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Catfish Science: Status and Trends in the 21st Century

Thomas J. Kwak*
U.S. Geological Survey, North Carolina Cooperative Fish and Wildlife Research Unit
Department of Biology, Campus Box 7617, North Carolina State University
Raleigh, North Carolina 27695, USA

Mark T. Porath
Nebraska Game and Parks Commission
2200 North 33rd Street, Lincoln, Nebraska 68503, USA

Paul H. Michaletz
Missouri Department of Conservation
1110 South College Avenue, Columbia, Missouri 65201, USA

Vincent H. Travnichek
Missouri Department of Conservation
701 James McCarthy Drive, St. Joseph, Missouri 64507, USA

Abstract.—Catfish science, the study of the fish order Siluriformes, is a diverse and expanding field in terms of advances and breadth of topics. We compiled literature from primary fisheries journals as an index of interest and advances in catfish science to examine temporal trends in the field. The number of catfish scientific publications varied over the past century with strong peaks during 1975–1979 and 2005–2010, which may be the result of interactive scientific and societal influences. Catfish biology was the predominant publication topic until the late 1990s, when ecology, techniques, and management publications became more prevalent. Articles on catfish ecology were most numerous in both the first and second international catfish symposia, but publications on techniques and conservation were more numerous in the second catfish symposium than the first. We summarize the state of knowledge, recent advances, and areas for future attention among topics in catfish science, including sampling and aging techniques, population dynamics, ecology, fisheries management, species diversity, nonnative catfish, and human dimensions, with an emphasis on the gains in this second symposium. Areas that we expect to be pursued in the future are development of new techniques and validation of existing methods; expansion of research to less-studied catfish species; broadening temporal, spatial, and organizational scales; interdisciplinary approaches; and research on societal views and constituent demands. Meeting these challenges will require scientists to span beyond their professional comfort zones to effectively reach higher standards. We look forward to the coming decade and the many advances in the conservation, ecology, and management of catfish that will be shared.

Introduction

Catfish science, the study of the fish order Siluriformes, is a diverse and expanding field in terms of advances and breadth of topics. Growth of catfish science presumably reflects increasing interest in these species by anglers as popular sport fishes, by consumers as palatable food fishes, by commercial fishers as an abundant and marketable catch, by aquaculturists as suitable species for propagation, and by natural resource agencies for their importance in management as sport fish, imperiled taxa, and invasive species. Furthermore, advances in science facilitate formulation of new hypotheses and management dilemmas that compel additional attention. As scientific methods and techniques for catfish research and management progress, fish scientists

* Corresponding author: tkwak@ncsu.edu

may more rapidly address timely research questions and pursue a more informed management process.

Recent expansion of catfish science prompted leaders in the field to organize and convene "Catfish 2000: The First International Ictalurid Symposium" in 1998 and to publish the resulting proceedings (Irwin et al. 1999b). A decade later, the science had built to a point where the utility and need for another symposium was apparent. "Catfish 2010: The Second International Symposium" was organized and held in St. Louis, Missouri during June 2010 and resulted in this published volume of current research and management advances. Topics presented in the second international symposium and these proceedings focus on catfish conservation, ecology, and management; while recognizing the importance of basic biology, aquaculture, and other areas to the field as critical, this effort focused on catfish as natural resources.

Trends in Catfish Science

We compiled literature in the form of publications in primary fisheries journals as an index of interest and advances in catfish science to examine temporal trends. We searched for publications from the past century in applicable journals published in North America, including *Fisheries*, *Transactions of the American Fisheries Society*, *North American Journal of Fisheries Management*, *North American Journal of Aquaculture* (and *The Progressive Fish-Culturist*), *Journal of Aquatic Animal Health*, and *Canadian Journal of Fisheries and Aquatic Sciences* (and *Journal of the Fisheries Research Board of Canada* and precursors). Other fisheries, aquatic science, and ecology journals publish articles on catfish, but we considered those listed above as the most applicable North American outlets for examining temporal trends in catfish publications. We searched for articles with catfish-related terms in the title or keywords (i.e., common and scientific names). We then categorized each of the 641 articles or notes into one of six primary topical areas spanning those covered in this symposium and aquaculture, which was not a symposium topic; those topics included biology (N = 120), ecology (N = 64), techniques (N = 64), fisheries management (N = 36), conservation (N = 8), and aquaculture (N = 349).

The overall trend of increasing interest and advances in catfish science over time is marked by temporal variation in direction and magnitude of changes (Figure 1). The number of catfish scientific publications has varied over the past century with strong peaks during 1975–1979 and 2005–2010.

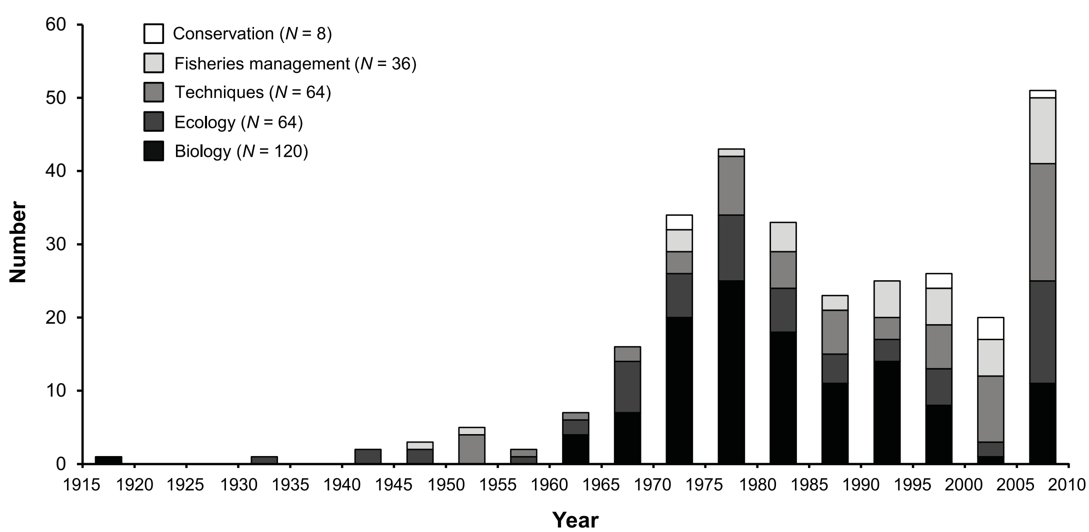

FIGURE 1. The trend over time during the last century in the number and topic of catfish science publications in six primary fisheries journals published in North America. These data include 292 publications plotted; 349 publications on catfish aquaculture were found but are not included here. Publications in the proceedings of the first and second international catfish symposia (Irwin et al. 1999b; Michaletz and Travnichek 2011) are presented in Figure 2 and are not included here.

This bimodal pattern in catfish journal publications is not readily explained by any single correlative factor, but rather, it may be the result of multiple interactive scientific and societal influences.

The period after World War II is considered the modern era of fisheries management and was characterized by significant increases in fishing participation and management, education and employment of fisheries scientists, and supporting funding. That surge in fisheries science activity was stimulated by the passage of the Federal Aid in Sport Fish Restoration Act in 1950 (also known as the Dingell-Johnson Act; Nielsen 1999). During that period, the number of catfish scientific publications increased sharply to a peak of 43 publications during 1975–1979, followed by a notable decline until 2005, despite additional funding for sport fisheries associated with the Wallop-Breaux Act of 1985. Federal Sport Fish Restoration funding to state agencies has generally increased since 1985 (U.S. Fish and Wildlife Service, unpublished data) and does not solely explain the bimodal pattern in catfish science publications. The number of fishing licenses sold in the United States shows a similar bimodal temporal pattern (U.S. Fish and Wildlife Service, unpublished data) but does not correspond precisely with the catfish publication trend. Membership in the American Fisheries Society (i.e., an index of the number of practicing fisheries biologists) also increased with a slight mode in the early 1980s (American Fisheries Society, unpublished data) but does not otherwise correspond to the bimodal trend in catfish publications.

Increased catfish habitat in the form of impoundment construction may also have influenced catfish scientific activity. The accelerated construction of ponds and reservoirs in the United States began with federal and state programs initiated in the 1930s and peaked in the 1960s (Jenkins 1970; Collier et al. 1996). Although recreational and commercial fishing was a secondary function of many of these impoundments, natural resource agencies responded with management and research programs to enhance pond and reservoir fisheries. Many of these programs included catfish, presumably contributing to the elevated publication rate in the 1960s that peaked in the 1970s (Figure 1).

The publication of 48 articles on catfish science in the proceedings of "Catfish 2000" (Irwin et al. 1999b) likely contributed to the low number of journal publications during the immediately following years but may have stimulated publications thereafter (i.e., 20 publications, 2000–2004; 51 publications, 2005–2010; Figure 1). If these publications (48 from "Catfish 2000") were spread among the subsequent years following (2000–2010) in fisheries journals, the resulting trend would probably reveal a steady increase in publications from 1985 to 2010. Likewise, publication of this proceedings volume (62 articles; Michaletz and Travnichek 2011) may result in a temporarily reduced number of catfish publications in journals during subsequent years. Our overall conclusion is that a number of factors related to societal interests, government funding, and the fisheries science profession interacted to create the resulting temporal trends in catfish science depicted in Figure 1.

The trend in topics of catfish science publications has also varied over time. Catfish biology was the predominant topic among publications until the late 1990s, when catfish ecology, techniques, and management became more prevalent in the literature. Conservation of nongame catfishes and studies on the effects of introduced catfishes have appeared only sporadically in the literature but were important topics in this proceedings. Although not a focus of either of the two international catfish symposia, aquaculture of catfish, primarily channel catfish *Ictalurus punctatus*, was the most prevalent topic of catfish literature during the past century. Of the 641 publications we found in our literature search, 349 were categorized with aquaculture as the primary topic, with the remaining 292 publications covering the five other topical areas presented in Figure 1. The number of publications on catfish aquaculture revealed in our search also generally conformed to the bimodal temporal pattern shown for the other five topical areas.

The published proceedings of the two international catfish symposia (Irwin et al. 1999b; Michaletz and Travnichek 2011) are inarguably among the most important modern volumes on catfish science. Combined, these proceedings contributed 110 papers to catfish science. Topics covered within these volumes varied somewhat, reflecting changes in interest and concerns over the decade spanning them (Figure 2). Articles on catfish ecology were the most numerous in both catfish symposia, and fisheries management was equivalently represented in the "Catfish 2000" proceedings, but ranked third in abundance behind techniques in the "Catfish 2010" proceedings. The increase in articles on catfish conservation between the two symposia is noteworthy, reflecting expanded contributions covering non-

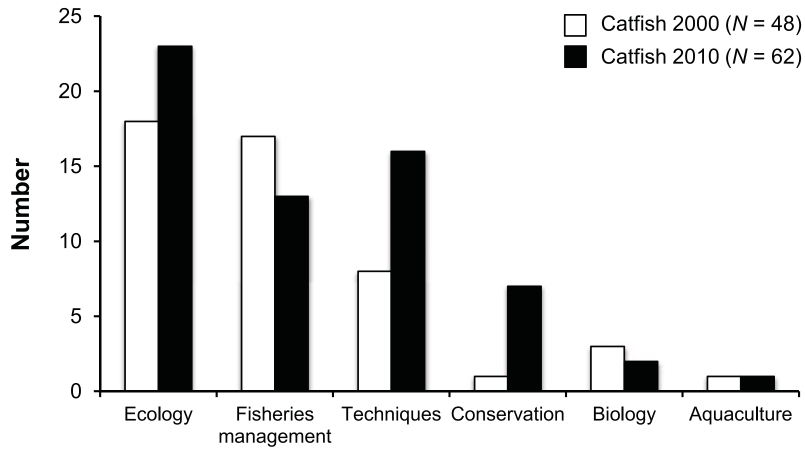

FIGURE 2. Comparison by number and topic of publications appearing in the proceedings of the first (Irwin et al. 1999b) and second (Michaletz and Travnichek 2011) international catfish symposia.

game fish conservation and issues related to introduced catfish populations. While biology has been the predominant topic of journal publications on catfish over the past century, that topic was poorly represented in the two symposia (Figures 1 and 2). The lack of biological publications may be owing to changes in research and management priorities, and perhaps, the general background and expertise of symposia participants.

General approaches and priorities in catfish science have evolved over time. Scientific attention to catfish as a natural resource has lagged behind that of other sport fish (Michaletz and Dillard 1999), but the interest in catfish by society, mass media, recreational and commercial fishers, management agencies, and fisheries scientists is increasing at a relatively rapid rate. This renewed interest may be facilitated by the two international catfish symposia, or perhaps the symposia were organized in response to the demand for such exchanges of information. Some general observations about temporal trends in catfish science include more holistic studies on the functional role of catfish in aquatic systems, additional emphasis on catfish as sport fish species and associated management, an increased reliance on objective science to guide management, and recognition of catfish as imperiled or invasive species. Below, we summarize the state of knowledge, recent advances, and areas for future attention among topics in catfish science that were covered in the two international symposia, with an emphasis on the gains facilitated by this second symposium.

Sampling and Aging Techniques

Sampling

The lack of effective sampling methods for catfish was identified as an important impediment to understanding and managing catfish populations in a 1997–1998 survey of management agencies (Michaletz and Dillard 1999). Since that survey, significant advances have been made in the development of sampling techniques for catfish. This is especially the case for the three major sport fish species in North America: channel catfish, blue catfish *I. furcatus*, and flathead catfish *Pylodictis olivaris*. Lotic channel catfish populations have been effectively sampled with single-set hoop nets (Gale et al. 1999; Vokoun and Rabeni 1999), and Vokoun and Rabeni (2001) further developed a sampling strategy using multiple hoop nets. However, single-set hoop nets have not been effective for sampling lentic populations of channel catfish. Sullivan and Gale (1999) reported that cheese-baited hoop nets set in tandem were more effective at capturing channel catfish and caused less mortality of captured fish than gill nets in a Missouri impoundment. Since that study, this method has proven effective for sampling channel catfish in numerous lentic systems (Michaletz and Sullivan 2002; Flammang and Schultz 2007; Buckmeier and Schlechte 2009) and has been shown to be relatively unbiased for sizes of fish larger than 250 mm total length (Michaletz and Sullivan 2002; Buckmeier and Schlechte 2009). Several papers in these proceedings report refinements of this technique among different sampling seasons, soak durations, baits, or throat configurations (Neely and Dumont 2011; Porath et al. 2011; Wallace et al. 2011; all this volume), have confirmed that this technique is more efficient than gill netting (Richters and Pope 2011, this volume), and have shown that it can be used to effectively assess channel catfish populations (Flammang et al. 2011, this volume).

Advances in sampling methods for blue catfish and flathead catfish have also been made during recent years. In particular, low-frequency electrofishing methods have proven effective for sampling many lentic and lotic populations of these species (Stauffer and Koenen 1999; Cunningham 2000, 2004; Daugherty and Sutton 2005b; Buckmeier and Schlechte 2009; Bodine and Shoup 2010). In addition to the electrofishing boat, chase boats are commonly used to aid in capturing stunned fish (Vokoun and Rabeni 1999; Cunningham 2004), but the use of a chase boat may not improve the efficiency of the technique, depending on habitat conditions (Cunningham 2004; Daugherty and Sutton 2005b). Perhaps the greatest concern with using low-frequency electrofishing is that it may be biased toward small fish, as few large fish are typically collected (Stauffer and Koenen 1999; Boxrucker and Kuklinski 2008; Travnichek 2011b, this volume). However, Buckmeier and Schlechte (2009) and Bodine and Shoup (2010) found that low-frequency electrofishing was not size selective for blue catfish longer than 250 mm in their evaluations. Similar size-selection studies have not been conducted for flathead catfish.

In these symposium proceedings, further developments of low-frequency electrofishing are reported. Travnichek (2011b) suggested that electrofishing for flathead catfish should be conducted in September on the Missouri River because sampling during this period maximized catch rates, minimized variation in catch rates, and captured adequate numbers of large fish. For smaller rivers in Missouri, Ford et al. (2011, this volume) recommended that a combination of electrofishing and hoop netting be used during spring to midsummer to sample flathead catfish. They found that hoop netting captured proportionally larger flathead catfish than electrofishing. Evans et al. (2011, this volume) found that electrofishing was usually more effective than gill netting at measuring relative abundance of blue catfish in reservoirs, and Bodine et al. (2011, this volume) assessed different sampling strategies and recommended sample sizes for using electrofishing to assess blue catfish populations in reservoirs.

While substantial progress has been made in the development of effective sampling methods for catfish, there remains much to learn. In most situations, accuracy of samples to reflect true population abundance and size structure is unknown. More sampling of populations with known abundance and size structure is needed to determine biases of various sampling methods. Sampling methods for the numerous species other than channel catfish, blue catfish, and flathead catfish have not been extensively studied and need further development. Even for the three well-studied species, sampling methods for larvae and early juveniles have not been thoroughly evaluated, especially for lentic waters. Finally, development of new statistical methods designed to more appropriately address highly variable catch data, such as described by Arab et al. (2008), would aid in accurate interpretation of sampling data.

Age Estimation

Traditionally, pectoral spines were used to estimate ages of catfish (e.g., Mayhew 1969; Graham and DeiSanti 1999). However, beginning with a study published in the first catfish symposium (Nash and Irwin 1999), there has been mounting evidence that otoliths provide more accurate and precise age estimates than pectoral spines (Buckmeier et al. 2002; Barada et al. 2011, this volume; Olive et al. 2011, this volume). However, depending on the fish species, age, and environment, pectoral spines may provide age estimates that are comparable to those from otoliths (Colombo et al. 2010; Olive et al. 2011; Steuck and Schnitzler 2011, this volume). Age estimate comparisons have been conducted on channel catfish, blue catfish, and flathead catfish. However, it appears that the use of pectoral spines for aging is most suited for channel catfish (Colombo et al. 2010; Olive et al. 2011) and less appropriate for flathead catfish (Olive et al. 2011). Age bias usually increases with fish age when using pectoral spines relative to otoliths (Olive et al. 2011). While otoliths may be preferable to pectoral spines for aging, they may be less desirable for back-calculating lengths at previous ages (Michaletz et al. 2009) and require sacrificing the fish. In contrast, removal of pectoral spines may not cause significant mortality (Michaletz 2005). Recently, Long and Stewart (2010) reported that most scientists have incorrectly identified the otoliths used for aging as sagittae, when they are actually lapilli, and papers in these symposium proceedings acknowledge that correction. In addition to annual markings, larvae and early juvenile catfish can be aged by counting daily rings that are formed on otoliths using techniques described by Sakaris and Irwin (2008) and Sakaris et al. (2011a, this volume).

In many of the published age estimate comparisons among catfish bony structures, it was assumed that those from otoliths were most accurate. However, this assumption may not be valid. While difficult, additional validation studies are needed, especially for older fish. Additionally, age comparison and validation studies conducted on the numerous, unstudied species of catfish that exist throughout the world would provide important advances in catfish techniques. These studies will be especially essential for understanding, managing, and conserving imperiled species of catfish that are at risk of extirpation or extinction.

Population Dynamics

Irwin and Hubert (1999) noted in their summary of the first international ictalurid symposium that population dynamics (i.e., growth, recruitment, and mortality) of almost all catfish species were poorly understood; however, those proceedings included six articles that contained population dynamics information (Crumpton 1999; Graham and DeiSanti 1999; Hightower et al. 1999; Mayo and Schramm 1999; Mosher 1999; Timmons 1999). Since publication of the proceedings from the first symposium, most population dynamics publications have examined growth in catfish. The general consensus is that growth of channel catfish in lotic environments is independent of density (Shephard and Jackson 2009) and has been shown to be strongly related to environmental variables such as floodplain connectivity (Quist and Guy 1998; Schramm et al. 2000), watershed fertility (Shephard and Jackson 2006), latitude (Shephard and Jackson 2006), and flow regime (Sakaris 2006). Growth of channel catfish in lentic environments has been shown to be related to both biotic (Shoup et al. 2007) and abiotic (Leonard 2009) factors. Several studies have estimated blue catfish growth (Grist 2002; Goeckler et al. 2003; Mauck and Boxrucker 2004; Stewart et al. 2009), but these investigators made comparisons among populations without regard to influential factors. Schramm and Eggleton (2006) examined growth of blue catfish and flathead catfish in the lower Mississippi River and found a positive influence from water temperature and duration and size of floodplain inundation. Additionally, Boxrucker and Kuklinski (2008) noted that blue catfish growth was negatively related to blue catfish catch rates from nine Oklahoma reservoirs, suggesting density-dependent processes. As with blue catfish, studies examining factors influencing growth of flathead catfish were rare since the first symposium, but several investigators have estimated and compared flathead catfish growth among populations and drawn broad conclusions (Daugherty and Sutton 2005a; Kwak et al. 2006; Makinster 2006; Sakaris et al. 2006; Marshall et al. 2009).

Six articles from these proceedings examined catfish growth. Michaletz et al. (2011, this volume) assessed density-dependent growth of stocked channel catfish from small impoundments in Missouri and developed growth increment indices to assess relative growth among populations. Jolley and Irwin (2011, this volume) examined growth of channel catfish, blue catfish, and flathead catfish from reservoir and tailwater areas along the Coosa River in Alabama and found no differences among habitats for any of the three species. Greenlee and Lim (2011, this volume) examined growth of introduced populations of blue catfish in several Virginia river systems. Bouska et al. (2011, this volume) examined channel catfish growth in Missouri River main-stem reservoirs and found that length-at-age steadily decreased in more northern reservoirs. Steuck and Schnitzler (2011) examined flathead catfish growth from portions of the pooled Mississippi River and found that this population was generally faster growing than other populations that have been examined. Finally, Rypel (2011, this volume) synthesized all available growth data for five catfish species, including bullheads *Ameiurus* spp., to examine large-scale drivers in catfish growth. While catfish growth was highly variable within and among species, catfish growth was intensely shaped by climatic variables, habitat type (lentic versus lotic), and latitudinal countergradients.

Recruitment is typically the strongest determinant influencing populations among the three major factors affecting populations (i.e., growth, recruitment, and mortality; Maceina and Pereira 2007). However, given the importance of recruitment processes to population dynamics, a paucity of information exists on this parameter for most catfish populations. Irwin et al. (1999a) examined habitat use of juvenile channel catfish and flathead catfish in riverine systems and hypothesized that flow regulation could limit recruitment by reducing habitats used by young catfish. Recent publications associated increased recruitment in catfish populations with habitat availability (Makinster 2006), river discharge (Shrader et al. 2003; Holley 2006; Sakaris 2006; Sakaris and Irwin 2010), reservoir water elevations (Shrader et al. 2003), and floodplain connectivity (Quist and Guy 1998).

Only two studies in these proceedings directly addressed recruitment in catfish populations. Greenlee and Lim (2011) examined long-term trends in blue catfish populations in four Virginia tidal rivers and found variable recruitment through time, but trends in year-class strength were consistent among populations, suggesting that landscape-level environmental variables shaped recruitment success in these populations. Muro and Amezcua (2011, this volume) examined reproductive biology in chihuil sea catfish *Bagre panamensis*, a mouth-brooding species from the Gulf of California; they noted that seasons prohibiting harvest during the fry incubation could potentially increase recruitment because many harvested males were still incubating fry. Three other studies within these proceedings may inform recruitment dynamics in catfish populations. Daugherty et al. (2011, this volume) found that substrate interstitial space diameter and depth characteristics were important habitat characteristics for juvenile flathead catfish. Sakaris et al. (2011a) validated daily ring deposition in otoliths from blue catfish and flathead catfish, allowing investigation of variables associated with recruitment. Finally, Smith and Whitledge (2011, this volume) examined trace element and stable isotope signatures in otoliths and pectoral spines of channel catfish, blue catfish, and flathead catfish. They found that chemical signatures in these bony structures allow reconstruction of environmental history when spatial differences in water chemistry are present, thus enabling investigations of stock mixing and recruitment sources within these species.

Hubert (1999) indicated that prior to publication of the first international catfish symposium proceedings, more than 50 published estimates of channel catfish annual mortality ranged from 0.13 to 0.88, and 10 published studies estimated annual angler exploitation from 0.01 to 0.30. While numerous estimates of mortality were published for channel catfish prior to the first symposium proceedings, little information existed for flathead catfish and blue catfish. Quinn (1993) indicated that annual angler exploitation of flathead catfish ranged from 0.14 to 0.25 annually from Flint River, Georgia, and Graham (1999) cited two studies on annual mortality rates for blue catfish (0.36–0.63). Only three studies were published in the first catfish symposium proceedings that reported either annual mortality or angler exploitation rates for catfish (Graham and DeiSanti 1999; Parrett et al. 1999; Timmons 1999). Since publication of the first catfish symposium proceedings, several additional studies have reported channel catfish annual mortality rates (Shrader et al. 2003; Colombo 2007; Barada 2009; Donabauer 2009; Holley et al. 2009) and angler exploitation rates (Holley et al. 2009). A similar number of studies reported flathead catfish annual mortality rates (Daugherty and Sutton 2005a; Kwak et al. 2006; Makinster 2006; Sakaris et al. 2006; Barada 2009; Donabauer 2009), angler exploitation rates (Marshall 2008), or both (Makinster and Paukert 2008; Marshall et al. 2009). Similarly, several studies published blue catfish annual mortality rates or angler exploitation rates (Mauck and Boxrucker 2004; Boxrucker and Kuklinski 2008; Donabauer 2009; Holley et al. 2009).

These proceedings expand on existing knowledge of mortality rates among catfish populations. One article presented annual mortality estimates for channel catfish (Bouska et al. 2011), one included flathead catfish rates (Kaeser et al. 2011, this volume), and one article estimated mortality for all three large ictalurid species (Jolley and Irwin 2011). Sullivan and Vining (2011, this volume) provided estimates of angler exploitation for blue catfish and flathead catfish from a Missouri reservoir while Travnichek (2011a, this volume) provided similar information on flathead catfish from the Missouri River. No prior published information existed to our knowledge regarding mortality estimates for bullheads; however, Sakaris et al. (2011b, this volume) provided information on life history of snail bullhead *Ameiurus brunneus* from Georgia, including annual mortality estimates of 0.40–0.44.

Many gaps in estimating and understanding catfish population dynamics remain as areas for future research. Population dynamics of bullheads, white catfish *A. catus*, and marine catfish populations is an area that demands more attention in the future. Virtually nothing is known about growth, recruitment, and mortality for these catfishes (see Keller 2011, this volume, for an exception). Given the importance of recruitment to understanding and managing populations, additional scientific attention toward this parameter is warranted for all catfish species. Additional population dynamics information is required to better manage catfish resources from conservation, commercial, and recreational standpoints.

Ecology

Catfish have existed on every continent (Armbruster 2011, this volume), and the enormous range of landforms, aquatic systems, and climatic conditions they currently occupy present many challenges in understanding their ecology. Despite these challenges, significant advances in the foundational knowledge of catfish have occurred. The first catfish symposium provided summary information on the biology and management for channel catfish (Hubert 1999), flathead catfish (Jackson 1999), and blue catfish (Graham 1999), important recreational and commercial catfish species in North America. Also included was the first overview of North America's madtoms *Noturus* spp., highlighting their ecological importance to the scientific community (Burr and Stoeckel 1999).

Ultimately, it is human interactions with catfish that provide the impetus to increase our understanding of their ecology. We are motivated to collect information on recreational and commercially important species for three primary purposes: (1) to facilitate their current or future management, (2) to increase their production, or (3) because we are compelled to investigate how our actions affect sensitive species, communities, or their habitats. Collectively, this information is derived from anthropogenic purposes, but combined with research emphasizing community and system relationships among multiple species and scales, it may significantly contribute to our current understanding of catfish ecology. Furthermore, anthropogenic forces on the lotic landscape have altered hydrologic cycles through impoundment and channelization of many of the world's riverine systems (Søndergaard and Jeppesen 2007).

Research conducted over the previous decade demonstrated that catfish populations are linked to numerous habitat variables at multiple scales. At relatively small scales, latitudinal differences in channel catfish growth were found within Alabama small impoundments (Leonard et al. 2010), and growth and maturation rates varied among Mississippi streams (Shephard and Jackson 2005, 2006). In Texas reservoirs, an intermediate-length growing season was optimal for channel catfish growth (Durham et al. 2005), and blue catfish density was related to primary productivity and surface area (Bartram et al. 2011, this volume). In South African reservoirs, feeding and growth of sharptooth catfish *Clarias gariepinus* were related to trophic status (Potts et al. 2008).

Knowledge of native nongame catfish ecology was greatly enhanced with these proceedings. Information gains resulted from the study of the reproductive behavior and characteristics for Ouachita madtom *Noturus lachneri* (Stoeckel et al. 2011, this volume) and chihuil sea catfish (Muro and Amezcua 2011) and population characteristics of snail bullhead (Sakaris et al. 2011b). Environmental and anthropogenic impacts to native species were also evident through studies on the reduced distribution of the Carolina madtom *N. furiosus* (Wood and Nichols 2011, this volume), species richness of catfish assemblages in Iowa (Sindt et al. 2011, this volume), and populations of endangered Neosho madtom *N. placidus* affected by gravel mining, heavy metals, impoundments, and reduced annual flows (Wildhaber 2011, this volume). Catfish species were also shown to negatively affect other communities when they invade or are introduced beyond their native range. While some catfish species appear sensitive to environmental change or degradation, (e.g., madtoms), others show great plasticity in habitat requirements and are able to colonize nonnative environments rapidly (e.g., bullheads and large ictalurids; see nonnative catfish section below).

Ecological understanding of the three large ictalurid species was also enhanced by these proceedings. Within lotic systems, habitat use by channel catfish, blue catfish, and flathead catfish differed between pool and open river portions and by habitat type in the Mississippi River (McCain et al. 2011; Miranda and Killgore 2011; both this volume). Flathead catfish population size structure differed between channelized and unchannelized portions of the middle Missouri River (Porter et al. 2011, this volume) and by habitat type within the lower Missouri River (Travnichek 2011b). Barada and Pegg (2011, this volume) found that channel catfish abundance varied among flow regimes found between the middle and lower Platte River, Nebraska. These studies reaffirm that catfish populations are linked to their habitats, whether they are in natural or highly disturbed systems.

A number of movement studies illustrate differing uses of lotic habitats by catfish species. Flathead catfish displayed strong site fidelity in the Fox and Wolf rivers, Wisconsin (Piette and Niebur 2011, this volume); lower Minnesota River, Minnesota (Shroyer 2011, this volume); and Iowa River, Iowa (Gelwicks and Simmons 2011, this volume). However, only a portion of flathead catfish and blue catfish populations migrated into tributaries of the upper Mississippi (Tripp et al. 2011, this volume) and lower Missouri (Garrett and Rabeni 2011, this volume) rivers. Variation in site fidelity and the proportion of migrating individuals between mainstem and tributary habitats suggest that study scale is an important consideration, as subpopulations may exhibit distinct differences in behavior and life history characteristics from a larger connected population.

The second international catfish symposium highlighted the need to expand catfish ecology research in several areas. Information on many nongame catfish species in North America and most catfish species worldwide is lacking, especially in providing a basic understanding of how anthropogenic alterations to habitat conditions affect these populations. Continued examination of these effects is needed, and management may be greatly improved by distinguishing information collected in native versus nonnative habitats. Current evidence suggests that while it is common to observe variation in life history information across a species' native distribution, recently established and expanding populations exhibit significant levels of plasticity, and combining information from both native and nonnative populations may decrease the overall value of each. Finally, research investigations must be established at the appropriate scale to understand parameters of interest. As habitat conditions and biotic composition often vary both temporally and spatially, the collection and evaluation of species information would be improved by scaling within the same framework. While in situ studies are well suited for examining specific species–habitat interactions (e.g., microhabitat use or diet studies), large-scale investigations over multiple watersheds may be required to accurately assess migration to spawning or overwintering areas for catfish species. Such future studies, as well as others approached at the community and ecosystem levels, will better define the ecological function of catfish in aquatic systems.

Recreational Fisheries Management

Over the past decade, there has been a shift in importance from commercial to recreational fisheries for catfishes, especially in North America, and articles in these proceedings expand existing knowledge in management of catfish as sport fish. Declines in commercial fisheries have resulted from closures in some water bodies (e.g., Mestl 1999; Stanovick 1999) and declining markets because of increased competition from aquaculture industries (Krogman et al. 2011; Quinn 2011; both this volume). Elimination of commercial fisheries in some waters has led to improvements in size structure of catfish populations (Mestl 1999; Stanovick 1999; Travnichek and Clemons 2001). As commercial catfish fisheries have declined, management for recreational fisheries has increased, especially for high-quality or trophy fisheries (Dorsey et al. 2011; Kuklinski and Patterson 2011; both this volume; Quinn 2011). This increase has been in response to the rising popularity of catfishes among anglers and anglers' desires for trophy fisheries (Arterburn et al. 2002). Restrictive regulations, especially size limits, have become more commonly applied to develop quality fisheries (Dorsey et al. 2011; Kuklinski and Patterson 2011; Quinn 2011) as biologists discovered that catfishes are intensively exploited in some waters (Slipke et al. 2002; Weimin et al. 2010; Sullivan and Vining 2011, this volume), reducing the potential for these fishes to maintain desirable populations or achieve large sizes (Slipke et al. 2002; Kuklinski and Patterson 2011).

Stocking catfishes to maintain fisheries or to introduce species into new environments remains a common management strategy. Put-take and put-grow-take fisheries for channel catfish are popular in small impoundments, especially in urban areas. Recent advances in sampling methods (see above) have enabled the assessment of these populations (Michaletz 2009; Flammang et al. 2011; Michaletz et al. 2011), thus enhancing managers' abilities to determine appropriate stocking rates for individual waters. Blue catfish have been stocked in various impoundments to create additional angler opportunities (e.g., Bartram et al. 2011). Several catfish species have been stocked outside of their native range (Bonvechio et al. 2011, this volume; Goradze et al. 2011, this volume; Greenlee and Lim 2011; Homer and Jennings 2011, this volume; Schloesser et al. 2011, this volume), sometimes with negative consequences on native fauna (see below).

Increased effort has been directed toward improving habitat for fishes in lotic and lentic systems (Barwick et al. 2004; Duehr et al. 2006; Roni et al. 2008; Weimin et al. 2010). However, most habitat improvement projects have not been specifically directed toward improving catfish populations. Nonetheless, catfish species likely benefit from these projects. For example, additions of large woody debris along eroded banks of a Mississippi creek resulted in higher catches of catfishes in treated areas (Shields et al. 2003, 2006). Reconnection of secondary channels and floodplain lakes to the main channel of a Bangladesh river resulted in increased catches of large migratory catfishes (Payne and Cowan 1998). Porter et al. (2011) found that flathead catfish were larger and grew faster in unchannelized portions of the middle Missouri River and suggested that habitat restoration would benefit not only flathead catfish, but other native fishes as well. Many restoration projects have probably benefited catfishes, but responses of catfishes to these projects have not been a primary objective nor consistently documented.

A growing number of studies have confirmed that many large-bodied catfishes can be highly migratory (Garrett and Rabeni 2011; Gelwicks and Simmons 2011; Hogan 2011, this volume; Tripp et al. 2011; but see Travnichek 2004). In many cases, catfish populations migrate across jurisdictional boundaries, indicating the need for multi-agency management. Interagency cooperation in managing these highly mobile species has increased in recent years. For example, adjoining jurisdictions sometimes develop common fishing regulations for a shared water body.

Management efforts have intensified due to the increased popularity of sport fishing for catfish and the development of effective sampling and aging methods. While restrictive size limits on large species have been implemented, long-term evaluations of these regulations will be necessary to determine success of these regulations. Responses of catfishes to habitat restoration also require evaluation so that future restoration efforts can be modified if necessary. Increased cooperation among management agencies is essential for maintaining and enhancing populations of highly migratory catfishes. Caution should be exercised when considering any stocking of a species outside its native range, and potential impacts to native species may warrant alternate management approaches. New techniques such as bony-structure microchemistry methods (e.g., Smith and Whitledge 2011) will be useful in determining natal areas of various populations and the mixing of these populations in large water bodies that span multiple jurisdictions. Although major advances in the management of catfish have occurred in North America since the first catfish symposium, similar advances will be required in other continents such as South America and Asia if the numerous species of catfish existing there are to be effectively managed (Hogan 2011).

Diversity

Catfish with commercial and recreational value are relatively well studied in North America, especially when compared to the many other catfish species around the world. A significant advance of this second international catfish symposium was to provide information on the worldwide biological diversity of catfishes and some of the challenges being faced outside of North America. Since the first symposium, the U.S. National Science Foundation established a Planetary Biodiversity Inventory Program that funded the All Catfish Species Inventory (ACSI), and a review of worldwide catfish taxonomy was presented by Armbruster (2011), a member of the ACSI team. Also within the past decade, the National Geographic Society has funded efforts to assess the status of the world's largest freshwater fishes, and Hogan (2011) reported on the conservation status and issues faced by large catfish species worldwide.

The catfish of North America share similar morphologies and exhibit low diversity when compared to species on other continents (Armbruster 2011). Therefore, the majority of work on catfish taxonomy, genetics, behavior, and paleontology has been conducted outside of North America. A couple of notable exceptions include the genetic status of headwater catfish (McClure-Baker et al. 2010) and interactions with freshwater mussels (Tiemann et al. 2011, this volume). The past decade has seen a number of revisions in catfish taxonomy (Gustiano et al. 2003; Ng 2003; Geerinckx et al. 2004) from Africa, Asia, and South America, with significant contributions from the paleontological record (Sanchez-Villagra and Aguilera 2006; Otero et al. 2007; Pinton et al. 2011). Examining venom glands and delivery structures provided insight into the taxonomic origins and selective processes that form the current order of catfishes (Wright 2009; Egge and Simmons 2011). Genetic investigations have helped describe the phylogeography of African catfish *Chrysichthys maurus* (Agnèse 2003) and elucidate the composition of *Corydoras* communities in South American streams, where species with similar morphology school together but do not compete for resources (Alexandrou et al. 2011).

Catfishes are a diverse order and are present in nearly all freshwater habitats around the world (Armbruster 2011). Thanks largely to the efforts surrounding ACSI, the number of valid species continues to grow, with another 961 added between 2002 and 2011 (Eschmeyer and Fong 2011). The adaptability of catfish to various land forms and hydrologic regimes is evident by the diverse body shapes, behaviors, and unique adaptations that catfish possess. Sizes range from the Mekong giant catfish *Pangasianodon gigas* and the wels *Silurus glanis*, known to exceed 3 m in length (Hogan 2011), to the minute species of the Scoloplacidae (spiny dwarf catfishes) family that measure less than 25 mm (Armbruster 2011). Body coverings range from smooth skin to armored bony plates. The use of modified pelvic fins in a walking motion allows *Clarias* spp. to climb waterfalls (Nelson 2006), permitting these catfishes to overcome obstacles that serve as barriers for most other fishes. Several species of *Clarias* are even able to breathe and feed on land (Graham 1997; Van Wassenbergh et al. 2006). Feeding methods range from benthic omnivory through piscivory and include specialists in seed and wood eating (Goulding 1980; German 2009), while parasitism is one of the more unusual forms of feeding observed in catfishes (Burgess 1989; Zuanon and Sazima 2004).

Many physiological adaptations to living in low oxygen conditions run prominent through this order of fishes, including the ability to absorb oxygen through the buccal cavity, stomach, or modified intestines (Munshi 1962; Armbruster 1998; Persaud et al. 2006). A number of unique behaviors suggest the adaptation of catfishes to a diverse set of habitats and biological circumstances. Nest building and mouth brooding are regarded as relatively common reproductive behaviors in catfish, but it is less well known that some species will feed young in a nest or practice nest parasitism (Sato 1986; LoVullo et al. 1992; Stauffer and Loftus 2010). Females of some *Corydoras* spp. are able to ingest and pass milt to inseminate their eggs (Kohda et al. 1995), the circadian rhythms of Indian walking catfish *Clarias batrachus* stimulate locomotion by night (Ramteke et al. 2009), and auditory sensitivity changes with age in the squeaker catfish *Synodontis schoutedeni* (Lechner et al. 2010). These ranges of body size and shapes, diversity in trophic level, habitat use, and behavior illustrate that catfish are one of the more adaptable orders of fishes globally.

While the observed diversity of catfish suggests that they have been very adaptive in the past, how will they adjust to the many challenges posed by climate change, human alterations of habitat, and expanding exploitation for consumption? The anthropogenic forces at work on the natural landscape continue (Dudgeon et al. 2006; Søndergaard and Jeppesen 2007), with evidence of declining catfish populations in South America's Amazon basin (Barthem and Goulding 2007), India (Hossain et al. 2008), and Southeast Asia (Hogan et al. 2004). These factors spurred the development of the National Science Foundation's Planetary Biodiversity Inventory Program, as well as the National Geographic Society's Megafish Project. Not only are the large migratory catfishes in Southeast Asia facing threats from excessive harvest, but from environmental pollutants as well (Phanwichien et al. 2010).

Lessons learned from North America's native nongame catfish impacted by human activities (Davis and Paukert 2008; Sindt et al. 2011; Wildhaber 2011; Wood and Nichols 2011; all this volume) can certainly be applied to other populations, and likewise, research conducted on other continents can inform management and conservation in North America. Despite a rising interest in public awareness to conservation needs of large riverine species through recent television programming (e.g., Discovery Animal Planet's River Monsters or National Geographic's Monster Fish), there remains a significant lack of information to manage and conserve species globally where nongame catfish are yet poorly studied, relatively unknown, and minimally managed.

Nonnative Catfish Ecology and Impacts

Catfish have been widely introduced beyond their native ranges intentionally and by accident as potential sport and food fish, as bait releases, by the aquarium trade, and through aquaculture activities. In the United States, ictalurids are the most widespread introduced catfishes, with the three large species (channel catfish, blue catfish, and flathead catfish) and bullheads most ubiquitous (Fuller et al. 1999). However, six other nonnative catfish families have been introduced to U.S. waters (Clariidae, Doradidae, Auchenipteridae, Pimelodidae, Callichthyidae, and Loricariidae; Fuller et al. 1999), and they are quite diverse in their morphology, biology, behavior, and ecology.

Timing and method of introduction of most of these species is not precisely known. Channel catfish is among the most widespread catfishes in North America due to intentional introductions as a sport and food fish (Fuller et al. 1999). Populations of many of these species, and most ictalurids, are easily and rapidly established where introduced (Guier et al. 1984; Jenkins and Burkhead 1994). Furthermore, many catfish species are tolerant of salinity gradients and may be able to disperse among coastal river systems (Bringolf et al. 2005). Once established, eradication of nonnative catfish populations appears impossible. Large-scale efforts to remove nonnative catfish have met with limited success, primarily by shifting population structure for flathead catfish in Georgia (Bonvechio et al. 2011) and black bullhead *Ameiurus melas* in Europe (Cucherousset et al. 2006).

Ecological effects of introduced catfish populations vary widely in their function and degree on the receiving ecosystem and are not easily documented, studied, and quantified; consequently, the effect of many species remains unknown. Nonnative catfish may affect an aquatic ecosystem by altering the native fish assemblage or other biota directly by predation, by physical alteration of habitat, indirectly through competition, or in more subtle ways, such as introduction of diseases or parasites (Taylor et al. 1984). Introduced ictalurids have been most studied with regard to their ecological effect, especially as predators. They have been implicated for the decline and decimation of a number of sport fishes, imperiled fishes, and amphibians (Fuller et al. 1999 and papers cited therein). Similarly, the sharptooth catfish in Africa has impacted aquatic, amphibian, and avian biota (Cambray 2003). In a number of catfish introductions, nonnative catfish appear to have decimated native catfish species (Guier et al. 1984; Thomas 1995; Pine et al. 2007; Keller 2011; Schloesser et al. 2011). Many of the impact links to nonnative catfish are anecdotal, are correlative, and lack direct causal evidence, which is extremely difficult to demonstrate in field studies. Field research documenting native species in the diet of nonnative catfish, along with population declines, may imply a predation effect, but vulnerable native species may be quickly decimated to such low densities that they are no longer available for detectable predation.

Diet studies of introduced populations of large ictalurids and bullheads have been inferred as an impact on native fishes in a number of studies. Nonnative channel catfish and black bullheads are known to prey on several species of imperiled fish in the western United States (Marsh and Brooks 1989; Marsh and Douglas 1997). Blue catfish are known to feed on mollusks (Graham 1999), and introduced populations of that species may impact imperiled freshwater mussels. Flathead catfish introductions have been among those most implicated in impacting native fishes by predation.

Flathead catfish are of special concern as an introduced predator because they are an aggressive obligate carnivore and have great potential to alter native fish assemblages (Jackson 1999). They have been considered among the most biologically harmful fish introductions in North America (Fuller et al. 1999). Food-web simulation modeling projected declines of up to 50% in the biomass of native fish groups after the establishment of introduced flathead catfish (Pine et al. 2007). A major reason for concern is that flathead catfish have been introduced into waters that are inhabited by rare and endangered fishes, and the effect of co-occurrence with these species is poorly understood (Bart et al. 1994; Brown et al. 2005; Flowers et al. 2011; Baumann and Kwak, in press).

Nonnative catfish studies were featured rather prominently in the proceedings of the two international catfish symposia (Irwin et al. 1999b; Michaletz and Travnichek 2011). Five articles in the first international catfish symposium and six in the second symposium proceedings were on nonnative catfish as invasive species. Articles in the first symposium covered research associated with nonnative catfish population dynamics (Dobbins et al. 1999; Helfrich et al. 1999), ecological impacts (Moser and Roberts 1999; Odenkirk et al. 1999), and angler attitudes (Weller and Geihsler 1999). All but one of those articles focused on flathead catfish, with one article on a multispecies assemblage of nonnative catfish (Helfrich et al. 1999).

Nonnative catfish literature in the second international symposium covered population dynamics (Greenlee and Lim 2011; Homer and Jennings 2011; Kaeser et al. 2011, this volume), ecological impacts (Keller 2011; Schloesser et al. 2011), and management as invasive species (Bonvechio et al. 2011). Three of these articles focused on nonnative blue catfish, two were on flathead catfish, and one was on channel catfish. Two additional articles were published in the second international symposium on nonnative catfish but were from the perspective of the species (blue catfish and channel catfish) as sport and food fish managed for population enhancement (Dorsey et al. 2011; Goradze et al. 2011). This illustrates a common dilemma that management agencies face when nonnative catfish populations develop into popular or economically viable fisheries, and agencies may be pressured to manage them with protective measures to support fishing, rather than with control measures to protect native species.

Recent published literature on nonnative catfish populations has greatly enhanced understanding in the areas of population dynamics and the ecological effects of introduced populations, but additional knowledge and understanding will be required by agencies to plan and implement management strategies. Population dynamics of introduced populations are easily studied and rather well documented. The ecological effects of nonnative catfish on native fauna, however, have been largely deduced through correlation assessments after introductions, usually at the population level. Assessments of community-level effects, similar to that by Pine et al. (2007), would enhance a broader understanding. Broad-scale comparisons among introduced and native catfish populations of population dynamics, trophic relations, and behavior, such as those by Kwak et al. (2006) and Sakaris et al. (2006), may further elucidate the unique biology and ecology of nonnative populations. Research into the social aspects of nonnative catfish fisheries, such as that conducted by Weller and Geihsler (1999), is surprisingly rare and is a critical knowledge gap in managing these populations. Finally, management options for controlling nonnative catfish populations are limited, and a need exists for creative experimentation by fish biologists, ecologists, physiologists, ethologists, and managers to collaborate toward developing mechanisms to contain, capture, or otherwise reduce the abundance of established nonnative catfish populations when required for management. This may include experimentation with sound, olfaction, vision, or mechanical or electrical stimuli, such as that initiated for flathead catfish (Horwitz et al. 2004) and that proven effective for controlling invasive sea lamprey *Petromyzon marinus* in the Great Lakes (Wagner et al. 2006). Advances in these and other topics in nonnative catfish ecology will support informed and improved management of their populations.

Human Dimensions

Prior to the first international catfish symposium (Irwin et al. 1999b), there was a paucity of information on human dimension aspects of catfish anglers (Gill 1980; Wilde and Riechers 1994). The proceedings of "Catfish 2000" (Irwin et al. 1999b) contained seven articles that were categorized as "human dimensions," comprising 15% of articles published in the volume. The desire to know more about catfish angler backgrounds, interests, and opinions has persisted since publication of the first catfish symposium.

One topic that arose from the first symposium was the possibility of managing some catfish populations as trophy fisheries. However, no information existed on angler attitudes or biologist opinions regarding this topic. Arterburn et al. (2002) conducted a survey of anglers and biologists from the entire Mississippi River basin, and they found that while anglers reported that fishing for "fun" was the most important reason they fished, an increase in size of fish caught also enhanced their trip. More than 70% of the anglers surveyed indicated that they took at least one trip per year to pursue trophy catfish, and a majority (66%) of anglers supported more stringent fishing regulations on catfish populations. However, biologists lacked information on effects of harvest regulations on catfish populations and state-specific information on angler opinions (Reitz and Travnichek 2004, 2006). Yet three states have recently approved catfish management plans (i.e., Missouri [Dames et al. 2003], Kansas [Mosher et al. 2007], and Oklahoma [Kuklinski and Patterson 2011]) while other states are in the process of developing statewide catfish management plans (e.g., Texas and Pennsylvania).

One potentially contentious social issue related to catfish management that emerged since "Catfish 2000" is that of hand fishing, a primitive way of capturing large catfish by hand (Bilger 2000; Salazar 2002). Hand fishing for catfish is legal throughout most of the southern United States but is generally prohibited elsewhere. Grigsby (2009) provided an insightful summary of thoughts, beliefs, and culture of Missouri hand fishers. Surveys conducted by Reitz and Travnichek (2005) and Morgan (2008) provide opinions of the general public and known hand fishers from Missouri on this issue. Morgan (2006) examined the social hierarchy of hand fishers (lower status) to trout anglers (higher status) and found few differences between the two groups; however, it was noted that hand fishers were more interested in social aspects, given that they "enjoyed discussing their fishing method with friends" and "most of their friends were connected to the fishing method," more so than trout anglers. Finally, Steffen and Hunt (2011) found that anglers from Mississippi who fished with rod and reel generally preferred to catch a higher number of fish while those who hand fished generally favored larger fish. Various national media outlets have reported on hand fishing and those who participate in the activity during the past decade. Videos and Web sites have highlighted the activity, and many consider hand fishing an extreme sport.

Two studies appear in these proceedings of the second catfish symposium related to the issue (Brown 2011; Winkelman 2011; both this volume), and both indicate that participation in the activity is minimal. Yet controversy over hand fishing will likely remain for some time, given strong opinions of individuals on both sides of the issue.

Approximately 11% of the articles in these proceedings have some aspect of human dimensions pertaining to catfish or anglers that pursue them. While this percentage is slightly less than that from the first catfish symposium, it does not diminish the timely importance of this area to catfish management and ecology. Three of the four plenary speakers at the second symposium discussed various social aspects of catfish. Jackson (2011, this volume) began by writing poetically about catfish and how they "can take us places beyond science." He then asked "What is the meaning of catfishes, their world, and the fisheries they support?" These are deeply philosophical thoughts but, nonetheless, demonstrate the sociological importance of catfish to humans. Quinn (2011) discussed the historical importance of catfish dating back to ancient Egypt with a king whose name translated to "catfish chisel." He continued with a discussion of the importance of catfish and utilization by Native Americans, as did Eder (2011, this volume). Quinn (2011) then explored the historical importance of commercial fishing for catfish to many people, a topic also examined by Eder (2011) and Krogman et al. (2011) in these proceedings. Catfish are important to cultures around the world, folk stories are passed down through generations, and a great deal of interest is generated in catfish due to their large size and interesting life histories and given that they often live in mysterious environments (Armbruster 2011; Hogan 2011; Quinn 2011). Catfish species that attain large sizes are often considered charismatic megafauna, and this was the focus of the plenary presentation of Hogan (2011), who discussed the importance of many of these large species to local tribes and cultures. While Hogan (2011) focused on megafauna, Quinn (2011) discussed the importance of the fish hobbyist and the multibillion-dollar aquarium trade for small diminutive species. While most small species of catfish are sold in the aquarium trade, Cochran (2011, this volume) described commercialized use of "willow cats" (i.e., tadpole madtom *Noturus gyrinus*) as bait along the upper Mississippi River. Finally, Quinn (2011) discussed the importance of public aquaria: "More than mere attractions, exhibited fish serve to inspire visitors with their fascinating appearance and size. Exhibits also seek to inform the public about conservation threats and other challenges species may face." While many mysteries remain in the deep and murky waters inhabited by members of the catfish family, the socioeconomic importance of this group of fishes and their interactions with humans will continue to enlighten and fascinate us for generations to come.

Summary and Future Directions

The topical review of catfish science that we present above reflects the breadth and volume of research and management in this area that is facilitated by our interest in this fish order by anglers and commercial fishers, hobbyists, natural resource agencies, academicians and their students, politicians, and varied components of society. Our analysis of temporal trends demonstrates that catfish science is a growing field and that the various topics pursued within the field are evolving, even at a decadal time scale. The information presented in the proceedings of the first international catfish symposium represented a significant advance in knowledge, and in just a single decade, the second symposium proceedings reflect the fulfilled need for further understanding of the conservation, ecology, and management of catfish.

Each section above emphasized the scientific advances of the past decade but also looked ahead to knowledge gaps that represent the future of the field. Areas that we expect to be pursued in the future decade are development of new techniques and the validation of existing methods; expansion of research to other less-studied catfish species; broadening perspectives in temporal, spatial, and organizational scales; interdisciplinary approaches; and research to objectively understand societal views and constituent demands. Meeting these challenges to fill future information needs will require scientists to span beyond their professional comfort zones to be effective. The first two international catfish symposia were successful in achieving objectives of expanding and exchanging knowledge in catfish science, but the standard will be higher with each successive scientific gathering. We look forward to the coming decade and the many advances in the conservation, ecology, and management of catfish that will be shared.

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References

Agnèse, J. F. 2003. Phylogeography of the African catfish *Chrysichthys maurus* (Valenciennes, 1839). African Journal of Aquatic Science 28:169–174.

Alexandrou, M. A., C. Oliveira, M. Maillard, R. A. McGill, J. Newton, S. Creer, and M. I. Taylor. 2011. Competition and phylogeny determine community structure in Mullerian co-mimics. Nature (London) 469:84–88.

Arab, A., M. L. Wildhaber, C. K. Wikle, and C. N. Gentry. 2008. Zero-inflated modeling of fish catch per unit area resulting from multiple gears: application to channel catfish and shovelnose sturgeon in the Missouri River. North American Journal of Fisheries Management 28:1044–1058.

Armbruster, J. W. 1998. Modifications of the digestive tract for holding air in loricariid and scoloplacid catfishes. Copeia 1998:663–675.

Armbruster, J. W. 2011. Global catfish biodiversity. Pages 15–37 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Arterburn, J. E., D. J. Kirby, and C. R. Berry, Jr. 2002. A survey of angler attitudes and biologist opinions regarding trophy catfish and their management. Fisheries 27(5):10–21.

Barada, T. J. 2009. Catfish population dynamics in the Platte River, Nebraska. Master's thesis. University of Nebraska, Lincoln.

Barada, T. J., A. J. Blank, and M. A. Pegg. 2011. Bias, precision, and processing time of otoliths and pectoral spines used for age estimation of channel catfish. Pages 723–731 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Barada. T. J., and M. A. Pegg. 2011. Population characteristics of channel catfish in the Platte River, Nebraska. Pages 81–94 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Bart, H. L., M. S. Taylor, J. T. Harbaugh, J. W. Evans, S. L. Schleiger, and W. Clark. 1994. New distribution records of Gulf Slope drainage fishes in the Ocmulgee River system, Georgia. Southeastern Fishes Council Proceedings 30:4–9.

Barthem, R., and M. Goulding. 2007. An unexpected ecosystem: the Amazon as revealed by fisheries. Missouri Botanical Garden Press, St. Louis.

Bartram, B. L., J. E. Tibbs, and P. D. Danley. 2011. Factors affecting blue catfish populations in Texas reservoirs. Pages 187–197 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Barwick, R. D., T. J. Kwak, R. L. Noble, and D. H. Barwick. 2004. Fish populations associated with habitat-modified piers and natural woody debris in Piedmont Carolina reservoirs. North American Journal of Fisheries Management 24:1120–1133.

Baumann, J. R., and T. J. Kwak. In press. Trophic relations of introduced flathead catfish in an Atlantic river. Transactions of the American Fisheries Society 140.

Bilger, B. 2000. Noodling for flatheads: moonshine, monster catfish, and other southern comforts. Simon and Schuster, New York.

Bodine, K. A., D. L. Buckmeier, J. W. Schlechte, and D. E. Shoup. 2011. Effect of electrofishing sampling design on bias of size-related metrics for blue catfish in reservoirs. Pages 607–620 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Bodine, K. A., and D. E. Shoup. 2010. Capture efficiency of blue catfish electrofishing and the effects of temperature, habitat, and reservoir location on electrofishing-derived length structure indices and relative abundance. North American Journal of Fisheries Management 30:613–621.

Bonvechio, T. F., M. S. Allen, D. Gwinn, and J. S.

Mitchell. 2011. Impacts of electrofishing removals on the introduced flathead catfish population in the Satilla River, Georgia. Pages 395–407 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Bouska, W. W., C. Longhenry, P. Bailey, D. Fryda, and H. Headley. 2011. Channel catfish populations, management, and angler use in the main-stem Missouri River reservoirs. Pages 167–176 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Boxrucker, J., and K. Kuklinski. 2008. Abundance, growth, and mortality of selected Oklahoma blue catfish populations: implications for management of trophy fisheries. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 60:152–156.

Bringolf, R. B., T. J. Kwak, W. G. Cope, and M. S. Larimore. 2005. Salinity tolerance of flathead catfish: implications for dispersal of introduced populations. Transactions of the American Fisheries Society 134:927–936.

Brown, J. J., J. Perillo, T. J. Kwak, and R. J. Horwitz. 2005. Implications of *Pylodictis olivaris* (flathead catfish) introduction into the Delaware and Susquehanna drainages. Northeastern Naturalist 12:473–484.

Brown, J. L., Jr. 2011. A survey of hand grabbing catfish anglers at Ross Barnett Reservoir, Mississippi. Pages 219–225 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Buckmeier, D. L., E. R. Irwin, R. K. Betsill, and J. A. Prentice. 2002. Validity of otoliths and pectoral spines for estimating ages of channel catfish. North American Journal of Fisheries Management 22:934–942.

Buckmeier, D. L., and J. W. Schlechte. 2009. Capture efficiency and size selectivity of channel catfish and blue catfish sampling gears. North American Journal of Fisheries Management 29:404–416.

Burgess, W. E. 1989. An atlas of freshwater and marine catfishes. A preliminary survey of the Siluriformes. T. F. H. Publications, Neptune City, New Jersey.

Burr, B. M., and J. N. Stoeckel. 1999. The natural history of madtoms (genus *Noturus*), North America's diminutive catfish. Pages 51–101 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Cambray, J. A. 2003. The need for research and monitoring on the impacts of the translocated sharptooth catfish, *Clarias gariepinus*, in South Africa. African Journal of Aquatic Science 28:191–195.

Cochran, P. A. 2011. Back to the fifties: historical use of "willow cats" as bait in the upper Mississippi River valley. Pages 305–311 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Collier, M., R. H. Webb, and J. C. Schmidt. 1996. Dams and rivers: a primer on the downstream effects of dams. U.S. Geological Survey Circular 1126, Denver.

Colombo, R. E. 2007. Demographics and the ecological role of the channel catfish (*Ictalurus punctatus*) in commercially exploited and un-exploited reaches of the Wabash River with implications for the flathead catfish (*Pylodictis olivaris*). Doctoral dissertation. Southern Illinois University, Carbondale.

Colombo, R. E., Q. E. Phelps, C. M. Miller, J. E. Garvey, R. C. Heidinger, and N. S. Richards. 2010. Comparison of channel catfish age estimates and resulting population demographics using two common structures. North American Journal of Fisheries Management 30:305–308.

Crumpton, J. E. 1999. Relative abundance, age, growth, and food habitats of channel and white catfish from the Clermont Chain of Lakes, Florida. Pages 115–119 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Cucherousset, J., J. Paillison, and A. Carpentier. 2006. Is mass removal an efficient measure to regulate the North American catfish *Ameiurus melas* outside of its native range? Journal of Freshwater Ecology 21:699–704.

Cunningham, K. K. 2000. Influence of environmental variables on flathead catfish electrofishing catch. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 52:125–135.

Cunningham, K. K. 2004. Efficacy of a chase boat for electrofishing flathead catfish in three Oklahoma reservoirs. North American Journal of Fisheries Management 24:1427–1430.

Dames, R., D. Brown, M. Colvin, R. Farr, P. Michaletz, C. Morrow, G. Pitchford, R. Shifflet, K. Sullivan, V. Travnichek, and T. Yasger. 2003. Managing Missouri's catfish: a statewide catfish management plan. Missouri Department of Conservation, Jefferson City.

Daugherty, D. J., J. W. Schlechte, and R. W. Wienecke. 2011. Selection of interstice size by juvenile flathead catfish. Pages 485–493 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Daugherty, D. J., and T. M. Sutton. 2005a. Population abundance and stock characteristics of flathead catfish in the lower St. Joseph River, Michigan. North American Journal of Fisheries Management 25:1191–1201.

Daugherty, D. J., and T. M. Sutton. 2005b. Use of a chase boat for increasing electrofishing efficiency for flathead catfish in lotic systems. North American Journal of Fisheries Management 25:1528–1532.

Davis, N., and C. Paukert. 2008. Impact of gravel bar scalping on Neosho madtom (*Noturus placidus*) populations from the lower Neosho River, Kansas. Journal of Freshwater Ecology 23:501–511.

Dobbins, D. A., R. L. Cailteux, and J. L. Nordhaus. 1999. Flathead catfish abundance and movement in the Apalachicola River, Florida. Pages 199–202 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Donabauer, S. B. 2009. Population dynamics of flathead, channel, and blue catfish in the Wabash River. Indiana Department of Natural Resources, Work Plan 204771 Final Report, Indianapolis.

Dorsey, L. G., B. J. McRae, and T. M. Thompson. 2011. Evaluation of an 813-mm maximum size limit for blue catfish in two North Carolina reservoirs. Pages 177–185 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Dudgeon, D., A. H. Arthington, M. O. Gessner, Z. Kawabata, D. J. Knowler, C. Leveque, R. J. Naiman, A. Prieur-Richard, D. Soto, M. Stiassny, and C. S. Sullivan. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biological Reviews 81:163–182.

Duehr, J. P., M. J. Siepker, C. L. Pierce, and T. M. Isenhart. 2006. Relation of riparian buffer strips to in-stream habitat, macroinvertebrates and fish in a small Iowa stream. Journal of the Iowa Academy of Science 113:49–55.

Durham, B. W., K. L. Pope, and G. R. Wilde. 2005. Factors affecting regional variation in growth of channel catfish. North American Journal of Fisheries Management 25:93–97.

Eder, S. 2011. Missouri's catfish: a history of utilization, management, and culture. Pages 55–70 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Egge, J. J., and A. M. Simmons. 2011. Evolution of venom delivery structures in madtom catfishes (Siluriformes: Ictaluridae). Biological Journal of the Linnean Society 102:115–129.

Eschmeyer, W. N., and J. D. Fong. 2011. Species of fishes by family/subfamily. Available: http://research.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp (May 2011).

Evans, N. T., D. E. Shoup, and K. E. Kuklinski. 2011. Comparison of electrofishing and experimental gill nets for sampling size structure and relative abundance of blue catfish in reservoirs. Pages 599–606 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Flammang, M. K., and R. D. Schultz. 2007. Evaluation of hoop-net size and bait selection for sampling channel catfish in Iowa impoundments. North American Journal of Fisheries Management 27:512–518.

Flammang, M. K., R. D. Schultz, and D. N. Cashatt. 2011. Utility of tandem hoop nets for indexing channel catfish structure and growth. Pages 545–555 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Flowers, H. J., T. F. Bonvechio, and D. L. Peterson. 2011. Observation of Atlantic sturgeon predation by a flathead catfish. Transactions of the American Fisheries Society 140:250–252.

Ford, Z. L., K. P. Sullivan, I. W. Vining, T. G. Kulowiec, G. D. Pitchford, H. R. Dames, R. J. Dent, and E. Colvin. 2011. Sampling statistics and size distributions for flathead catfish populations in four Missouri rivers. Pages 95–104 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Fuller, P. L., L. G. Nico, and J. D. Williams. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society, Special Publication 27, Bethesda, Maryland.

Gale, C. M., K. Graham, K. DeiSanti, and J. S. Stanovick. 1999. Sampling strategies for blue catfish and channel catfish in the Harry S Truman Dam tailwater, Missouri. Pages 301–307 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Garrett, D. L., and C. F. Rabeni. 2011. Intra-annual movement and migration of flathead catfish and blue catfish in the lower Missouri River and tributaries. Pages 495–509 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Geerinckx, T., D. Adriaens, G. G. Teugels, and W. Verraes. 2004. A systematic revision of the African catfish genus *Parauchenoglanis* (Siluriformes: Claroteidae). Journal of Natural History 38:775–803.

Gelwicks, G. T., and G. A. Simmons. 2011. Range and seasonal movements of flathead catfish in the Iowa River, Iowa. Pages 443–453 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

German, D. P. 2009. Inside the guts of the wood-eating catfishes: can they digest wood? Journal of Comparative Physiology 179:1011–1023.

Gill, A. D. 1980. The social circle of catfishermen: a contribution to the sociology of fishing. Master's thesis. Kansas State University, Manhatten.

Goeckler, J. M., M. C. Quist, J. A. Reinke, and C. S. Guy. 2003. Population characteristics and evidence of natural reproduction of blue catfish in Milford Reservoir, Kansas. Transactions of the Kansas Academy of Science 106:149–154.

Goradze, R. K., A. Komakhidze, and I. Goradze. 2011. Naturalization of channel catfish in the country of Georgia. Pages 437–442 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Goulding, M. J. 1980. The fishes and the forest: explorations in Amazonian natural history. University of California Press, Berkeley and Los Angeles.

Graham, J. B. 1997. Air-breathing fishes: evolution, diversity, and adaptation. Academic Press, San Diego, California.

Graham, K. 1999. A review of the biology and management of blue catfish. Pages 37–49 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Graham, K., and K. DeiSanti. 1999. The population and fishery of blue catfish and channel catfish in the Harry S Truman Dam tailwater, Missouri. Pages 361–376 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Greenlee, R. S., and C. N. Lim. 2011. Searching for equilibrium: population parameters and variable recruitment in introduced blue catfish populations in four Virginia tidal river systems. Pages 349–367 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Grigsby, M. 2009. Masculine identity work among Missouri noodlers: community providers, pleasure seeking comrades and family men, and tough courageous men. Southern Rural Sociology 24:218–243.

Grist, J. D. 2002. Analysis of a blue catfish population in a southeastern reservoir: Lake Norman, North Carolina. Master's thesis. Virginia Polytechnic Institute and State University, Blacksburg.

Guier, R. C., L. E. Nichols, and R. T. Rachels. 1984. Biological investigation of flathead catfish in the Cape Fear River. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 35:607–621.

Gustiano, R., G. G. Teugels, and L. Pouyard. 2003. Revision of the *Pangasius kunyit* catfish complex, with description of two new species from South-East Asia (Siluriformes; Pangasiidae). Journal of Natural History 37:357–376.

Helfrich, L. A., C. Liston, and D. L. Weigmann. 1999. Trends in catfish abundance in the Sacramento-San Joaquin Delta, California determined from salvage at the Tracy Fish Collection Facility: 1957–1996. Pages 341–352 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Hightower, J. E., W. J. Fleming, and M. A. Hayman.

1999. Effects of contaminated sediments on brown bullhead age structure, growth, and condition in a North Carolina tidal creek. Pages 161–172 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Hogan, Z. S. 2011. Ecology and conservation of large-bodied freshwater catfish: a global perspective. Pages 39–53 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Hogan, Z. S., P. Moyle, B. May, J. Vander Zanden, and I. Baird. 2004. The imperiled giants of the Mekong: ecologists struggle to understand and protect Southeast Asia's large, migratory catfish. American Scientist 92:228–237.

Holley, M. P. 2006. An evaluation of the catfish fishery in Wilson Reservoir, Alabama. Master's thesis. Auburn University, Auburn, Alabama.

Holley, M. P., M. D. Marshall, and M. J. Maceina. 2009. Fishery and population characteristics of blue catfish and channel catfish and potential impacts of minimum length limits on the fishery in Lake Wilson, Alabama. North American Journal of Fisheries Management 29:1183–1194.

Homer, M. D., Jr., and C. A. Jennings. 2011. Historical catch, age structure, sizes, and relative growth for an introduced population of blue catfish in Lake Oconee, Georgia. Pages 383–394 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Horwitz, R. J., T. K. O'Donnell, P. F. Overbeck, A. Kindt, J. Perillo, J. Teeter, L. Butler, A. Faulds, and S. Currey. 2004. Introduced flathead catfish pilot study. National Oceanic and Atmospheric Administration, Pennsylvania Coastal Zone Management Program, Technical Report, Project 2002-PD. 08, Philadelphia.

Hossain, M., Z. Ahmed, J. Ohtomi, A. Ibrahim, M. El-kady, B. Fulanda, and S. Chakraborty. 2008. Threatened fishes of the world: *Wallago attu* (Bloch Schneider, 1801). Environmental Biology of Fishes 82:277–278.

Hubert, W. A. 1999. Biology and management of channel catfish. Pages 3–22 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Irwin, E. R., M. C. Freeman, and K. M. Costley. 1999a. Habitat use by juvenile channel catfish and flathead catfish in lotic systems in Alabama. Pages 223–230 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Irwin, E. R., and W. A. Hubert. 1999. Biology and management of Ictaluridae: a summary of the proceedings of the international catfish symposium. Pages 495–500 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Irwin, E. R., W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. 1999b. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Jackson, D. C. 1999. Flathead catfish: biology, fisheries, and management. Pages 23–35 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Jackson, D. C. 2011. From our science comes our song: an introductory essay. Pages 1–2 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Jenkins, R. E., and N. M. Burkhead. 1994. Freshwater fishes of Virginia. American Fisheries Society, Bethesda, Maryland.

Jenkins, R. M. 1970. Reservoir fish management. Pages 173–182 *in* N. G. Benson, editor. A century of fisheries in North America. American Fisheries Society, Special Publication 7, Bethesda, Maryland.

Jolley, J. C., and E. R. Irwin. 2011. Catfish population characteristics in tailwater and reservoir habitats of the Coosa River, Alabama. Pages 155–166 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Kaeser, A. J., T. F. Bonvechio, D. Harrison, and R. R. Weller. 2011. Population dynamics of introduced flathead catfish in rivers of southern Georgia. Pages 409–422 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Keller, D. H. 2011. Population characteristics of white catfish and channel catfish in the Delaware River estuary. Pages 423–436 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Kohda, M., M. Tanimura, M. Kikue-Nakamura, and S. Yamagishi. 1995. Sperm drinking by female catfishes: a novel mode of insemination. Environmental Biology of Fishes 42:1–6.

Krogman, R. M., J. R. Fischer, M. C. Quist, M. J. Steuck, and M. M. Marron. 2011. Historical trends in ictalurid catfish commercial harvest in the upper Mississippi River. Pages 127–140 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Kuklinski, K. E., and C. P. Patterson. 2011. Development of a blue catfish management program in Oklahoma: a case history. Pages 71–79 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Kwak, T. J., W. E. Pine, III, and D. S. Waters. 2006. Age, growth, and mortality of introduced flathead catfish in Atlantic rivers and a review of other populations. North American Journal of Fisheries Management 26:73–87.

Lechner, W., L. E. Wysocki, and F. Ladich. 2010. Ontogenetic development of auditory sensitivity and sound production in the squeaker catfish *Synodontis schoutedeni*. BMC Biology [online serial] 8:10. DOI: 10.1186/1741–7007-8–10.

Leonard, D. M. 2009. Investigating interactions between channel catfish and other sport fishes in Alabama's state fishing lakes. Master's thesis. Auburn University, Auburn, Alabama.

Leonard, D. M., D. R. DeVries, and R. A. Wright. 2010. Investigating interactions between channel catfish and other sport fishes in small impoundments. North American Journal of Fisheries Management 30:732–741.

Long, J. M., and D. R. Stewart. 2010. Verification of otolith identity used by fisheries scientists for aging channel catfish. Transactions of the American Fisheries Society 139:1775–1779.

LoVullo, T. J., J. R. Stauffer, Jr., and K. R. McKaye. 1992. Diet and growth of a brood of *Bagrus meridionalis* Gunther (Siluriformes: Bagridae) in Lake Malawi, Africa. Copeia 1992:1084–1088.

Maceina, M. J., and D. L. Pereira. 2007. Recruitment. Pages 121–185 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Makinster, A. S. 2006. Flathead catfish population dynamics in the Kansas River. Master's thesis. Kansas State University, Manhattan.

Makinster, A. S., and C. P. Paukert. 2008. Effects and utility of minimum length limits and mortality caps for flathead catfish in discrete reaches of a large prairie river. North American Journal of Fisheries Management 28:97–108.

Marsh, P. C., and J. E. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to reestablishment of hatchery-reared razorback suckers. Southwestern Naturalist 34:188–195.

Marsh, P. C., and M. E. Douglas. 1997. Predation by introduced fishes on endangered humpback chub and other native species in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 126:343–346.

Marshall, M. D. 2008. Assessment of electrofishing bias, angler exploitation, and a creel survey, and flathead catfish population assessment in Lake Wilson, Alabama. Master's thesis. Auburn University, Auburn, Alabama.

Marshall, M. D., M. P. Holley, and M. J. Maceina. 2009. Assessment of the flathead catfish population in a lightly exploited fishery in Lake Wilson, Alabama. North American Journal of Fisheries Management 29:869–875.

Mauck, P., and J. Boxrucker. 2004. Abundance, growth, and mortality of the Lake Texoma blue catfish population: implications for management. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 58:57–65.

Mayhew, J. K. 1969. Age and growth of flathead catfish in the Des Moines River, Iowa. Transactions of the American Fisheries Society 98:118–120.

Mayo, R. M., and H. L. Schramm, Jr. 1999. Growth of flathead catfish in the lower Mississippi River. Pages 121–124 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

McCain, K. N. S., J. W. Ridings, Q. Phelps, and R. A. Hrabik. 2011. Population trends of flathead catfish, channel catfish, and blue catfish in impounded and unimpounded reaches of the upper Mississippi River (1993–2007). Pages 141–153 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

McClure-Baker, S. A., A. A. Echelle, R. A. Van den Bussche, A. F. Echelle, D. A. Hendrickson, and G. G. Garrett. 2010. Genetic status of headwater catfish in Texas and New Mexico: a perspective from mtDNA and morphology. Transactions of the American Fisheries Society 139:1780–1791.

Mestl, G. 1999. Changes in Missouri River channel catfish populations after closing commercial fishing. Pages 455–460 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Michaletz, P. H. 2005. Does pectoral spine extraction cause mortality to channel catfish? North American Journal of Fisheries Management 25:533–535.

Michaletz, P. H. 2009. Variable responses of channel catfish populations to stocking rate: density-dependent and lake productivity effects. North American Journal of Fisheries Management 29:177–188.

Michaletz, P. H., E. L. Dennis, M. A. Engel, and C. S. Gemming. 2011. Assessing channel catfish stocking rates with simple growth increment indices. Pages 589–598 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Michaletz, P. H., and J. G. Dillard. 1999. A survey of catfish management in the United States and Canada. Fisheries 24(8):6–11.

Michaletz, P. H., D. M. Nicks, and E. W. Buckner, Jr. 2009. Accuracy and precision of estimates of back-calculated channel catfish lengths and growth increments using pectoral spines and otoliths. North American Journal of Fisheries Management 29:1664–1675.

Michaletz, P. H., and K. P. Sullivan. 2002. Sampling channel catfish with tandem hoop nets in small impoundments. North American Journal of Fisheries Management 22:870–878.

Michaletz, P. H., and V. H. Travnichek, editors. 2011. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Miranda, L. E., and K. J. Killgore. 2011. Catfish spatial distribution in the free-flowing Mississippi River. Pages 521–534 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Morgan, M. 2006. The social hierarchy of fishing: myth or reality. Human Dimensions of Wildlife 11:317–327.

Morgan, M. 2008. Outlaw fishing in Missouri. Fisheries 33:165–171.

Moser, M. L., and S. B. Roberts. 1999. Effects of nonindigenous ictalurids and recreational electrofishing on the ictalurid community of the Cape Fear River drainage, North Carolina. Pages 479–485 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Mosher, T., C. Bever, L. Davignon, H. Jagerson, L. Jirak, and R. Marteney. 2007. Catfish in Kansas: a management plan. Kansas Department of Wildlife and Parks, Topeka.

Mosher, T. D. 1999. Characteristics of channel catfish in Kansas state fishing lakes: effects of watershed on growth. Pages 353–360 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Munshi, J. S. 1962. On the accessory respiratory organs of *Heteropneustes fossilis* (Bloch). Proceedings of the Royal Society of Edinburgh 68:128–146.

Muro, V., and F. Amezcua. 2011. Observations on the reproductive biology of the chihuil sea catfish in the southeast Gulf of California: implications for management. Pages 325–333 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Nash, M. K., and E. R. Irwin. 1999. Use of otoliths versus pectoral spines for aging adult flathead catfish. Pages 309–316 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Neely, B. C., and S. C. Dumont. 2011. Effect of soak duration on precision of channel catfish catch with baited, tandem hoop nets. Pages 557–561 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Nelson, J. S. 2006. Fishes of the world. Wiley, New York.

Ng, H. H. 2003. A revision of the south Asian sisorid catfish genus *Sisor* (Teleostei: Siluriformes). Journal of Natural History 37:2871–2883.

Nielsen, L. A. 1999. History of inland fisheries management in North America. Pages 3–30 *in* C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Odenkirk, J., E. Steinkoenig, and F. Spuchesi. 1999. Response of a brown bullhead population to flathead catfish introduction in a small Virginia impoundment. Pages 475–477 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Olive, J., H. L. Schramm, Jr., P. D. Gerard, and E. Irwin. 2011. An evaluation of agreement between pectoral spines and otoliths for estimating ages of catfishes. Pages 679–688 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Otero, O., A. Likius, P. Vignaud, and M. Brunet. 2007. A new claroteid catfish (Siluriformes) from the upper Miocene of Toros-Menalla, Chad: *Auchenoglanis soye*. Journal of Vertebrate Paleontology 27:285–294.

Parrett, T. P., J. A. Marshall, and D. J. Bright. 1999. An investigation in the applicability of length limits on the channel catfish populations in two small Ohio reservoirs. Pages 447–454 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Payne, A. I., and V. Cowan. 1998. Review of stock enhancement in the floodplains of Bangladesh. FAO Fisheries Biology Technical Paper 374.

Persaud, D., I. W. Ramnarine, and J. B. Agard. 2006. Trade-off between digestion and respiration in two air breathing callichthyid catfishes *Holosternum littorale* (Hancock) and *Corydoras aeneus* (Gill). Environmental Biology of Fishes 79:159–165.

Phanwichien, K., A. Pradermwong, H. E. Keenan, K. Masawang, N. Lauhachinda, A. Songsasen, A. Sakultantimetha, S. Bangkedphol, and A. F. Gaines. 2010. The ecological complexity of the Thai-Laos Mekong River: III. Health status of Mekong catfish and cyprinids, evidence of bioaccumulative effects. Journal of Environmental Science and Health Part A Toxic-Hazardous Substances & Environmental Engineering 45:1681–1688.

Piette, R. R., and A. D. Niebur. 2011. Movement of adult male flathead catfish in the upper Fox River and Wolf River systems determined by radiotelemetry. Pages 455–471 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Pine, W. E., III, T. J. Kwak, and J. A. Rice. 2007. Modeling management scenarios and the effects of an introduced apex predator on a coastal riverine fish community. Transactions of the American Fisheries Society 136:105–120.

Pinton, A., O. Otero, A. Likius, H. T. Mackaye, P. Vignaud, and M. Brunet. 2011. Giants in a minute catfish genus: first description of fossil *Mochokus* (Siluriformes, Mochokidae) in the late Mioene of Chad, including *M. gigas*. Journal of Vertebrate Paleontology 31:22–31.

Porath, M. T., L. D. Pape, L. K. Richters, K. L. Pope, and M. A. Pegg. 2011. Influence of throat configuration and fish density on escapement of channel catfish from hoop nets. Pages 563–571 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Porter, T. K., G. E. Mestl, and M. T. Porath. 2011. Population characteristics of flathead catfish in channelized and unchannelized reaches of the middle Missouri River from 1997 to 2008. Pages 105–118 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Potts, W. M., T. Hecht, and T. G. Andrew. 2008. Does reservoir trophic status influence feeding and growth of the sharptooth catfish, *Clarias gariepinus* (Teleostei: Clariidae)? African Journal of Aquatic Science 33:149–156.

Quinn, S. 2011. Human interactions with catfish. Pages 3–13 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Quinn, S. P. 1993. Description of a multiuse fishery for flathead catfish. North American Journal of Fisheries Management 13:594–599.

Quist, M. C., and C. S. Guy. 1998. Population characteristics of channel catfish from the Kansas River, Kansas. Journal of Freshwater Ecology 13:351–359.

Ramteke, A. K., P. Poddar, and A. K. Pati. 2009. Circadian rhythms of locomotor activity in Indian walking catfish, *Clarias batrachus*. Biological Rhythm Research 40:201–209.

Reitz, R. A., and V. H. Travnichek. 2004. An analysis of Missouri catfish angler demographics and opinions for fisheries management alternatives. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 58:66–81.

Reitz, R. A., and V. H. Travnichek. 2005. Angler opinions regarding handfishing for catfish in Missouri. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 59:273–281.

Reitz, R. A., and V. H. Travnichek. 2006. Examining the relationship between species preference and catfish angler demographics, angling behavior, and management opinions. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 60:145–151.

Richters, L. K., and K. L. Pope. 2011. Catch of channel catfish with tandem-set hoop nets and gill nets in lentic systems of Nebraska. Pages 573–580 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Roni, P., K. Hanson, and T. Beechie. 2008. Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. North American Journal of Fisheries Management 28:856–890.

Rypel, A. L. 2011. Meta-analysis of growth for five North American catfishes: effects of climate, hydrologic habitat, and latitudinal countergradients. Pages 661–677 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Sakaris, P. C. 2006. Effects of hydrologic variation on dynamics of channel catfish and flathead catfish populations in regulated and unregulated rivers in the southeast USA. Doctoral dissertation. Auburn University, Auburn, Alabama.

Sakaris, P. C., D. J. Daugherty, and D. L. Buckmeier. 2011a. Validation of daily ring deposition in the otoliths of age-0 blue catfish and flathead catfish. Pages 689–697 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Sakaris, P. C., and E. R. Irwin. 2008. Validation of daily ring deposition in the otoliths of age-0 channel catfish. North American Journal of Fisheries Management 28:212–218.

Sakaris, P. C., and E. R. Irwin. 2010. Tuning stochastic matrix models with hydrologic data to predict the population dynamics of a riverine fish. Ecological Applications 20:483–496.

Sakaris, P. C., E. R. Irwin, J. C. Jolley, and D. Harrison. 2006. Comparison of native and introduced flathead catfish populations in Alabama and Georgia: growth, mortality, and management. North American Journal of Fisheries Management 26:867–874.

Sakaris, P. C., D. Smith, E. Davis, and B. Macham. 2011b. Life history and population structure of the snail bullhead in Nickajack Creek, Georgia. Pages 313–323 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Salazar, D. A. 2002. Noodling: an American folk fishing technique. Journal of Popular Culture 35:145–155.

Sanchez-Villagra, M. R., and O. A. Aguilera. 2006. Neogene vertebrates from Urumaco, Falcon, Venezuela: diversity and significance. Journal of Systematic Palaeontology 4:213–220.

Sato, T. 1986. A brood parasitic catfish of mouthbrooding cichlid fishes in Lake Tanganyika. Nature (London) 323:58–59.

Schloesser, R. W., M. C. Fabrizio, R. J. Latour, G. C. Garman, B. Greenlee, M. Groves, and J. Gartland. 2011. Ecological role of blue catfish in Chesapeake Bay communities and implications for management. Pages 369–382 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Schramm H. L., Jr., and M. A. Eggleton. 2006. Applicability of the flood-pulse concept in a temperate floodplain river ecosystem: thermal and temporal components. River Research and Applications 22:543–553.

Schramm, H. L., Jr., M. A. Eggleton, and R. M. Mayo. 2000. Habitat conservation and creation: invoking the flood-pulse concept to enhance fisheries in the lower Mississippi River. Polish Archives for Hydrobiology 47:45–62.

Shephard, S., and D. C. Jackson. 2005. Channel catfish maturation in Mississippi streams. North American Journal of Fisheries Management 25:1467–1475.

Shephard, S., and D. C. Jackson. 2006. Difference in channel catfish growth among Mississippi stream basins. Transactions of the American Fisheries Society 135:1224–1229.

Shephard, S., and D. C. Jackson. 2009. Density-independent growth of floodplain river channel catfish *Ictalurus punctatus*. Journal of Fish Biology 74:2409–2414.

Shields, F. D., Jr., S. S. Knight, N. Morin, and J. Blank. 2003. Response of fishes and aquatic habitats to sand-bed stream restoration using large woody debris. Hydrobiologia 494:251–257.

Shields, F. D., Jr., S. S. Knight, and J. M. Stofleth. 2006. Large wood addition for aquatic habitat rehabilitation in an incised, sand-bed stream, Little Topashaw Creek, Mississippi. River Research and Applications 22:803–817.

Shoup, D. E., S. P. Callahan, D. H. Wahl, and C. L. Pierce. 2007. Size-specific growth of bluegill, largemouth bass, and channel catfish in relation to prey availability and limnological variables. Journal of Fish Biology 70:21–34.

Shrader, T. M., B. Moody, and M. Buckman. 2003. Population dynamics of channel catfish in Brownlee Reservoir and the Snake River, Oregon. North American Journal of Fisheries Management 23:822–834.

Shroyer, S. M. 2011. Movement and site fidelity of flathead catfish in the Minnesota River. Pages 473–483 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Sindt, A. R., J. R. Fischer, M. C. Quist, and C. L. Pierce. 2011. Ictalurids in Iowa's streams and rivers: status, distribution, and relationships with biotic integrity. Pages 335–347 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Slipke, J. W., A. D. Martin, J. Pitlo, and M. J. Maceina. 2002. Use of the spawning potential ratio for the upper Mississippi River channel catfish fishery. North American Journal of Fisheries Management 22:1295–1300.

Smith, K. T., and G. W. Whitledge. 2011. Trace element and stable isotopic signatures in otoliths and pectoral spines as potential indicators of catfish environmental history. Pages 645–660 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Søndergaard, M., and E. Jeppesen. 2007. Anthropogenic impacts on lake and stream ecosystems, and approaches to restoration. Journal of Applied Ecology 44:1089–1094.

Stanovick, J. S. 1999. Recreational harvest rates, release rates, and average length of catfish on the Missouri River, Missouri before and after the commercial catfishing ban. Pages 443–446 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Stauffer, J. R., Jr., and W. F. Loftus. 2010. Brood parasitism of a bagrid catfish (*Bagrus meridionalis*) by a clariid catfish (*Bathyclarias nyasensis*) in Lake Malawi, Africa. Copeia 2010:71–74.

Stauffer, K. W., and B. D. Koenen. 1999. Comparison of methods for sampling flathead catfish in the Minnesota River. Pages 329–339 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Steffen, S. F., and K. M. Hunt. 2011. Catch-related attitudes of Mississippi catfish anglers: hand grabblers and rod-and-reel anglers. Pages 227–237 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Steuck, M. J., and C. C. Schnitzler. 2011. Age and growth of flathead catfish from Pools 12 and 13 of the upper Mississippi River. Pages 699–712 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Stewart, D. R., G. W. Benz, and G. D. Scholten. 2009. Weight–length relationships and growth data for blue catfish from four Tennessee waterbodies. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 63:140–146.

Stoeckel, J. N., C. J. Gagen, and R. W. Standadge. 2011. Feeding and reproductive biology of Ouachita madtom. Pages 267–279 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Sullivan, K. P., and C. M. Gale. 1999. A comparison of channel catfish catch rates, size distributions, and mortalities using three different gears in a Missouri impoundment. Pages 293–300 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Sullivan, K. P., and I. W. Vining. 2011. Assessing angler exploitation of blue catfish and flathead catfish in a Missouri reservoir using reward tags. Pages 199–207 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Taylor, J. N., W. R. Courtenay, Jr., and J. A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pages 322–373 *in* W. R. Courtenay, Jr., and J. R. Stauffer, Jr., editors. Distribution, biology, and management of exotic fishes. Johns Hopkins University Press, Baltimore, Maryland.

Thomas, M. E. 1995. Monitoring the effects of introduced flathead catfish on sport fish populations in the Altamaha River, Georgia. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 47:531–538.

Tiemann, J. S., S. E. McMurray, M. C. Barnhart, and G. T. Watters. 2011. A review of interactions between catfishes and freshwater mollusks in North America. Pages 733–743 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Timmons, T. J. 1999. Movement and exploitation of blue and channel catfish in Kentucky Lake. Pages 187–191 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Travnichek, V. H. 2004. Movement of flathead catfish in the Missouri River: examining opportunities for managing river segments for different fishery goals. Fisheries Management and Ecology 11:89–96.

Travnichek, V. H. 2011a. Angler size selectivity and exploitation of flathead catfish from the Missouri River. Pages 119–126 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Travnichek, V. H. 2011b. Monthly variation and influence of habitat and river stage on electrofishing catch rates and population indices of flathead catfish from the lower Missouri River. Pages 621–635 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Travnichek, V. H., and H. D. Clemons. 2001. Utility of tournament data for assessing effects of eliminating commercial catfish harvest in the Missouri River. North American Journal of Fisheries Management 21:688–691.

Tripp, S. J., M. J. Hill, H. A. Calkins, R. C. Brooks, D. P. Herzog, D. E. Ostendorf, R. A. Hrabik, and J. E. Garvey. 2011. Blue catfish movement in the upper Mississippi River. Pages 511–519 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Van Wassenbergh, S., A. Herrel, D. Adriaens, F. Huysentruyt, S. Devaere, and P. Aerts. 2006. A catfish that can strike its prey on land. Nature (London) 440:881.

Vokoun, J. C., and C. F. Rabeni. 1999. Catfish sampling in rivers and streams: a review of strategies, gears, and methods. Pages 271–286 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Vokoun, J. C., and C. F. Rabeni. 2001. A standardized sampling protocol for channel catfish in prairie streams. North American Journal of Fisheries Management 21:188–197.

Wagner, C. M., M. L. Jones, M. B. Twohey, and P. W. Sorensen. 2006. A field test verifies that pheromones can be useful for sea lamprey (*Petromyzon marinus*) control in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 63:475–479.

Wallace, B. C., D. M. Weaver, and T. J. Kwak. 2011. Efficiency of baited hoop nets for sampling catfish in southeastern U.S. small impoundments. Pages 581–588 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Weimin, M., S. DeSilva, and B. Davy, editors. 2010. Inland fisheries resource enhancement and conservation in Asia. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, RAP Publication 2010/22, Bangkok, Thailand.

Weller, R. R., and M. R. Geihsler. 1999. Angler attitudes concerning the management of the introduced flathead catfish in the Altamaha River system, Georgia. Pages 435–442 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, editors. Catfish 2000: proceedings of the international ictalurid symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Wilde, G. R., and R. K. Riechers. 1994. Demographic and social characteristics and management preferences of Texas freshwater catfish anglers. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 46:393–401.

Wildhaber, M. L. 2011. The Neosho madtom and the multifaceted nature of population limiting factors. Pages 281–294 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Winkelman, D. L. 2011. Evaluation of the flathead catfish population and fishery on Lake Carl Blackwell, Oklahoma, with emphasis on effects of noodling. Pages 209–217 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Wood, C. J., and R. B. Nichols. 2011. Status assessment of the Carolina madtom: a rare North Carolina endemic. Pages 295–303 *in* P. H. Michaletz and V. H. Travnichek, editors. Conservation, ecology, and management of catfish: the second international symposium. American Fisheries Society, Symposium 77, Bethesda, Maryland.

Wright, J. J. 2009. Diversity, phylogenetic distribution, and origins of venomous catfishes. BMC Evolutionary Biology [online serial] 9:282. DOI: 10.1186/1471–2148-9–282.

Zuanon, J. A., and I. Sazima. 2004. Vampire catfishes seek the aorta not the jugular: candirus of the genus *Vandella* (Trichomycteridae) feed on major gill arteries of host fishes. Journal of Ichthyology and Aquatic Biology 8:31–36.