VOL 32 NO 8
AUGUST 2007

Fisheries

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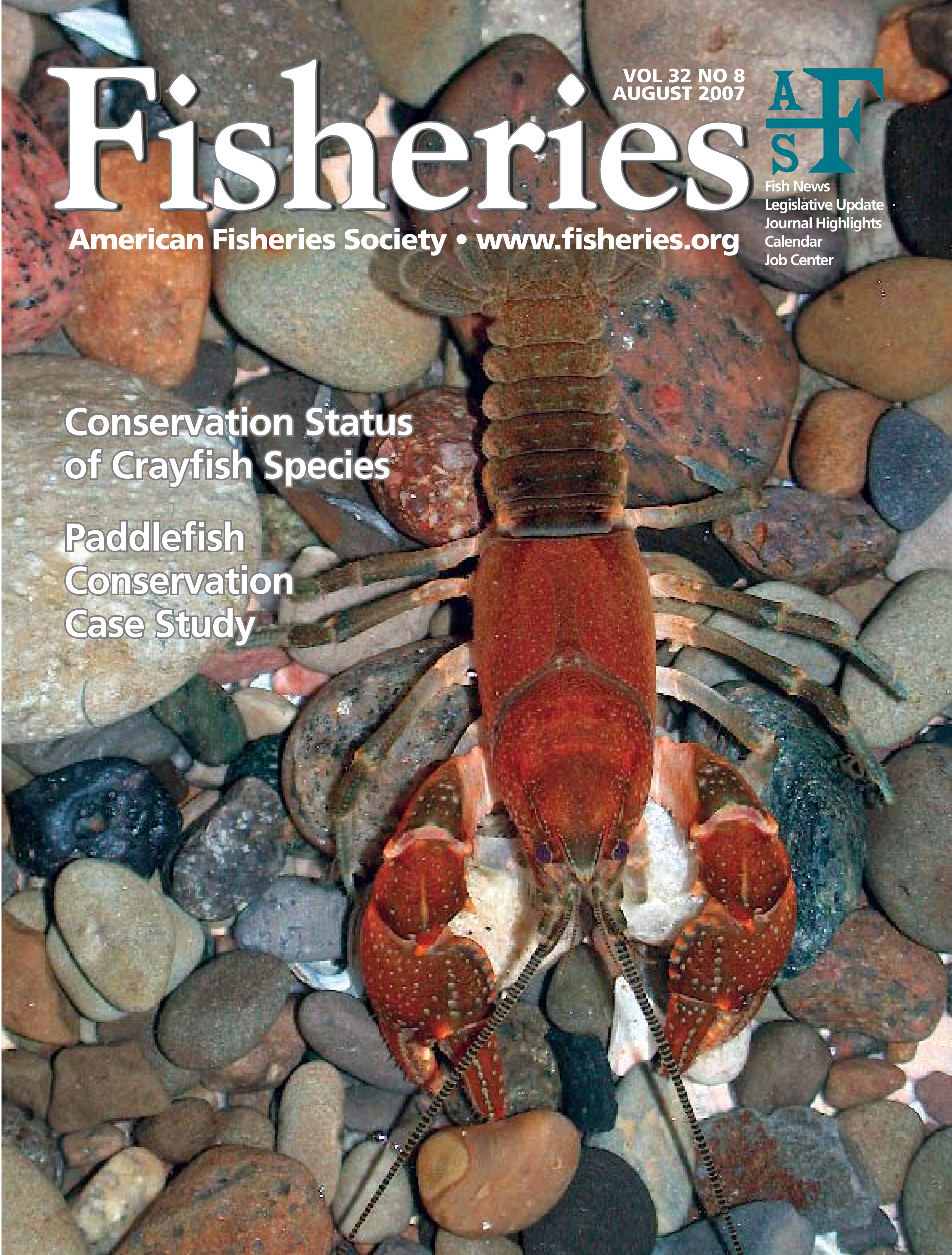
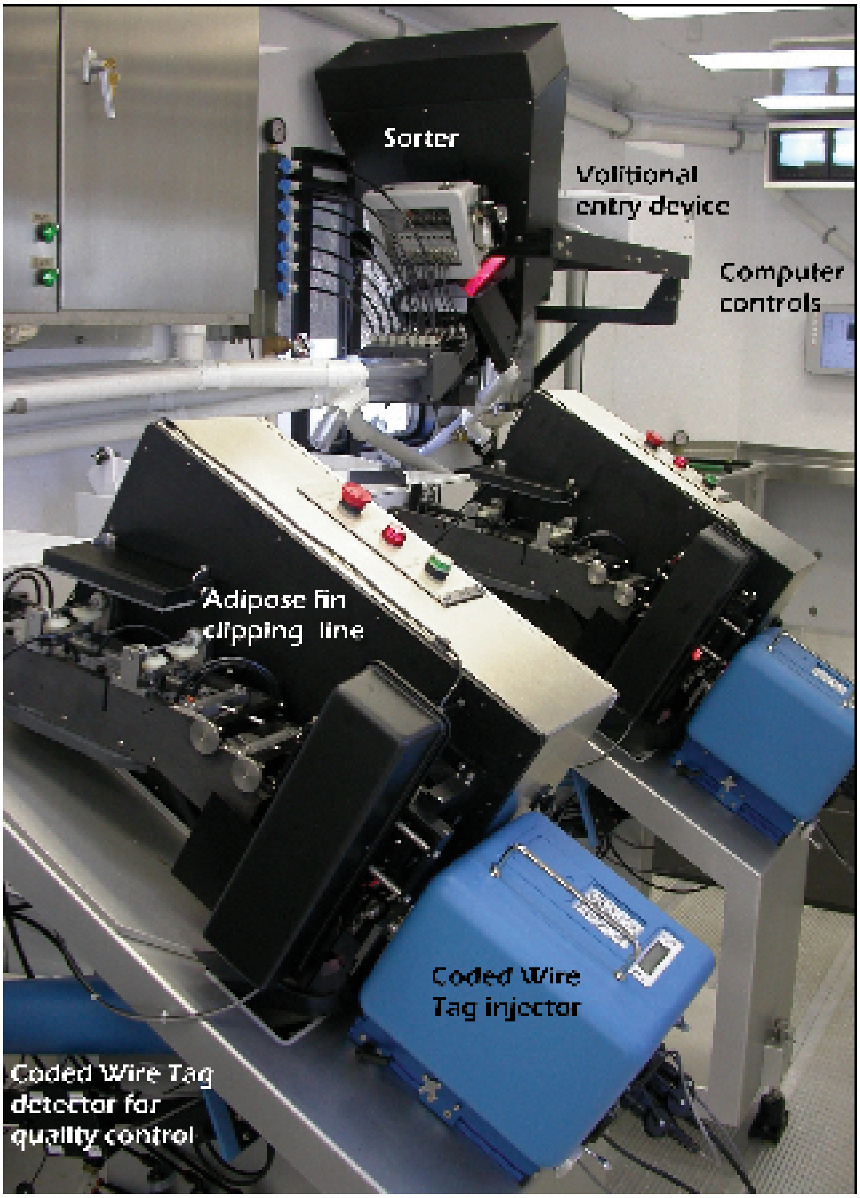
Conservation Status of Crayfish Species

Paddlefish Conservation Case Study



High-Tech Tagging



California's program became feasible with Northwest Marine Technology's AutoFish System (above). The system uses advanced technology to sort and process salmonids at a hatchery. The fish are first measured and sorted, then their adipose fins are clipped, or they are coded wire tagged, or both. The fish are returned to the pond, never having been dewatered, anesthetized, or handled by humans. These systems can mark and tag >60,000 fish per day.

More than 32 million fall Chinook salmon are released annually from hatcheries in California's Sacramento River Basin, USA. These fish contribute substantially to sport and commercial fisheries, but they have been tagged sporadically, leaving biologists with sparse management data. In 2007, the California Dept. of Fish and Game, U.S. Fish and Wildlife Service, and the Pacific States Marine Fisheries Commission began a new program to provide a consistent rate of marking and tagging.

The Constant Fractional Marking program requires all 32 million fall Chinook to be brought into one of four AutoFish Systems (left) for counting. About 25% of the fish also have their adipose fin clipped and a Coded Wire Tag injected into their snout. Coded Wire Tags are tiny pieces of stainless steel wire (1.1 mm long) etched with a numeric code. In the first year, over 8 million Chinook salmon were marked and tagged, with >99% tag retention.

Tag recoveries will provide critical data for determining the status of wild and hatchery salmon and steelhead in the Sacramento River Basin. These data are essential for evaluating the hatchery programs, monitoring restoration efforts, stock recovery planning, and managing water projects and harvest.

We congratulate these agencies on the successful implementation of their program. Please contact us if we can help with your tagging needs.

Northwest Marine Technology, Inc.

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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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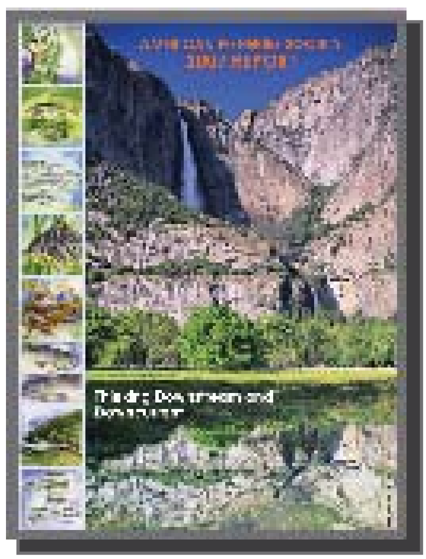


COVER: The Short Mountain crayfish (*Cambarus clivosus*) is a narrowly endemic species found only in central Tennessee and ranked as Threatened.
PHOTO: R. Thoma.

COLUMN: PRESIDENT'S HOOK

Jennifer L. Nielsen
AFS President Nielsen can be contacted at jlnielsen@usgs.gov.

Thanks for an Incredible Year

The last Hook of an AFS president's term is typically dedicated to listing her/his accomplishments during the previous year and looking forward to the impending Annual Meeting. While this has been a year of many activities, with significant changes in direction at AFS and a long-awaited sea change in information technology and membership services, I feel like the vehicle, not the primary force, behind these accomplishments. It is the volunteer membership, working hard with unending commitment, that makes this Society what it is. The president, at best, helps to guide the ship of state across calm and turbulent waters as the business of the Society moves forward. So, in my last column, I would like to highlight a few of the behind-the-scenes accomplishments made by others this year. These folks are the heroes of our Society and they deserve all the acknowledgements and thanks you can muster.

Gwen White—The role of constitutional consultant for AFS is a poorly recognized but critical component of our governance. Gwen has been the most significant contributor to the final stages of reformatting the procedures for the Society and defining the roles of the different officer positions for future reference and guidance. I cannot begin to tell you how important this documentation is. Once you are elected to a leadership position at AFS, the procedures manual provides guidance and continuity for structure and management at all levels. Gwen's commitment and contributions in 2007 have been beyond exceptional. Thanks, Gwen, for always being there for the membership with all the "right" answers.

John Whitehead—As president of the Socioeconomics Section, John has weathered one of the most controversial issues one of our Sections has faced in recent memory—micro- and macro-economic policy. Our membership splits divisively over these issues and we will still be in the thick of the arguments in San Francisco. John has his own opinion on the issue, but has retained a professional approach to maintain the status of leadership in his Section and to present both sides of the dialogue. It is a commitment to sound scientific dialogue and professional leadership like John's that makes Section membership at AFS a valuable commitment. Thanks, John, for setting an excellent example of leadership in divisive times.

Steve Cooke—Last year, we had a difficult situation centering on the development of our new coastal and marine journal. The chair of the Publications Overview Committee (POC) resigned after our meeting in Lake Placid and I needed a quick and effective replacement. Steve Cooke's long list of publications made him seem the appropriate choice to lead AFS back into forward motion on this issue. He was a good choice indeed! Through difficult times and with a knack for handling diverse personalities, Steve has brought a sea change to the POC. He has overseen and guided the selection of our new marine journal development editor, Jim Cowan. He has set the goals high for changes in time-to-publication at our current journals and assisted in development options for increased impact for all AFS publications. Thanks, Steve, for your guidance, reconciliation skills, and leadership over the last year.

Joel Carlin—Out of the dark corners of the Genetics Section, I pulled a whopper of a candidate to lead the renewal and revitalization of information technology (IT) at AFS. Joel came to the table at our IT workshop in Bethesda with his guns loaded and we made important progress on implementation of new member-centric IT services. Joel has the background and leadership skill to bring together a team whose purpose is to make IT at AFS user-friendly and focused on membership needs and opportunities. Making the "old" system new and useful was the first priority of Joel's leadership. But new information technologies are also coming to the table, including podcasts and virtual Student Subunits. Joel is leading an IT workshop at San Francisco for the webmasters from all Units and Sections of AFS. Communications is the lifeblood of our volunteer Society and Joel has facilitated and implemented corrections that will keep communications on the radar screen for membership for years to come. Thanks, Joel, for contributing significantly to one of toughest jobs we had this year—the IT fix.

Dave Manning, Larry Brown, Eric Wagner, Mike Meador, Peggy Wiltzbach, Kathy Hieb, Bellory Fong, Diana Watters, Noriko Kawamoto, Joe Margraf, Mark Gard, Shawn Chase, Jean Baldridge, Ted Frink, Betsy Fritz, Tom Keegan, Mike Meinz, Steve Herrera, Dan Logan, Victoria Poage, Rob Aramyo, David Hu, Jeff McLain, Tim Heyne, Lourdes Rugge, Holly Herod, Sharon Shiba, Sarah Giovanetti, Chris Wilkinson, Demian Ebert, Michael Carbiener, Natalie Cosentino-Manning, Ken Hashagen, Chuck Knutson, Tricia Parker, Zeke Grader, Don Potz, Walt Duffy, Joe Cech, Bill Kier, Pat Coulston, Jerry Morinaka, Bob Fujimura, Darren Fong, David Cook, Lenny Grimaldo, Josh Fuller, Louise Conrad, Tina Swanson, Russ Bellmer, and **Peter LaCivita**—This fine group of people has worked tirelessly over the last two years to bring you the 2007 AFS Annual Meeting in San Francisco. You have no idea of all of the work involved in planning and implementation of this meeting! It is a work of absolute commitment and true love. We are entirely dependent on local Chapters and Units to provide the driving force and energy for these meetings and the volunteer hours and contributions are enormous. Everyone named above, and all of the other volunteers that will make "Thinking Downstream and Downcurrent" in San Francisco the absolute success I am sure it will be, deserve your thanks and appreciation. Thanks, Team 2007, for everything you have accomplished.

Mary Fabrizio—Mary's assistance and professional back up as president elect during the last year has been invaluable to me. Her commitment to this Society is strong and sound. I feel I am leaving the reins in excellent hands. Thanks, Mary, for all your support and assistance, it was greatly appreciated—and good luck as the Fabrizio era dawns on our Society! We are all here to help in any way we can.

Finally, thanks to the AFS membership at large for the opportunity to serve as president of such a prestigious society. It was a distinct pleasure to serve all of you to be best of my ability.

HTI

The Hydroacoustic Update

Project Location:
Jaragua National Park,
Dominican Republic

Trabajo de Hidroacústica

Located in the southwestern corner of the Dominican Republic is Jaragua National Park. It was there that a hydroacoustic short course was conducted in May as part of an initiative to strengthen partnerships in support of sustainable development in the Wider Caribbean. The ultimate goal was to help MPA personnel in ecosystem-based management by enhancing marine acoustic skills used for habitat mapping and fish detection. This successful venture was primarily funded by the White Water to Blue Water (WW2BW) initiative through the National Marine Sanctuary Foundation.

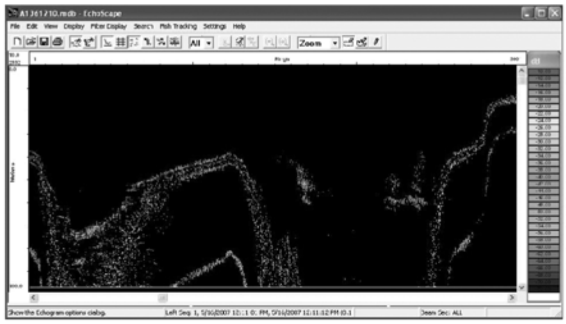
Fourteen participants from five countries, trained in coastal and marine habitats, came together to learn about side-scan sonar and fisheries hydroacoustics. The side-scan sonar work included techniques, applications, and categorizing bottom habitat. The hydroacoustic work included recording raw digital split-beam, high-resolution hydroacoustic sample data (up to 1400 m range strata each as small as 10 cm).

To address their needs, this group of marine professionals requested an HTI short course to describe the advantages and limitations on using a hydro-acoustic system for obtaining fish biomass information within tropical reef environments. An HTI *Model 244 Multi-Frequency System* was used to acquire data off the western shores of Jaragua National Park, presenting real-time data as well as post-processing procedures. The participants gained familiarity with the menu-driven HTI Windows™ user interface, which allows the operator to enter calibration, operation, and data processing parameters, as well as select real-time data displays and several output options. For the majority of the attendees this was their first exposure to a hydroacoustic system in action.

Using *EchoScape*, HTI's post-processing software, the course participants were able see how basic statistics could be obtained on fish schools detected by the hydroacoustic system. It also gave them the ability to view and analyze the collected data in various ways within a database, which is an important tool for analysis. *EchoScape* gave them a straightforward means of selecting individual fish traces or fish aggregations from data files, which is useful for quickly refining tracking parameters (e.g., pulse shape, minimum threshold, etc.) and immediately seeing the results. Illustrating that point, Mr. Rivera, a contractor for NOAA Fisheries in Puerto Rico, demonstrated detection of small pelagic fish (approx. 6 cm in length) schooling just off the shelf edge reef.

HTI is happy to be a part of these researchers' work as they continue to improve sustainable development in the Caribbean. For more info about this course or the equipment used, call us at 206-633-3383 or visit HTIsonar.com.


Short Course Team preparing for field tests.



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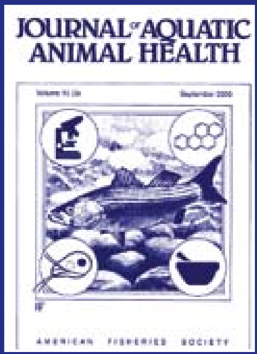
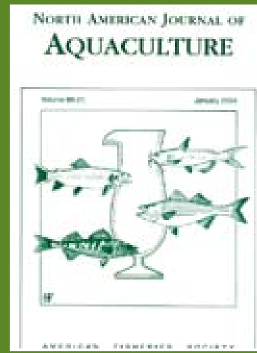


JOURNAL HIGHLIGHTS



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VOLUME 19, ISSUE 2 (JUNE 2007)

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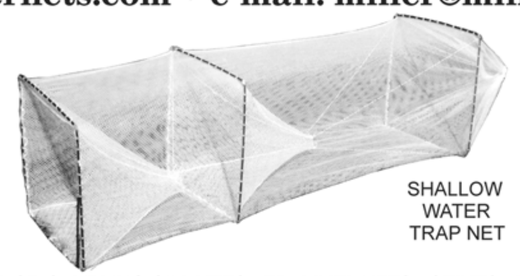

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FLASH
TECHNOLOGY

FEATURE:
ENDANGERED SPECIES

A Reassessment of the Conservation Status of Crayfishes of the United States and Canada after 10+ Years of Increased Awareness

Christopher A. Taylor,
Guenter A. Schuster,
John E. Cooper,
Robert J. DiStefano,
Arnold G. Eversole,
Premek Hamr,
Horton H. Hobbs III,
Henry W. Robison,
Christopher E. Skelton,
and Roger F. Thoma

Taylor is a research scientist at the Illinois Natural History Survey, Division of Biodiversity and Ecological Entomology, Champaign, and can be contacted at ctaylor@mail.inhs.uiuc.edu. Schuster is a professor of biological sciences at Eastern Kentucky University, Richmond, and can be contacted at Guenter.Schuster@eku.edu. Cooper is curator of crustaceans at the North Carolina Museum of Natural Sciences, Raleigh. DiStefano is a resource scientist with the Missouri Department of Conservation, Columbia. Eversole is a professor of forestry and natural resources at Clemson University, Clemson, South Carolina. Hamr is an environmental science teacher at Upper Canada College, Toronto, Ontario. Hobbs III is a professor of biology at Wittenberg University, Department of Biology, Springfield, Ohio. Robison is a professor of biology at Southern Arkansas University, Department of Biology, Magnolia. Skelton is an assistant professor of biological and environmental sciences at Georgia College and State University, Milledgeville. Thoma is a senior research scientist with Midwest Biodiversity Institute, Columbus, Ohio and an adjunct assistant professor at The Ohio State University Museum of Biological Diversity, Columbus.

ABSTRACT: The American Fisheries Society Endangered Species Committee herein provides a list of all crayfishes (families Astacidae and Cambaridae) in the United States and Canada that includes common names; state and provincial distributions; a comprehensive review of the conservation status of all taxa; and references on biology, conservation, and distribution. The list includes 363 native crayfishes, of which 2 (< 1%) taxa are listed as Endangered, Possibly Extinct, 66 (18.2%) are Endangered, 52 (14.3%) are Threatened, 54 (14.9%) are Vulnerable, and 189 (52.1%) are Currently Stable. Limited natural range continues to be the primary factor responsible for the noted imperilment of crayfishes; other threats include the introduction of nonindigenous crayfishes and habitat alteration. While progress has been made in recognizing the plight of crayfishes, much work is still needed.

Una revaluación del estado de conservación de langostinos en los Estados Unidos y Canadá después de más de 10 años de conciencia creciente

RESUMEN:. En el presente trabajo, El Comité para el Estudio de Especies Amenazadas de la Sociedad Americana de Pesquerías presenta una lista de todos los langostinos (familias Astacidae y Cambaridae) presentes en los Estados Unidos y Canadá, que incluye nombres comunes, distribución estatal y municipal, una revisión del estado de conservación de todos los taxa y referencias sobre su biología, conservación y distribución. La lista incluye 363 langostinos autóctonos, de los cuales dos taxa (< 1%) se catalogan como amenazados, posiblemente extintos; 66 (18.2%) se consideran en peligro; 52 (14.3%) están amenazados; 54 (14.9%) son vulnerables; y 189 (52.1%) se encuentran actualmente en condición estable. El principal factor responsable de la vulnerabilidad de los langostinos es su limitado rango natural de distribución; otras amenazas incluyen la introducción de especies foráneas de langostinos y la alteración del hábitat. Si bien se ha progresado en cuanto al reconocimiento de las amenazas hacia los langostinos, aún existe mucho trabajo por hacer.

The Short Mountain crayfish (*Cambarus clivosus*) a narrowly endemic species found only in central Tennessee and ranked as Threatened.
Photo by R. Thoma.

Cambarus cymatilis, a burrowing species ranked as Endangered by the AFS Endangered Species Crayfish Subcommittee.
Photo by C. Lukhaup.

The greensaddle crayfish (*Cambarus manningi*) is a Currently Stable species found in rocky creeks of the Coosa River drainage.
Photo by C. Lukhaup.

INTRODUCTION

The term biodiversity has become intimately intertwined with the conservation movement of the last quarter-century, and in North America no serious discussion of biodiversity and conservation can neglect the status of that continent's freshwater fauna. The presence of a highly diverse aquatic fauna in a densely populated, economically developed country such as the United States demands the continued attention of scholars, resource managers and biologists, politicians, and private conservation groups. Current biological information for species and species groups at risk is crucial to making sound decisions on all conservation fronts.

The plight of North American aquatic biodiversity, particularly invertebrate biodiversity, was brought to the forefront with the compilation of Natural Heritage / The Nature Conservancy Global (G) conservation status ranks for that continent's fauna by Master (1990). Master (1990) found a disproportionate number of aquatic organisms in need of conservation attention when compared to their terrestrial counterparts. Since then a steady stream of literature has highlighted the need for action and identified threats to the aquatic fauna (e.g., Allan and Flecker 1993; Richter et al. 1997; DeWalt et al. 2005). Through the American Fisheries Society (AFS) Endangered Species Committee and others, the conservation status of North America's freshwater fish fauna has been assessed at regular intervals (Deacon et al. 1979; Williams et al. 1989; Warren et al. 2000) while that of other aquatic taxa such as freshwater mussels (Williams et al. 1993) and crayfishes (Taylor et al. 1996) have only recently received their first conservation reviews. With the passing of a decade since the first, and last, conservation review of North American crayfishes, the purposes of this article are to (1) reassess the conservation status and threats to native crayfishes in the United States and Canada using the best information available, (2) provide updated state/provincial distributions, (3) update the list of references on the biology, conservation, and distribution of crayfishes in the United States and Canada provided in Taylor et al. (1996), and (4) assign standardized common names to those species lacking them.

Crayfishes are placed in the order Decapoda, which also includes crabs, lobsters, and shrimps. They are most closely related to marine lobsters (Crandall et al. 2000) and differ from those organisms by possessing direct juvenile development rather than dimorphic larval stages. Also known regionally as crawfish, mudbugs, or crawdads, crayfishes are assigned to three families and are native inhabitants of freshwater ecosystems on every continent except Africa and Antarctica. Two families, Astacidae and Cambaridae, occur natively in North America and it is here that crayfishes reach their highest level of diversity. Approximately 77% (405 species and subspecies) of the world's 500+ species occur in North America (Taylor 2002), with the overwhelming majority of that continent's fauna (99%) assigned to the family Cambaridae. With over two-thirds of its species endemic to the southeastern United States, the distribution of crayfish diversity in North America closely follows those observed in other freshwater aquatic taxa such as fishes (Warren and Burr 1994 and mussels (Williams et al. 1993).

Crayfishes are important ecologically as predators, bioprocessors of vegetation and carrion, and as a critical food resource for fishes and numerous other terrestrial and aquatic organisms (Hobbs III 1993; DiStefano 2005). In some aquatic habitats they can comprise greater than 50% of macroinvertebrate biomass (Momot 1995). They are equally important from an economic standpoint, supporting bait fisheries and a multi-million dollar human food fishery (Huner 2002). Finally, crayfishes in the family Cambaridae also possess unique life-history traits such as reproductive form alteration and burrowing abilities that allow numerous species to colonize seasonally wet and terrestrial habitats (Hobbs 1981; Welch and Eversole 2006). Because the purpose of this article is to report on the conservation status of the North American fauna north of Mexico, we refer readers interested in the economic and ecological aspects of crayfish to previously published syntheses (Huner 1994; Taylor et al. 1996; Holdich 2002).

RATIONALE AND THREATS

Taylor et al. (1996) pointed to the broad disparity in the recognition of actual or potential imperilment of crayfishes between governmental agencies charged with protecting natural resources and non-profit conservation organizations as a rationale for their conservation assessment. At that time, only four crayfish species (*Pacifastacus fortis*, *Cambarus aculabrum*, *Cambarus zophonastes*, and *Orconectes shoupi*) received protection under the federal Endangered Species Act of 1973 (ESA) and 47 species received varying levels of protection at the state level. This was in stark contrast to the 197 species listed by Master (1990) as in need of conservation attention. Taylor et al. (1996) surmised that 48% of the U.S. and Canadian crayfish fauna was imperiled. While some changes have been made at the state level (see below), the number

Cambarus carolinus is a burrowing species found along the margins of Appalachian streams in North Carolina, South Carolina, and Tennessee.
Photo by A. Braswell.

The bottlebrush crayfish (*Barbicambarus cornutus*) is currently stable and found in the Green River drainage of Kentucky and Tennessee.
Photo by G. Schuster.

Crayfishes have historically been classified as opportunistic omnivores; however, our expanding knowledge of crayfish ecology indicates that they may be primary carnivores in some streams.
Photo by C. Lukhaup.

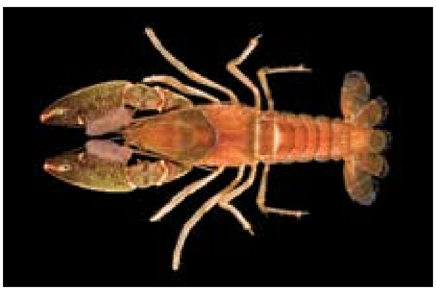
and identity of species listed under the ESA remains unchanged. This continuing disparity serves as the underlying justification for the current reassessment.

The causes of aquatic species losses and population declines have been thoroughly discussed in the literature and are usually ascribed to four major categories: (1) loss, degradation, or alteration of habitat; (2) chemical pollution; (3) introduction of nonindigenous organisms; and (4) overexploitation (Allan and Flecker 1993; Richter et al. 1997; Wilcove et al. 2000). For crayfishes, most of these threats are applicable. As benthic invertebrates susceptible to fish predation, the impoundment of lotic habitat can affect crayfishes by increasing concentrations of major crayfish predators such as centrarchid bass and sunfish and altering both the physical and chemical structure of streams (Williams et al. 1993). Crayfish depend on gravel and boulder substrates, woody debris, and vegetation for refuge from predators (Stein 1977). Loss of such habitat components through dredging and channelization can drastically affect crayfish populations by making them more susceptible to predation. Finally, draining wetlands and dewatering of springs can have obvious impacts on crayfishes dependent on those types of habitats. The possible extinction of *Cambarellus alvarezi* after the removal of spring water from its only known location in northern Mexico (Contreras-Balderas and Lozano-Vilano 1996) serves as a prime example of the negative consequences of the latter type of habitat alteration.

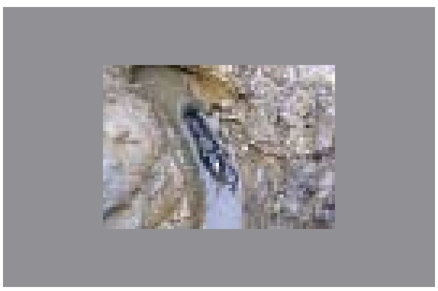
Crustacea are known to be among the most sensitive aquatic organisms when exposed to pesticides and metals (Mayer and Ellersieck 1986, Jarvinen and Ankley 1999). While acute toxicity tests (usually expressed as LC50 values) have been performed using many crayfish species and toxicants (Eversole and Seller 1996), field studies examining the effects of chemical or heavy metal pollutants on crayfishes are lacking. The available data suggest significant variability among genera, species, and life stages (Berrill et al. 1985; NCDENR 2003, Peake et al. 2004, Wigginton and Birge 2007). Recently Wigginton and Birge (2007) reported higher mortality rates for juvenile than adult crayfishes exposed to cadmium, which they attributed to increased cadmium uptake and calcium metabolic disruption in the more rapidly molting juveniles. Besser et al. (2006) found evidence for heavy metal accumulation, including cadmium, in crayfishes found near mining sites while Allert et al. (in press) noted increased sensitivity in at least one species to these same metals. These observations indicate that crayfish may prove to be indicators of habitat degradation from pollutants and that future research is warranted.

The introduction of nonindigenous organisms may represent the gravest of all threats to this planet's biodiversity (Clavero and García-Berthou 2005) and crayfish could represent the proverbial posterchild of the damage wrought by these species (Lodge et al. 2000). In North America crayfishes are transported easily over land and inadvertently introduced into aquatic habitats when they are discarded as unused bait. Such bait-bucket introductions have led to dramatic range extensions of several species, most notably the rusty crayfish (*Orconectes rusticus*). The rusty crayfish is native to the lower Ohio River drainage in Ohio, Indiana, and Kentucky and the Maumee River drainage in extreme southeastern Michigan. Over the past 50 years the species has been introduced across the upper midwestern United States and Canada (Page 1985; Lodge et al. 2000). Once introduced, *O. rusticus* rapidly expands its range and displaces native crayfishes (Taylor and Redmer 1996). This behavior has led to the complete elimination of local populations and reductions in total ranges of native species in at least three midwestern states and one Canadian province (Lodge et al. 2000; C. A. Taylor, unpub. data). Possible displacement mechanisms include faster individual growth rates (Hill et al. 1993), differential susceptibility to fish predation (DiDonato and Lodge 1993), and hybridization (Perry et al. 2001). Imperiled crayfishes also have been affected by nonindigenous species. The federally endangered Shasta crayfish, (*Pacifastacus fortis*) has been displaced in large portions of its native range by the nonindigenous signal crayfish (*P. leniusculus*; Erman et al. 1993). Nonindigenous crayfishes can also serve as disease vectors. The introduction of three North American species, *Procambarus clarkii*, *O. limosus*, and *Pacifastacus leniusculus*, into western Europe has contributed to massive die-offs of native crayfishes in that region. A fungus-like protist, *Aphanomyces astaci* (Class Oomycetes), causes a lethal disease known as the "crayfish plague" in native European species while North American species are immune to its effects. By carrying spores of *A. astaci*, North American species act as a plague vector between water bodies. Outbreaks of the crayfish plague have been occurring in Europe since the introduction of the North American species in the late 1880s (Ackefors 1999; Holdich 1999) and have led to 85% or greater reductions in native crayfish populations in several countries (Fjälling and Fürst 1988; Ackefors 1999; Holdich 1999).

While the introduction of nonindigenous crayfishes through their use as bait continues to represent a significant threat to crayfish biodiversity, the Internet revo-



Procambarus escambiensis is an endemic species found in narrow region of the Gulf Coastal Plain of Alabama and Florida.
Photo by G. Schuster.



Numerous species of crayfishes spend all or a significant portion of their lives in subterranean burrows. Basic ecological information can be very hard to collect for these species.
Photo by C. Lukhaup.

The eastern red swamp crayfish, *Procambarus troglodytes,* is a Currently Stable species found on the Atlantic Slope of Georgia and South Carolina.
Photo by C. Lukhaup.

lution of the past 10 years has spawned an equally disconcerting vector. Conservation biologists have for years warned of the risk posed from the release/escape of pets. From monk parakeets in Chicago (Kleen et al. 2004) to burmese pythons in the Florida Everglades (McGrath 2005), established populations of organisms kept as pets have become an unwelcome component of the North American fauna. Currently over a half-dozen Internet businesses (www.google.com search conducted 03/23/07) and numerous individuals on the Internet auction site eBay® (www.ebay.com) offer for sale dozens of live crayfish species from North America and around the world. While the aquarium pet trade has been around for more than half a century, crayfishes are a recent arrival to the aquarium marketplace. The ease of 24-hour shopping and overnight delivery to anywhere in the world facilitated by the Internet has dramatically increased the potential for accidental introductions of crayfishes.

While no known cases of overexploitation of crayfish have been documented in North America, it has been cited as a contributing factor in the decline of at least one Australian crayfish species. The Tasmanian crayfish (*Astacopsis gouldi*) can reach sizes in excess of 0.8 meters in length (> 5 kg in weight), and its meat is valued by local inhabitants. The species has experienced local extirpations and population declines throughout a significant portion of its range, and over-harvesting has been implicated as a contributing factor (Horwitz 1994). We acknowledge that overexploitation is not an imminent threat to United States and Canadian crayfish populations; however, we believe that it is prudent to acknowledge this potential threat and be proactive in future crayfish fishery decisions.

The above-listed threats are not unique to crayfishes; however, they are compounded by a single overarching factor—limited natural ranges (Taylor et al. 1996). Crayfishes show a level of endemism not seen in other aquatic groups. Approximately 43% of the U.S. crayfish fauna is distributed entirely within one state's political boundaries, compared to 16% for freshwater fishes and 15% for unionid mussels (Lodge et al. 2000). In their first conservation assessment, Taylor et al. (1996) documented 11 crayfish species known from single localities and another 20 known from 5 or fewer localities. While taxa with restricted natural ranges are particularly vulnerable to habitat destruction or degradation, the known displacement abilities of nonindigenous crayfishes when coupled with a high level of endemism represent a threat of unequalled severity.

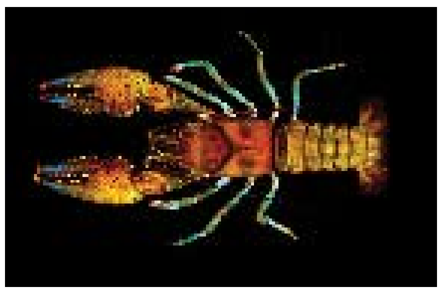
PROGRESS AND CHANGES

The conservation status of 30 taxa has changed since the previous assessment (Taylor et al. 1996). These changes have been facilitated by an increased awareness of crayfishes (Butler et al. 2003) and a subsequent increase in field efforts undertaken by federal (e.g.; Simon and Thoma 2003), state (e.g.; Thoma and Jezerinac 2000; Westhoff et al. 2006), and academic (e.g.; Ratcliffe and DeVries 2004; Taylor and Schuster 2004) personnel. These efforts have provided new distributional records that led to downgrading 25 taxa by at least one conservation category. Simultaneously, these efforts documented the introduction of nonindigenous species into the ranges of narrow endemics (Flinders and Magoulick 2005) and the subsequent reductions in range sizes, leading to the upgrading of four taxa. Promising signs of increased awareness are the proposed changes in bait regulations by several states in an attempt to thwart the spread of nonindigenous crayfishes, as well as an increase in the number of crayfishes listed by state agencies as endangered, threatened, or vulnerable/special concern. Virginia now bans the sale of crayfish as bait while Missouri has followed the lead of other states and recently created a prohibited species list for use by bait dealers which includes several nonindigenous crayfishes (B. Watson, VA Dept. Game and Inland Fisheries, pers. com.; B. DiStefano, pers. com.). Since 1996 at least two new states, Pennsylvania and North Carolina, have added the rusty crayfish to their lists of banned species (www.fish.state.pa.us/newsreleases/2005/rusty_cray.htm; NCWRC 2006). North Carolina also banned the transport, purchase, and possession of the nonindigenous virile crayfish (*O. virilis*). While the level of protection afforded to species listed at the state level ranges from bans on taking to token lists for future research efforts, it is noteworthy that the number of species listed at some level has increased from 47 to 66 since 1996. Finally, seven states (Arkansas, Missouri, New Mexico, North Carolina, South Carolina, Tennessee, Virginia) now have at least one field biologist in their respective natural resource agencies whose position requires them, at least on a part time basis, to monitor and assess crayfish populations. Taken together, these regulatory actions and field efforts can be interpreted as nothing less than progress in the domain of crayfish conservation. However, the majority of states with highly diverse crayfish faunas and high levels of endemism lack any protective measures and adequate funding structures to ascertain the statuses of their respective faunas.

While little research is being conducted in Canada at present, its crayfish fauna was

Members of the genus *Fallicambarus*, such as the burrowing bog crayfish (*F. burrisi*) here, are all burrowing species.
Photo by G. Schuster.

Due to their restricted ranges, specialized habitats, and the development of groundwater recharge areas, many obligate cave dwelling crayfish species such as the Orlando cave crayfish (*Procambarus acherontis*) are listed as Endangered.
Photo by D. McShaffrey.



Meek's crayfish (*Orconectes meeki meeki*) is a common inhabitant of Ozark streams in Missouri and Arkansas.
Photo by C. Taylor.

reviewed by Hamr (1998, 2003). This work resulted in new provincial records for several species. Most recently, the Framework for Conservation of Species at Risk in Canada (a federal and provincial initiative) has classified the status of Canadian crayfish species based on existing information (www.wildspecies.ca).

Taxonomic efforts since Taylor et al. (1996) have resulted in the description of 27 new crayfish species in the United States. At slightly more than two new species per year, these efforts clearly demonstrate that undiscovered biodiversity continues to exist in North America. Using the best available information, 21 of these 27 species are recognized as requiring conservation attention in the following analysis. Clearly, more field efforts will yield new discoveries and improve the basis for future conservation assessments.

METHODS AND DEFINITIONS

Our review of the conservation status of crayfishes includes all species and subspecies from the United States and Canada as recognized by Taylor et al. (1996) with minor exceptions. *Cambarus laevis* and *C. ornatus* are not recognized following Taylor (1997), *Procambarus ferrugineus* is not recognized following Robison and Crandall (2005), and *Cambarus bartonii carinirostris* is recognized as *C. carinirostris* following Thoma and Jezerinac (1999). Twenty-seven taxa are also included that were described subsequent to Taylor et al. (1996). Both scientific and common names are given for each taxon (Appendix 1). Common names were taken from McLaughlin et al. (2005) and other peer-reviewed literature, including original species descriptions, and were available for approximately 50% of crayfish taxa; those taxa that lacked common names were assigned one after soliciting input from all authors and active species authorities. In most cases, we looked at the original descriptions to try to find a name that fit the spirit of what the author was trying to convey with the specific epithet. In other cases we simply used the English translation of the specific epithet. In determining conservation status and distribution, a variety of sources was used including state and federal endangered species lists, government agency reports and websites, research publications, and books. In addition, the observations and field experiences of the authors, reviewers, and other biologists working with crayfishes were actively solicited and incorporated.

The American Fisheries Society Endangered Species Committee, Subcommittee on Crayfishes has reviewed the best available distributional and status information and is responsible for the resulting conclusions. The assigned conservation category is based on the status of the taxon throughout its range without consideration of political boundaries (Appendix 1). Restricted range was the primary criterion for assignment of endangered or threatened status. Other threats, such as introductions of nonindigenous crayfishes, unique habitat requirements, and proximity to metropolitan areas, were taken into account in category assignments, but known range and consequent rarity were uppermost in applying category definitions. Conservation status categories generally follow Williams et al. (1993) and are defined as: Endangered (**E**)—a species or subspecies in danger of extinction throughout all or a significant portion of its range—an asterisk (*) following the letter "**E**" indicates the taxon is possibly extinct; Threatened (**T**)—a species or subspecies likely to become endangered throughout all or a significant portion of its range; Vulnerable (**V**)—a species or subspecies that may become endangered or threatened by relatively minor disturbances to its habitat and deserves careful monitoring of its abundance and distribution; Currently Stable (**CS**)—a species or subspecies whose distribution is widespread and stable and is not in need of immediate conservation management actions. Following Warren et al. (2000), the category of Vulnerable replaces the category of Special Concern used by Taylor et al. (1996) and Williams et al. (1993). In addition, criteria responsible for designating species as E, T, or V are noted (Appendix 1). These criteria have been formulated by the AFS Endangered Species Committee as: (1) existing or potential destruction, modification, or reduction of a species' habitat or range; (2) over-utilization for commercial, sporting, scientific, or educational purposes; (3) disease; (4) other natural or anthropogenic factors affecting a species' continued existence (e.g., hybridization, introduction of nonindigenous or transplanted species, predation, competition); and (5) restricted range (Deacon et al. 1979; Williams et al. 1989).

To allow state natural heritage programs across the United States to make comparisons between AFS Crayfish Subcommittee ranks and heritage ranks, we have also included the conservation ranks for each taxon following the system developed over the past 25 years by The Nature Conservancy/NatureServe and the Network of Natural Heritage Programs (Master 1991; Appendix 1). This system ranks taxa on a 1 to 5 (1 being the rarest) scale based on best available information and considers a variety of factors including abundance, distribution, population trends, and threats (www.natureserve.org/explorer/ranking.htm). Since our assessments are based on the statuses of crayfishes across their entire

The St. Francis River crayfish, *Orconectes quadruncus* is a species classified as Threatened due to its narrow range and the establishment of nonindigenous species near its range. Photo by C. Lukhaup.

Over 50% of crayfish species are classified as Currently Stable. The golden crayfish, *Orconectes luteus* is one of those. Photo by C. Lukhaup.

The Barren River crayfish, *Orconectes barrenensis,* is a species that occurs under gravel and cobble in creeks and rivers in the Barren River drainage of Kentucky and Tennessee. Photo by C. Taylor.

native ranges, we use the G or Global scale for conservation status rankings. Categories follow Master (1991) and are defined as follows: G1 = critically imperiled, G2 = imperiled, G3 = vulnerable to extirpation or extinction, G4 = apparently secure, G5 = demonstrably widespread, abundant, and secure, GH = possibly extinct, known only from historical collections, and GX = presumed extinct.

LIST OF TAXA (APPENDIX 1)

The list of crayfish species and subspecies is arranged alphabetically by genus and by species and subspecies within the genus. Following the scientific name and author(s), the common name is followed by assigned conservation status using a letter code: **E** = Endangered; **E*** = Endangered, Possibly Extinct; **T** = Threatened; **V** = Vulnerable; **CS** = Currently Stable. Criteria used to determine conservation statuses are indicated by numerals 1 through 5 and correspond to those defined in Methods. Global Heritage ranks (see Methods) immediately follow listing criteria. A dagger denotes a species complex currently under taxonomic investigation. Finally, the distribution of each taxon is indicated by an alphabetical listing of U. S. states and Canadian provinces where that taxon occurs. Parentheses around states indicate known or suspected introductions. Standard two-letter abbreviations for states and provinces follow Williams et al. (1989).

SUMMARY AND CONCLUSIONS

The list of crayfishes of the United States and Canada includes 363 taxa. Possibly Extinct, Endangered, Threatened, or Vulnerable statuses are recognized for 174 taxa (47.9%). Of these, 2 (< 1%) are possibly Extinct, 66 (18.2%) are Endangered, 52 (14.3%) are Threatened, and 54 (14.9%) are Vulnerable. Taxa classified as currently stable total 189 (52.1%). The number of imperiled crayfishes (48%) parallels the high levels of imperilment of fishes and freshwater mussels, almost 33% and 72%, respectively (Williams et al. 1989; Williams et al. 1993; Warren and Burr 1994). These assessments support the contention that aquatic diversity in North America is in far worse condition than its terrestrial counterpart (Master 1990, Master et al. 2000).

For some crayfishes, limited natural range (e.g., one locality or one drainage system) precipitates recognition as Endangered or Threatened; but for many others, status assignments continue to be hampered by a paucity of recent distributional information. While progress has been made in this arena, basic ecological and current distributional information are lacking for 60% of the U.S. and Canadian fauna. In addition, threats highlighted by Taylor et al. (1996) such as habitat loss and the introduction of nonindigenous crayfishes continue to persist and are greatly magnified by the limited distributions of many species. The threat of nonindigenous species has even increased (Lodge et al. 2000; Flinders and Magoulick 2005) due to actual introductions and emerging conduits for potential introductions. As stated by Taylor et al. (1996), lack of recent species-specific information, whether distributional or biological, does not warrant neglect by resource agencies. Recognition of the potential for rapid decimation of crayfish species, especially those with limited ranges, should provide impetus for proactive efforts toward conservation as espoused by the American Fisheries Society (Angermeier and Williams 1994).

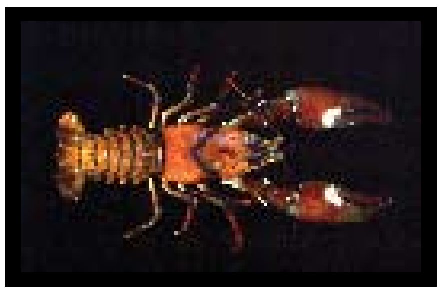
In publishing this list, the American Fisheries Society Endangered Species Committee summarizes for fisheries professionals, natural resource agencies, university researchers, conservation organizations, lawmakers, and citizens, the conservation status of crayfishes in the United States and Canada. The results of this reassessment provide some signs of improvement in the recognition of crayfish conservation. Because the number of crayfish taxa in need of conservation attention has changed little, suggested actions for natural resource personnel mirror those proposed by Taylor et al. (1996). These include, but are not limited to: (1) critically examine the findings of this reassessment and bring to our attention additional information; (2) use the list as a planning and prioritization tool for conducting recovery efforts, status surveys, and biological research on imperiled crayfishes; (3) support graduate research and training in the distribution, taxonomy, and ecology of crayfishes; (4) propagate education of citizens; and (5) recognize the plight of aquatic resources and act accordingly and proactively.

ADDITIONAL INFORMATION

We provide this section to aid the reader in accessing additional information on crayfishes of the United States and Canada. The papers and Internet resources, organized alphabetically by state, are primarily taxonomic or distributional in nature but also cover topics associated with a variety of aspects of the biology of crayfishes. Additional crayfish information can also be found by following links found on some of the websites listed below.

The digger crayfish (*Fallicambarus fodiens*) is one of the most widespread crayfish species in North America. It occurs from Ontario, Canada to Texas.
Photo by C. Taylor.

While generally inhabiting lentic habitats, a few members of the genus *Procambarus,* such as *P. lophotus* shown here, can occur in high gradient streams.
Photo by G. Schuster.



The signal crayfish (*Pacifastacus leniusculus leniusculus*) is a widespread species found in the Pacific Northwest and is harvested for human consumption in parts of its range.
Photo by C. Taylor.

ALABAMA

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ARKANSAS

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CALIFORNIA

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COLORADO

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Over 70, 000 metric tons of the red swamp crayfish (*Procambarus clarkii*) are harvested each year for human consumption.
Photo by C. Taylor.

Since 1996 several species such as the rusty gravedigger (*Cambarus miltus*) have had their conservation statuses downgraded due to intensive field surveys.
Photo by G. Schuster.

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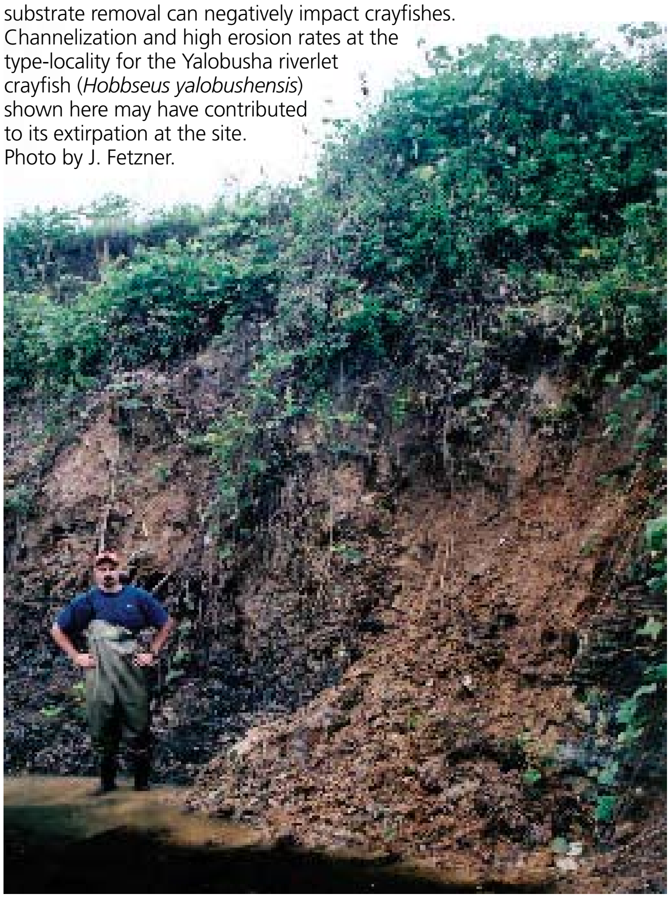
Habitat alteration, such as stream channelization and substrate removal can negatively impact crayfishes. Channelization and high erosion rates at the type-locality for the Yalobusha riverlet crayfish (*Hobbseus yalobushensis*) shown here may have contributed to its extirpation at the site. Photo by J. Fetzner.



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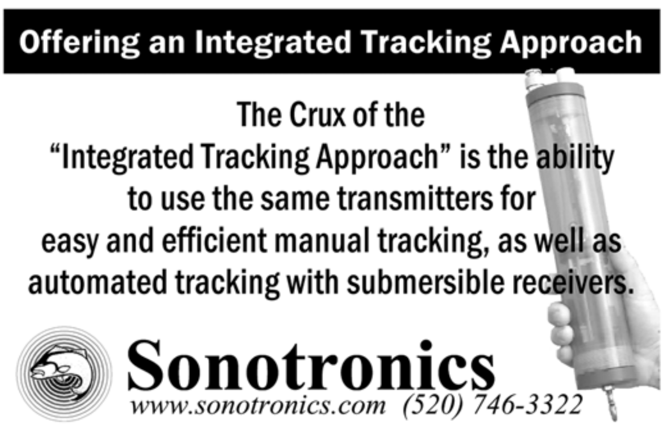

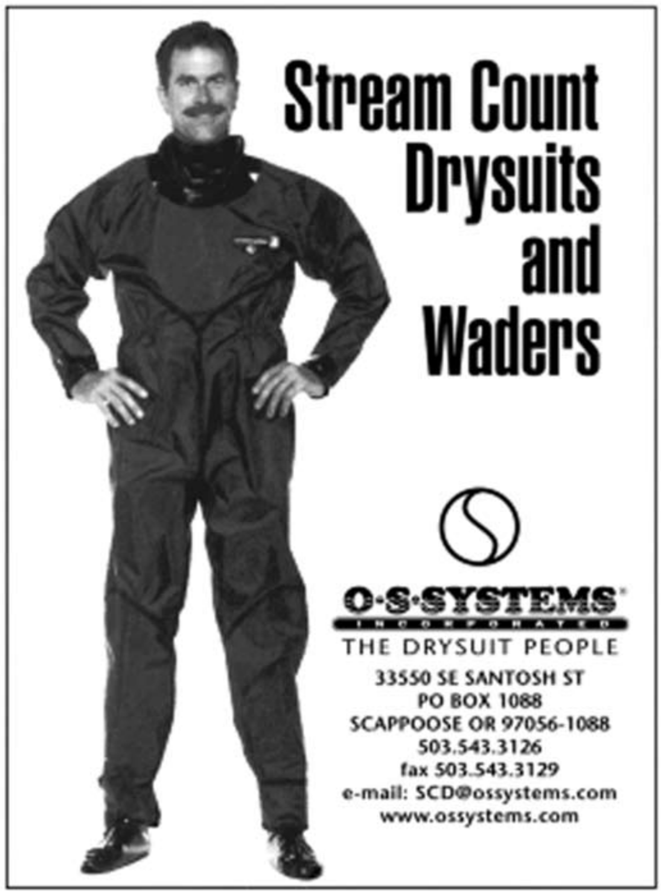

Appendix 1.

Species	Common name	AFS status	Listing criteria	Heritage rank	Known distribution
Family Astacidae					
Pacifastacus connectens (Faxon)	Snake River Pilose Crayfish	CS		G4	ID, OR
Pacifastacus fortis (Faxon)	Shasta Crayfish	E	4, 5	G1	CA
Pacifastacus gambelii (Girard)	Pilose Crayfish	CS		G4,G5	(CA), ID, MT, NV, OR, UT, WA, WY
Pacifastacus leniusculus klamathensis (Stimpson)	Klamath Signal Crayfish	CS		G5	CA, ID, OR, WA. BC
Pacifastacus leniusculus leniusculus (Dana)	Signal Crayfish	CS		G5	(CA), ID, (NV), OR, (UT), WA. BC
Pacifastacus leniusculus trowbridgii (Stimpson)	Columbia River Signal Crayfish	CS		G5	(CA), ID, (NV), OR, MT, WA. BC
Pacifastacus nigrescens (Stimpson)	Sooty Crayfish	E*		GX	CA
Family Cambaridae					
Barbicambarus cornutus (Faxon)	Bottlebrush Crayfish	CS		G4	KY, TN
Bouchardina robisoni Hobbs	Bayou Bodcau Crayfish	V	5	G2,G3	AR
Cambarellus blacki Hobbs	Cypress Crayfish	E	1, 5	G1	FL
Cambarellus diminutus Hobbs	Least Crayfish	T	5	G3	AL, MS
Cambarellus lesliei Fitzpatrick and Laning	Angular Dwarf Crawfish	T	5	G3	AL, MS
Cambarellus ninae Hobbs	Aransas Dwarf Crawfish	V	5	G3	TX
Cambarellus puer Hobbs	Swamp Dwarf Crayfish	CS		G5	AR, IL, KY, LA, MS, MO, OK, TN, TX
Cambarellus schmitti Hobbs	Fontal Dwarf Crawfish	CS		G3	FL
Cambarellus shufeldtii (Faxon)	Cajun Dwarf Crayfish	CS		G5	AL, AR, IL, KY, LA, MS, MO, TN, TX
Cambarellus texanus Albaugh and Black	Brazos Dwarf Crawfish	CS		G3,G4	TX
Cambarus acanthura Hobbs	Thornytail Crayfish	CS		G4,G5	AL, GA, NC, TN
Cambarus aculabrum Hobbs and Brown	Benton County Cave Crayfish	E	1, 5	G1	AR
Cambarus acuminatus Faxon	Acuminate Crayfish	†CS		G4	MD, NC, SC, VA
Cambarus angularis Hobbs and Bouchard	Angled Crayfish	CS		G3	TN, VA
Cambarus asperimanus Faxon	Mitten Crayfish	CS		G4	GA, NC,SC, TN
Cambarus bartonii bartonii (Fabricius)	Common Crayfish	CS		G5	AL, CT, DE, GA, ME, MD, MA, NJ, NY, NC, PA, RI, SC, TN, VT, VA, WV. NB, ON, QC
Cambarus bartonii cavatus Hay	Appalachian Brook Crayfish	CS		G5	AL, GA, KY, IN, OH, TN, VA, WV
Cambarus batchi Schuster	Bluegrass Crayfish	V	5	G3	KY
Cambarus bouchardi Hobbs	Big South Fork Crayfish	E	5	G2	KY, TN
Cambarus brachydactylus Hobbs	Shortfinger Crayfish	CS		G4	TN
Cambarus brimleyorum Cooper	Valley River Crayfish	V	5	G3	NC
Cambarus buntingi Bouchard	Longclaw Crayfish	†CS		G4	KY, TN
Cambarus carinirostris Hay	Rock Crawfish	CS		G5	OH, PA, VA, WV
Cambarus carolinus (Erichson)	Red Burrowing Crayfish	CS		G4	NC, SC, TN
Cambarus catagius Hobbs and Perkins	Greensboro Burrowing Crayfish	V	1, 5	G3	NC
Cambarus causeyi Reimer	Boston Mountains Crayfish	V	1, 5	G2	AR
Cambarus chasmodactylus James	New River Crayfish	CS		G4	NC, VA, WV
Cambarus chaugaensis Prins and Hobbs	Chauga Crayfish	T	5	G2	GA, NC, SC
Cambarus clivosus Taylor and Soucek	Short Mountain Crayfish	T	5	G2	TN
Cambarus conasaugaensis Hobbs and Hobbs	Mountain Crayfish	V	5	G3	GA, TN
Cambarus coosae Hobbs	Coosa Crayfish	CS		G5	AL, GA, TN
Cambarus coosawattae Hobbs	Coosawattee Crayfish	E	1, 5	G1	GA
Cambarus cracens Bouchard and Hobbs	Slenderclaw Crayfish	E	5	G1	AL
Cambarus crinipes Bouchard	Hairyfoot Crayfish	CS		G3	TN
Cambarus cryptodytes Hobbs	Dougherty Plain Cave Crayfish	T	5	G2,G3	FL, GA
Cambarus cumberlandensis Hobbs and Bouchard	Cumberland Crayfish	CS		G5	KY, TN
Cambarus cymatilis Hobbs	Conasauga Blue Burrower	E	5	G1	GA, TN
Cambarus davidi Cooper	Carolina Ladle Crayfish	CS		G4	NC
Cambarus deweesae Bouchard and Etnier	Valley Flame Crayfish	CS		G4	KY, TN
Cambarus diogenes Girard	Devil Crawfish	†CS		G5	AL, AR, CO, DE, FL, GA, IL, IN, IA, KS, KY, LA, MD, MI, MN, MS, MO, NE, NJ, NC, ND, OH, OK, PA, SC, SD, TN, TX VA, WI, WY. ON
Cambarus distans Rhoades	Boxclaw Crayfish	CS		G5	AL, GA, KY, TN
Cambarus doughertyensis Cooper and Skelton	Dougherty Burrowing Crayfish	E	5	G1	GA
Cambarus dubius Faxon	Upland Burrowing Crayfish	CS		G5	KY, MD, NC, PA, TN, VA, WV
Cambarus eeseeohensis Thoma	Grandfather Mountain Crayfish	T	5	G2	NC
Cambarus elkensis Jezerinac and Stocker	Elk River Crayfish	T	1, 5	G2	WV
Cambarus englishi Hobbs and Hall	Tallapoosa Crayfish	V	5	G3	AL, GA
Cambarus extraneus Hagen	Chickamauga Crayfish	T	5	G2	GA, TN
Cambarus fasciatus Hobbs	Etowah Crayfish	T	1, 5	G3	GA
Cambarus friaufi Hobbs	Hairy Crayfish	CS		G4	KY, TN
Cambarus gentryi Hobbs	Linear Cobalt Crayfish	CS		G4	TN
Cambarus georgiae Hobbs	Little Tennessee Crayfish	V	5	G2	GA, NC
Cambarus girardianus Faxon	Tanback Crayfish	CS		G5	AL, GA, TN
Cambarus graysoni Faxon	Twospot Crayfish	CS		G5	AL, KY, TN
Cambarus halli Hobbs	Slackwater Crayfish	V	5	G3,G4	AL, GA
Cambarus hamulatus (Cope)	Prickly Cave Crayfish	CS		G3,G4	AL, TN
Cambarus harti Hobbs	Piedmont Blue Burrower	E	5	G1	GA
Cambarus hiwasseensis Hobbs	Hiwassee Crayfish	V	5	G3,G4	GA, NC, TN
Cambarus hobbsorum Cooper	Rocky River Crayfish	CS		G3,G4	NC, SC
Cambarus howardi Hobbs and Hall	Chattahoochee Crayfish	CS		G3	AL, GA, NC
Cambarus hubbsi Creaser	Hubbs' Crayfish	CS		G5	AR, MO
Cambarus hubrichti Hobbs	Salem Cave Crayfish	CS		G4	MO

Cambarus hystricosus Cooper and Cooper	Sandhills Spiny Crayfish	V	5	G2	NC
Cambarus jezerinaci Thoma	Spiny Scale Crayfish	†CS		G3	TN, VA
Cambarus johni Cooper	Carolina Foothills Crayfish	V	5	G3	NC
Cambarus jonesi Hobbs and Barr	Alabama Cave Crayfish	CS		G3	AL
Cambarus latimanus (Le Conte)	Variable Crayfish	CS		G5	AL, FL, GA, NC, SC, TN
Cambarus lenati Cooper	Broad River Stream Crayfish	T	5	G2	NC
Cambarus longirostris Faxon	Longnose Crayfish	†CS		G5	AL, GA, NC, (SC), TN, VA
Cambarus longulus Girard	Atlantic Slope Crayfish	CS		G5	NC, VA, WV
Cambarus ludovicianus Faxon	Painted Devil Crayfish	CS		G5	AL, AR, KY, LA, MS, MO, OK, TN, TX
Cambarus maculatus Hobbs and Pflieger	Freckled Crayfish	CS		G4	MO
Cambarus manningi Hobbs	Greensaddle Crayfish	CS		G4	AL, GA, TN
Cambarus miltus Fitzpatrick	Rusty Grave Digger	T	5	G1,G2	AL, FL
Cambarus monongalensis Ortmann	Blue Crawfish	CS		G5	PA, VA, WV
Cambarus nerterius Hobbs	Greenbrier Cave Crayfish	E	5	G2	WV
Cambarus nodosus Bouchard and Hobbs	Knotty Burrowing Crayfish	CS		G4	GA, NC, SC, TN
Cambarus obeyensis Hobbs and Shoup	Obey Crayfish	E	5	G1	TN
Cambarus obstipus Hall	Sloped Crayfish	V	5	G4	AL
Cambarus ortmanni Williamson	Ortmann's Mudbug	CS		G5	IN, KY, OH
Cambarus parrishi Hobbs	Hiwassee Headwater Crayfish	E	5	G1	GA, NC
Cambarus parvoculus Hobbs and Shoup	Mountain Midget Crayfish	CS		G5	AL, GA, KY, TN, VA
Cambarus polychromatus Thoma et al.	Paintedhand Mudbug	CS		G5	AL, IL, IN, KY, MI, OH, TN
Cambarus pristinus Hobbs	Pristine Crayfish	E	5	G1	TN
Cambarus pyronotus Bouchard	Fireback Crayfish	E	5	G2	FL
Cambarus reburrus Prins	French Broad Crayfish	CS		G3	NC
Cambarus reduncus Hobbs	Sickle Crayfish	CS		G4,G5	NC, SC
Cambarus reflexus Hobbs	Pine Savannah Crayfish	CS		G4	GA, SC
Cambarus robustus Girard	Big Water Crayfish	CS		G5	CT, IL, IN, KY, MI, NY, NC, OH, PA, TN, VA, WV, ON, QC
Cambarus rusticiformis Rhoades	Depression Crayfish	CS		G5	(AL), IL, KY, TN
Cambarus sciotensis Rhoades	Teays River Crayfish	CS		G5	KY, OH, VA, WV
Cambarus scotti Hobbs	Chattooga River Crayfish	T	5	G3	AL, GA
Cambarus setosus Faxon	Bristly Cave Crayfish	CS		G4	AR, MO
Cambarus speciosus Hobbs	Beautiful Crayfish	E	1, 5	G2	GA
Cambarus sphenoides Hobbs	Triangleclaw Crayfish	CS		G4	KY, TN
Cambarus spicatus Hobbs	Broad River Spiny Crayfish	V	5	G2	NC, SC
Cambarus striatus Hay	Ambiguous Crayfish	CS		G5	AL, FL, GA, KY, MS, SC, TN
Cambarus strigosus Hobbs	Lean Crayfish	T	5	G2	GA
Cambarus subterraneus Hobbs	Delaware County Cave Crayfish	E	1, 5	G1	OK
Cambarus tartarus Hobbs and Cooper	Oklahoma Cave Crayfish	E	1, 5	G1	OK
Cambarus tenebrosus Hay	Cavespring Crayfish	†CS		G5	AL, IL, IN, KY, OH, TN
Cambarus thomai Jezerinac	Little Brown Mudbug	CS		G5	KY, OH, PA, TN, WV
Cambarus truncatus Hobbs	Oconee Burrowing Crayfish	T	5	G2	GA
Cambarus tuckasegee Cooper and Schofield	Tuckasegee Stream Crayfish	T	5	G2	NC
Cambarus unestami Hobbs and Hall	Blackbarred Crayfish	T	5	G2	AL, GA
Cambarus veitchorum Cooper and Cooper	White Spring Cave Crayfish	E	1, 5	G1	AL
Cambarus veteranus Faxon	Big Sandy Crayfish	T	1, 5	G3	KY, VA, WV
Cambarus williami Bouchard and Bouchard	Brawleys Fork Crayfish	E	5	G1	TN
Cambarus zophonastes Hobbs and Bedinger	Hell Creek Cave Crayfish	E	1, 5	G1	AR
Distocambarus carlsoni Hobbs	Mimic Crayfish	T	5	G2,G3	SC
Distocambarus crockeri Hobbs and Carlson	Piedmont Prairie Burrowing Crayfish	T	1, 5	G3	SC
Distocambarus devexus (Hobbs)	Broad River Burrowing Crayfish	T	5	G2	GA
Distocambarus hunteri Fitzpatrick and Eversole	Saluda Burrowing Crayfish	E	5	G1	SC
Distocambarus youngineri Hobbs and Carlson	Newberry Burrowing Crayfish	E	5	G1	SC
Fallicambarus burrisi Fitzpatrick	Burrowing Bog Crayfish	T	5	G3	AL, MS
Fallicambarus byersi (Hobbs)	Lavender Burrowing Crayfish	CS		G4	AL, FL, MS
Fallicambarus caesius Hobbs	Timberlands Burrowing Crayfish	CS		G4	AR
Fallicambarus danielae Hobbs	Speckled Burrowing Crayfish	T	5	G2	AL, MS
Fallicambarus devastator Hobbs and Whiteman	Texas Prairie Crayfish	V	5	G3	TX
Fallicambarus dissitus (Penn)	Pine Hills Digger	V	5	G4	AR, LA
Fallicambarus fodiens (Cottle)	Digger Crayfish	CS		G5	AL, AR, FL, GA, IL, IN, KY, LA, MD, MI, MS, MO, NC, OH, OK, SC, TN, TX, VA, WV. ON
Fallicambarus gilpini Hobbs and Robison	Jefferson County Crayfish	E	5	G1	AR
Fallicambarus gordoni Fitzpatrick	Camp Shelby Burrowing Crayfish	T	5	G1	MS
Fallicambarus harpi Hobbs and Robison	Ouachita Burrowing Crayfish	V	5	G3	AR
Fallicambarus hortoni Hobbs and Fitzpatrick	Hatchie Burrowing Crayfish	E	5	G1	TN
Fallicambarus jeanae Hobbs	Daisy Burrowing Crayfish	V	5	G2	AR
Fallicambarus macneesei (Black)	Old Prairie Digger	V	1, 5	G3	LA, TX
Fallicambarus oryktes (Penn and Marlow)	Flatwoods Digger	V	1, 4, 5	G4	AL, LA, MS
Fallicambarus petilicarpus Hobbs and Robison	Slenderwrist Burrowing Crayfish	E	5	G1	AR
Fallicambarus strawni (Reimer)	Saline Burrowing Crayfish	T	5	G1,G2	AR
Faxonella beyeri (Penn)	Sabine Fencing Crayfish	CS		G4	LA, TX
Faxonella blairi Hayes and Reimer	Blair's Fencing Crayfish	CS		G3	AR, OK
Faxonella clypeata (Hay)	Ditch Fencing Crayfish	CS		G5	AL, AR, FL, GA, LA, MS, MO, SC, TX
Faxonella creaseri Walls	Ouachita Fencing Crayfish	V	1, 5	G2	LA
Hobbseus attenuatus Black	Pearl Riverlet Crayfish	E	1, 5	G2	MS
Hobbseus cristatus (Hobbs)	Crested Riverlet Crayfish	T	1, 5	G3	MS
Hobbseus orconectoides Fitzpatrick and Payne	Oktibbeha Riverlet Crayfish	T	1, 5	G3	MS
Hobbseus petilus Fitzpatrick	Tombigbee Riverlet Crayfish	T	1, 5	G2	MS
Hobbseus prominens (Hobbs)	Prominence Riverlet Crayfish	CS		G4,G5	AL, MS

Hobbseus valleculus (Fitzpatrick)	Choctaw Riverlet Crayfish	T	1, 5	G1	MS
Hobbseus yalobushensis Fitzpatrick and Busack	Yalobusha Riverlet Crayfish	E	1, 5	G3	MS
Orconectes acares Fitzpatrick	Redspotted Stream Crayfish	CS		G4	AR
Orconectes alabamensis (Faxon)	Alabama Crayfish	V	5	G5	AL, MS, TN
Orconectes australis australis (Rhoades)	Southern Cave Crayfish	CS		G4	AL, TN
Orconectes australis packardi Rhoades	Appalachian Cave Crayfish	T	1, 5	G2	KY
Orconectes barrenensis Rhoades	Barren River Crayfish	CS		G4	KY, TN
Orconectes bisectus Rhoades	Crittenden Crayfish	E	5	G1	KY
Orconectes blacki Walls	Calcasieu Crayfish	T	1,5	G2	LA
Orconectes burri Taylor and Sabaj	Blood River Crayfish	E	1, 5	G1	KY, TN
Orconectes carolinensis Cooper and Cooper	North Carolina Spiny Crayfish	CS		G4	NC
Orconectes causeyi Jester	Western Plains Crayfish	CS		G5	CO, KS, (NM), OK, TX
Orconectes chickasawae Cooper and Hobbs	Chickasaw Crayfish	CS		G5	AL, MS
Orconectes compressus (Faxon)	Slender Crayfish	CS		G5	AL, KY, MS, TN
Orconectes cooperi Cooper and Hobbs	Flint River Crayfish	E	5	G1	AL, TN
Orconectes cristavarius Taylor	Spiny Stream Crayfish	CS		G5	KY, OH, NC, TN, WV, VA
Orconectes deanae Reimer and Jester	Conchas Crayfish	CS		G4	NM, OK
Orconectes difficilis (Faxon)	Painted Crayfish	CS		G3	OK
Orconectes durelli Bouchard and Bouchard	Saddle Crayfish	CS		G5	AL, KY, TN
Orconectes erichsonianus (Faxon)	Reticulate Crayfish	CS		G5	AL, GA, TN, VA
Orconectes etnieri Bouchard and Bouchard	Ets Crayfish	CS		G4	MS, TN
Orconectes eupunctus Williams	Coldwater Crayfish	T	1, 4, 5	G2	AR, MO
Orconectes forceps (Faxon)	Surgeon Crayfish	CS		G5	AL, GA, TN, VA
Orconectes harrisonii (Faxon)	Belted Crayfish	V	5	G3	MO
Orconectes hartfieldi Fitzpatrick and Suttkus	Yazoo Crayfish	T	1, 5	G2	MS
Orconectes hathawayi Penn	Teche Painted Crawfish	V	5	G3	LA
Orconectes hobbsi Penn	Pontchartrain Painted Crawfish	CS		G4	LA, MS
Orconectes holti Cooper and Hobbs	Bimaculate Crayfish	V	5	G3	AL
Orconectes hylas (Faxon)	Woodland Crayfish	CS		G4	MO
Orconectes illinoiensis Brown	Shawnee Crayfish	CS		G4	IL
Orconectes immunis (Hagen)	Calico Crayfish	CS		G5	CO, (CT), IL, IN, IA, KS, KY, (ME), (MA), MI, MN, MO, MT, NE, (NH), NY, ND, OH, (RI), SD, TN, (VT), WI, WY. MB, ON, PQ
Orconectes incomptus Hobbs and Barr	Tennessee Cave Crayfish	E	5	G1	TN
Orconectes indianensis (Hay)	Indiana Crayfish	CS		G4	IL, IN
Orconectes inermis inermis Cope	Ghost Crayfish	CS		G4	IN, KY
Orconectes inermis testii (Hay)	Unarmed Crayfish	T	1, 5	G2	IN
Orconectes jeffersoni Rhoades	Louisville Crayfish	E	1, 5	G1	KY
Orconectes jonesi Fitzpatrick	Sucarnoochee River Crayfish	†V	5	G3	AL, MS
Orconectes juvenilis (Hagen)	Kentucky River Crayfish	CS		G4	IN, KY
Orconectes kentuckiensis Rhoades	Kentucky Crayfish	CS		G4	IL, KY
Orconectes lancifer (Hagen)	Shrimp Crayfish	CS		G5	AL, AR, IL, KY, LA, MS, MO, OK, TN, TX
Orconectes leptogonopodus Hobbs	Little River Creek Crayfish	CS		G4	AR, OK
Orconectes limosus (Rafinesque)	Spinycheek Crayfish	CS		G5	CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT, VA, WV. QC, NB
Orconectes longidigitus (Faxon)	Longpincered Crayfish	CS		G4	AR, MO
Orconectes luteus (Creaser)	Golden Crayfish	CS		G5	IA, IL, KS, MN, MO
Orconectes macrus Williams	Neosho Midget Crayfish	CS		G4	AR, KS, MO, OK
Orconectes maletae Walls	Kisatchie Painted Crayfish	T	1, 5	G2	LA
Orconectes marchandi Hobbs	Mammoth Spring Crayfish	T	1, 5	G2	AR, MO
Orconectes margorectus Taylor	Livingston Crayfish	T	5	G2	KY
Orconectes medius (Faxon)	Saddlebacked Crayfish	CS		G4	MO
Orconectes meeki brevis Williams	Meek's Short Pointed Crayfish	T	5	G2	AR, OK
Orconectes meeki meeki (Faxon)	Meek's Crayfish	CS		G5	AR, MO
Orconectes menae (Creaser)	Mena Crayfish	T	5	G3	AR, OK
Orconectes mirus (Ortmann)	Wonderful Crayfish	CS		G4	AL, TN
Orconectes mississippiensis (Faxon)	Mississippi Crayfish	V	5	G3	MS
Orconectes nais (Faxon)	Water Nymph Crayfish	CS		G5	KS, MO, OK, TX
Orconectes nana Williams	Midget Crayfish	V	5	G3	AR, OK
Orconectes neglectus chaenodactylus Williams	Gap Ringed Crayfish	V	5	G3	AR, MO
Orconectes neglectus neglectus (Faxon)	Ringed Crayfish	CS		G5	AR, CO, KS, MO, NE, (NY), OK, (OR), WY
Orconectes obscurus (Hagen)	Allegheny Crayfish	CS		G5	ME, MD, NY, OH, PA, VA, WV. ON, QC,
Orconectes ozarkae Williams	Ozark Crayfish	CS		G5	AR, MO
Orconectes pagei Taylor and Sabaj	Mottled Crayfish	CS		G4	TN
Orconectes palmeri creolanus (Creaser)	Creole Painted Crayfish	CS		G4	(GA), LA, MS
Orconectes palmeri longimanus (Faxon)	Western Painted Crayfish	CS		G5	AR, KS, LA, OK, TX
Orconectes palmeri palmeri (Faxon)	Gray-speckled Crayfish	CS		G5	AR, KY, LA, MS, MO, TN
Orconectes pardalotus Wetzel et al.	Leopard Crayfish	E	1, 5	G1	IL, KY
Orconectes pellucidus (Tellkampf)	Mammoth Cave Crayfish	CS		G5	KY, TN
Orconectes perfectus Walls	Complete Crayfish	CS		G4,G5	AL, MS
Orconectes peruncus (Creaser)	Big Creek Crayfish	T	4, 5	G2	MO
Orconectes placidus (Hagen)	Bigclaw Crayfish	CS		G5	AL, IL, KY, TN
Orconectes propinquus (Girard)	Northern Clearwater Crayfish	CS		G5	IL, IN, IA, MA, MI, MN, NY, OH, PA, VT, WI. ON, QC
Orconectes punctimanus (Creaser)	Spothanded Crayfish	CS		G4,G5	AR, MO
Orconectes putnami (Faxon)	Phallic Crayfish	CS		G5	AL, IN, KY, TN
Orconectes quadruncus (Creaser)	St. Francis River Crayfish	T	4, 5	G2	MO

Orconectes rafinesquei Rhoades	Rough River Crayfish	V	1, 5	G3	KY
Orconectes rhoadesi Hobbs	Fishhook Crayfish	CS		G4	TN
Orconectes ronaldi Taylor	Mud River Crayfish	T	5	G3	KY
Orconectes rusticus (Girard)	Rusty Crayfish	CS		G5	(CT), (IL), IN, (IA), KY, (ME), (MA), MI, (MN), (NH), (NJ), (NM), (NC), (NY), OH, (PA), (TN), (VT), (VA), (WV), (WI). (ON), (QC)
Orconectes sanbornii (Faxon)	Sanborn's Crayfish	CS		G5	KY, OH, (WA), WV
Orconectes saxatilis Bouchard and Bouchard	Kiamichi Crayfish	E	5	G1	OK
Orconectes sheltae Cooper and Cooper	Shelta Cave Crayfish	E	1, 5	G1	AL
Orconectes shoupi Hobbs	Nashville Crayfish	E	1, 5	G1	TN
Orconectes sloanii (Bundy)	Sloan Crayfish	V	1, 4	G3	IN, OH
Orconectes spinosus (Bundy)	Coosa River Spiny Crayfish	CS		G4	AL, GA, TN
Orconectes stannardi Page	Little Wabash Crayfish	V	1, 5	G3	IL
Orconectes stygocaneyi Hobbs	Caney Mountain Cave Crayfish	T	5	G1	MO
Orconectes theaphionensis Simon et al.	Sinkhole Crayfish	CS		G4	IN
Orconectes tricuspis Rhoades	Western Highland Crayfish	CS		G4	KY
Orconectes validus (Faxon)	Powerful Crayfish	CS		G4,G5	AL, MS, TN
Orconectes virginiensis Hobbs	Chowanoke Crayfish	CS		G4	NC, VA
Orconectes virilis Hagen	Virile Crayfish	CS		G5	(AL), (AZ), AR, (CA), CO, (CT), IL, IN, IA, KS, (ME), (MD), (MA), MI, MN, MO, MT, NE, (NH), (NJ), (NM), (NC), NY, ND, OH, OK, (PA), (RI), SD, (TN), TX, UT, (VT), (VA), (WA), (WV), WI, WY. AB, MB, ON, PQ, SK
Orconectes willliamsi Fitzpatrick	Williams Crayfish	CS		G4	AR, MO
Orconectes wrighti Hobbs	Hardin Crayfish	E	5	G2	MS, TN
Procambarus ablusus Penn	Hatchie River Crayfish	CS		G4	MS, TN
Procambarus acherontis (Lonnberg)	Orlando Cave Crayfish	E	1, 5	G1	FL
Procambarus acutissimus (Girard)	Sharpnose Crayfish	CS		G5	AL, GA, MS
Procambarus acutus (Girard)	White River Crawfish	†CS		G5	AL, AR, (CA), (CT), DE, FL, GA, IL, IN, IA, KS, KY, LA, (ME), MD (MA), MI, MN, MS, MO, NJ, NY, NC, OH, OK, PA, (RI), SC, TN, TX, VA, WV, WI
Procambarus advena (Le Conte)	Vidalia Crayfish	CS		G3	GA
Procambarus alleni (Faxon)	Everglades Crayfish	CS		G4	FL
Procambarus ancylus Hobbs	Coastal Plain Crayfish	CS		G4,G5	NC, SC
Procambarus angustatus (Le Conte)	Sandhills Crayfish	E*		GX	GA
Procambarus apalachicolae Hobbs	Coastal Flatwoods Crayfish	T	1, 5	G2	FL
Procambarus attiguus Hobbs and Franz	Silver Glen Springs Crayfish	E	5	G1,G2	FL
Procambarus barbatus (Faxon)	Wandering Crayfish	CS		G5	GA, SC
Procambarus barbiger Fitzpatrick	Jackson Prairie Crayfish	V	5	G2	MS
Procambarus bivittatus Hobbs	Ribbon Crayfish	CS		G5	AL, FL, LA, MS
Procambarus blandingii (Harlan)	Santee Crayfish	CS		G4	NC, SC
Procambarus braswelli Cooper	Waccamaw Crayfish	V	5	G3	NC, SC
Procambarus brazoriensis Albaugh	Brazoria Crayfish	E	1, 5	G1	TX
Procambarus capillatus Hobbs	Capillaceous Crayfish	V	5	G3	AL, FL
Procambarus caritus Hobbs	Poor Crayfish	CS		G4	GA
Procambarus ceruleus Fitzpatrick and Wicksten	Blueclaw Chimney Crawfish	E	5	G1	TX
Procambarus chacei Hobbs	Cedar Creek Crayfish	CS		G4	GA, SC
Procambarus clarkii (Girard)	Red Swamp Crawfish	CS		G5	AL, (AZ), AR, (CA), FL, (GA), (HI), (ID), IL, IN, KY, LA, (MD), MS, MO, (NV), (NM), (NC), (OH), OK, (OR), (SC), TN, TX, (UT), (VA), (WA)
Procambarus clemmeri Hobbs	Cockscomb Crayfish	CS		G5	AL, LA, MS
Procambarus cometes Fitzpatrick	Mississippi Flatwoods Crayfish	E	5	G1	MS
Procambarus connus Fitzpatrick	Carrollton Crayfish	E	5	GH	MS
Procambarus curdi Reimer	Red River Burrowing Crayfish	CS		G5	AR, OK, TX
Procambarus delicatus Hobbs and Franz	Bigcheek Cave Crayfish	E	5	G1	FL
Procambarus dupratzi Penn	Southwestern Creek Crayfish	CS		G5	AR, LA, OK, TX
Procambarus echinatus Hobbs	Edisto Crayfish	V	5	G3	SC
Procambarus econfinae Hobbs	Panama City Crayfish	E	1, 5	G1	FL
Procambarus elegans Hobbs	Elegant Creek Crayfish	CS		G5	AR, LA, MS
Procambarus enoplosternum Hobbs	Black Mottled Crayfish	CS		G4,G5	GA, SC
Procambarus epicyrtus Hobbs	Humpback Crayfish	V	5	G3	GA
Procambarus erythrops Relyea and Sutton	Santa Fe Cave Crayfish	E	1, 5	G1,G2	FL
Procambarus escambiensis Hobbs	Escambia Crayfish	E	5	G2	AL, FL
Procambarus evermanni (Faxon)	Panhandle Crayfish	CS		G4	Al, FL, MS
Procambarus fallax (Hagen)	Slough Crayfish	CS		G5	FL, GA
Procambarus fitzpatricki Hobbs	Spinytail Crayfish	T	5	G2	MS
Procambarus franzi Hobbs and Lee	Orange Lake Cave Crayfish	E	1, 5	G1,G2	FL
Procambarus geminus Hobbs	Twin Crawfish	CS		G3,G4	AR, LA
Procambarus geodytes Hobbs	Muddiver Crayfish	CS		G4	FL
Procambarus gibbus Hobbs	Muckalee Crayfish	T	4, 5	G3	GA
Procambarus gracilis (Bundy)	Prairie Crayfish	CS		G5	IL, IN, IA, KS, MO, NE, OK, TX, WI
Procambarus hagenianus hagenianus (Faxon)	Southeastern Prairie Crayfish	CS		G4	AL, MS
Procambarus hagenianus vesticeps Fitzpatrick	Egyptian Crayfish	V	5	G3	MS
Procambarus hayi (Faxon)	Straightedge Crayfish	CS		G5	AL, MS, TN
Procambarus hinei (Ortmann)	Marsh Crayfish	CS		G5	LA, TX

Procambarus hirsutus Hobbs	Shaggy Crayfish	CS		G4	SC
Procambarus horsti Hobbs and Means	Big Blue Springs Cave Crayfish	E	1, 5	G2	FL
Procambarus howellae Hobbs	Ornate Crayfish	CS		G5	GA
Procambarus hubbelli (Hobbs)	Jackknife Crayfish	CS		G4	AL, FL
Procambarus hybus Hobbs and Walton	Smoothnose Crayfish	CS		G5	AL, MS
Procambarus incilis Penn	Cut Crayfish	CS		G4	TX
Procambarus jaculus Hobbs and Walton	Javelin Crayfish	CS		G4	LA, MS
Procambarus kensleyi Hobbs	Free State Chimney Crawfish	CS		G4	LA, TX
Procambarus kilbyi (Hobbs)	Hatchet Crayfish	CS		G4	FL
Procambarus lagniappe Black	Lagniappe Crayfish	T	5	G2	AL, MS
Procambarus latipleurum Hobbs	Wingtail Crayfish	V	5	G2	FL
Procambarus lecontei (Hagen)	Mobile Crayfish	V	5	G3,G4	AL, MS
Procambarus leitheuseri Franz and Hobbs	Coastal Lowland Cave Crayfish	E	1, 5	G1	FL
Procambarus leonensis Hobbs	Blacknose Crayfish	CS		G1,G2	FL
Procambarus lepidodactylus Hobbs	Pee Dee Lotic Crayfish	†CS		G4	SC
Procambarus lewisi Hobbs and Walton	Spur Crayfish	V	5	G4	AL
Procambarus liberorum Fitzpatrick	Osage Burrowing Crayfish	CS		G4	AR, OK
Procambarus litosternum Hobbs	Blackwater Crayfish	CS		G4	GA
Procambarus lophotus Hobbs and Walton	Mane Crayfish	CS		G5	AL, GA, TN
Procambarus lucifugus alachua (Hobbs)	Alachua Light Fleeing Cave Crayfish	T	1, 5	G2,G3	FL
Procambarus lucifugus lucifugus (Hobbs)	Florida Cave Crayfish	E	1, 5	G1	FL
Procambarus lunzi (Hobbs)	Hummock Crayfish	CS		G4	GA, SC
Procambarus lylei Fitzpatrick and Hobbs	Shutispear Crayfish	V	5	G2	MS
Procambarus machardyi Walls	Caddo Chimney Crawfish	E	5	G1,G2	LA
Procambarus mancus Hobbs and Walton	Lame Crayfish	CS		G4	MS
Procambarus marthae Hobbs	Crisscross Crayfish	V	5	G3	AL
Procambarus medialis Hobbs	Pamlico Crayfish	V	5	G2	NC
Procambarus milleri Hobbs	Miami Cave Crayfish	E	1, 5	G1	FL
Procambarus morrisi Hobbs and Franz	Putnam County Cave Crayfish	E	1, 5	G1	FL
Procambarus natchitochae Penn	Red River Crayfish	CS		G5	AR, LA, TX
Procambarus nechesae Hobbs	Neches Crayfish	T	5	G2	TX
Procambarus nigrocinctus Hobbs	Blackbelted Crayfish	E	5	G1,G2	TX
Procambarus nueces Hobbs and Hobbs	Nueces Crayfish	E	5	G1	TX
Procambarus okaloosae Hobbs	Okaloosa Crayfish	CS		G4	AL, FL
Procambarus orcinus Hobbs and Means	Woodville Karst Cave Crayfish	T	1, 5	G3	FL
Procambarus ouachitae Penn	Ouachita River Crayfish	CS		G5	AR, MS
Procambarus paeninsulanus (Faxon)	Peninsula Crayfish	CS		G5	AL, FL, GA
Procambarus pallidus (Hobbs)	Pallid Cave Crayfish	V	1, 5	G3,G4	FL
Procambarus parasimulans Hobbs and Robison	Bismark Burrowing Crayfish	CS		G4	AR
Procambarus pearsei (Creaser)	Carolina Sandhills Crayfish	CS		G4	NC, SC
Procambarus pecki Hobbs	Phantom Cave Crayfish	E	5	G1,G2	AL
Procambarus penni Hobbs	Pearl Blackwater Crayfish	V	5	G3	LA, MS
Procambarus petersi Hobbs	Ogeechee Crayfish	V	5	G3	GA
Procambarus pictus (Hobbs)	Black Creek Crayfish	T	1, 5	G2	FL
Procambarus planirostris Penn	Flatnose Crayfish	CS		G4	LA, MS
Procambarus plumimanus Hobbs and Walton	Croatan Crayfish	CS		G4	NC
Procambarus pogum Fitzpatrick	Bearded Red Crayfish	E	5	G1	MS
Procambarus pubescens (Faxon)	Brushnose Crayfish	CS		G4,G5	GA, SC
Procambarus pubischelae deficiens Hobbs	Hookless Crayfish	CS		G5	GA
Procambarus pubischelae pubischelae Hobbs	Brushpalm Crayfish	CS		G5	FL, GA
Procambarus pycnogonopodus Hobbs	Stud Crayfish	CS		G4,G5	FL
Procambarus pygmaeus Hobbs	Christmas Tree Crayfish	CS		G4	FL, GA
Procambarus raneyi Hobbs	Disjunct Crayfish	CS		G4	GA, SC
Procambarus rathbunae (Hobbs)	Combclaw Crayfish	T	5	G2	FL
Procambarus regalis Hobbs and Robison	Regal Burrowing Crayfish	V	5	G2,G3	AR
Procambarus reimeri Hobbs	Irons Fork Burrowing Crayfish	E	1, 5	G1	AR
Procambarus rogersi campestris Hobbs	Field Crayfish	V	1, 5	G3	FL
Procambarus rogersi expletus Hobbs and Hart	Perfect Crayfish	E	5	G1	FL
Procambarus rogersi ochlocknensis Hobbs	Ochlockonee Crayfish	V	5	G3	FL
Procambarus rogersi rogersi (Hobbs)	Seepage Crayfish	E	5	G1,G2	FL
Procambarus seminolae Hobbs	Seminole Crayfish	CS		G5	FL, GA
Procambarus shermani Hobbs	Gulf Crayfish	CS		G4	AL, FL, LA, MS
Procambarus simulans (Faxon)	Southern Plains Crayfish	CS		G5	AR, CO, KS, LA, NM, OK, TX
Procambarus spiculifer (Le Conte)	White Tubercled Crayfish	†CS		G5	AL, FL, GA, SC, TN
Procambarus steigmani Hobbs	Parkhill Prairie Crayfish	E	5	G1,G2	TX
Procambarus suttkusi Hobbs	Choctawhatchee Crayfish	V	5	G3,G4	AL, FL
Procambarus talpoides Hobbs	Mole Crayfish	CS		G5	FL, GA
Procambarus tenuis Hobbs	Ouachita Mountain Crayfish	V	5	G3	AR, OK
Procambarus texanus Hobbs	Bastrop Crayfish	E	5	G1	TX
Procambarus troglodytes (Le Conte)	Eastern Red Swamp Crawfish	CS		G5	GA, SC
Procambarus truculentus Hobbs	Bog Crayfish	CS		G4	GA
Procambarus tulanei Penn	Giant Bearded Crayfish	CS		G5	AR, LA
Procambarus verrucosus Hobbs	Grainy Crayfish	CS		G4	AL, GA
Procambarus versutus (Hagen)	Sly Crayfish	CS		G5	AL, FL, GA
Procambarus viaeviridis (Faxon)	Vernal Crayfish	CS		G5	AL, AR, IL, KY, LA, MS, MO, TN
Procambarus vioscai paynei Fitzpatrick	Payne's Creek Crayfish	CS		G4	AL, MS, TN
Procambarus vioscai vioscai Penn	Percy's Creek Crayfish	CS		G5	AR, LA
Procambarus youngi Hobbs	Florida Longbeak Crayfish	T	5	G2	FL
Procambarus zonangulus Hobbs and Hobbs	Southern White River Crawfish	CS		G5	AL, LA, (MD), MS, TX, (VA)
Troglocambarus maclanei Hobbs	Spider Cave Crayfish	V	5	G3,G4	FL

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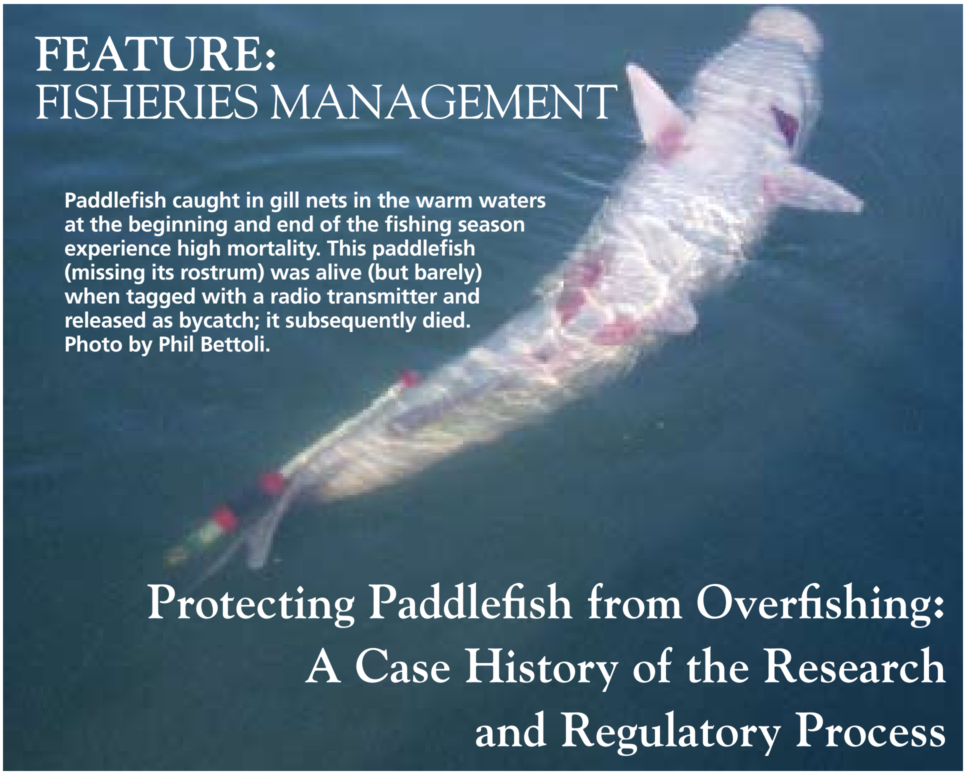

FEATURE:
FISHERIES MANAGEMENT

Paddlefish caught in gill nets in the warm waters at the beginning and end of the fishing season experience high mortality. This paddlefish (missing its rostrum) was alive (but barely) when tagged with a radio transmitter and released as bycatch; it subsequently died. Photo by Phil Bettoli.

Protecting Paddlefish from Overfishing: A Case History of the Research and Regulatory Process

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ABSTRACT: A commercial fishery for paddlefish (*Polyodon spathula*) in the Tennessee River was largely unregulated through the 1990s. Beginning in 2002, attention devoted to the plight of caviar-yielding species around the world resulted in much more scrutiny of the Tennessee paddlefish industry. This article describes the stock assessment of a paddlefish stock and the approach taken to present research findings to state and federal regulators and a skeptical fishing community. The end result for the fishery, and lessons learned from a series of public, facilitated, and state commission meetings are discussed. The need to compromise with the fishing industry meant that not all of the measures proposed to protect the fishery from overfishing were enacted; however, the fishery entered the 2006–2007 season with more regulations in place than ever before and with a promise by the regulatory commission that more restrictive regulations will be imposed in the future if warranted.

Protegiendo al "pez espátula" de la sobrepesca: historia de la investigación y el proceso regulatorio

RESUMEN: La pesca comercial del "pez espátula" (*Polyodon spathula*) en el Río Tennessee se mantuvo sin regulación durante la década de 1990. A principios de 2002, la atención dedicada a las especies productoras de caviar a nivel mundial dio como resultado un mayor escrutinio de la industria del "pez espátula" en Tennessee. En este artículo se describe la evaluación pesquera de una población de "pez espátula" y el enfoque adoptado para presentar los resultados de la investigación a las agencias estatales y federales de regulación y a la escéptica comunidad pesquera. También se discute el resultado final para la pesquería, las lecciones aprendidas por diferentes tipos de público y las reuniones de las comisiones estatales. La necesidad de compromiso con la industria pesquera significa que no se han puesto en marcha todas las medidas propuestas para evitar la sobrepesca; sin embargo, la pesquería comenzó la temporada 2006–2007 con más regulaciones que nunca antes y con la promesa de la comisión reguladora de que en el futuro se impondrá un control más estricto.

When the Convention on International Trade in Endangered and Imperiled Species of Flora and Fauna (CITES) designated paddlefish (*Polyodon spathula*) an Appendix II species in 1992, export of their caviar fell under the regulatory authority of the U.S. Fish and Wildlife Service's (FWS) Division of Management Authority (DMA). Although trade in products of any animal designated an Appendix II species is allowed under international law, CITES requires that the relevant management authority ensure that "trade will not imperil the survival of the species in the wild." In other words, the DMA is authorized to grant export permits to paddlefish caviar wholesalers and retailers if state fisheries personnel demonstrate to the DMA that the stocks within their state boundaries are healthy enough to withstand commercial fishing.

For at least a decade, DMA personnel were concerned over the number of export permits requested by purveyors of Tennessee paddlefish caviar. Tennessee was one of seven states that still allowed commercial harvest of paddlefish for their roe and Tennessee often led the nation in the amount of paddlefish caviar exported (Marie Maltese; DMA; pers. comm.); more than 17,000 kg of wild-caught paddlefish roe were exported from the United States between 2001 and 2005 (DMA 2006). Additionally, the successful prosecution in 2002 of three Tennessee wholesalers for violations of the Lacey Act, in which more than 3,500 kg of illegally obtained paddlefish roe were seized, revealed a flourishing illegal trade in paddlefish caviar. In Tennessee, most paddlefish are harvested from Kentucky Lake, Tennessee-Kentucky, a 65,000-hectare reservoir on the lower Tennessee River; therefore, the DMA was particularly interested in any stock assessments of the Kentucky Lake population.

When national attention began to focus on the Kentucky Lake fishery early in this century, little was known about the status of paddlefish in the Tennessee River. University researchers had assessed the age structure, size structure, and commercial exploitation of paddlefish in Kentucky Lake in the 1980s and early 1990s (Hoffnagle and Timmons 1989; Timmons and Hughbanks 2000), but no fishery independent data were collected in those studies, and little information existed other than numbers of fish harvested in the years between 1999 and 2003. In the absence of stock assessment data, the DMA is supposed to deny export permits, and some permits from Tennessee were denied in recent years (Marie Maltese; DMA; pers. comm.). It was clear to regulatory parties (i.e., DMA, Tennessee Wildlife Resources Agency [TWRA]) in 2001 that a stock assessment should be conducted at the earliest opportunity.

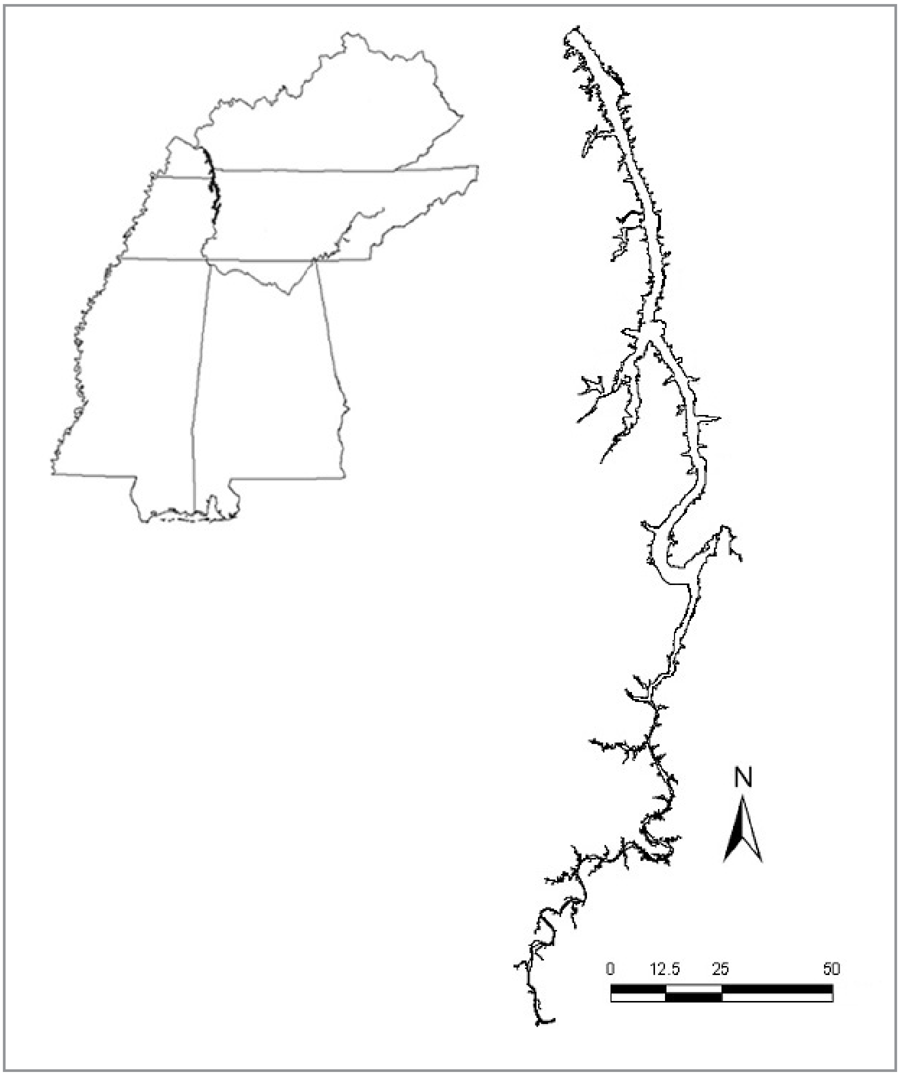
This article summarizes our stock assessment activities and the strategies we employed to convey our recommendations to the fishing industry, TWRA biologists, and the governing board of the TWRA, the Tennessee Wildlife Resources Commission (TWRC). We discuss what regulations were and were not enacted by the TWRC, and how a compromise was eventually reached to balance the state's mandate to conserve fisheries resources with the legitimate economic interests of private businesses. Finally, we discuss what the future might hold for Tennessee paddlefish in light of recent harvest trends.

STUDY AREA AND THE COMMERCIAL FISHERY

Kentucky Lake is the last impoundment on the Tennessee River before its confluence with the Ohio River (Figure 1). The lacustrine, downlake reach of the reservoir provides excellent habitat for paddlefish; whereas, the narrow, riverine headwaters serve as ideal fishing grounds for commercial fishers deploying gill nets during the winter and spring spawning migrations.

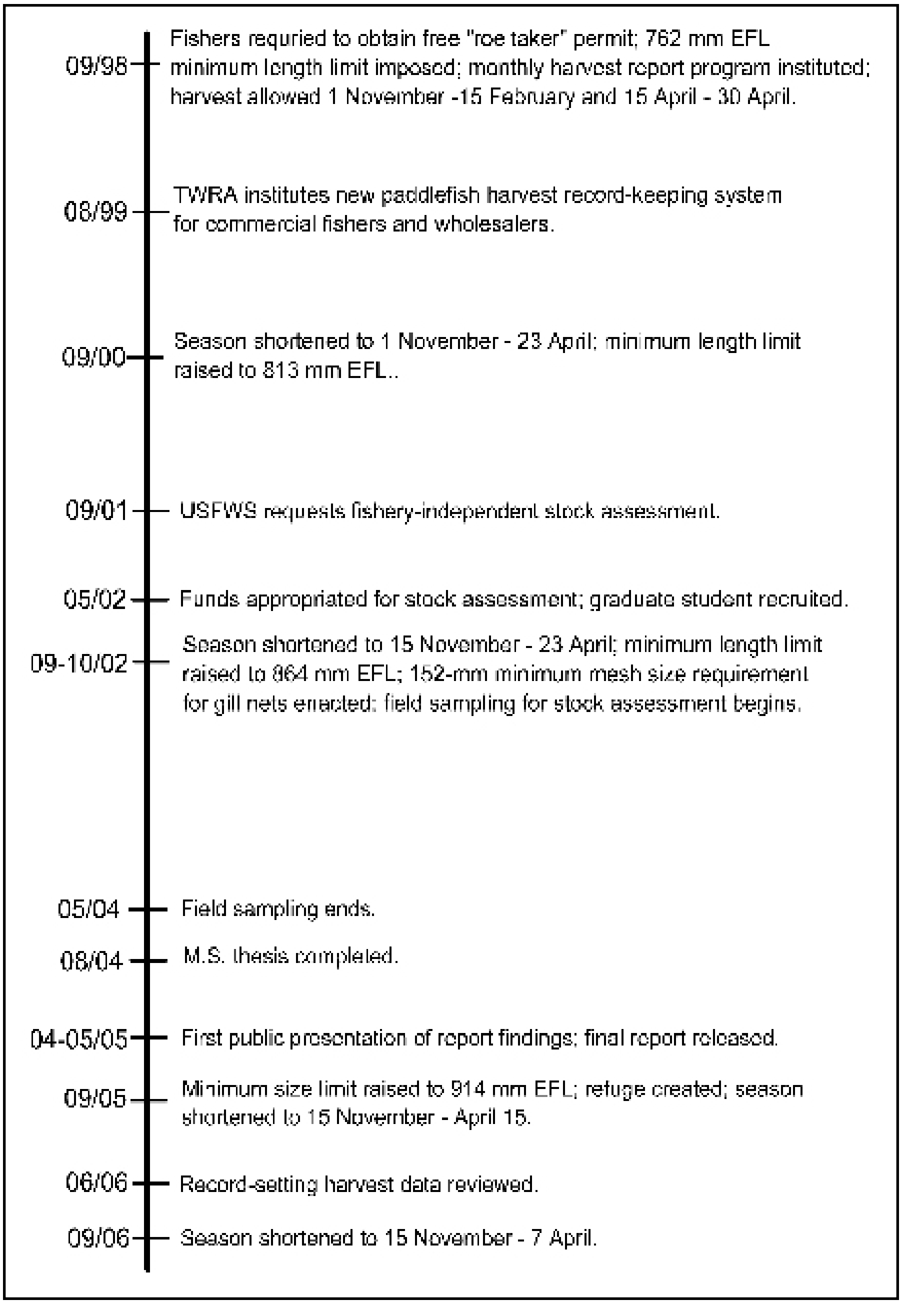
Before 2002, fishers harvesting paddlefish were required to possess a commercial fishing license (US$125) and a free paddlefish permit. The season ran from 1 November through 23 April and there were no quotas or other harvest restrictions other than a 813-mm eye-fork-length (EFL) minimum length

Figure 1. Kentucky Lake, a mainstream impoundment on the lower Tennessee River, is where most of the paddlefish harvested in Tennessee originate.



When river conditions are right, paddlefish are easily harvested in the Tennessee River, as demonstrated by Patsy Cornelius and Deb Blackwelder. Photo by Cory Goldsworthy.

Figure 2. Timeline of key events in the regulation of the paddlefish fishery in Kentucky Lake.



limit. During drought conditions in 1999 and 2000, the reported harvest from Kentucky Lake exceeded 10,000 paddlefish each year (compared to about 4,500 fish in years with high rainfall). Amid growing concerns that the stock in Kentucky Lake was being overfished, the commercial season in 2002 started two weeks later, fishers were required to use nets with at least 152-mm bar measure netting, and the minimum length limit was increased to 864-mm EFL. Despite these more restrictive regulations, federal authorities at the DMA requested more information on the exploited paddlefish stock in Kentucky Lake and a fishery independent assessment began in the fall of 2002 (Figure 2).

FISHERY ASSESSMENT

Research objectives, field sampling methods, and data analyses were presented by Scholten and Bettoli (2005) and Bettoli and Scholten (2006) and will not be repeated in detail here. In short, random samples of paddlefish in Kentucky Lake were collected with experimental gillnets before and after the commercial fishing season in two consecutive years. We also accompanied commercial fishers to sample their catch for additional ovary and dentary bone samples and record data on bycatch rates and initial mortality.

It was only after we established working relationships with several fishers concerned about overfishing that we tapped into their "Traditional Ecological Knowledge" (Price and Rulifson 2004). Under their tutelage, we fabricated new gear and altered where and how we fished our experimental gill nets. Most importantly, we learned that commercial fishing activity was linked to the amount of water discharged from Pickwick Dam. Commercial fishers avoid setting their nets at high flows (e.g., ~ 850 m^3/sec or more) because the nets catch too much debris and are damaged, the nets do not fish properly, or for both reasons.

By the spring of 2004 we were able to collect or observe enough paddlefish (n = 1,615) to meet our primary project objectives, which were (1) mathematically assess whether the population was experiencing recruitment or growth overfishing, and (2) determine whether the new harvest regulations were sufficient to protect the population from both forms of overfishing. Our findings were presented in a M.S. thesis in August 2004 (Scholten 2004) and in a final report submitted to the DMA in May 2005. Given the likelihood that our results would be scrutinized by a skeptical commercial fishing community, we delayed submitting our final report and posting it on the Internet until our key findings had been subjected to the peer-review process. Scholten and Bettoli (2005) concluded (1) the population was experiencing growth overfishing (i.e., the average size of harvested fish was less than the size that would maximize yield-per-recruit), and (2) severe recruitment overfishing (i.e., the adult stock is overfished to the point that it does not have the reproductive capacity to replenish itself) would occur whenever weather conditions (i.e., dry winters) allowed heavy fishing activity. These findings were not unexpected because species that can be harvested at a young age, but mature at an old age (which is true for paddlefish), are vulnerable to overfishing (Myers and Mertz 1998). The final report and subsequent publications (Bettoli and Scholten 2006; Scholten and Bettoli 2007) noted that for every mature (i.e., egg-laden) female paddlefish that was harvested, about 12 immature females and male paddlefish were captured by gill nets. More importantly, paddlefish bycatch (i.e., males and juvenile females; regulatory discards) suffered high rates of mortality at warm water temperatures (≥ 15 °C) at the end of the fishing season. Additionally, the hobbled gill nets used in this fishery did not exhibit size selectivity; thus, increasing the minimum mesh size regulation in 2002 to 152-mm did not reduce bycatch of juvenile paddlefish.

PUBLIC MEETINGS AND THE DECISION-MAKING PROCESS

The problem of overfishing—and how to fix it—was not a "messy problem" (McCool and Guthrie 2001) because (1) there was general agreement in the scientific community about the validity of the scientific data, and (2) the goal for the fishery (i.e., manage the stock for sustained roe harvest) was understood by all. The problem was going to be convincing fishers to participate in solving the problem. To that end, TWRA administrators sought public involvement in the decision-making process via the consultative group approach described by Vroom and Yetton (1973), as adapted by McMullin (1996). Informational presentations would be made at open public meetings to heterogenous audiences and questions and comments would be solicited. A more structured advisory meeting would follow and its agenda would be established by comments received from the open public meetings. The process loosely resembled "Fishbowl Planning" as discussed by McMullin (1996) because it was an iterative process of seeking inputs from stakeholders, redefining and communicating management goals and objectives, then seeking additional inputs from the public to produce a management plan that would be widely supported.

A schedule was drawn up for meetings at which the final report findings and recommendations would be presented to TWRA biologists and stakeholders (i.e., fishers, processors, caviar retailers, and politicians). The key recommendations that appeared in the final report to the USFWS (and TWRA) were to:

1. Immediately raise the length limit from 864 to 965-mm EFL;
2. Ban the use of monofilament gill nets (because they were shown to be more lethal to paddlefish released as bycatch than multifilament nets);
3. Establish a "no fishing" refuge in Kentucky Lake's largest embayment (because it was habitat used by immature fish, not mature fish, during the fishing season); and
4. End the season 16 days sooner in the spring (to avoid warm water temperatures and high bycatch mortality rates).

The first official PowerPoint presentation of project findings and recommendations was given to senior TWRA administrators at their headquarters in April 2005; the talk was not open to the public. Each PowerPoint presentation started off with a brief discussion of the two biggest threats to marine fisheries identified by high-profile commission reports (Pew Oceans Commission 2003; U.S. Commission on Ocean Policy 2005); namely, overfishing and bycatch. Problems in marine fisheries management were presented to make the point that the issues surrounding paddlefish exploitation and management were not unique. That "Director's Meeting" talk was followed two weeks later by a similar presentation to the commissioners of the TWRC, which was open to the public.

The final report of the stock assessment was posted on the Internet in early May 2005 (www.tntech.edu/fish/PDF/Paddlefish.pdf) and a presentation was made to a meeting of TWRA biologists in mid-May 2005. The biologists were not necessarily aware of the findings presented in the two earlier talks; thus, this talk gave them the opportunity to comment.

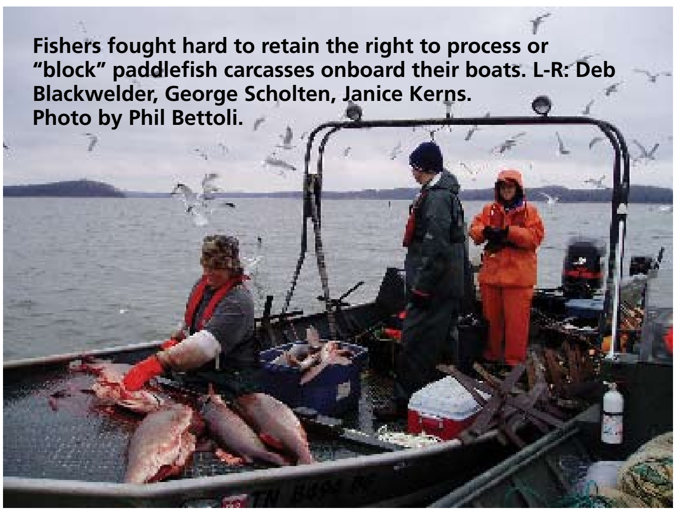
Public meetings targeting commercial fishers were presented in three Tennessee cities in late June 2005. Each meeting was hosted by the chief of fisheries for TWRA (WCR) and was attended by TWRA regional managers and biologists. Only seven commercial fishers, as well as a lawyer, stenographer, and videographer hired by a commercial fisherman, attended the first meeting in a pavilion on the banks of the Tennessee River in Chattanooga, about 400 km upstream of Kentucky Lake. Most of the local fishers in attendance targeted other commercial fish species besides paddlefish (e.g., Ictaluridae, *Ictiobus* spp.). After the presentation, commercial fishers took the opportunity to voice their anger over TWRA policies relating to commercial fishing and sport fishing. Most comments relating to paddlefish management revolved around opening up new waters to paddlefish harvest.

The next public meeting was held the following night in a west Tennessee city (Jackson) that was much closer to Kentucky Lake and most Tennessee roe buyers. Approximately 30 commercial fishers were in attendance, as well as two elected representatives from the Tennessee State House, several TWRC commissioners, and uniformed wildlife officers. The questions that followed the presentation left little doubt that no common understanding of the problem or potential solutions would be achieved that night. Questions covered a wide range of topics only distantly related to the issue of what steps should be taken to reduce overfishing and ensure the sustainability of the resource. Audience participation was largely limited to a handful of charismatic speakers, which is not uncommon at large public meetings.

The final meeting in the series was held three days later in Nashville. Only four commercial fishers attended and the most meaningful dialogue between biologists and fishers occurred at that meeting. Two fishers noted that the paddlefish they exploited in the Mississippi River matured at a smaller size than those in the Tennessee River. One fisher pointed out that a ban on monofilament netting would be unnecessary if fishing was restricted to the coldest months, when the lethality of the two types of net did not differ (according to Bettoli and Scholten 2006).

After three public meetings in five days, we learned that (1) opposition to all recommendations was strong and organized, (2) the possibility of important biological differences among paddlefish stocks should be considered when proposing new regulations, and (3) open public meetings are not conducive to problem solving. We also noted that fewer than 35% of the holders of free paddlefish permits attended any of the meetings.

The public meetings were followed by a TWRC meeting in late July 2005 at which the third author (as chief of fisheries) responded to an earlier request to open up more waters to commercial harvest of rough fish and paddlefish; proposed new paddlefish regulations were also unveiled. At least 23 commercial fishers



Fishers fought hard to retain the right to process or "block" paddlefish carcasses onboard their boats. L-R: Deb Blackwelder, George Scholten, Janice Kerns. Photo by Phil Bettoli.

were present, as well as representatives from various sport fishing and conservation groups. One common theme among proponents of opening up new waters was that removing rough fish is good for sport fish. Opponents opined that (1) the interests and economic impact of sport anglers in those reservoirs dwarfed the benefits that might be accrued by a handful of commercial fishers, and (2) those waters were too crowded with recreational boaters to permit widespread deployment of gill nets. The commissioners subsequently opted to keep the commercial fishing ban in effect in the upper Tennessee River and not open additional waters.

Following the July 2005 TWRC meeting, all (n = 112) fishers holding a free paddlefish permit were invited to attend a facilitated meeting in Nashville in August 2005. (Note: Beginning in March 2006, paddlefish and sturgeon permits previously issued by TWRA at no charge were replaced with a roe fish permit costing US$1,000 and the fee for a commercial fishing license was increased from US$125 to US$200; fishers were required to purchase a roe fish permit and commercial fishing license if they wanted to harvest paddlefish or shovelnose sturgeon *Scaphirhynchus platyrhynchus*.). Forty-two fishers attended and they were instructed (in their invitation letters) to choose seven of their peers to represent their views. The purpose of the meeting was to obtain the opinions of fishers on the proposed regulation changes (Table 1), but in a more structured environment than the open public meetings. The panel was seated and the facilitator (the personnel director of the TWRA) explained the rules of the meeting. Fishers not on the panel would not be allowed to speak until the panel addressed each regulation.

Despite the best efforts of the facilitator, panelists did not limit their comments to each regulation as each was considered. When the "no fishing refuge" recommendation was presented for discussion, few comments were directed at the idea of a refuge itself. Most fishers eventually agreed that it would not be a burden. After about an hour, the panel agreed to consider the next regulation.

Limited entry was not recommended in the final report but the TWRA included that option in their list of recommendations. That is, TWRA would be willing to limit the number of new roe fish permit holders to some percentage above the number that purchased this new permit before the end of the 2005–2006 fishing season. The panel was unanimously in favor of limited entry, which clearly benefited them and their colleagues.

The discussion on shortening the season was brief. TWRA staff indicated at the July 2005 TWRC meeting that they wanted to close the season on 31 March. The final report recommended moving the end of the season from 23 April to 7 April. A comment to "split the difference" between 7 April and 23 April (i.e., April 15) was met with approval by the full panel of seven commercial fishers. The brevity of their comments was surprising, considering how important season length was to their ability to make a living.

The ban on monofilament netting met with opposition from some fishers, particularly those fishing the Mississippi River. Many fishers prefer monofilament netting because it snags less debris (e.g., filamentous algae and other detritus) and shakes clean easier than multifilament netting.

The subsequent recommendation that fishers be prohibited from "blocking" paddlefish onboard their boats met with strong opposition. Removing the head, tail, and fins was commonplace, but this made the use of a minimum length limit (the next item up on the agenda) problematic. In the past, a fisher could keep an intact paddlefish longer than the minimum EFL limit, or a blocked carcass longer than a length calculated by TWRA officials to represent the minimum EFL length limit. For instance, when the minimum length limit was 864-mm (34") EFL, the blocked carcass had to be at least 635-mm (25") long. Allowing fishers to use either approach had long troubled TWRA enforcement officers because of the potential of fish being blocked in such a way as to make an illegal fish legal.

The discussion concerning blocking fish was followed by strong opposition to increasing the length limit from 864-mm EFL to 965-mm EFL over four years, with the option of going to a 1,016-mm EFL limit if the population did not show signs of recovering from overfishing. The panel generally agreed that a 914-mm length limit could be tolerated, but a 965-mm length limit would hurt business too much; raising the minimum size to over 1,000-mm EFL was totally unacceptable. The floor was subsequently open to comments from all fishers in attendance. Most comments revisited topics that had earlier been taken off the table (e.g., opening new waters to commercial paddlefish harvest; stocking fingerlings to mitigate for overfishing).

A regularly scheduled TWRC meeting in Knoxville in September 2005 followed the August 2005 "invitation only" facilitated meeting. This was the "Proclamation Meeting" at which new paddlefish regulations would be voted on by the commission. As chief of fisheries, the third author listed each proposed regulation change that the TWRA fisheries staff had crafted after considering three months of public meetings and comments; the audience was then allowed to speak to each proposed change. The TWRC received few complaints from the audience when they voted to establish the proposed refuge. In fact, when one commissioner questioned whether a refuge was necessary, a commercial fisher spoke up and defended the concept of a refuge.

The stepwise increase in the length limit (immediately raise the length limit from 864 to 914-mm EFL, then raise it to 965-mm EFL over a three-year period) was not debated on its merits by four fishers who opposed that change. For instance, the oft-repeated claim came up again that the researchers did not know what they were doing until they (the commercial fishers) helped them (the researchers) catch fish. The TWRC was not swayed by those arguments against the mini-

Table 1. Potential regulations presented for discussion by a Tennessee Wildlife Resources Agency facilitator to a panel of seven representatives of the commercial paddlefish fishing industry at a facilitated meeting in Nashville, Tennessee, August 2005. Another 35 fishers were in attendance.

Regulation	Rationale/justification
Establish a no-fishing refuge	Reduce bycatch rates and mortality by reducing encounters between juvenile paddlefish and gillnets.
Limited Entry	Prevent the number of fishers targeting paddlefish from increasing with ever-increasing roe prices.
Shorten Season	Reduce harvest and prevent fishing when high water temperatures will cause high bycatch mortality.
Ban monofilament nets	Reduce bycatch mortality.
Prohibit the blocking[1] of carcasses onboard	Improve the ability to enforce minimum length regulations.
Increase the minimum length limit	Reduce growth overfishing and eliminate concerns over recruitment overfishing.

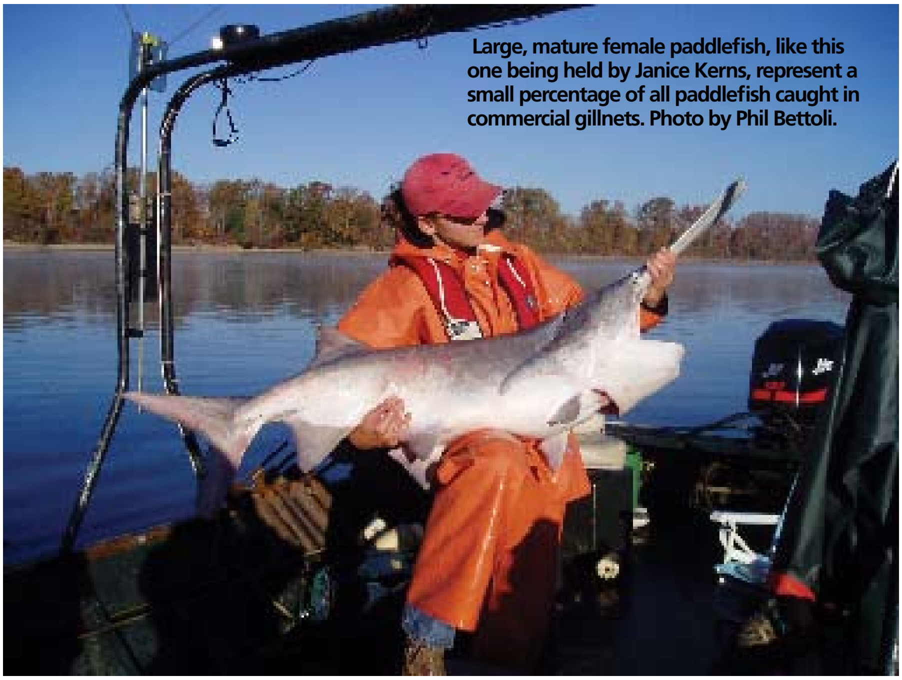
[1] Removing the head, tail, fins, and viscera to facilitate storage and chilling of the carcass.

mum length limit increases and that regulation change was subsequently enacted.

The proposal to shorten the season and end it on 31 March was met with comments from fishers that the commission should not confuse academic research with reality and that shortening the season and raising the length limit at the same time would hurt their businesses too much. The TWRC agreed with the latter assertion and amended the proclamation to end the season on 15 April. TWRA staff biologists were confident that the TWRC would approve the 31 March closure; thus, they did not propose a monofilament ban. Upon learning that the season would end two weeks later than proposed, an attempt was made to convince the commissioners that a later closure date should be accompanied by a monofilament ban, but that request was denied.

The regulation to ban blocking of carcasses was opposed, as expected, by the fishing industry and several fishers spoke forcefully to the issue. Several TWRA staff countered that sport anglers are not allowed to process their catch onboard and commercial fishers should not be treated any differently. The TWRC was unconvinced by that argument and voted to allow fishers to block their catch. The final recommendation (limited entry) met with no opposition and the TWRC voted to limit the number of roe fish permits that would be issued during future seasons to 115% of permit sales during the 2005–2006 license year.

In summary, the TWRC enacted two regulations (establish a refuge and limit the number of roe fish permits) that would help keep fishing pressure from rising higher than the Kentucky Lake stock was currently experiencing. However, those two regulations would do little to reverse the trend of declining size- and age-structure of the population. The new minimum length limit regulation that passed was intended to increase the average age and size of fish in the population, and reduce the likelihood of growth and recruitment overfishing. The higher minimum length limits also satisfied the desire to allow at least some female paddlefish to spawn at least once before they were vulnerable to harvest, a common theme in marine fisheries management plans (Myers and Mertz 1998). However, the efficacy of the higher minimum length limit regulation was in question because (1) already high bycatch rates would climb under the higher length limit, and (2) shortening the season by only eight days (and not banning monofilament netting) might not reduce bycatch mortality to acceptably low rates.



Large, mature female paddlefish, like this one being held by Janice Kerns, represent a small percentage of all paddlefish caught in commercial gillnets. Photo by Phil Bettoli.

With these new regulations in place (refuge area, cap on permits, higher minimum length limit, slightly shorter season), the 2005–2006 commercial season commenced. When fishery harvest data were tallied after the season ended in April 2006, it was clear that the 2005–2006 season was exceptional. Rainfall and river flows were modest, fishers had ample opportunity to deploy their gear, and the reported statewide harvest of egg-bearing paddlefish (n = 7,277 fish) and the egg harvest (12,827 kg) were the highest ever recorded by TWRA. Coupled with an increase in prices that fishers were getting for paddlefish eggs (approaching US$200/kg), such high harvests prompted TWRA to redouble their efforts to shorten the season to their original target of 31 March.

Another facilitated meeting was held in June 2006 to present the previous season's harvest data and discuss possible regulation changes; in particular, shortening the season from 15 April to 31 March. As before, the fishing industry chose seven representatives to represent its interests. Fishers were adamant in not wanting to shorten the season any further for the same reasons voiced at earlier meetings. The fishers themselves put forth several proposals, most notably to cease fishing when a certain temperature was reached and to ban the use of monofilament netting after 31 March. These two recommendations were an acknowledgment by fishers that bycatch mortality is problematic when waters are warm and that monofilament netting is more injurious than multifilament netting. These recommendations were proposed to forestall what the fishers probably suspected was inevitable: shortening the season yet again to further reduce harvest.

The TWRA representatives responded by stating (1) closing the season when a certain temperature is reached might have some merit, and (2) the possibility of a monofilament ban was taken off the table last year and should not be brought up again at this time. When asked to rank the various management options discussed at this meeting, the fishers ranked "No change" (which was not an option) as number 1, followed by ending the season when a specific temperature was reached, and closing the fishery each year on 7 April (8 days sooner). After a heated debate, a consensus was reached among the fishers that closing the season on 7 April was acceptable. That consensus was reached after one fisher noted that the TWRC would view them very unfavorably if they failed to act responsibly and agree to do something to reduce what many agreed (either privately or publicly) was an unsustainable harvest.

At the regularly scheduled TWRC monthly meeting in September 2006, the commissioners saw one more PowerPoint presentation. The high harvest numbers from the previous season were discussed and it was recommended (again) that the paddlefish season should end on 31 March each year. It was also proposed that the number of roe fish permits should be limited to 80 each year (this was 115% of 2005–2006 permit sales). The 16+ commercial fishers in the audience argued many points, in particular that they had already given up enough and that they couldn't and shouldn't be asked to give up any more. The full commission subsequently compromised and proclaimed that the season would end on 7 April each year, one week later than TWRA biologists proposed, but eight days sooner than the fishers might have hoped. Additionally, everyone agreed that no new paddlefish regulations would be proposed (except for the Mississippi River paddlefish fishery where possible regulation changes were still being discussed with border states) until after the 2009–2010 fishing season and the effects of the new regulations were evaluated.

LESSONS LEARNED

Initial discouragement following several of the open public meetings turned out to be unjustified. Although two of three public meetings were unproductive in terms of having a meaningful dialogue, they allowed us to gather the information needed to subsequently host more productive, facilitated meetings. Secondly, we suspect that forgoing the open public meetings and moving right to a facilitated meeting would have been a mistake: many fishers were angry that their industry was being closely scrutinized and they wanted to make their feelings publicly known. Thus, the open meetings were a perfect forum for publicly voicing opposition to the government (in general) and fisheries scientists (in particular). Of course, managers should not think that simply hosting a few boisterous public meetings and letting stakeholders vent their anger or frustration will make a "messy problem" go away. The TWRA made that mistake in the 1990s when a controversy erupted over management of a trophy striped bass (*Morone saxatilis*) fishery, which pitted anglers targeting that transplanted species against anglers pursuing native species such as walleyes (*Sander vitreus*) and crappies (*Pomoxis* spp.; Churchill et al. 2002).

The fact that commercial paddlefish fishers and industry representatives were given multiple opportunities in different settings to participate in the regulatory process (Table 2) was clearly not lost on members of the TWRC. Although not all of the regulations proposed by the TWRA staff were adopted, the TWRC's actions at the September 2005 meeting collectively represented the largest steps ever taken by the TWRC to conserve the resource. Additional proposals to further restrict fishing were also entertained (and compromise versions were enacted) by the TWRC at their September 2006 meeting. Although the regulations currently in effect will probably not help rebuild the stock of paddlefish in the lower Tennessee River, the TWRC noted that stronger measures to rebuild the stock would be considered if future sampling indicates such measures are necessary.

How did the USFWS and its DMA staff react to what was (or was not) accomplished to protect paddlefish in the lower Tennessee River? The DMA was kept apprised during the regulatory process and indicated that (1) the regulations passed in September of 2005 and 2006 were positive first steps towards conserving the resource, and (2) export permits would be provided to purveyors of Tennessee paddlefish caviar (M. Maltese, DMA, pers. comm.). The DMA also indicated that future requests for export permits would not be automatically granted.

The 2005–2006 and 2006–2007 commercial paddlefish seasons in Tennessee proceeded against the backdrop of a recent ban on the importation into the United States of caviar from beluga sturgeon (*Huso huso*), followed by a CITES ban (albeit temporary) on the exportation of other sturgeon products (e.g., sevruga caviar from *Acipenser stellatus*) from Caspian Sea states. Perhaps not coincidentally, the wholesale prices for paddlefish roe in Tennessee jumped from around US$110/kg in 2004–2005 to US$143-187/kg during the 2005–2006 season; in some locales during the 2006–2007 season, fishers were receiving more than US$200/kg for paddlefish roe taken from Tennessee waters. In other words, negotiations to more tightly regulate paddlefish harvest in Tennessee occurred at a time when a single large female carrying 3.5 kg of roe was worth more than US$650 wholesale (and twice that or more at retail prices). The new Tennessee regulations, coupled with rising prices for paddlefish roe, may be contributing to increased commercial fishing activity on the Ohio River, particularly by Tennessee residents (D. Henley, Kentucky Department of Fish and Wildlife, pers. comm.). These observations serve as justification for biologists throughout the Mississippi River basin to continue to work together to monitor their respective paddlefish fisheries, and for the DMA to continue to scrutinize requests for export permits for paddlefish roe, especially if unambiguous signs of overfishing exist.

In conclusion, our approach to assessing the likelihood of overfishing, communicating research findings, and moving paddlefish management and conservation in Tennessee into the twenty-first century yielded positive results. Our approach could be summarized as (1) conduct a fishery independent stock assessment that can withstand peer-scrutiny, (2) interact with fishers and provide them with opportunities to participate in data collections, (3) carefully schedule how, when, and where research findings and management recommendations will be presented to the industry and decision makers, (4) provide ample and varied opportunities for fishers to learn about the research and participate in crafting new regulations, and (5) take what-

Table 2. List of presentations and meetings during the regulatory process with commercial paddlefish fishers, the Tennessee Wildlife Resource Agency (TWRA) staff, and the Tennessee Wildlife Resource Commission (TWRC). A PowerPoint presentation was made at every meeting except the August 2005 facilitated meeting.

Date	Audience and Type of Meeting	Objective or Action
April 2005	TWRA administrators and senior staff	Presented final report findings and recommendations.
April 2005	TWRC monthly meeting	Presented final report findings and recommendations to commissioners and the public.
June 2005	Open Public meeting	Presented final report findings and recommendations to commercial fishers in and around Chattanooga, Tennessee; solicited comments.
June 2005	Open Public meeting	Presented final report findings and recommendations to commercial fishers in and around Jackson, Tennessee; solicited comments.
une 2005	Open Public meeting	Presented final report findings and recommendations to commercial fishers in and around Nashville, Tennessee; solicited comments.
July 2005	TWRC monthly meeting	Argued against opening up new waters to paddlefish harvest; unveiled proposed new regulations.
August 2005	Facilitated meeting	Proposed new harvest regulations to commercial fishers and solicited their comments; sought consensus.
September 2005	TWRC monthly meeting	Commissioners voted on proposed new regulations.
June 2006	Facilitated meeting	Reviewed past season's harvest data and sought consensus on management actions that should be proposed to further restrict harvest.
September 2006	TWRC Monthly meeting	Commissioners voted on proposed new regulations

ever time is necessary to educate commercial fishers and decision makers on the issues.

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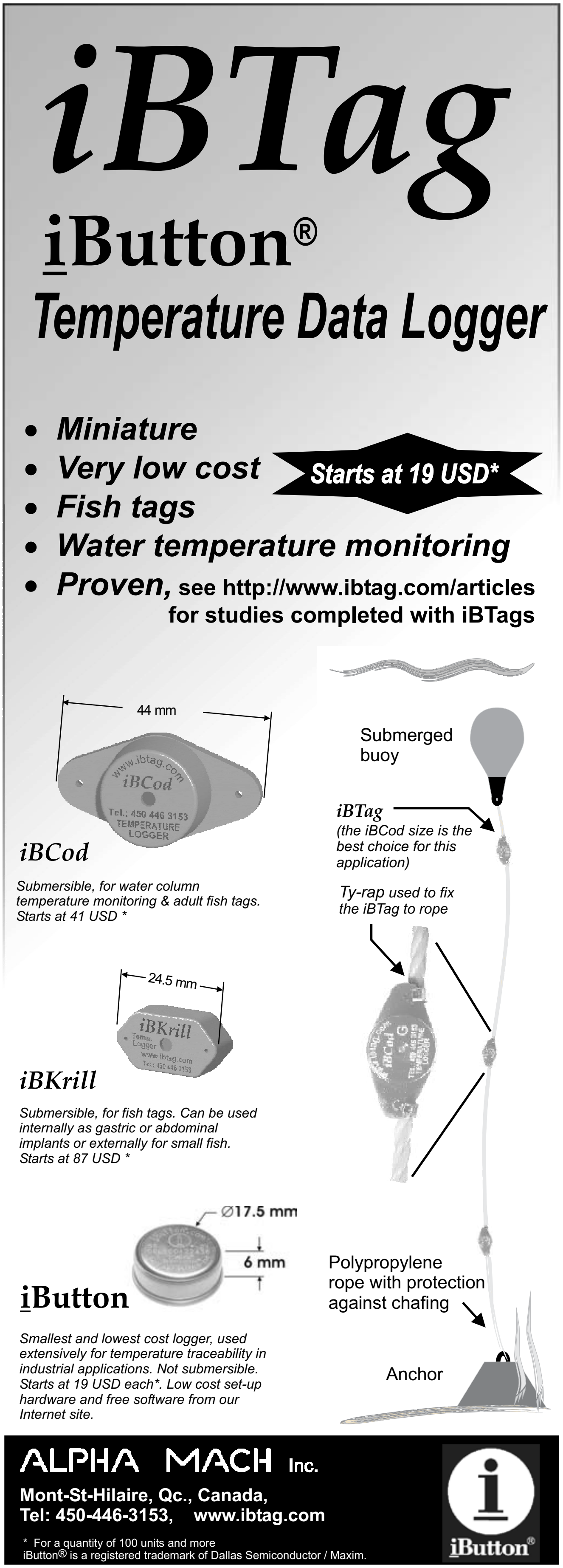

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OPINION: FARM BILL

2007 Farm Bill Advisory Committee of the American Fisheries Society

The committee is chaired by James E. Garvey, Fisheries and Illinois Aquaculture Center, Southern Illinois University, Carbondale. Garvey can be contacted at jgarvey@siu.edu.

Farm Bill 2007: Placing Fisheries Upstream of Conservation Provisions

OVERVIEW

Although policy issues likely cause most fisheries professionals to feel sleepy and move on to more enticing reading material, we hope that our colleagues will take the time to explore the implications of upcoming reauthorization of the U.S. Farm Bill. The name of the bill may imply corn and cattle; however, it is potentially the most influential aquatic conservation legislation to be considered by the U.S. federal government and requires the focused attention of all fisheries and aquaculture professionals, especially those within the United States. Below, we describe the history and inner workings of this legislation and provide a list of issues to be addressed in the 2007 version of the Farm Bill. By understanding this bill, contributing to its genesis, and fully participating in its implementation as fisheries scientists, we have the opportunity to benefit fisheries resources immensely and create an important precedent for a future technical presence in the process.

INTRODUCTION

The 2002 Farm Security and Rural Investment Act (i.e., the Farm Bill) is slated for reauthorization in 2007. This legislation is vast and complex; the amount of fiscal resources appropriated (> $1 billion annually) by the U.S. Congress to conservation (i.e., promoting the sustainable use of natural resources) within this bill is considerable and equivalent to or greater than the conservation budgets within other resource-oriented agencies (e.g., U.S. Fish and Wildlife Service). A Farm Bill has existed in some form since the Dust Bowl era when it provided funding for soil conservation and implementation of improved farming techniques. In the mid-1980s, Farm Bill provisions dramatically expanded in scope by increasing the reach of agriculture-related conservation programs. The 2002 Farm Bill was even more comprehensive, expanding incentives for practicing sound conservation and setting aside land in protected reserves.

Mention of aquatic conservation, particularly as it relates to fisheries, is scarce in the 2002 Farm Bill language. The linkages among sound agricultural and forestry practices, water quality, and aquatic habitat integrity are implied rather than explicitly stated. In recent years, the importance of land use to aquatic ecosystems, resident fishes, and other aquatic organisms has become exceedingly clear (e.g., Naiman and Turner 2000; Vanni et al. 2005; Hughes et al. 2006). Unlike identifying the effects of point-source pollutants, which can be directly quantified as water leaves the pipes, non-point sources such as those typically associated with farming, ranching, and forestry are often difficult to precisely quantify and relate to aquatic resources. However, improved geographic-based tools for assessing land use and other technological advances such as intensified computer modeling power have greatly improved our ability to link land use patterns to aquatic ecosystems and fisheries at local, regional, national, and even global scales. Given recent Internet access to free and easy-to-use geographic-information programs, it has become very easy for professionals and laypeople alike to envision the complex and far-reaching relationships between land and water: a lake, stream, or ocean is always downhill. For example, seasonal hypoxia in the Gulf of Mexico is now believed to be a consequence of the widespread use of nitrogen-based fertilizers in the Mississippi River basin (Scott et al. 2007). Loss of fishery production due to this phenomenon as well as impacts of agriculture-related activities on other aquatic systems is a major concern of fisheries professionals. Riparian disturbance, and excess nutrients and sediments are the major stressors of 25-30% of U.S. streams, with those percentages increasing in agricultural regions (Stoddard et al. 2005; USEPA 2006). The conservation programs outlined within the next Farm Bill should provide opportunities by which fisheries biologists and aquatic scientists can begin to tackle global and local problems such as stream channelization, headwater loss, and, more generally, aquatic habitat degradation.

There are indeed opportunities for fisheries professionals to influence the direction of Farm Bill programs ,as outlined previously by many authors (Pajak et al. 1994; Pajak 2000; Thomas et al. 2001). To do so in the next bill, we should explicitly outline relationships between land use (both agricultural and urban) and fisheries.

The Farm Bill is an extremely long and complicated piece of legislation. In this white paper, we will not review the bill in its entirety. Throughout the bill, provisions exist that affect fisheries, such as funding for land-grant universities where many fisheries programs reside. We limit our effort to reviewing some of the most germane programs in the previous Farm Bill that have had direct implications for fish conservation and fisheries resources. We then discuss the pros and cons of the recent U.S. Department of Agriculture (USDA) proposal for the 2007 Farm Bill as it pertains to fisheries and aquatic ecosystem condition . We close with some recommendations for the upcoming legislation and the participation of the fisheries profession in future Farm Bill-related programs.

2002 FARM BILL: A SHORT PRIMER

The 2002 Farm Bill is divided into major subsections, with the one called "Title II: Conservation and Enhancement" being most germane to fisheries. This section contains most of the major provisions for conservation, including many well-known programs such as the Wetlands Reserve Program (WRP) and Conservation Reserve Program (CRP). However, other programs not included in Title II can have indirect socioeconomic effects on fisheries. To illustrate, fluctuations in the environment and markets translate to variable economic returns in agriculture; government support is occasionally required to maintain farming as a viable economic option. Thus, Farm Bill programs can affect the balance between farming and other forms of land use (e.g., urbanization) within many regions, influencing aquatic condition, human perceptions of natural resources, and behavior of the fishing public. Fisheries science cannot afford to ignore the indirect effects of these programs on human use of the environment, aquatic resources, and fisheries.

The complex tangle of Title II programs within the expiring Farm Bill are administered by the USDA Natural Resources Conservation Service (NRCS). Most of these programs are either (1) oriented toward conservation of marginal agricultural lands by taking them out of production and compensating land owners for the loss or (2) rewarding land owners that have adopted best-management practices (BMPs) associated with farming, ranching, and forestry. The NRCS, in concert with the Cooperative State Research Education and Extension Service (CSREES), also provides extension services to local land owners to bring their properties into compliance with the most recent suite of BMPs or to develop new, innovative BMPs.

The conservation programs within the 2002 Farm Bill are broad and many are difficult to tease apart. The Environmental Quality Incentives Program (EQIP) is among one of the most important to the use of private lands and its ultimate impact on watersheds and aquatic ecosystems. This is a cost-sharing mechanism by which farmers and ranchers are rewarded for adopting BMPs on their properties. The program is voluntary and involves land owners submitting proposals and then NRCS selecting proposals through a complex, tiered process. Based on our non-scientific census of EQIPs throughout the United States and a review by Berkland and Rewa (2005), it appears the program is largely assessed though its apparent benefits to wildlife rather than fish, although fish are presumed to be a beneficiary (Gray and Teels 2006). The USDA has wide latitude in choosing how to allocate EQIP support, allowing NRCS to focus on watersheds in greatest need. The Conservation Security Program (CSP) is similar in spirit, providing fiscal incentive to farmers and ranchers for adhering to sound soil conservation practices, but it is more equitably distributed nationwide.

In contrast to EQIP and CSP, CRP and WRP provide opportunities for land to be turned over to other parties (typically a state or federal agency) for management and restoration. There is a cap on annual enrollment, and the easements are leased in a variety of ways. Use of land in CRP or WRP is restricted; putting protected land back into production incurs penalties often called "sod buster" for CRP and "swamp buster" for WRP.

Although our summary appears straightforward, this is a simplification and represents a mere tip of the iceberg, with many other programs and subprograms containing their own galaxy of associated acronyms, guidelines, and restrictions. The programs within Title II need to be streamlined and refined to better distribute incentives to the land in greatest need of watershed conservation. The watershed (i.e., a drainage basin) should be the basic conservation unit from our fisheries perspective because a stream, lake, or estuary will always be downstream of some agricultural practice. However, the approach needs to extend beyond water flowing off or percolating through the landscape. We review how the proposed 2007 legislation builds upon the 2002 Farm Bill and discuss the potential for its many programs to provide tangible benefits to U.S. fisheries and aquatic ecosystems.

PROPOSED 2007 FARM BILL

In preparation for the upcoming legislation, the U.S. Secretary of Agriculture solicited comments in 52 forums conducted across the nation. Given the resources available through this legislation, interest among individuals and organizations within the farming and ranching communities was keen. In response to these comments, the USDA proposed 2007 Farm Bill conservation provisions that, in its view, are more streamlined, less redundant, and ultimately cheaper than the previous legislation.

In the 2007 proposal, the flexible EQIP is given more weight and scope, encompassing other cost-sharing incentives programs under a single programmatic awning. This program would be focused on critical agricultural landscapes within important watersheds. Most notably to fisheries and aquatic conservation, the proposal outlines a Regional Watershed Enhancement Program, which would invest $175 million annually to conduct environmentally-friendly agriculture, affecting systems in need of enhancement or protection (e.g., the Mississippi River delta system, the Chesapeake Bay system). The program also would house a Conservation Innovation Grants program that provides up to $100 million annually to develop market-based models of sustainable watersheds deemed critical by USDA. Guidelines provided by NRCS would be simpler than in the past and more accessible and transparent to the producers. Given the proposed 10-year horizon of this 2007 Farm Bill, the proposed EQIP could inject well over $2 billion into innovative programs to improve water quality within key watersheds throughout the United States. However, this is a federal cost-sharing program, requiring that considerable non-federal funds be generated to match the authorized budget. Thus, we recommend that the required match be minimized or be allowed as in-kind to make this program widely available to cash-strapped agencies, non-government organizations (NGOs), and private citizens. Affected watersheds typically extend beyond local and state-government borders; thus, by the interstate nature of the problem, the lion's share of the responsibility is federal, although the problems do begin at the local scale and need to be administered by local NRCS offices with stakeholder input.

The proposed CSP continues to uphold the spirit of private stewardship of working land by enrolling up to 96.5 million acres and investing $8.5 billion across 10 years. Eligibility would depend on a ranking process based on the adoption of BMPs on the land. Although this program has been criticized in the past for rewarding individuals for following the rules, the lucrative nature of this program does create a strong incentive among agricultural producers to compete successfully for federal support by practicing sound conservation.

Three easement programs are proposed in the 2007 conservation title. (1) A Private Lands Protection Program would invest $190 million annually toward keeping agricultural land from being developed and maintaining it in a natural state. The owner would be able to actively manage the site for conservation. Given that urban and suburban development and sprawl negatively affect aquatic ecosystems in many ways (e.g., modified hydrographs, polluted run-off, fragmentation; see Roy et al. 2005), providing strong incentives for private citizens to maintain land in a more natural state rather than paving it over irrevocably for urban use is a good idea. (2) The CRP would continue to strive to maintain protected lands; it would allow for harvest of biomass production related to cellulosic (e.g., forest products, corn, switch grass, sugar cane) energy production during non-sensitive periods (e.g., when birds are not breeding) of the year. (3) The WRP would only be supported for an additional 5 years before reassessment; the enrollment target would remain at 250,000 acres per year. Obviously, with these collective easement programs, USDA is proposing to provide land-owners more flexibility in their use, rather than investing a greater proportion of land toward complete


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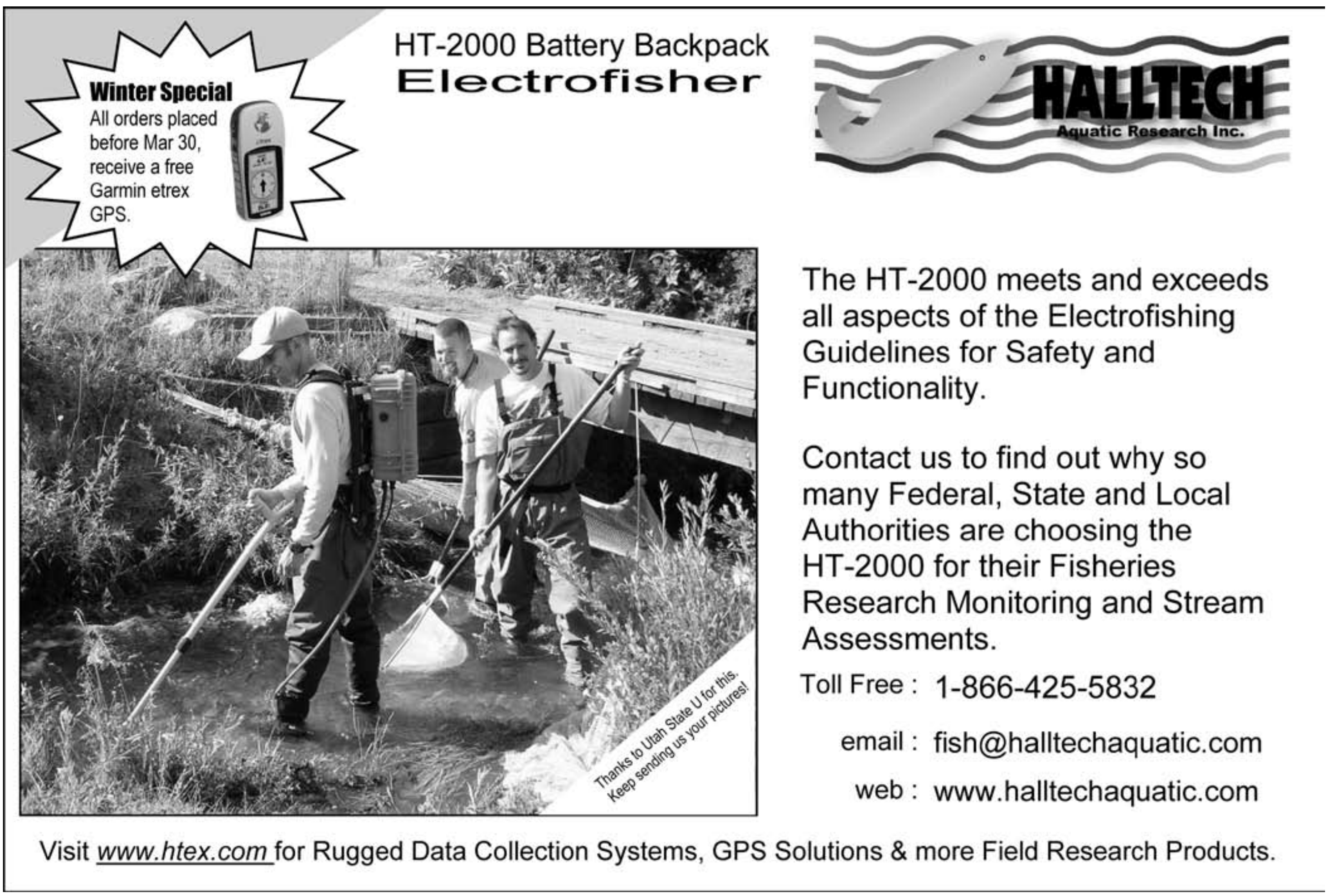
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protection. The key appears to center on providing incentives for keeping private land from falling to the fiscally lucrative lure of urbanization while still allowing natural resources managers the ability to directly access and protect critical areas for wildlife and fish. In terms of benefiting fish and wildlife, we are unsure whether the USDA's proposed balance between private and non-private stewardship is allocated in the correct proportions. Most likely, the relative value of private versus third-party ownership programs will depend on the various socioeconomic forces affecting land owners within their region. For example, the local NRCS should be allowed the flexibility of asking questions such as: "What is the risk that a fast food restaurant or housing development will be built on the local pasture or across a headwater stream?" and "What is the proximity of this land to critical habitat or a sensitive watershed?"

SUMMARY AND RECOMMENDATIONS

Like its relatively successful predecessor, the proposed 2007 Farm Bill is incentive-based and voluntary rather than imposing strict regulations and restrictions on land use. Given the economic importance of agriculture in the United States plus its strong political ties (i.e., well-organized lobbying groups), this legislation will be the source of much debate within the federal government and will likely continue to be sweeping in scope and budget.

Pressures on agriculture and its impact on aquatic resources are sure to rise during the life of this next bill. World population and thus demand for U.S. food, fiber, and energy products will increase, particularly if climate change leads to food shortages via agricultural failure in many parts of the world (including regions within the United States). As the conversion of plants to biofuels becomes economically feasible, market forces will likely encourage green biomass production for conversion to ethanol or biodiesel. For example, corn production in Illinois in 2007 is set to be near or perhaps exceed historic highs, given contemporary demand for ethanol (Illinois Corn Growers Association 2007). Even given huge increases in conservation provisions to combat potentially negative conservation effects on aquatic resources, the proposed programmatic funds will simply be guidelines; the appropriations will likely be smaller, depending on federal priorities during any given year. For that reason, we recommend the following:

- Fish must have co-equal status with other wildlife throughout the language of the next version of the bill.
- Conservation provisions within the next Farm Bill need to incorporate a landscape-based, watershed-scale perspective (USEPA 2005) while still providing the NRCS and other relevant agencies with the tools necessary to help landowners conserve our limited soil and water resources.
- The general consensus is that the 2002 Farm Bill was cumbersome and inefficient. The accessibility and implementation of conservation programs need to be streamlined in the next bill, as the USDA proposal attempts to do. Redundancy among programs should be eliminated.
- Although the 2002 Farm Bill implied that good land use translates to healthy watersheds, the 2007 USDA proposal explicitly recognizes the issue through development of special watershed programs within EQIP. We endorse this approach and encourage its expansion. Like any human activity, agriculture and forestry always have a downstream impact on aquatic systems and need to be continually managed in this context.
- Cost sharing is an attempt to form good-faith partnerships between the federal government and other entities. It also can limit participation of worthy stakeholders in programs. For programs with a clear interstate reach, cost sharing should be reduced, eliminated, or allowed to be matched through in-kind mechanisms. Innovative mechanisms for cost-sharing (e.g., by using land value as match) need to be explored.
- Wetland protection and restoration are critical for maintaining aquatic integrity and fisheries resources. Target acreage to be placed in WRP should be substantially increased relative to the current USDA proposal.
- Agricultural practices affect aquatic and fisheries resources through pathways other than increased sedimentation and reduced water quality. Intensive agriculture requires water, which is diverted from waterways, held in reservoirs, or permanently removed from aquifers. The deleterious effects on fish passage and habitat are clearly issues that should be considered in the next incarnation of the Farm Bill.
- Aquaculture is a form of agriculture that receives no consideration in the current conservation title. However, as fisheries resources are reduced through environmental degradation (e.g., as a function of modified aquatic ecosystems due to farming and ranching) and increased harvest, aquaculture and mariculture will increase in importance both within the United States and abroad. Incentives for developing low-impact, ecologically sound, and sustainable freshwater and marine culture to mitigate the effects of land-based agriculture should be strongly considered.
- Introduction of harmful exotic plant and animal species through agriculture or aquaculture mitigation (see above) should not be supported by Farm Bill programs. Clearly, many invasive species have had deleterious effects on wetlands and aquatic systems.
- Urban sprawl threatens fisheries resources as well as agriculture by reducing a way of life and a source of economic strength. The 2007 Farm Bill needs to provide strong incentives for preventing land slated to be taken out of agricultural production from being developed, particularly in areas with sensitive watersheds.
- Technical guidance teams to USDA-NRCS need to be assembled and must include fisheries and aquatic professionals. Much expertise about land use, aquatic resources, and conservation exists beyond the USDA-NRCS and would help guide targets for special programs (e.g., EQIP). Funds to support these experts should be made available through a competitive contracting mechanism. All federal conservation funds routed through Farm Bill programs must be implemented in a wise, concerted, and streamlined fashion.
- The current legislation and the proposed USDA 2007 Farm Bill do not contain clear guidelines for evaluating the success of conservation programs extending much beyond the land area enrolled in the watershed in which a fishery exists. The "success stories" are likely truthful but largely anecdotal. Without well-designed monitoring and research, the positive impacts of conservation programs on aquatic resources will remain enigmatic. We recommend that some provision for guiding and then evaluating major programs such as those outlined in EQIP be made in the next bill. Perhaps this could be accomplished through partnerships with other federal agencies or research institutions (e.g., universities) that have an existing research and monitoring infrastructure rather than the NRCS.

DIDSON datum

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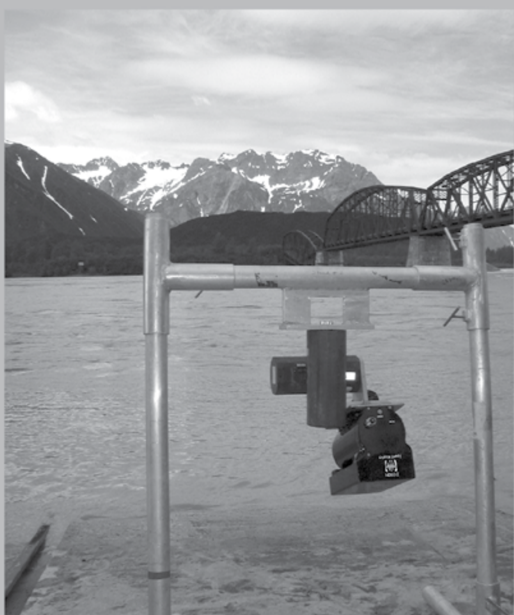

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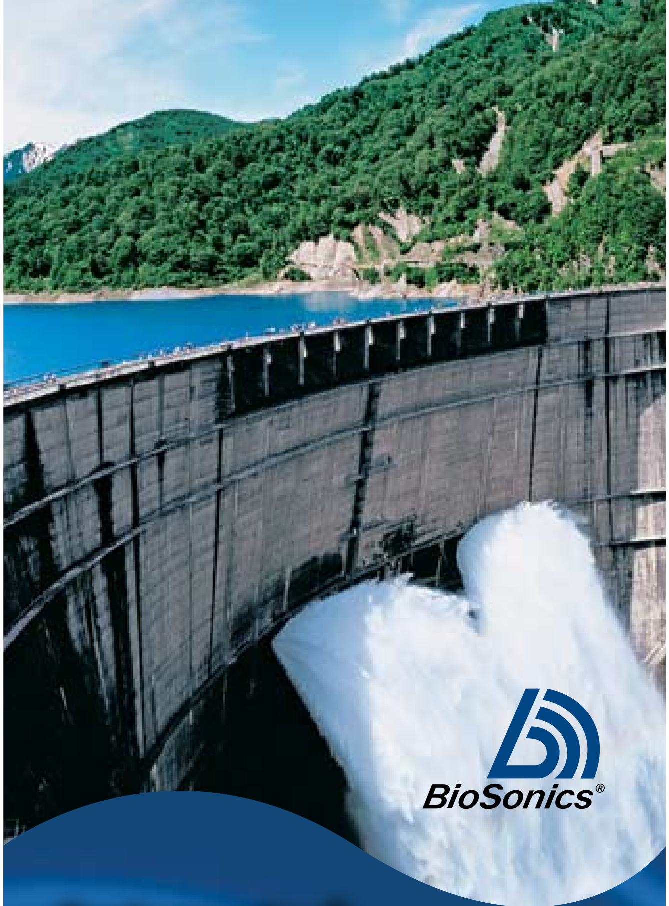

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- Many agricultural practices have disproportionately negative impacts on aquatic ecosystems relative to others. For example, some crops (e.g., corn) are nitrogen intensive and require the application of high concentrations of nitrogen-based fertilizer that can lead to hypoxia and perhaps nitrogen toxicity to fishes. Feedlots and other mass livestock operations generate tremendous burdens on aquatic systems by increasing eutrophication of waterways and perhaps leading to blooms of toxic microorganisms (e.g., red tides in estuaries). Crops that are bioengineered to produce BT insecticide may contain residue that is harmful to aquatic insects within streams and thereby other organisms that require these insects as a food supply (i.e., fish). Subsidies provided to these and other high-risk types of agriculture by the 2007 Farm Bill need to have strict associated safeguards to ensure the integrity of aquatic ecosystems within associated watersheds.
- When implementing the various Farm Bill programs, NRCS must give equal status to soil and water conservation issues in their decision-making. State-of-the-art BMPs must be adopted to minimize the impact of farming, ranching, and forestry on adjacent and downstream water resources. In addition to nutrient loading, soil erosion and resulting sedimentation of streams and associated backwaters continues to be an alarming problem. Ultimately, increased sedimentation caused by poor soil conservation leads to choked waterways and increased dredging. Dredging in navigable rivers is expensive and potentially damaging to main-channel communities in large rivers. BMPs to conserve soil and minimize degradation of stream habitat include but are not limited to:
  - o Maintain vegetative buffer strips, especially shade trees, adjacent to waterways.
  - o Eliminate dams, avoid stream channelization, and discourage removal of woody debris.
  - o Eliminate, when possible, direct access of livestock to waterbodies.
  - o Provide controls for run-off associated with concentrated animal feeding and other livestock operations.
  - o Protect headwater streams and wetlands, which many times contain sensitive and rare aquatic species and are often lost to impoundments or drainage; loss of wetlands and small streams may have far-reaching effects on food web interactions and habitat integrity in downstream reaches. Also, headwater streams are important for absorbing nitrogen (Peterson et al. 2001).
- Most states have developed plans for the conservation of wildlife and fish. In developing and implementing Farm Bill programs, these plans should be used for guidance.
- Unobligated or surplus Farm Bill programmatic funds should be reserved for fish and wildlife conservation and reallocated back to states in a competitive fashion.
- Use partnerships of like-minded organizations and initiatives such as the National Fish Habitat Action Plan (AFWA 2006) and the American Land Conservancy when participating in Farm Bill policy development.

Clearly, the USDA's 2007 proposal is taking steps in the right direction. However, many issues including those outlined in the points above need to be addressed to balance terrestrial-based agriculture with sustenance of aquatic resources in the United States. It is important that members of the fisheries and aquaculture community make their scientific views known to the crafters of the next Farm Bill and participate fully in the shaping the future of the nation's natural resources. The aquatic environment and the fisheries resources dependent on it are vitally affected by Farm Bill provisions and should be fully considered when debating the future of agriculture in the United States and the role of the federal government in that future.

ACKNOWLEDGMENTS:

Members of the Farm Bill Advisory Committee were Phaedra Budy, David Bunnell, Scott Hale, Craig Paukert, and Russell Wright. The committee represented a broad geographical range as well as a cross-section of federal, state, and academic expertise in fisheries. The committee thanks Rob Colombo, Robert Hughes, Chris Kohler, Paul Pajak, Quinton Phelps, Gus Rassam, and Matt Whiles for their helpful input.

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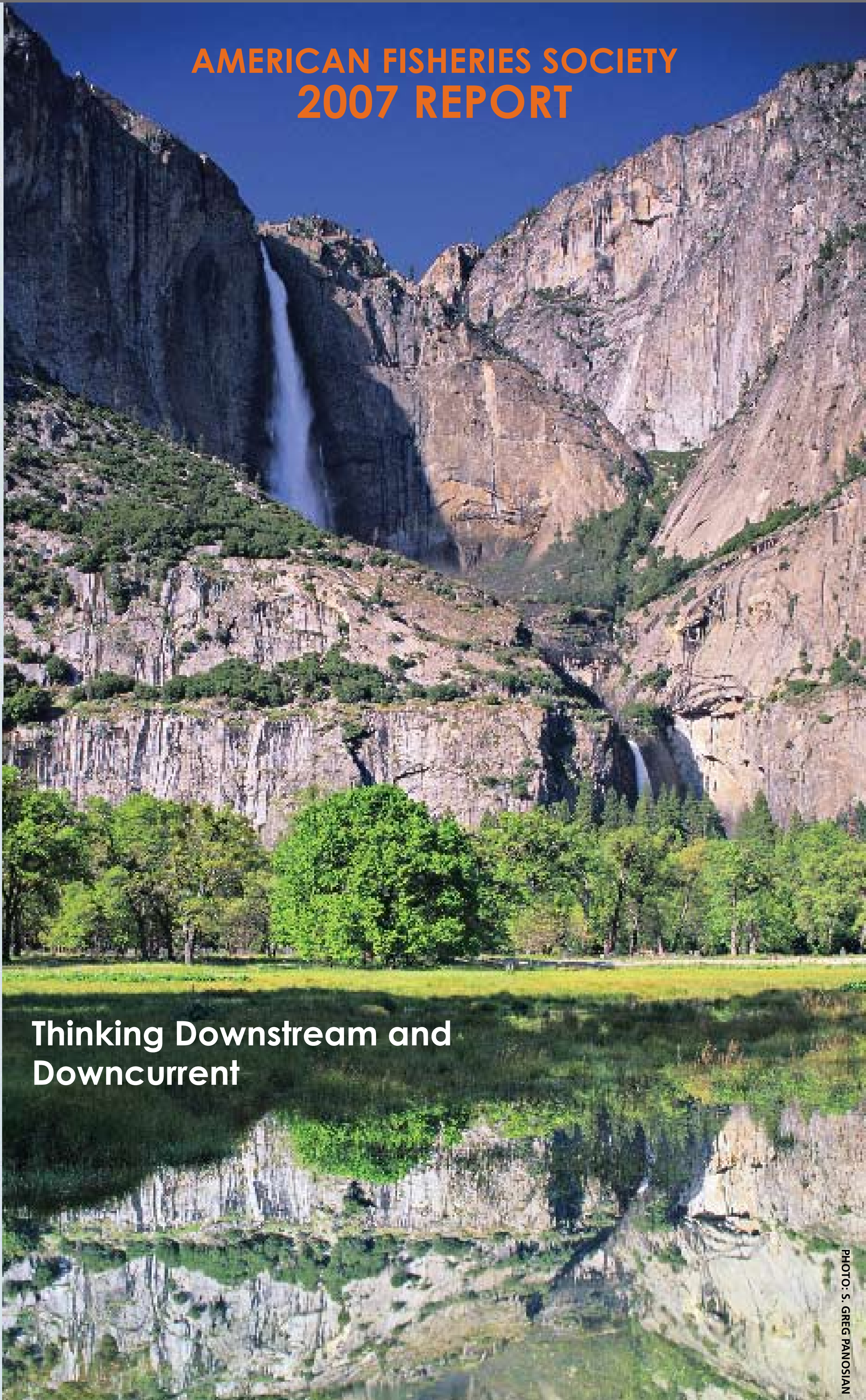

Thinking Downstream and Downcurrent

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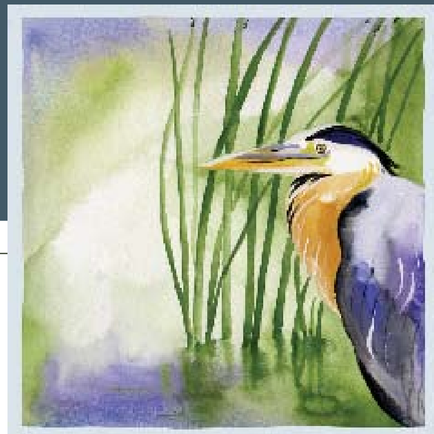
Introduction



This has been a very productive and effective year at the American Fisheries Society. We have made significant headway in the development of new communication tools designed to enhance and provide exciting opportunities for membership.

INFORMATION TRANSFER AND OUTREACH

The AFS Governing Board voted to develop a new journal project dedicated to marine and coastal fisheries issues. Using an online, open-access format, this journal will be a significant contribution to the scientific community and may set a trend for future publication activities at AFS. We are also moving forward with making *Fisheries* available online to the full membership. At the same time, we are embarking on an effort to make some of the significant science published in AFS journals more accessible to the general public.

AQUATIC STEWARDSHIP

AFS is working hard to increase the collaborative advantage of increased outreach activities with our sister resource societies, both in North America and internationally. *Fisheries* abstracts in Spanish are increasing the awareness of AFS activities and publications in Central and South America. Full participation in planning a fish tagging meeting in New Zealand in February 2008 and the Fifth World Fisheries Congress in Yokohama, Japan, in October 2008 shows a clear awareness of the value of international engagement. Increased inter-society liaisons and the appointment of a new staff position in Bethesda for outreach services greatly increases our communications tools.

MEMBER SERVICES

Membership in AFS remains stable and this year we made important efforts to increase student participation in the society. The new $19 student membership, which includes free access to all of our online publications, is an incredible opportunity for students at any level and has helped recruitment in this demographic. We are also shifting to a member-centric information technology (IT) vision. We have greatly improved the structure and design of IT at AFS in an effort to provide the required information interface between the different AFS Units and their memberships. This change is critical for future developments in information exchange and membership services. It also points the way for new web-based tools and communication links at AFS, such as podcasting the Plenary Session at the AFS Annual Meeting in San Francisco. Our goal is to develop the technology and services that will carry our Society into the next decade with clear and efficient tools for the membership.

Jennifer L. Nielsen
President

Gus Rassam
Executive Director

AMERICAN FISHERIES SOCIETY: 2007 REPORT

Special Projects

NATIONAL FISH HABITAT ACTION PLAN

In April, the first anniversary of the launch of the National Fish Habitat Action Plan (NFHAP) was celebrated with the unveiling of "10 Waters to Watch," which collectively illustrate the promising partnerships at the heart of this program. These 10 waters are bringing together community groups, non-profit organizations, local watershed groups, Native American tribes, and state and federal agencies to plant streamside vegetation, remove structures blocking fish from accessing habitat, and protect rivers from the effects of agriculture and livestock. The idea is to provide clean water and robust, healthy habitats for the many fish and wildlife species and people who call these areas home. NFHAP currently supports 40 local, grassroots-driven projects, like those on the Waters to Watch list, as well as U.S. national efforts to identify the root causes of aquatic habitat declines, identify and implement corrective actions, and measure and communicate its progress. Projects in the "10 Waters to Watch" are being coordinated through five "National Fish Habitat Partnerships" and organized as regional-scale efforts to implement NFHAP. These regional partnerships are currently "pilots" that include the Southeast Aquatic Resources Partnership, Eastern Brook Trout Joint Venture, the Western Native Trout Initiative, the Midwest Driftless Area Restoration Effort, and the Matanuska-Susitna Basin Salmon Conservation Partnership. The plan calls for the creation of 12 or more Fish Habitat Partnerships by 2010.

2007 AFS-SEA GRANT SYMPOSIUM

The American Fisheries Society and Sea Grant continue their biennial series of special symposia with "Mitigating Impacts of Natural Hazards on Fishery Ecosystems." The symposium, which will be held at this year's Annual Meeting in San Francisco, will explore how to better mitigate the impacts of natural hazards on fish populations, fish habitat and fishing communities. An associated proceedings volume will be published early next year for use by fisheries professionals hoping to be better prepared for the next hazard event.

Here, natural hazards are defined as sudden events which can lead to rapid, significant ecosystem impacts of various geographic scopes. Such events can be characterized as producing large impact (biological, economic and social), and occurring with little or no warning. Hazards that will be discussed during our symposium include hurricanes and other coastal storms, earthquakes, tsunamis, volcanoes, harmful algal blooms, and localized or regional anoxic events.

Researchers will discuss their work as well as lessons learned from well-known hazard events such as the 2004 Indian Ocean tsunami and Hurricanes Katrina and Rita, in addition to smaller scale hazards that occur on a more regular basis, such as harmful algal blooms off the Florida coast. A synthesis piece and moderator-led audience participation discussion will close out the session to draw out common themes from the hazards discussed. A total of 32 presentations will occur over the 2-day symposium (5-6 September), in addition to 5 posters. More information is available at www.fisheries.org/units/afs-sgsymposium.

FIFTH WORLD FISHERIES CONGRESS PLANNING

Planning is well underway for the Fifth World Fisheries Congress (WFC), which will be held in Yokohama, Japan, from 20-24 October 2008. The goal of WFC meetings is to convene fisheries scientists from around the world to discuss and bring attention to the primary issues facing global fisheries. The 5th WFC is being organized by the Japanese Society of Fisheries Science (JSFS) as the lead society, and members of the World Council of Fisheries Societies are also included in the program planning. AFS has been heavily involved in the program planning for the 5th WFC and many of the priorities that AFS has brought to the WFC program planning committee have been incorporated into what will be an excellent WFC program.

The objective of the 5th WFC is to address issues that contribute to the global welfare and environmental conservation of the world's fisheries. WFC will be organized around nine topical sessions, which include fisheries and fish biology; aquaculture; biotechnology; post-harvest science and technology; material cycling in aquatic ecosystems—linking climate change and fisheries; freshwater, coastal, and marine environments; biodiversity and management; fisheries economics and social science; and education and international cooperation. Under each topical session, a series of subsessions will be developed to address specific issues surrounding each topic. There also will be an open call for papers during the fall of 2007, for those wishing to submit papers for possible inclusion into the program. The 5th WFC will be held at the Pacifico Yokohama convention center, a short bus or train trip from Tokyo and Narita International Airport. For more details on the 5th WFC, please see www.5thwfc2008.com.

HUTTON UPDATE

The Hutton Junior Fisheries Biology Program is a summer mentoring program for high school students. The principal goal of the Hutton Program is to stimulate interest in careers in fisheries science and management among groups underrepresented in the profession, including minorities and women. Hutton provides students with a summer-long hands-on experience in fisheries research with a mentor who is working in some aspect of the field. A scholarship and an AFS student membership are provided to each student accepted into the program. The Class of 2007 includes 36 outstanding students who worked with more than 40 mentors in 21 states (Alaska, Arizona, California, Colorado, Connecticut, Hawaii, Idaho, Illinois, Kansas, Maryland, Michigan, Missouri, Montana, Nebraska, New York, North Carolina, Tennessee, Texas, Virginia, Washington, Wisconsin). As in past years, the group of student applicants was ethnically diverse. A majority of the selected students were either women and/or were from a minority group.

The program is evaluated annually through a survey of all previous alumni. The ultimate success of the program will be determined by the number of students that enter the fisheries profession. According to the 2006 survey, 78% of alumni are studying or considering studying fisheries or biology. The 2007 survey is currently underway, and the results will be printed in *Fisheries* this winter.

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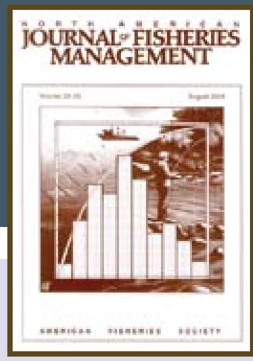
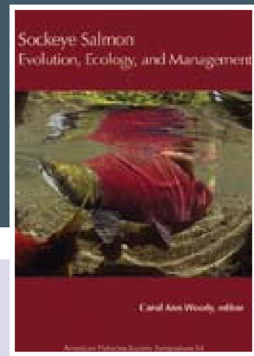
Publications





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The Fisheries InfoBase now includes all AFS journals back to 1870, including all issues of ***The Progressive Fish Culturist.***

AFS MAGAZINE

The AFS membership magazine, ***Fisheries***, offers up-to-date information on fisheries science, management, and research, as well as AFS and professional activities. Featuring peer-reviewed scientific articles, analysis of national and international policy, commentary, chapter news, and job listings, ***Fisheries*** gives AFS members the professional edge in their careers as researchers, regulators, and managers of local, national, and world fisheries. ***Fisheries*** is available to members online at **www.fisheries.org**.

AFS JOURNALS

- ***Transactions of the American Fisheries Society***, bimonthly, Volume 136
- ***North American Journal of Aquaculture***, quarterly, Volume 69
- ***North American Journal of Fisheries Management***, quarterly, Volume 27
- ***Journal of Aquatic Animal Health***, quarterly, Volume 18

Journals are also available to subscribing members online at **http://afs.allenpress.com**.

AFS TO START NEW MARINE AND COASTAL FISHERIES JOURNAL

In 2008 AFS will begin a new open access electronic-only journal devoted to the science and management of marine and coastal fish, fisheries, and fish habitat. This peer-reviewed publication will provide a highly visible outlet for the growing number of marine and coastal fisheries papers. The format will encourage lively, current, and transparent debate on controversial topics through use of comments, viewpoints, and invited perspectives. The scope is international and includes open ocean, coastal, and estuarine environments. Since there will be no charge to access articles, AFS hopes to reach the global fisheries research and management community. Editors and staff will focus on rapid review and publication.

James Cowan, a professor of oceanography and coastal sciences at Louisiana State University, is the new journal's development editor. He can be reached at jhcowan@lsu.edu.

AFS BOOKS: RECENT AND UPCOMING TITLES

Analysis and Interpretation of Freshwater Fisheries Data

Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations

Bluegills: Biology and Behavior

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Proceedings of the Fourth World Fisheries Congress: Reconciling Fisheries with Conservation

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Distinguished Service Award William J. Wilson, Michael D. Porter, Eric E. Knudsen
Excellence in Fisheries Education Joseph E. Hightower
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2005 Best Student Poster Award Honorable Mention Donald Ratcliff
2005 AFS/Sea Grant Outstanding Student Paper Beth Gardner, Brandon J. Puckett
2005 AFS/Sea Grant Outstanding Student Paper Honorable Mention Katie Bertrand

BEST PAPER AWARDS

Mercer Patriarche Award for the Best Paper in the *North American Journal of Fisheries Management* Brett T. van Poorten and John R. Post
Robert L. Kendall Best Paper in *Transactions of the American Fisheries Society* Brian J. Pyper, Franz J. Mueter, and Randall M. Peterman
Best Paper in the *Journal of Aquatic Animal Health* Heather Harbottle, Karen P. Plant, and Ronald L. Thune
Best Paper in the *North American Journal of Aquaculture* Alexander Brinker, Wolfgang Koppe, and Roland Rösch

SECTION AWARDS

Computer User Section Best Student Poster Award Thomas Lang
Education Section Certificate of Appreciation David Hewitt
Estuaries Section Nancy Foster Habitat Conservation Award Elliott Norse
Estuaries Section Student Travel Award Bernice Bediako, Bradly Trumbo, Benjamin Ciotti and William Smith
Fish Culture Section Student Travel Award Jesse Trushenski
Fish Culture Section 2005 Most Significant Paper in the *North American Journal of Aquaculture* Alexander Brinker, Wolfgang Koppe, and Roland Rosch
Fish Culture Section 2005 Most Significant Paper Honorable Mentions Eugene Torrans; R. L. Hedrick, T. J. Popma, and D. Davis
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Fish Health Section Distinguished Service Award Ben LaFrentz, Nicole White
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Fisheries Management Section Award of Merit Fred Jannsen
Fisheries Management Section Conservation Achievement Award Great Lakes Fishery Commission, Missouri River Natural Resources Council
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Tennessee Wildlife Resources Agency
Texas Parks and Wildlife Department
USDA Animal and Plant Health Inspection Service
U.S. Fish and Wildlife Service
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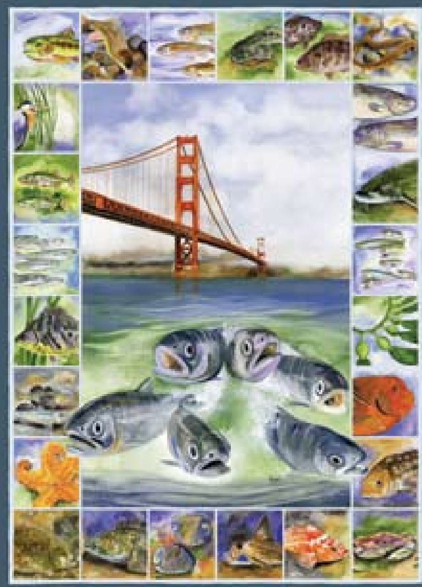


REVENUE

	Amount	%
Publications	1,551,190	46.71%
Advertising	178,429	5.37%
Contributions	44,701	1.35%
Membership Dues	484,166	14.58%
Annual Meeting & Trade Show	189,376	5.46%
Grants & Contracts	618,717	18.63%
Other	404,664	12.18%
Total	**3,471,242**	**100.00%**

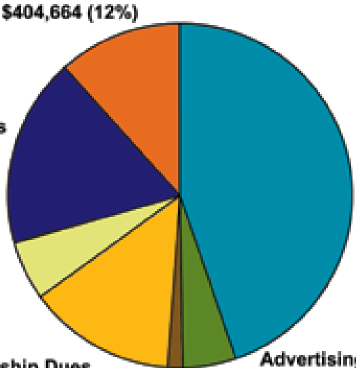
EXPENSES

Publications	1,199,156	38.40%
Membership Services	225,431	7.22%
Administration & Fund Raising	265,273	8.49%
Annual Meeting & Trade Show	210,779	6.75%
Grants & Contracts	524,886	16.81%
Other	697,485	22.33%
Total	3,123,011	100.00%
Change in Net Assets	**198,232**	
Net Assets at the beginning of the year	**3,926,437**	
Net Assets at the end of the year	**4,124,669**	

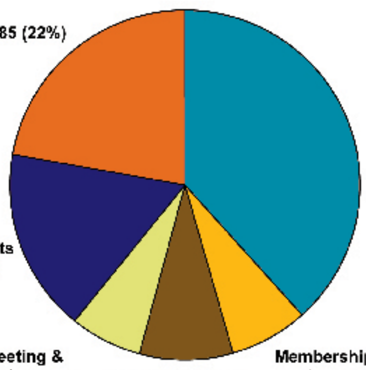
STATEMENT OF FINANCIAL POSITION AS OF DECEMBER 31, 2006

Assets		**Liabilities**	
Cash	2,801,153	Accounts Payable	279,271
Investments	1,550,111	Deferred Revenue	1,157,043
Accounts Receivable	214,643	Net Assets	4,124,669
Prepaid Expenses	17,685		
Property & Equipments	767,819		
Inventory	209,571		
Total	**5,560,983**	**Total**	**5,560,983**

2006 PROGRAM INCOME



2006 PROGRAM EXPENSES



Sep 2-6—**American Fisheries Society 137th Annual Meeting,** San Francisco, California. See www.fisheries.org/sf/.

Sep 11-13—**Second Global Conference on Large Marine Ecosystems,** Qingdao. China. See www.ysfri.ac.cn.?GLME-Conference2Qingdao/homepage.htm.

Sep 11-15—**Fish Stock Assessment Methods for Lakes and Reservoirs Conference: Towards the True Picture of Fish Stock,** Ceske Budejovice, Czech Republic. See www.fsamlr2007.czweb.org.

Sep 15—**Ocean Conservancy's 22nd Annual International Coastal Cleanup.** See www.oceanconservancy.org/iccmedia.

Sep 17-21—**Northwest Environmental Training Center: Introduction to Engineered Log Jam—Technology and Applications for Erosion Control and Fish Habitat,** Olympic Peninsula, Washington. See www.nweec.org.

Sep 16-21—**Association of Fish and Wildlife Agencies,** Louisville, Kentucky. See www.fishwildlife.org/annualmeet.html.

Sep 17-21—**International Council for the Exploration of the Sea,** Helsinki, Finland. See www.ices.dk.

Sep 18-21—**International Conference on Freshwater Habitat Management for Salmonid Fisheries,** University of Southampton, UK. See www.salmonidhabitat.co. Contact Lynn Field, admin@salmonidhabitat.com.

Oct 2-3—**Second Thermal Ecology and Regulation Workshop,** Westminster, Colorado. See www.rd.tetratech.com/EPRIThermalWorkshop.com. Contact Bob Goldstein, rogoldst@epri.com, 650/855-2593.

Oct 8-11—**Second International Symposium on Tagging and Tracking of Marine Fish with Electronic Devices,** San Sebastian, Guipuzcoa, Pais Vasco, Spain. See http://unh.edu/taggingsymposium/.

Oct 9-10—**Symposium on Anadromous Salmonid Tagging and Identification Techniques in the Greater Pacific Region,** Portland, Oregon. See www.rmpc.org/2007-marking-symposium.html Contact george_nandor@psmfc.org 503/595-3100.

Oct 9-10—**Seattle-Bioneers Conference 2007,** Seattle, Washington. See www.nwetc.org.

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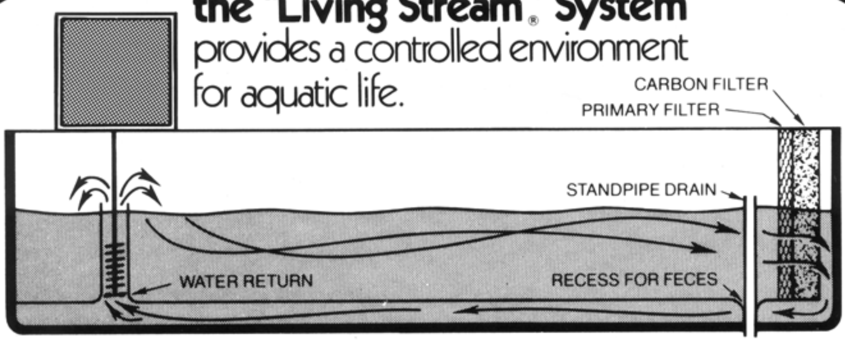

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To see more job listings go to www.fisheries.organd click Job Postings.

Assistant Professor Riparian Ecology, College of Natural Resources, Department of Fish and Wildlife Resources, University of Idaho, Moscow.
Responsibilities: Academic year, tenure track assistant professor. 40% teaching; 40% scholarship; 20% advising/outreach/service. Successful candidate expected to develop comprehensive, externally funded research program involving graduate students; teach undergraduate course in riparian ecology and management; participate in other undergraduate courses as needed; teach a graduate course in riparian ecology, management, and restoration; and a graduate course in specialty area.
Qualifications: Successful candidate must have Ph.D. with focus on riparian ecology emphasizing impacts of humans on riparian systems from headwater systems to large rivers, biotic-abiotic interactions, and restoration; must demonstrate successful research productivity through external funding and refereed publications; and must demonstrate a commitment to teaching excellence. Post-doctoral or equivalent experience desired.
Closing date: Review begins 12 October 2007 and continues until successful candidate identified.
Contact: Apply online at www.hr.uidaho.edu. Questions can be addressed to Carrie Barron at cbarron@uidaho.edu.

M.S./Ph.D. Assistantship, Brown Trout Bioenergetics, USGS South Dakota Cooperative Fish and Wildlife Research Unit/South Dakota State University, Brookings.
Responsibilities: Evaluate the effects of an invasive diatom *Didymosphenia geminata* on brown trout foraging ecology in the Black Hills, South Dakota. Interest/experience with bioenergetics modeling, stable isotope analysis, and food web ecology are desired.
Qualifications: B.S. or M.S. degree in fisheries science or related field; motivated M.S. or Ph.D. student ; strong written and oral communication skills; competitive GPA and GRE scores.
Salary: $16,000–20,000 research stipend, ncludes out-of-state tuition waiver.
Closing date: 1 September 2007.
Contact: Submit a letter of interest, resume, names and addresses of three references, copies of academic transcripts and GRE scores to Steven R. Chipps, USGS South Dakota Cooperative Fish and Wildlife Research Unit, Department of Wildlife and Fisheries Sciences, NPBL 2140B, South Dakota State University, Brookings, SD 57007; Steven.Chipps@sdstate. edu; 605/688-5467.

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Life (*Fisheries* only, 2 installments, payable over 1 year)	$1,000	$1,000

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Transactions of the American Fisheries Society	$43	$25	$48	$25
North American Journal of Fisheries Management	$43	$25	$48	$25
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