

The relatively recent introduction of the Australian red claw crayfish (*Cherax quadricarinatus*) to Puerto Rico inland waters poses an additional threat, as yet unquantified, to the ecological integrity and native fauna of these systems. Red claw crayfish were illegally introduced to Puerto Rico in early 1997, and escaped from a private culture facility in the Loiza River drainage in 1998 during Hurricane Georges. García (2008) reported *Cherax* from the Loiza, Carite, and Cidra reservoirs, as well as a Lajas drainage canal and the Loiza and Gurabo rivers, noting no evident environmental damage from the species, though this was not the focus of the research. The negative impacts of nonnative crayfishes have been well documented in both Europe and North America and include ecosystem alterations, damage to fisheries, and extirpation of native invertebrates (Lodge et al. 2000).

FUTURE OF FISHERIES RESOURCES IN PUERTO RICO

The Caribbean in general has very limited freshwater supplies when compared to other parts of the world. With current infrastructure, Puerto Rico supplies drinking water to 97% of the population (Barbosa 2005), and human water use on the island is projected to continue to increase (PRDNER 2008). The needs of water for human consumption and industry will always compete with those for fishing and recreational uses, and economic development may come at a cost to natural resources. However, the ecological services and economic value of maintaining ecological integrity of aquatic ecosystems are becoming increasingly recognized and incorporated into water resource planning (González-Cabán and Loomis 1997; March et al. 2003; PRDNER 2008). Those responsible for managing water and land require information about biodiversity and ecosystem health to consider when establishing policy that balances the needs of water for human uses with those for natural resources.

Based on available literature and the authors' collective experience, six principal areas have been identified that are important influences on the current and future status of the freshwater fish resources of Puerto Rico. While these may be relevant to a broad geographic landscape and other faunas, they are especially applicable to Puerto Rico resources. Specific management recommendations proposed by March et al. (2003) relate directly to Puerto Rico aquatic systems and to the six topics we present below. Some of these topics and recommendations are included in a recently developed water use plan for the island (PRDNER 2008).

1. **Point and nonpoint sources of contaminants.** Water quality is a primary requirement for freshwater fish habitat and stream ecosystem health, as well as human uses. Industrial and municipal effluents, as well as diffuse sources of chemicals and sediment from agriculture and urbanization, can be detrimental to native fish communities. Household waste may litter streams and reservoirs with potential to leach toxic chemicals.
2. **Instream habitat and river flows.** Dams are the single greatest human impact to Puerto Rico native fishes. These structures degrade river habitat and disrupt ecological function, and they are detrimental to amphidromous fish reproduction and recolonization. Remedial approaches to mitigate the effects of dams attempted elsewhere include regulation of flow releases downstream of dams, installation of fish passage devices, or dam removal and habitat restoration. Such measures are being considered and implemented on a limited basis in Puerto Rico. Stream diversions, reduced flows, and channelization, independent of dams, are also detrimental to lotic fish populations and their habitat, especially for amphidromous species that require adequate water flow for migration cues

Dos Bocas Dam impounds the Río Arecibo to form Lago Dos Bocas in Puerto Rico. High dams like this one are important for water supply, power generation, flood control, and recreation, but form barriers to fish migration that exclude native fishes from upstream river habitat and enhance the environment for exotic species.

Photo: Patrick B. Cooney

and reproduction, as well as unobstructed passage in both upstream and downstream directions.

3. **Introductions of exotics and invasive species.** Exotic and invasive species introductions in Puerto Rico have been extensive and detrimental to native fishes and other taxa. While studies conducted elsewhere have documented and elucidated negative impacts of exotic fish introductions, research on the effects on the native fishes and aquatic ecosystems of Puerto Rico is limited and needed to better understand direct and cascading mechanisms.
4. **Human interactions with resources.** Interaction of humans with freshwater fishery and aquatic resources for recreation appears limited, relative to that for marine environments. Contributing causes may be limited access, facilities, and promotion, or concerns over schistosomiasis. Public surveys could help determine perceptions about freshwater resources.
5. **Survey and research efforts.** Knowledge is the basis for successful management and conservation of natural resources. An understanding of the biology, ecology, and sociology associated with aquatic resources and their use is required for informed management. Comprehensive programs to gather, interpret, and evaluate relevant data have improved our understanding of influences on Puerto Rico aquatic resources and can justify and guide effective management activities.
6. **Environmental education and consciousness.** Native freshwater fishes are an important component of Puerto Rico's natural heritage. Interactions with public constituents while sampling fishes in rivers and reservoirs suggest that local residents are indeed interested in freshwater fishes and concerned for their conservation, but their knowledge of the resource is limited. Our personal observations were confirmed by a survey of households in Puerto Rico that indicated that although the public's knowledge of specific river systems was limited, they would be willing to pay for maintaining ecological integrity of Puerto Rico rivers (González-Cabán and Loomis 1997). Such valuations of natural resources facilitate economic comparison of management alternatives; however, the economic value of Puerto Rico freshwater fishes has not been assessed. The coquí (*Eleutherodactylus* spp.) has become a symbol of Puerto Rico pride and heritage, and this popularity facilitates its protection. If a genus of tiny tree frogs can charm the public, the same could be true for the freshwater fishes, given their morphological diversity, unique adaptations, and recreational and food values. Public support is the first step toward effective conservation.

Effective protection and conservation of Puerto Rico freshwater fish resources will require consideration of these six influential areas and sustained commitment among public officials, agency administrators, biologists, and the public toward cooperative resource management.

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Black guillemot on Cooper Island east of Barrow, Alaska.

Photo: George Divoky.

A New Management Plan for the Arctic Waters of the United States

The fishery resources in the Arctic seas controlled by the United States are under a new management regime. In August 2009, the Secretary of Commerce approved a fishery management plan (FMP) for all federal waters north of Bering Strait. This FMP was a joint effort between the North Pacific Fishery Management Council (NPFMC) and National Oceanic and Atmospheric Administration (NOAA) Fisheries. The new FMP effectively closes the U.S. Arctic to commercial fishing until sufficient data become available for sustainable management of Arctic fish stocks. In this article, we describe the conception and crafting of this FMP.

Under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the NPFMC is authorized to conserve and manage the fishery resources of the U.S. Exclusive Economic Zone (EEZ) off Alaska (waters between 3 and 200 nautical miles [nm] from shore). To date, no commercial fisheries have developed in U.S. Arctic waters and the NPFMC has not had a compelling reason to develop an FMP for this region. However, due to growing concerns over global climate change and impacts on marine ecosystems, and to continue the policy of the NPFMC and NOAA Fisheries to integrate ecosystem considerations into fisheries science and management, the NPFMC recognized the need to prepare for potential changes in U.S. northern marine waters. These changes are likely to include a reduction of seasonal sea ice coverage, which would increase vessel accessibility to the Arctic, and may result in changes to fish distribution and abundance that could make Arctic fisheries a profitable venture.

These concerns parallel a growing awareness of and interest in Arctic ecosystems on the part of NOAA Fisheries and other organizations. The Fourth International Polar Year was declared for 2007–2008; this is a period of time where nations decide to coordinate research, policy, and outreach concerning the polar regions. Through the Russian-American Long-term Census of the Arctic (RUSALCA), NOAA and the Russian Academy of Sciences have jointly been conducting multidisciplinary marine research in the Bering and Chukchi seas since 2004. The U.S. Coast Guard icebreaker *Healy* has been carrying scientists from NOAA, the University of Alaska, and other institutions into Arctic waters for the last several years. Concerns about increased ocean temperatures have also led NOAA to launch the Loss of Sea Ice Initiative, a research effort designed to investigate the consequences of reduced seasonal sea ice cover on the Bering, Chukchi, and Beaufort seas. See NOAA's Arctic website at www.arctic.noaa.gov for more information.

Beginning in 2006, the NPFMC began discussing strategies to prepare for future change in the Arctic region. It explored various policy options, including an FMP, to address management of any existing or potential future commercial fisheries in this region. Under the MSA and other government regulations, the fishery management process requires thorough analyses of the biological, economic, and social impacts of proposed actions. These analyses typically include a consideration of the status quo as well as one or more action alternatives that are reasonable and may accomplish the stated objectives. In the case of the Arctic FMP, the process began with an initial discussion document that helped frame the issues and included several alternative actions. Staff from the NPFMC and NOAA Fisheries conducted the analysis, which was reviewed by the NPFMC as well as its Ecosystem Committee, Scientific and Statistical Committee, and Advisory Panel. At each step in the process the council also solicited public comments.

As a result of the above process, the NPFMC and NOAA Fisheries developed an Arctic FMP that would (1) close the Arctic to commercial fishing until sufficient information is available to allow sustainable fishing, (2) clarify the management authorities in the Arctic and create a vehicle for addressing future management issues, and (3) implement an ecosystem-based management policy that recognizes the sensitive resources of the U.S. Arctic and the potential for fishery development that might affect those resources, particularly in the face of a changing climate.

Because human residents of the Arctic are extremely dependent on natural resources for survival, a special effort was made to enhance public participation in the policy-making process. Outreach efforts were designed to involve Arctic residents, particularly Native Alaskans, regional Native resource management entities, and other groups interested in the Arctic, in the dialogue and decision making related to adoption of an Arctic FMP. Staff from the NPFMC traveled to Arctic communities to participate in planning commission meetings, borough assembly meetings, and other regional gatherings, and participated in interviews on local radio stations. Flyers, e-mail, and a website were also used to publicize Arctic fisheries issues.

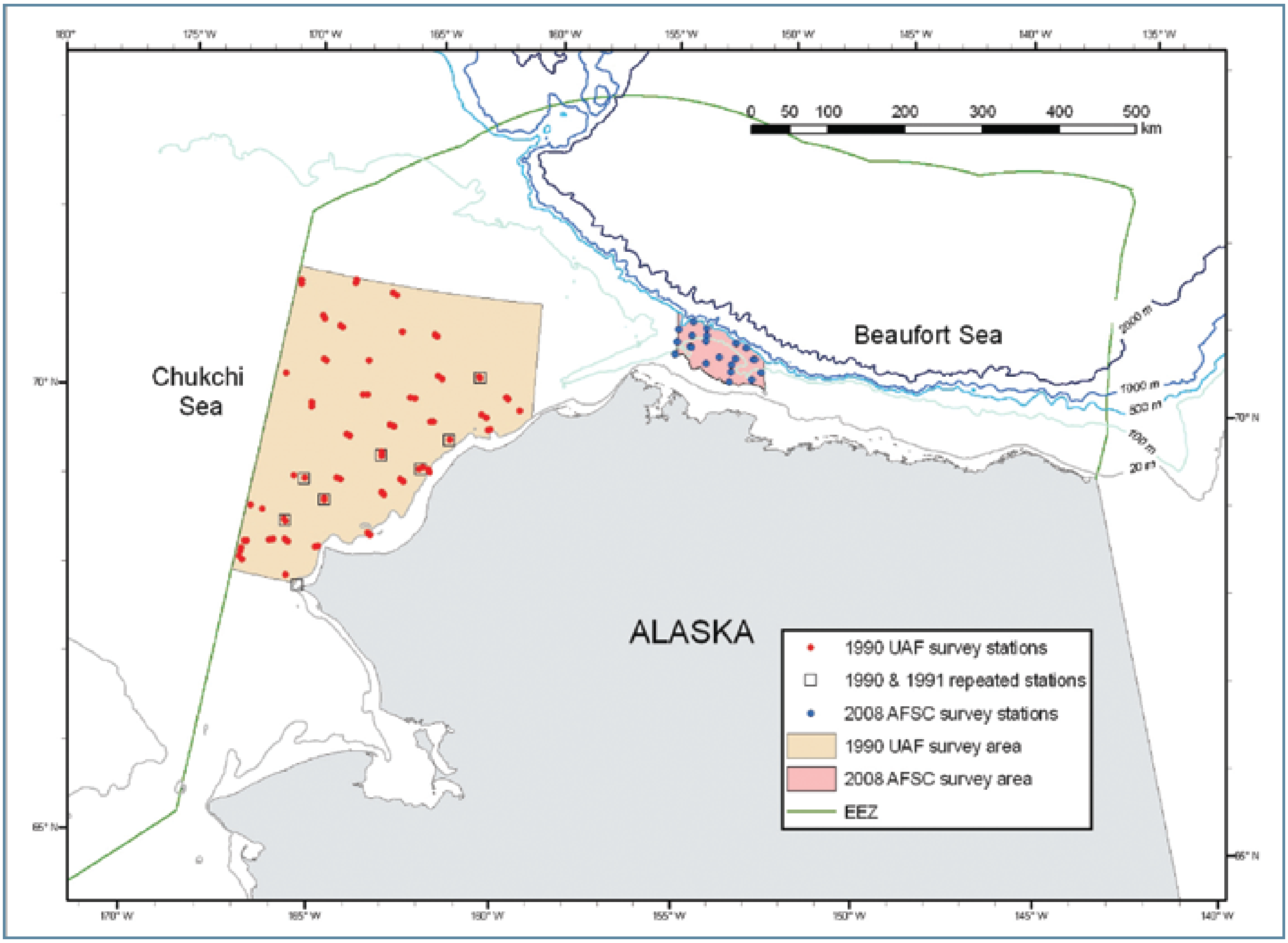
Meeting the requirements of the NOAA Fisheries guidelines for FMPs was particularly challenging for the Arctic. Fishery management plans must specify management quantities, including maximum sustainable yield (MSY) and annual catch limits (ACLs) for target fish species. Estimating such quantities typically requires estimates of abundance or biomass, as well as information on life history variables such as natural mortality. The small amount of fisheries research that has been conducted in the Alaskan Arctic has been infrequent, and rarely of the type that would allow for quantitative assessment of fish stocks. In addition, surveys conducted at the same sites in the Chukchi Sea in 1990 and 1991 (Figure 1) suggested that there is substantial interannual variability in species composition and abundance. Biologists from the NOAA Fisheries Alaska Fisheries Science Center (AFSC) provided scientific advice for overcoming these challenges.

The results of two surveys were usable for estimating the biomass of fish and invertebrates in the Alaskan Arctic. A survey conducted in 1990 by researchers from the University of Alaska Fairbanks provided data regarding the density of fish and crab stocks in the northeastern Chukchi Sea (Figure 1). In August 2008, the AFSC conducted a survey in the western Beaufort Sea that provided density estimates for species there (Figure 1). Both surveys employed identical gear, a bottom otter trawl of the same design used for standard assessment surveys in the Bering Sea. The trawls were equipped with electronic sensors that provided data on bottom contact, net width, and other variables that allowed precise measurement of the area sampled. The density of each species was calculated for each survey haul by dividing the catch weight by the area swept, and a mean density for the survey area was calculated. Those densities were multiplied by the spatial area covered by the surveys to provide estimates of biomass. Because the surveys covered only a portion of the Arctic Management Area (Figure 1 and see side bar), those biomass values are probably underestimates.

Ringed seal.
Photo: National Marine Mammal Laboratory.

The other main challenge was creating an FMP for an area where no commercial fisheries currently exist. This seeming paradox posed legal difficulties, but was

Figure 1. Map of the Alaskan Arctic showing management boundaries and locations of survey areas and stations. The Arctic Management Area is bounded by the U.S. Exclusive Economic Zone (EEZ; green line), a line 3 nm from shore (within which is state waters), and Bering Strait (see side bar).



NEW U.S. ARCTIC FISHERY MANAGEMENT PLAN MANAGEMENT POLICY AND GOALS

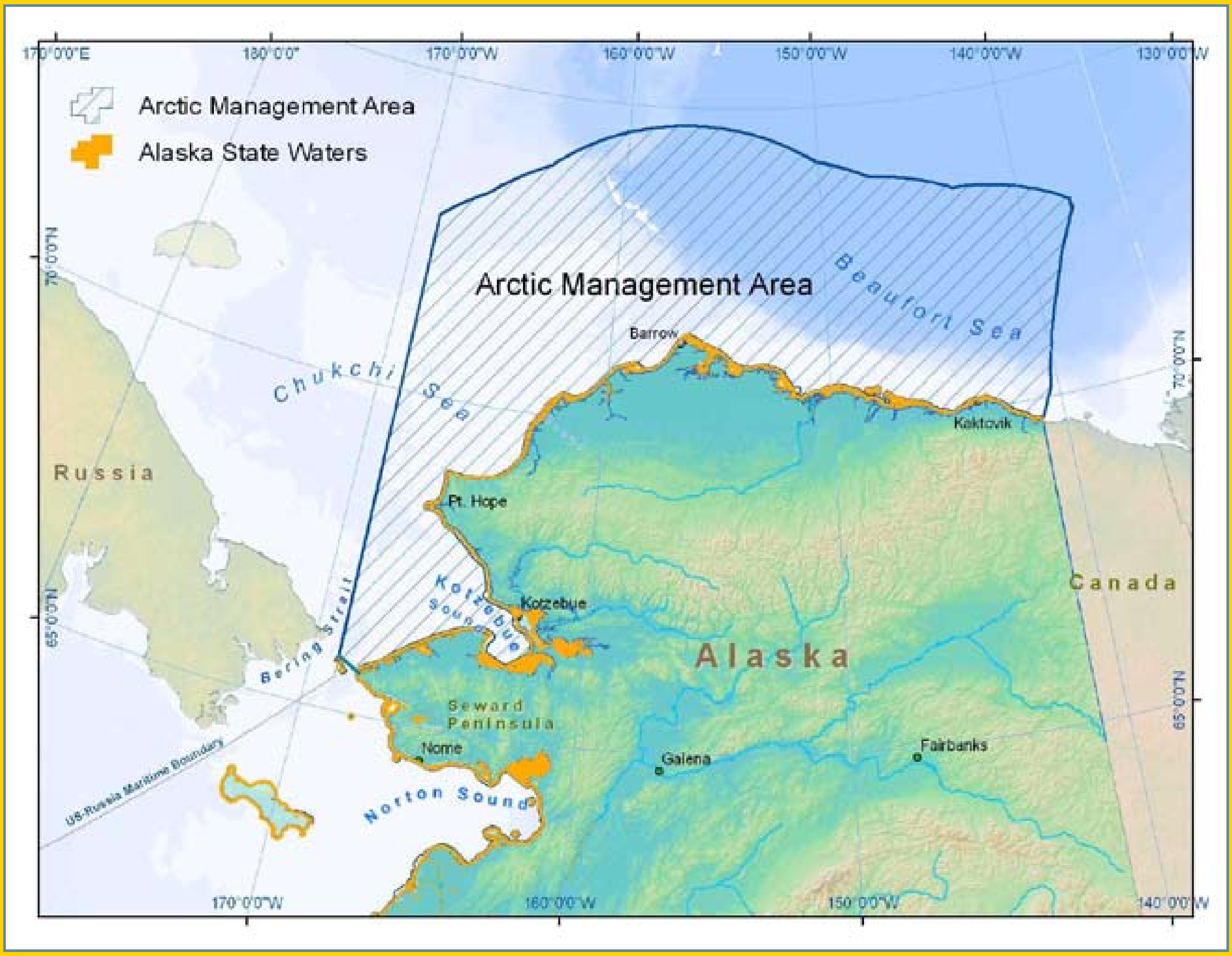
ADOPTED BY THE NORTH PACIFIC FISHERY MANAGEMENT COUNCIL, FEBRUARY 2009

The council recognizes the different and changing ecological conditions of the Arctic, including warming trends in ocean temperatures, the loss of seasonal ice cover, and the potential long-term effects from these changes on the Arctic marine ecosystem. More prolonged ice-free seasons coupled with warming waters and changing ranges of fish species could together create conditions that could lead to commercial fishery development in the U.S. Arctic EEZ off Alaska. The emergence of unregulated, or inadequately regulated, commercial fisheries in the U.S. Arctic EEZ off Alaska could have adverse effects on the sensitive ecosystem and marine resources of this area, including fish, fish habitat, and non-fish species that inhabit or depend on marine resources of the U.S. Arctic EEZ, and the subsistence way of life of residents of Arctic villages. The council views the development of an Arctic FMP as an opportunity for implementing an ecosystem-based management policy that recognizes these issues in the U.S. Arctic EEZ.

The council's management policy for the U.S. Arctic EEZ is an ecosystem-based management policy that proactively applies judicious and responsible fisheries management practices, based on sound scientific research and analysis, to ensure the sustainability of fishery resources, to prevent unregulated or poorly regulated commercial fishing, and to protect associated ecosystems for the benefit of current users and future generations. This management policy recognizes the need to balance competing uses of marine resources and different social and economic goals for sustainable fishery management, including protection of the long-term health of the ecosystem and the optimization of yield from its fish resources. Recognizing that potential changes in productivity may be caused by fluctuations in natural oceanographic conditions, fisheries, and other non-fishing activities, the council intends to continue to take appropriate measures to insure the continued sustainability of the managed species and to prepare for possible fishery development in the Arctic. This policy will use and improve upon the council's existing open and transparent process of public involvement in decision making.

Given this management policy, the council's fishery management goals for the U.S. Arctic EEZ are to provide sound conservation and sustainability of fish resources, provide socially and economically viable commercial fisheries for the well-being of fishing communities, minimize human-caused threats to protected species, maintain healthy habitat for marine resources, and incorporate ecosystem-based considerations into management decisions. This policy recognizes the complex interactions among ecosystem components, and seeks to protect important species utilized by other ecosystem component species, potential target species, other organisms such as marine mammals and birds, and local residents and communities.

In implementing the management policy and goals, the council will consider and adopt, as appropriate, measures that prevent unregulated or poorly regulated fishing; apply ecosystem-based management principles that protect managed species from overfishing and protect the health of the entire marine ecosystem; where appropriate and practicable, include habitat protection and bycatch constraints; authorize and regulate commercial fishing in the U.S. Arctic EEZ consistent with the goals and objectives of the management policy should commercial fishery development be proposed in the future; and apply the council's precautionary, adaptive management approach through community-based or rights-based management. All management measures will be based on the best scientific information available.



Map of the Arctic Management Area under authority of the North Pacific Fishery Management Council's newly-adopted Arctic Fishery Management Plan. Note: the boundaries of the EEZ shown are the U.S. claim.

solved using an elegant mathematical approach to identify target fisheries that could be commercially viable. Briefly, fish prices from existing fisheries in the Bering Sea were combined with catch-per-unit-effort (CPUE) data from the Bering Sea to produce an estimate of "revenue-per-unit-effort," i.e., the money that could be earned from a particular fishery given a certain amount of effort. Those data were used to create benchmarks for an expected level of CPUE and price that would make a commercial fishery viable. When this formula was applied to the Arctic, three species met these benchmarks: snow crab (*Chionoecetes opilio*), Arctic cod (*Boreogadus saida*), and saffron cod (*Eleginus gracilis*). For each target species, MSY and status determination criteria were calculated.

The last step in the specification process was the determination of optimum yield (OY). Federal fisheries must be managed to achieve OY, which the MSA defines as the catch that "will provide the greatest overall benefit to the nation…taking into account the protection of marine ecosystems." This means that catch limits are formulated by reducing MSY based on scientific uncertainty as well as economic and ecological considerations. Because the level of uncertainty in the Arctic is very high (due to the scarcity of data), fishing there is very expensive, and all three species are important ecosystem components, the OY for each species was set at essentially zero. A small amount of catch was allowed to meet subsistence needs. The FMP specifies a number of requirements, including the collection of data sufficient for effective management and an impacts analysis, that need to be met before opening a target fishery is considered.

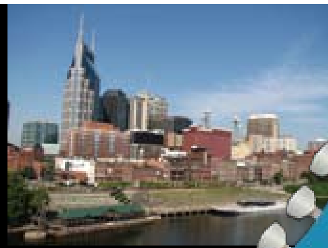
Typical catch during a survey conducted by the Alaska Fisheries Science Center in the western Beaufort Sea. The catch is dominated by brittle stars with a few opilio crabs and fishes.

Photo: NOAA Fisheries.

In addition to the three target species, all remaining fish species in Arctic waters were designated "ecosystem component" species. This is a new FMP category created as a result of the reauthorization of the MSA and provides the authority for conservation of non-target species without requiring specification of optimum yield and other status determination criteria as is required for target species (the entire environmental and socioeconomic analysis document prepared to support the decision to adopt a new Arctic FMP is available at www.fakr.noaa.gov/analyses/arctic/earirfrfa0809final.pdf).

At its February 2009 meeting, the NPFMC voted unanimously to adopt the new FMP for the Arctic Management Area (side bar). This action does not affect the management of Pacific salmon species because an existing salmon-specific FMP closes the entire Arctic to salmon fishing. In addition, fishing for Pacific halibut (*Hippoglossus stenolepis*) is managed by the International Pacific Halibut Commission, which has closed the Arctic to halibut fishing. The commercial fishing closure also does not apply to subsistence or personal use fisheries, or any fisheries prosecuted in Alaska state waters of the Arctic. The Arctic FMP was approved by the Secretary of Commerce in August 2009. For more information, visit either the NPFMC Arctic fishery management web page (www.fakr.noaa.gov/npfmc/current_issues/Arctic/arctic.htm) or the NOAA Arctic fisheries page (www.alaskafisheries.noaa.gov/sustainablefisheries/arctic).

WRAP-UP:
AFS 139TH ANNUAL MEETING
30 AUGUST–3 SEPTEMBER, 2009
NASHVILLE, TENNESSEE


BETH BEARD

Music to Our Ears

BY BETH BEARD

Even with tight travel budgets and a still recovering economy, more than 1,500 fisheries professionals, students, and guests convened in Nashville from 30 August to 3 September 2009 for the 139th Annual Meeting of the American Fisheries Society. By day attendees discussed the latest science on crucial topics such as climate change and freshwater fisheries in crisis, but at night they enjoyed world-class music venues and unforgettable barbecue and other Southern foods. This year's meeting theme was "Diversity—The Foundation of Fisheries and the AFS: Are We Gaining Ground?"

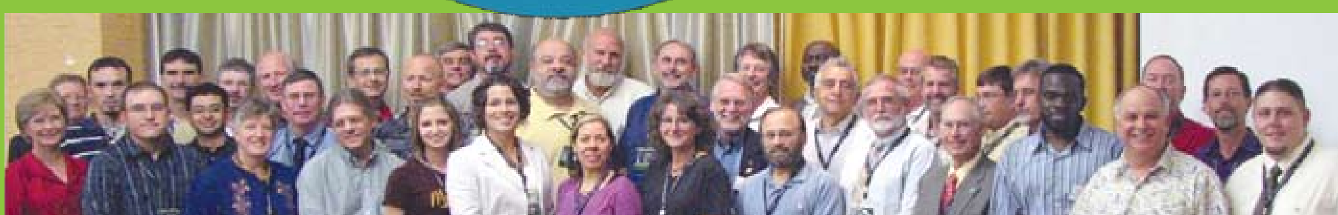
The Governing Board kicked off the meeting activities on Friday with a retreat at rustic Camp Marymount, where they discussed long-term planning for the AFS publications program. However, on Saturday the Board faced the challenge of closing the Society's moderate budget deficit. A final decision had to be postponed until further data could be gathered and more discussions could be held, but several options are now on the table. Continuing education workshops also began on Saturday, with almost all being very well-attended.

BETH BEARD

See more Annual Meeting photos at www.fisheries.org

DON KING, TWRA

The 2008–2009 Governing Board and Mentees.


BETH BEARD

The Welcome Social at the Ryman Auditorium.

LEE WILMOT, TWRA

LEE WILMOT, TWRA

Section meetings and continuing education workshops were the main activities on Sunday, which ended with a Welcome Social featuring a buffet of Southern favorites like bread pudding and green beans and bacon. Afterwards, attendees crossed the street to gather in the historic Ryman Auditorium. The bluegrass band 2nd Nature, comprised of Tennessee Wildlife Resources Agency employees, opened the concert with charming songs like "The Roadkill Bill," and they were followed by the reality television-starring band Six Wire, whose powerful finale kept attendees talking for days.

JASON HARMON, TWRA

The Plenary Session on Monday featured several major Society awards, which will be highlighted in the December issue of *Fisheries*. The first speaker was Jeff Hutchings, a professor at Dalhousie University and chair of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). He discussed the Convention on Biological Diversity's goal of achieving a significant reduction in the rate of loss of biodiversity worldwide by 2010 and how this was and was not reflected in the abundance slopes of regional commercial marine fish species. On a graph of fishing mortality vs. maximum sustainable yield, Hutchings showed how depleted stocks might be expected to make a circular pattern on their route to recovery and why some recovering stocks seemingly get stuck at low levels despite very low fishing pressure. Hutchings suggested that fishery

BETH BEARD

Continuing education workshop on public speaking.

BETH BEARD

Fisheries Management Section meeting.


BETH BEARD

Jeff Hutchings


BETH BEARD

Peter Moyle


DON KING, TWRA

Doug Austen


DON KING, TWRA

Ambrose Jerald, Jr.

managers need to rethink the reductions in fishing necessary and sufficient for recovery and rebuilding, the influence of fish age and size in stock/recruitment relationships, and the expected time lag since recovery targets also require timelines.

Peter Moyle of the University of California Davis then took the podium to discuss the worldwide crisis in freshwater fish biodiversity losses. Beginning with the example of Putah Creek on the Davis campus, he showed how the diversity losses in this local stream reflected overall problems with freshwater fishes in California and also worldwide. In California, 73% of fish species are in decline, and the past two decades have seen 22 more species added to the imperiled species list of the state. Worldwide, only 17% of freshwater species have been assessed, with the tropical species being the least studied despite being the most diverse. Moyle noted that solutions for this global problem must cycle back to the local level, with AFS members being able to make a policy difference in addressing this huge task.

Next to speak was Doug Austen of the Pennsylvania Fish and Boat Commission, who talked about how AFS members could make such a difference in the area of fish habitat. He explained that the profession needs to take advantage of opportunities such as the Farm Bill and the National Fish Habitat Action Plan (NFHAP) as traditional license revenue streams begin to dry up. Fisheries biologists should be engaged locally for discussions on climate change, land conservation, and new sources of conservation funding such as bond funds. Austen suggested it was time to broaden the definition of fish biologist to include communication skills and collaboration in multidisciplinary projects. Despite a lack of a national fish habitat data sharing structure to support synthesis, people rather than technical problems are the main obstacle. NFHAP can help define issues of prioritization in the programmatic tug-of-war, aligning agency priorities with ecological goals.

Finally, Ambrose Jearld, Jr., of NOAA, spoke about diversity in the fisheries profession. Diversity is important because good management brings people with different talents, experiences, and strategies to the table. He told a personal story about driving with other Oklahoma graduate students to his first AFS meeting in New Orleans in the 1960s, when seemingly minor considerations like where to have dinner, where to stay, or where to stop for a restroom became major professional obstacles. Since then he has attended many AFS meetings and has seen major improvements, especially in female membership numbers. However, scientific professions still face a chasm in diversity, prompting programs like the Woods Hole Diversity Initiative, in which six institutions have come together to nurture a spark of scientific curiosity in minority and female students. Ambrose ended by saying that diversity is the moral thing to do, but it requires hard work and persistence to gain ground.

Following the Plenary Session, the first of 32 symposia began, including the Best Student Paper symposium and sessions on functional genomics and gene expression, Pacific cod,


BETH BEARD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bycatch reduction developments, headwater streams, sustainable global fisheries, lake trout threats to western salmonids, inland striped bass management, and innovation in fish passage and protection. Monday also brought the opening of the largest AFS Trade Show ever, with an evening social providing an opportunity for attendees to interact with both vendors and poster authors. Vendors who have been exhibiting at the Annual Meeting for 10 or more years were honored with special plaques in thanks for their continued participation.

Several symposia from Monday continued into Tuesday, while others that began on Tuesday included sessions exploring environmental factors in stock assessments, mapping distributions of North American freshwater fishes, advances in bass culture, Acipenserformes on North America, and diversity in natural resource science professions. Meanwhile, Tuesday also brought a number of student activities, including a colloquium, a very well-attended career fair, and a social at the Wild Horse Saloon.

JASON HARMON, TWRA

BETH BEARD

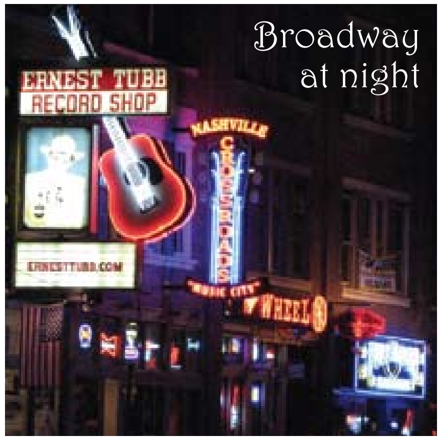
JASON HARMON, TWRA

JASON HARMON, TWRA

LEE WILMOT, TWRA

Career Fair

LEE WILMOT, TWRA



Broadway at night

BETH BEARD

The AFS Business Meeting on Tuesday afternoon featured the introduction of honored guests from around the world, a report on AFS finances, the announcement of the election of John Boreman as second vice president, a preview of the 2010 Annual Meeting in Pittsburgh, and a resolution of appreciation to our Nashville hosts. Bill Franzin passed the president's gavel to Don Jackson, who presented a plan of work based on the theme, "Merging Our Deeper Currents." Jackson urged AFS members to delve into what motivates them, look for common denominators, seek inspiration and encouragement for the young, and celebrate the power of synergism through AFS. Awards from the Business Meeting will be featured in the December issue of *Fisheries*.

Wednesday's program kicked off early with the Spawning Run being held at Centennial Park. Symposia topics for the day included genetic diversity in unexploited populations, a North American spatial framework for rivers, carp biology and control, effective conservation on private lands, big river fish communities, water scarcity and coastal fisheries of western North America, catch share management, fisheries science in the Year of Science, and bioelectrical impedance analysis.

TODD MASZAROS, TWRA

President Don Jackson and Past President Bill Franzin.

TODD MASZAROS, TWRA

Mary Fabrizio and Carolyn Griswold escort Second Vice President John Boreman into office.

SPAWNING RUN WINNERS

Will Schreck finished first for the males in the age 0-29 division as well as first for the men overall, while Danielle Brzezinski won the female 0-29 division. Jessica Mistak came in first in the female age 30-39 category as well being first for the women overall, and Patrick Lynch took first for the males age 30-39. Kevin Wehrly and Lisa Harlan were the first in the men's and women's 40-49 divisions, respectively, and Mark Mattson and Anne Hollowed were the first man and woman in the age 50-59 category. Finally, Nancy Utter won the 60 and over division for the women, and Mike Lewis was first for the 60 and over men.

Spawning Run in Centennial Park

TODD MASZAROS, TWRA

Smiley Hollow Social.

BETH BEARD

BETH BEARD

Hundreds of attendees then boarded a fleet of buses for a trip across the gently rolling Tennessee countryside to Smiley Hollow farm, where old-fashioned amusements such as miniature golf, horseshoes, and hay rides brought out the lighter side of AFS members. Authentic Tennessee hickory barbecue and fried catfish were eaten at long tables with red-checkered tablecloths, as diners tapped their feet to the sounds of the band Next of Kin.

Symposia attendance was impressively strong even late into Thursday afternoon, with sessions on society's role in instream flows, energy production and fisheries in the coastal zone, the hidden crisis in inland fisheries, fisheries in a changing climate, fisheries education in the twenty-first century, conservation of fishes through partnerships, endemic black bass species of the southern United States, and advances in surgical tagging and procedures. The meeting wrapped up with one last chance to socialize at the Goodbye Nashville—Hello Pittsburgh reception Thursday evening.

Next year's meeting in Pittsburgh will be held in the David Lawrence Convention Center, the largest certified green building in the world, and the meeting will feature a social at the impressive Carnegie Museum of Natural History, where attendees can dine among dinosaurs, dodos, and ancient Egyptian mummies. Pittsburgh has shed its "rust-belt" image, and is now considered one of the cleanest and economically strong cities in the country. This recent host of the G20 summit provides ample cultural and entertainment options while being conveniently located and easily accessible by plane, train, or car. As AFS members look forward to exploring the Three Rivers area next year, there is no doubt that memories of Nashville's Southern hospitality will linger like an old country song.

BETH BEARD

Team AFS 2010 Pittsburgh.

COLUMN: PRESIDENT'S HOOK

Continued from page 524

societies. We are engaged in dialogue with respect to the synergistic relationships that currently exist and which can be enhanced between our two societies. We are discussing development of joint ventures programmatically and are making plans to work together on issues that concern both societies (e.g., federal employee full participation in scientific societies). We both also want to enhance relationships with science-based conservation organizations because we recognize the important role that they play in advancing messages into the political arena in ways that would be inappropriate for professional scientific societies. Through this emerging initiative, it is our hope that the professional scientific societies and science-based conservation organizations that address natural resources stewardship will begin a process that ultimately will transform the current assemblage into a functionally integrated community.

NEWS: FISHERIES

Continued from page 525

- o Publications: including "gray literature" contributions
- o Presentations: including oral presentations, posters, and those presented by co-authors (as acknowledged)
- o Transcripts (unofficial) of undergraduate and graduate coursework should be attached.

3. Research proposal, limited to 4 pages (excluding title page, abstract, references, tables, and figures), single spaced, 11 pt font or higher. Proposals should be organized in the following format:
   - o Title page and abstract: including research area, all contact information, and advisor's name and affiliation, abstract of 300 words or less outlining major objectives and rationale of research program
   - o Introduction: providing a clear background of need for the research project and justification, any specific hypotheses or objectives
   - o Methods
   - o Preliminary or anticipated results
   - o Significance of research for the field of marine conservation
   - o References
4. Three letters of recommendation, one of which must be from the student's major advisor. Letters should address the relevance of the thesis research to marine conservation, the academic qualifications of the applicant, and anticipated future scientific contributions by the applicant. Letters of recommendation should be sent directly from the individual reference to AFS at the following e-mail address: hwilliams@fisheries.org

APPLICATION ADDRESS AND DEADLINE:

Complete applications should be compiled into a Word or PDF file and e-mailed to: hwilliams@fisheries.org. **Applications must be received by 1 February 2010.**

CRITERIA FOR SELECTION:

The fellowship will be awarded on the basis of the relevance of the proposed research, academic achievement, and anticipated future contributions by the applicant. Submission of an application acknowledges the applicant's acceptance of the committee's decision as final.

PUBLIC ANNOUNCEMENT AND NOTIFICATION:

The fellowship recipient will be notified and the award granted by 1 June 2010. Public announcement will be made at the AFS Annual Meeting and in *Fisheries* magazine. Publications that result from research supported by the award should recognize the specific support of the fellowship as well as that of AFS.

AMERICAN FISHERIES SOCIETY 140TH ANNUAL MEETING

3RD CALL FOR PAPERS

The Pennsylvania Chapter of the American Fisheries Society and the Pennsylvania Fish and Boat Commission will host the 140th Annual Meeting of the American Fisheries Society in downtown Pittsburgh, Pennsylvania, 12–16 September 2010. The Westin Convention Center Hotel and the David L. Lawrence Convention Center provide a world class venue for this gathering of fisheries students and professionals. The center is the first and largest certified "green" convention center in the world and is the only meeting venue to be awarded the Gold LEED (Leadership in Energy and Environmental Design) by the U.S. Green Building Council. Scheduled meeting activities will include a social at the Carnegie Museum of Natural History. The AFS 2010 meeting's theme, "Merging Our Deeper Currents," couldn't be more appropriate given the merging of two great rivers to form the Ohio River in the heart of Pittsburgh, just blocks from the meeting venue on the banks of the Allegheny River.

FISHERIES AROUND PITTSBURGH HAVE COME A LONG WAY!

The Pittsburgh area recently hosted two national bass tournaments in the Three Rivers—the Bassmaster Classic Tournament in 2005 and the Forrest Wood Cup in 2009—and this interest in recreational fishing is reflective of the great improvement in water quality in these rivers. This improvement in sportfish is emblematic of the changes in general fish biodiversity. For example, from 2003–2007, fish sampling in the Monongahela River yielded 35 species comprising 13 families, including several Pennsylvania Species of Special Concern. In 2007, a fish survey by the Ohio River Valley Sanitation Commission collected 42 species in the Pittsburgh Pool, with bluegill and smallmouth bass as the two most abundant species. Other notable species included muskie, golden shiner, and four redhorse species.

This biodiversity represents an incredible improvement to the stark conditions of the early twentieth century. Pittsburgh has fought hard to shed itself of the images of smoke stacks, dirty air, and polluted waterways. In the early 1900s, experts said, "The Ohio River immediately below Pittsburgh is in deplorable condition. Generally there is not much life in this part of the Ohio." Also, they said that "the substances discharged into the Allegheny River at Oil City and Franklin are simply amazing, and render the river entirely unfit for life. For 30 miles and more below there is not a mussel, not a crawfish, nor a fish able to live in the water." Fortunately, for these rivers, the conditions described are a thing of the past.

GENERAL INFORMATION

Aquatic resource professionals are invited to submit symposia proposals and abstracts for papers in a range of topics and disciplines. Participation by scientists at all levels and backgrounds, especially students, is encouraged.

The scientific program includes two types of sessions: Symposia (oral and poster presentations that focus on a single topic) and Contributed Papers (oral and poster presentations on any relevant topic).

Oral presentations are limited to 20 minutes (15 minutes for presentation plus 5 minutes for speaker introduction and questions). All oral presenters are expected to deliver PowerPoint presentations. Presenters must bring their PowerPoint file to the meeting on CD or USB flash memory stick by 7 p.m. the evening before their presentation. Laptop computers and LCD projectors will be provided and technicians will be available to help.

Traditionally, symposia have been dominated by oral presentations and sometimzes supplemented by posters. The Pittsburgh '10 Program Committee is considering following the example set at the Ottawa and Nashville meetings and allowing "Speed Presentations" coupled with posters to shorten the time required for symposia and enhance interactions. This new format elevates the profile of symposium posters through a "Speed Presentation Subsession" that provides a time slot for short (i.e., 3-minute) oral presentations, followed by dedicated viewing of symposium posters. Speed presentations serve, in essence, as "advertisements" for posters (and the people doing new and interesting work). They are an exciting new way to disseminate information and foster one-on-one interactions among symposium participants.

SYMPOSIA

The Program Committee invites proposals for symposia. Topics must be of general interest to AFS members. Topics related to the meeting theme will receive priority. Symposium organizers are responsible for recruiting presenters, soliciting their abstracts, and directing them to submit their abstracts through the AFS online abstract submission form. A symposium should include a minimum of 10 presentations and we encourage organizers to limit their requests to one-day symposia (about 20 oral presentations). Regular oral presentations are limited to 20 minutes, but double time slots (i.e., 40 minutes) may be offered to keynote speakers. Symposia with less than 15 or more than 20 presentations are strongly discouraged.

Symposium proposals must be submitted by 8 January 2010. All symposium proposal submissions must be made using the AFS online symposium proposal submission form, which is available on the AFS website (www.fisheries.org). If you do not receive confirmation by 15 January 2010, please contact Dave Argent at (watershed@calu.edu). The Program Committee will review all symposium proposals and notify organizers of acceptance or refusal by 5 February 2010. If accepted, organizers must submit a complete list of all confirmed presentations and titles by 26 February 2010. Symposium abstracts (in the same format as contributed abstracts; see below) are due by 5 March 2010.

FORMAT FOR SYMPOSIUM PROPOSALS

Submit using AFS online symposium submission form.

When submitting your abstract include the following:

1. **Symposium title:** Brief but descriptive.
2. **Organizer(s):** Provide name, address, telephone number, fax number, and e-mail address of each organizer. Indicate by an asterisk the name of the main contact person.
3. **Description:** In 300 words or less, describe the topic addressed by the proposed symposium, the objective of the symposium, and the value of the symposium to AFS members and participants.
4. **Format and time requirement:** Indicate the mix of formats (oral and poster). State the time required for regular oral presentations (i.e., 20 minutes per speaker) and the time required for speed presentations and poster viewing (3 minutes per speaker plus 1 hour of poster viewing).
5. **Chairs: Supply name(s) of individual(s) who will chair the symposium.**
6. **Presentation requirements:** We encourage speakers to use PowerPoint for presentations. All Mac-based presentations must be converted to PC format prior to the meeting.

Presentations in other software programs must be approved prior to acceptance.

7. **Audiovisual requirements:** LCD projectors and laptops will be available in every room. Other audiovisual equipment needed for the symposium will be considered, but computer projection is strongly encouraged.
8. **Special seating requests:** Standard rooms will be arranged theatre-style. Please indicate special seating requests (for example, "after the break, a panel discussion with seating for 10 panel members will be needed").
9. **List of authors:** Please supply information in the following format:

Presenters:	1.	___________
	2.	___________
Tentative title:	1.	___________
	2.	___________
Confirmed: (yes/no)	1.	___________
	2.	___________
Format: (regular or speed)	1.	___________
	2.	___________
Name of presentation :	1.	___________
	2.	___________

10. **Sponsor(s), if applicable.** (Note: A sponsor is not required.)

1. ___________

2. ___________

CONTRIBUTED ORAL AND POSTER PAPERS

The program committee invites abstracts for presentations (oral and poster) at contributed paper sessions. Authors must indicate their preferred presentation format: (1) oral only, (2) poster only, (3) oral preferred, but poster acceptable. Only one oral presentation will be accepted for each senior author. Poster submissions are encouraged because of the limited time available for oral presentations. The program will include a dedicated poster session to encourage discussion between poster authors and attendees.

Abstracts for contributed oral and poster papers must be received by 5 February 2010. All submissions must be made using the AFS online abstract submission form, which is available on the AFS website (www.fisheries.org). When submitting your abstract:

- Use a brief but descriptive title, avoiding acronyms or scientific names in the title unless the common name is not widely known;
- List all authors, their affiliations, addresses, telephone numbers, and e-mail addresses;
- Provide a summary of your findings and restrict your abstract to 200 words.

All presenters will receive a prompt e-mail confirmation of their abstract submission and will be notified of acceptance and the designated time and place of their presentation by 30 April 2010.

For contributed papers, you will have the opportunity during the abstract submission process to indicate which two general topics best fit the concept of your abstract. Topics include: Bioengineering, Communities and Ecosystems, Contaminants and Toxicology, Education, Fish Culture, Fish Health, Fish Conservation, Freshwater Fish Ecology, Freshwater Fisheries Management, Genetics, Habitat and Water Quality, Human Dimensions, Marine Fish Ecology, Marine Fisheries Management, Native Fishes, Physiology, Policy, Population Dynamics, Statistics and Modeling, Species Specific (specify), and Other (specify). Including this information in your submission will help the Program Committee assign your talk, if accepted, to the most appropriate session.

Late submissions will not be accepted. AFS does not waive registration fees for presenters at symposia, workshops, or contributed paper sessions. All presenters and meeting attendees must pay registration fees. Registration forms will be available on the AFS website (www.fisheries.org) in May 2010; register early for cost savings.

For information on how to construct a great poster, please take a moment to consult Carline (2007. Guidelines to designing posters. Fisheries 32[6]:306-307). The maximum allowable poster size will be 91 cm X 112 cm (36" x 44") in a landscape or portrait format.

STUDENT SYMPOSIUM

The AFS Education section will once again be sponsoring a Student Symposium. Students interested in being chosen to participate and compete for Best Student Paper and Best Student Poster will have the opportunity to indicate that during the abstract submission process. We urge interested students to read about the process *before* going online to submit an abstract: *Sutton, T.M., D.L. Parrish, and J.R. Jackson. 2007. Time for a change: revision of the process for judging student presentations at the annual meeting. Fisheries 32(1):42-43.* Please contact Richard Fulford (chair, Best Student Paper Committee; Richard.Fulford@usm.edu) or Jim Long (Chair, Best Student Poster Committee; longjim@okstate.edu) for additional information.

FORMAT FOR SUBMITTED ABSTRACTS

For abstracts submitted to a Symposium

1. **Enter Symposium title:**
2. **Format:** (oral or speed) (accompanied by poster)
3. **For abstracts submitted as a Contributed Paper:** Enter 2 choices for topic:
4. **Specify format:** Oral—preferred, or poster—acceptable)

For all abstracts

Title: An example abstract for the AFS 2010 Annual Meeting

Authors:

Hartman, Kyle. West Virginia University, 322 Percival Hall, Morgantown, West Virginia 26506; 304-293-4797; hartman@wvu.edu

Mazik, Patricia. USGS/West Virginia Cooperative Fish and Wildlife Research Unit, 322 Percival Hall, West Virginia University, Morgantown, West Virginia 26506; 304-293-4943; pmazik@wvu.edu

Presenter: Kyle Hartman

Abstract: Abstracts are used by the Program Committee to evaluate and select papers for inclusion in the scientific and technical sessions of the 2010 AFS Annual Meeting. An informative abstract contains a statement of the problem and its significance, study objectives, principal findings and application, and it conforms to the prescribed format.

Student presenter? (Work being reported was completed while a student) Student presenters must indicate if they wish their abstract to be considered for competition for a best presentation (i.e., paper or poster, but not both) award. If they respond "no," the presentation will be considered for inclusion in the Annual Meeting by the Program Committee, but will not receive further consideration by the Student Judging Committee. If students indicate "yes," they will be required to submit an application to the Student Judging Committee. Components of the application will include an extended abstract and a check-off from their mentor indicating that the study is at a stage appropriate for consideration for an award.

CONTACTS

General Meeting Co-Chairs

Leroy Young
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leyoung@state.pa.us
814/359-5177

David M. Day
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717/346-8137

Local Arrangements Chair

Rick Spear
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412/442-5874

Program Co-Chairs:

Pat Mazik
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304/293-4943

Kyle Hartman
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Contributed Papers Subcommittee Co-Chair

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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 cworth@fisheries.org.

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

More events listed at www.fisheries.org.

Nov 23-25		**International Conference on Evolutionary Ecology of Fishes Diversification, Adaptation, and Speciation** Berlin, Germany	www.adaptfish.igm-berllin.de
Dec 6-9	AFS	**70th Midwest Fish and Wildlife Conference** Springfield, Illinois	http://dnr.il.us/midwest
Dec 9-12		**Fourth Shanghai International Fisheries and Seafood Expo** Shanghai, China	www.gehuaexpo.com
2010			
Feb 11-12		**Using Hydroacoustics for Fisheries Assessment** Seattle, Washington	www.htisonar.com/at_short_course.htm
Feb 15-17		**Societal Applications in Fisheries and Aquaculture Using Remote Sensing: Remote Sensing and Fisheries** Kochi, India	www.geosafari.org/kochi
Mar 1-5	AFS	**Aquaculture 2010** San Diego, California	www.was.org

ANNOUNCEMENTS: JOB CENTER

EMPLOYERS: To list a job opening on the AFS Online Job Center submit a position description, job title, agency/company, city, state, responsibilities, qualifications, salary, closing date, and contact information (maximum 150 words) to jobs@fisheries.org. Online job announcements will be billed at $350 for 150 word increments. Please send billing information. Listings are free (150 words or less) for organizations with Associate, Official, and Sustaining memberships, and for Individual members, who are faculty members, hiring graduate assistants. If space is available, jobs may also be printed in *Fisheries* magazine, free of additional charge.

Post Masters Research Associate, Pacific Northwest National Laboratory, WA.
Salary: To be determined.
Closing: 30 November 2009.
Responsibilities: Database management and technical report writing in support of fish tagging programs. Specifically, process, proof, and input data to database, review data quality and integrity, create data reports, conduct analysis, and write technical reports.
Qualifications: M.S. in fisheries or wildlife science, natural resource or environmental science or a related degree in the field of biology, ecology, or environmental sciences from an accredited college or university. Minimum overall GPA of 3.5 required. Several years experience working with large databases and superior attention to detail preferred. Analytical skills required include data management, statistical approaches for ecological data analysis, and technical report writing. Ability to participate in research team activities and to work safely and independently.
Contact: Kenneth Ham, kenneth.ham@pnl.gov, 509/371-7156, or apply at www.jobs.pnl.gov, Job 117960.

Ph.D. Student, University of Florida.
Salary: $22,000 per year in- and out-of-state tuition waived and health insurance package included.
Closing: 15 November 2009.
Responsibilities: Interest in aquatic ecology and fisheries research. Work as part of a collaborative effort between the University of Florida and the Illinois Natural History Survey to investigate reproductive biology and effects of fishing on black bass populations across large latitudinal gradients. Enrolled at the University of Florida.
Qualifications: B.S. and M.S. in ecology/biology with a 3.5 GPA and 1200 v q GRE score required.
Contact: E-mail letter of intent and resume with contact information, phone, and e-mail for three references to: Mike S. Allen, Professor, School of Forest Resources and Conservation, University of Florida, and to Dave Philipp and Cory Suski, Illinois Natural History Survey, University of Illinois. Availability of this position is contingent on the award of a research grant. E-mail addresses: msal@ufl.edu, philipp@illinois.edu, and suski@illinois.edu

Ph.D. Graduate Assistantship, Oregon State University.
Salary: Funded primarily by research assistantships, with the opportunity to hold a teaching assistantship during some quarters.
Closing: 15 January 2010.

Responsibilities: Use fieldwork and laboratory methods with mtDNA and microsatellites to understand how hydrologic connectivity influences aquatic organisms.
Qualifications: B.S. or M.S. in ecology, zoology, or related field with a competitive GPA and GRE scores. Priority to applicants with previous experience studying aquatic invertebrates, quantitative skills, and/or a background in landscape genetics. A demonstrated ability to publish in peer-reviewed journals is preferred, but not required.
Contact: Send CV, unofficial transcripts, and GRE scores to Dave Lytle, lytleda@oregonstate.edu.

Program Director, Freshwater Initiatives (Water Fellow)—Special Project, National Geographic Society Mission Program.
Salary: TBD. Two-year staff contract (term agreement) with the possibility of renewal.
Closing: 18 February 2010.
Responsibilities: Help develop and direct a major initiative focused on freshwater conservation, coordinate efforts within programs and across divisions, and lead initiatives in collaboration with partnership organizations. Raise public awareness around the global water crisis, and engage and empower a broad audience to take action on both an individual and collective basis. Identify and lead cross-platform media opportunities such as the implementation of a freshwater web portal for outreach to consumers. Serve as a public spokesman. Oversee strategic project calendar, events, and key deliverables. Help shape and implement a compelling public engagement component to the project. Lead development of project components and the direct day-to-day project activities. Research, prioritize, and develop partnerships with other organizations. Manage all bi- and multilateral relationships on a daily basis.
Qualifications: Experience supervising one to five staff members. M.S. plus 5 years in conservation/project management. Graduate degree in hydrology, water resources and policy, or related field a plus. Experience as an effective manager, collaborator, and connector within and between multidimensional organizations. Expertise on the topic of freshwater. Ability to deliver results while managing competing priorities under tight deadlines. Demonstrated negotiation skills. Excellent track record of growing and achieving sustainable results. Outstanding written, verbal, and presentation skills. Excellent computer skills (Word, PowerPoint, Photoshop, Excel, etc.). Ability to travel.
Contact: See http://nationalgeographic.com/jobs. EOE.