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Historical Trends in Ictalurid Catfish Commercial Harvest in the Upper Mississippi River

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Abstract.—Ictalurids compose a substantial portion of the commercial harvest in the upper Mississippi River (UMR). The purpose of this investigation was to examine spatial and temporal trends in commercial harvest of ictalurids in the UMR. The study focused on four species: channel catfish *Ictalurus punctatus*, flathead catfish *Pylodictis olivaris*, blue catfish *I. furcatus*, and black bullhead *Ameiurus melas*. We described trends in yield and market value and evaluated the influence of numerous factors on commercial catfish harvest in Pools 3–26 of the UMR between 1953 and 2001. Spatial and temporal variations in commercial harvest of catfish appeared to be driven by different factors through time. Early factors included habitat loss and overexploitation, and later factors included loss of the market share and increased market competition with aquaculture. Ictalurids have maintained a consistent proportion of the total commercial harvest in the UMR, and decreases in catfish harvest may indicate larger declines in commercial fishing.

Introduction

Ictalurids represent one of the most important groups of sport fishes in the United States and constitute an important component of the upper Mississippi River (UMR) ecosystem and its fishery. Due to their commercial value, ictalurids have been called the "most sought after of the Mississippi River fishes" (Carlander 1954). From 1953 to 2001, nonbullhead ictalurids (NBI) collectively maintained the highest market value of any commercially harvested fish in the UMR (authors' unpublished data). Similarly, bullheads consistently ranked among the highest five market values of any commercially harvested fish in the UMR from 1953 to 1990. According to Ziegenhorn (2000), a commercial fisherman who seeks to maximize profits would rationally maximize the catch of catfishes. As a result, ictalurids may compose a stable proportion of total commercial harvest.

Early records of commercial harvest from the UMR were inconsistently maintained, but those that exist suggest major declines in catfish harvest during the late 1800s and early 1900s. For example, between 1894 and 1946, ictalurid catfish harvest in the pools bordering Iowa decreased by about 60% (Barnickol and Starrett 1951). Although declines were noted, a paucity of information exists as to the potential causes of ictalurid declines. One possible cause of major declines in UMR catfish fisheries is substantial anthropogenic alteration of the UMR. The Mississippi River Improvement Committee, founded in 1845, initiated projects on the river, including channel dredging, wing dam construction, and levee construction (Carlander 1954). These

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improvement projects were coupled with land cover alterations associated with human settlement and increased agriculture. The Rivers and Harbors Act of 1878 authorized development and maintenance of a 1.37-m-deep channel, after which bank revetments, longitudinal wing dams, and closing dams were constructed (Chen and Simons 1986). A revision of the Rivers and Harbors Act in 1930 authorized the creation of a 2.75-m channel through a series of locks and dams. After the passage of the Rivers and Harbors Act in 1930, impoundment of the UMR may have resulted in substantial habitat alterations, such as reductions in catfish spawning habitat (Helms 1975). Additionally, regulation of commercial harvest was complex in the UMR; management strategies differed among agencies, resulting in inconsistent regulations within pools and among states. Inconsistency rendered more restrictive regulations on one side of the channel ineffective because commercial fishermen could purchase an out-of-state license for the opposite side of the channel (Barnickol and Starrett 1951). Given apparent declines in fish abundances in the UMR, representatives from the managing agencies formed the Upper Mississippi River Conservation Commission (UMRCC) in 1943 to facilitate cooperative research and collaborative management activities.

An initial investigation of the status of various commercial and sport fish species (i.e., Barnickol and Starrett 1951) revealed numerous insights into catfish populations in the UMR. Their study found that flathead catfish *Pylodictis olivaris* composed 69% of the total catfish harvest by weight while channel catfish *Ictalurus punctatus* composed 18%. Notably, no blue catfish *I. furcatus* were sampled north of Warsaw, Illinois, and no brown bullheads *Ameiurus nebulosus* or yellow bullheads *A. natalis* were sampled upstream of Pool 16. While black bullheads *A. melas* were sampled throughout the reach, populations were sporadically distributed and composed less than 4% of the total catfish catch weight. Barnickol and Starrett (1951) concluded that the UMR was largely a channel catfish–flathead catfish commercial fishery, with minor contributions from black bullheads and blue catfish.

In 1947, the UMRCC recommended establishment of uniform minimum length regulations for both channel catfish (381 mm) and flathead catfish (457 mm; UMRCC 1947), based on preliminary data from Barnickol and Starrett (1951). In accord with these recommendations, Minnesota, Wisconsin, and Missouri adopted the minimum length limits, making harvest regulations in Pools 3–8 (Minnesota–Wisconsin waters) uniform on both sides of the channel. In 1975, Illinois also implemented the UMRCC length regulations, making regulations in Pools 20–26 (Missouri–Illinois waters) consistent with Pools 3–8. Between 1984 and 1985, Iowa (Pools 9–19) adopted the regulations, making the minimum length regulations uniform throughout the UMR; however, gear, season, and daily harvest restrictions remained variable from state to state.

Despite the UMRCC's efforts to standardize commercial fishing regulations, catfish harvest continued to decline. Past analyses of commercial harvest records in the UMR have been restricted to channel catfish harvest in waters of specific states (e.g., Helms 1975; Pitlo 1997; Ziegenhorn 2000). Factors associated with harvest trends included habitat loss (Barnickol and Starrett 1951; Helms 1975), overexploitation (Pitlo 1997), and market competition (UMRCBSCC 1970; Ziegenhorn 2000), but it was unclear whether harvest was driven largely by supply (i.e., population dynamics) or demand (i.e., market dynamics). No previous studies evaluating ictalurid fisheries have encompassed the entire UMR. Therefore, the objective of this study was to describe spatial and temporal trends in commercial harvest of channel catfish, flathead catfish, blue catfish, and bullhead species in Pools 3–26 of the UMR from 1953 to 2001.

Methods

Study Area

The UMR is defined as the 1,374 river kilometers between St. Anthony Falls, Minnesota and Cairo, Illinois (Figure 1). The northern portion, from Minneapolis to the confluence of the Missouri River near Alton, Illinois, has been impounded by a system of locks and dams, channelized, and lined with levees to improve navigation on the river. The main channel in Pools 3–26 serves as the boundary between states along the UMR. During construction of the locks and dams, Lock and Dam 23 was named but never built (Figure 1). In addition, a lock and dam (i.e., Lock and Dam 5A) was required between Pools 5 and 6 to facilitate navigation. This study was restricted to the impounded reaches of the UMR, thereby excluding the open reach from St. Louis, Missouri to Cairo, Illinois.

Data Collection and Analysis

Commercial catfish data (i.e., kilograms harvested, average flesh price, and total market value) were ob-

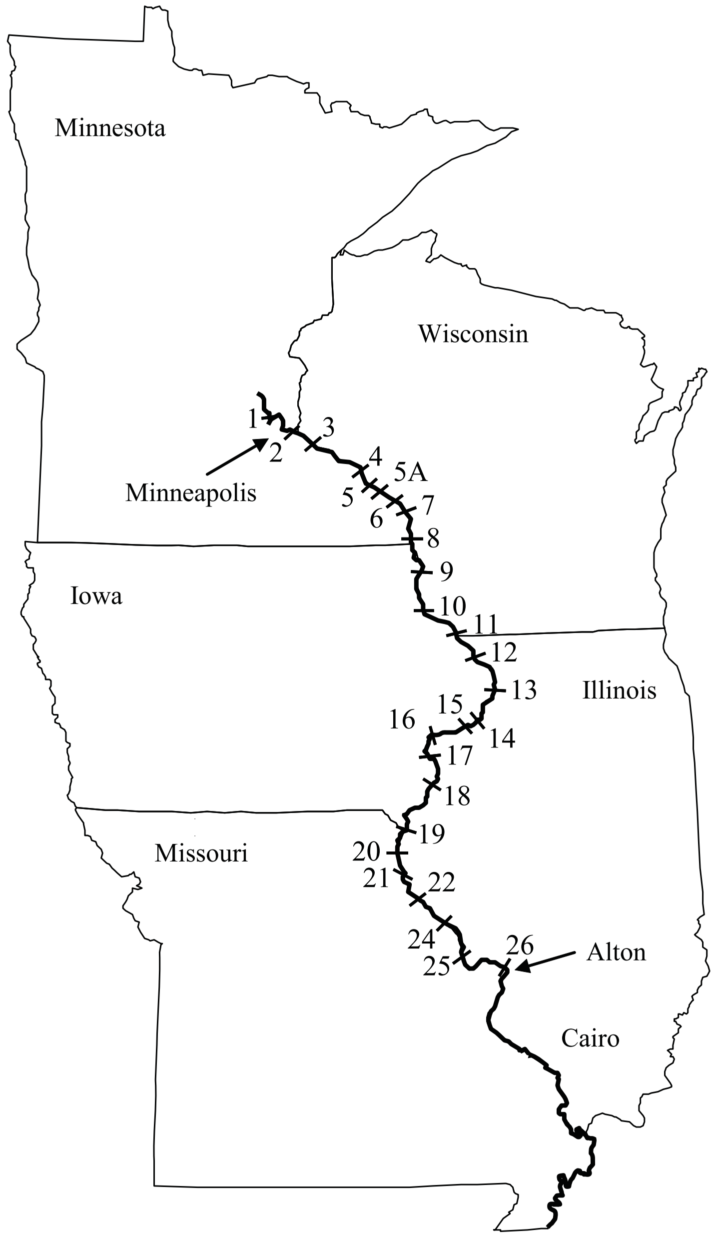

FIGURE 1. Map of the upper Mississippi River. Numbers correspond with Lock and Dam enumeration by the U.S. Army Corps of Engineers. Pools are numbered by the dam forming the pool.

tained from the UMRCC. Each state in the UMRCC requires reporting of commercial harvest by licensed fishermen (i.e., kilograms harvested by species), and all reported data have been recorded in an electronic database since 1985. Data prior to 1985 were published in UMRCC annual reports and were recently compiled to extend the electronic database back to 1953 (e.g., Quist et al. 2009). Although we used data collected from commercial fishermen, which may contain errors, we examined trends over long-temporal and large-spatial scales, likely mitigating effects of incomplete or incorrect reporting.

Total and mean harvest weights of each group (i.e., NBI, bullheads, individual species) were summarized for each pool and year. Mean harvest weights of NBI and bullheads were also summarized by decade to evaluate temporal changes in each pool's contribution to commercial harvest. Average flesh price of each group was adjusted to 2010 United States dollars using the consumer price index (Tietenberg 1996). Data from Pools 5 and 5A were combined.

Gross aquaculture production as live weight of catfish in the United States was obtained from the Fisheries and Aquaculture Information and Statistics Service of the Food and Agriculture Organization of the United Nations using Fishstat Plus (FAO 2007). Average flesh prices paid by processors for farmed catfish were obtained from the National Agricultural Statistics Service of the U.S. Department of Agriculture (USDA NASS 2010).

Until 1991, ictalurids were grouped into two categories, "Bullheads" and "Ictalurids," partly because commercial fishermen were often ambiguous when reporting their catch. All bullhead species, including black bullhead, brown bullhead, and yellow bullhead, were grouped as "Bullheads." In accord with the conclusions of Barnickol and Starrett (1951), the majority of "Bullheads" were likely black bullheads during the earlier years of the data set. More recently, the majority of "Bullheads" comprised yellow bullheads, followed by black bullheads and brown bullheads (S. McNitt, Schafer Fisheries Inc., personal communication; R. Mohn, Lansing Fish Market, personal communication). Nonbullhead ictalurids (i.e., channel catfish, flathead catfish, and blue catfish) were grouped as "Ictalurids" until 1991. Beginning in 1992, species-specific catch weight and flesh price data were reported. For clarity, data were analyzed from 1953 to 2001 as "Bullheads" and "NBI," and NBI data from 1992 to 2001 were analyzed by species.

Results

Spatial Trends

From 1953 to 2001, mean annual bullhead harvest varied among pools from 3 kg (SE; ±1) in Pool 3 to 17,527 kg (±1,609) in Pool 9 (Figure 2A). Mean annual NBI harvest varied among pools from 468 kg (±85) in Pool 3 to 110,289 kg (±7,325) in Pool 19 (Figure 2B). From 1992 to 2001, mean annual harvest of channel catfish was highest in Pool 19 (mean ± SE; 97,639 ± 5,738 kg; Figure 3), followed by Pool 9 (91,670 ± 7,408 kg), Pool 13 (86,759 ± 5,292 kg), and Pool 10 (56,127 ± 3,017 kg). These pools contributed more than half (52.8%) of the total channel catfish harvest in the UMR from 1992 to 2001. Mean annual harvest of flathead catfish was more equally distributed among pools than for channel catfish, with highest mean harvest observed in Pool 19 (12,900 ± 1,310 kg), Pool 18 (12,617 ± 886 kg), and Pool 10 (12,586 ± 811 kg; Figure 3). These pools contributed 30.0% of the total flathead catfish harvest in the UMR from 1992 to 2001. Mean annual harvest of blue catfish was highest in Pool 26 (10,727 ± 3,105 kg), which contributed 62.9% of the total blue catfish harvest from 1992 to 2001. No blue catfish were commercially harvested upstream of Pool 16.

Temporal Trends

Commercial harvest of bullheads has been substantially lower through time than harvest of NBI (Figure 4A). From 1953 to 2001, mean bullhead harvest per pool varied from 85 (±45) to 2,767 kg (±1,732), and total harvest varied among years from 1,944 to 60,871 kg. Bullhead harvest steadily increased during the 1950s but became sporadic from the 1960s until the 1980s. The highest commercial harvest of bullheads occurred in 1973. Bullhead harvest declined to extremely low numbers after 1988, reaching a minimum in 1997. Since 1997, mean annual harvest has fluctuated between 85 (±45) and 228 kg (±149). The majority of bullhead harvest occurred in Pool 9 throughout each decade, while other pools contributed little to bullhead harvest (Figure 5A).

From 1953 to 2001, mean NBI harvest per pool varied from 18,487 (±3,171) to 46,863 kg (±14,273), and total harvest varied among years from 425,206 to 1,077,853 kg (Figure 4A). Total harvest peaked in 1958 and declined until reaching a minimum in 1982. In 1987, harvest increased and then continued a slow decline throughout the 1990s to 2001. The contribution of different pools to NBI harvest varied considerably across decades (Figure 5B). In the 1950s, Pools 9, 18, and 19 together accounted for more than half (52.5%) of the total harvest in the UMR. In the 1960s, Pools 9, 11, and 19 accounted for approximately one-third (36.0%) of the harvest. Pools 13, 18, and 19 accounted for approximately one-fourth of the harvest in the 1970s (24.0%) and 1980s (28.4%). In the 1990s, Pools 9, 13, and 19 accounted for 27.7% of the harvest and continued to contribute the highest commercial harvest in a similar trend in the early 2000s (30.6%).

When data were evaluated by species (i.e., 1992 to 2001), several patterns were observed. Harvest of

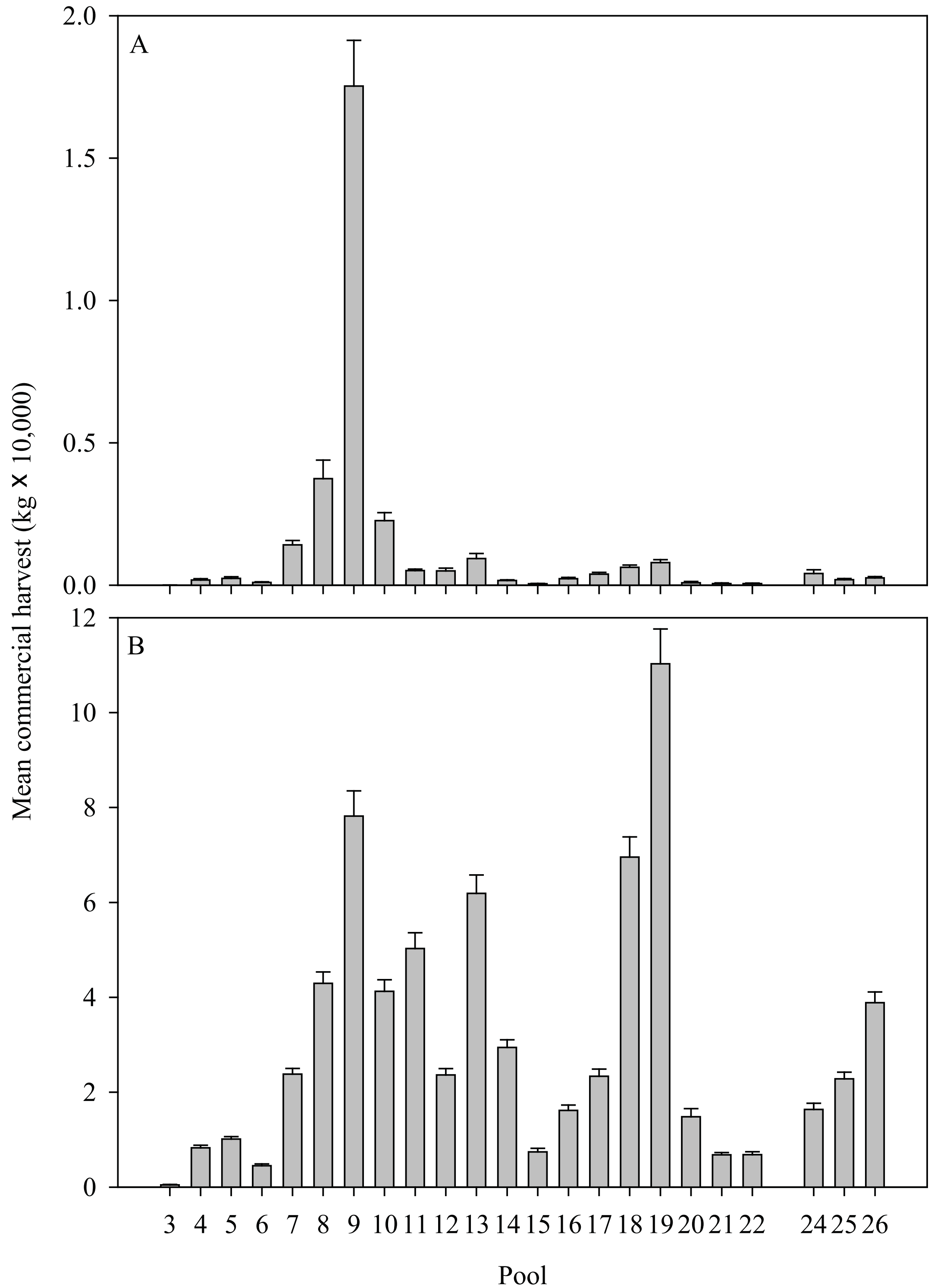

FIGURE 2. Mean commercial harvest by pool of bullheads (A) and nonbullhead ictalurids (B) in the upper Mississippi River from 1953 to 2001. Error bars represent 1 SE.

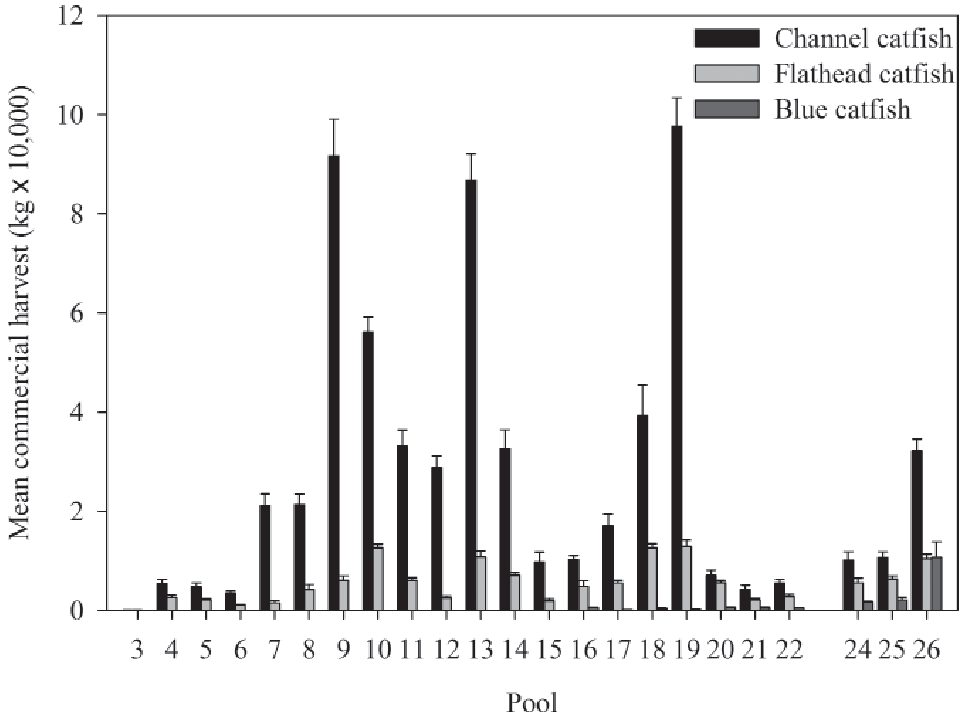

FIGURE 3. Mean commercial harvest by pool of nonbullhead ictalurid species in the upper Mississippi River from 1953 to 2001. Error bars represent 1 SE.

nonbullhead ictalurids was dominated by channel catfish (81.2 ± 0.8%), followed by flathead catfish (16.5 ± 0.5%) and blue catfish (2.3 ± 0.5%). From 1992 to 2001, mean channel catfish harvest varied from 20,861 kg (±5,564) to 32,986 kg (±6,877; Figure 6) per pool among years. Mean flathead catfish harvest per pool varied among years from 4,454 kg (±821) to 6,241 kg (±1,161), and total commercial harvest was highly variable among years. Mean blue catfish harvest per pool varied from 234 kg (±131) to 1,848 kg (±1,569), and total harvest increased substantially from 1992 to 2001. No blue catfish were harvested from Pools 3–15 during that time.

Market Trends

From 1953 to 2001, ictalurids contributed 16.1% (±0.4) of the total weight and 42.4% (±0.6) of the total market value annually to the commercial fishery in the UMR. Bullhead flesh reached a maximum market value in 1953 (US$3.57/kg; Figure 4B). Flesh prices declined steadily from the 1950s to the 1980s. In the early 1990s, prices stagnated, reaching a record low in 1996 ($0.52/kg). Similar to bullheads, the highest market value of NBI flesh sold in the UMR occurred in 1953 ($5.01/kg). Prices remained relatively high during the 1960s and early 1970s. During late 1970s, prices declined rapidly from $4.03/kg in 1976 to $1.69/kg in 1989. Prices declined more slowly in the 1990s, with the lowest price occurring in 1999 ($1.30/kg). Total market value of NBI was inversely related to catfish production by the U.S. aquaculture industry from 1953 to 2001 (Figure 7). Market values of all NBI and farmed catfish (i.e., channel catfish) declined overall from 1992 to 2001 (Figure 8).

Discussion

In contrast with recent estimates of relative abundance (Koel et al. 1998), commercial harvest did not generally follow a longitudinal gradient for bullheads, channel catfish, or flathead catfish. Koel et al. (1998) found a distinct north-to-south gradient in channel catfish density, with relative abundance increasing downstream. Similarly, an assessment conducted during the late 1940s in Pools 12–26 found the highest relative abundance of catfish species in Pools 15, 16, and 22 (Barnickol and Starrett 1951),

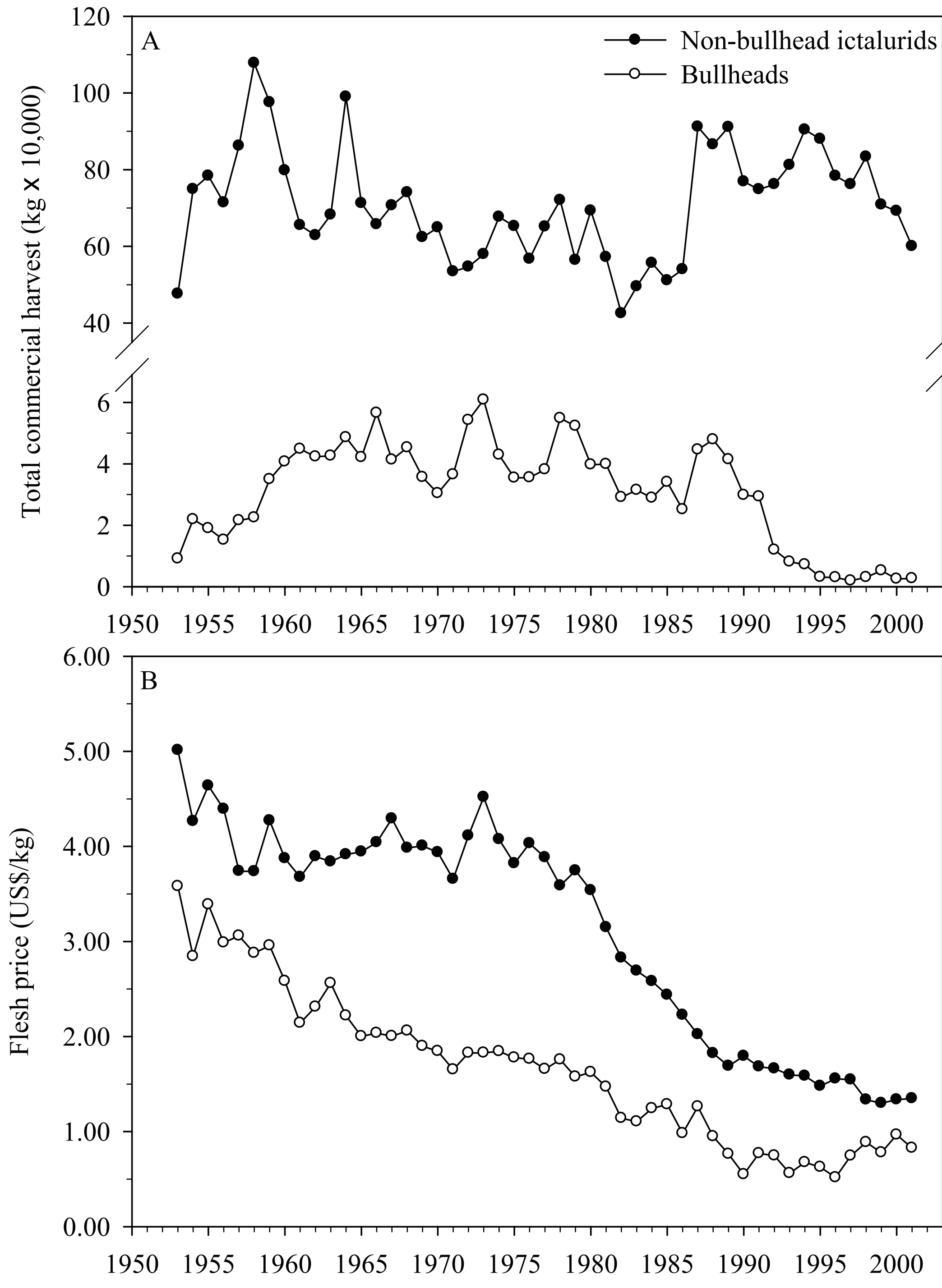

FIGURE 4. Total commercial harvest (A) and mean inflation-adjusted flesh price (B) of bullheads and nonbullhead ictalurids in the upper Mississippi River from 1953 to 2001.

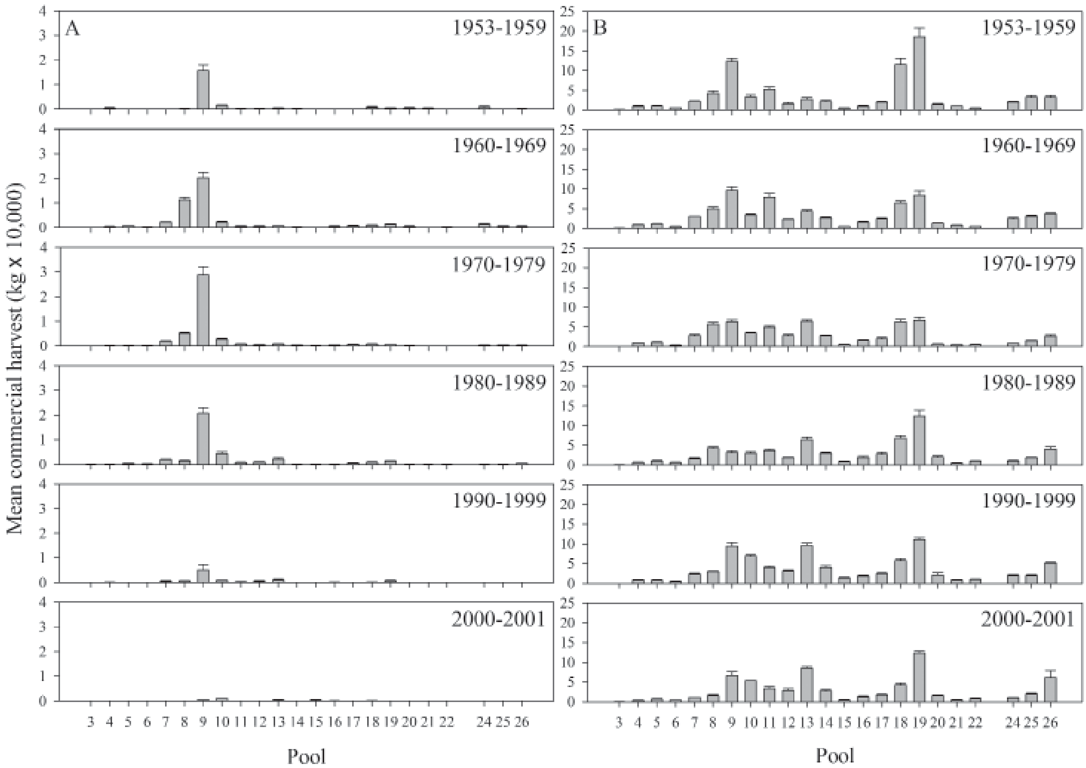

FIGURE 5. Mean commercial harvest by pool of bullheads (A) and nonbullhead ictalurids (B) in the upper Mississippi River from 1953 to 2001 by decade. Error bars represent 1 SE.

whereas commercial NBI harvest in the 1950s was highest in Pools 9, 18, and 19. Our results suggest that spatial trends in commercial catfish harvest may not reflect spatial trends in catfish abundance.

Bullheads have been less abundant than NBI in the UMR since the earliest known estimates (Barnickol and Starrett 1951). Likewise, commercial harvest of bullheads has been comparatively lower throughout the years than NBI harvest. Concentration of bullhead harvest in Pool 9 may be attributed to fishing effort targeting bullheads rather than higher abundance. For example, a local market or distributor may exist nearby (e.g., Lansing, Iowa), providing an outlet for harvested fish. However, demand for bullheads in fish markets has decreased, and some fishermen have difficulty selling their catch locally (McNitt, personal communication). To compensate for a lack of demand in local markets, bullheads are frequently shipped to ethnic markets in urban areas (e.g., New York; Mohn, personal communication). Because bullheads require unique fishing methods (i.e., hoop nets in backwater areas) but are not exceptionally valuable, many fishermen choose instead to target more valuable or common species (McNitt, personal communication). The rapid decline in bullhead harvest in the 1990s may have been related to flesh prices dropping below a threshold beyond which commercial harvest was no longer economically feasible for most fishermen.

In addition to market dynamics, commercial harvest of bullheads may also be related to their abundance. Bullhead abundance (and harvest) declined in the UMR during the 1990s (K. S. Irons, Illinois Natural History Survey, personal communication). Numerous studies have demonstrated correlations between bullhead abundance and vegetation dynamics. All three bullhead species were more abundant in areas with submerged aquatic macrophytes (e.g., wild celery *Vallisneria americana*; Killgore et al. 1989; Slade et al. 2005; Cross and McInerny 2006). Black bullheads were more abundant than yellow bullheads or brown bullheads in areas with lower densities of submerged vegetation and higher densities of emergent species (e.g., bulrushes *Scirpus* spp.; Cross and McInerny 2006). Before the late 1980s drought, Pool 9 had the greatest concentration

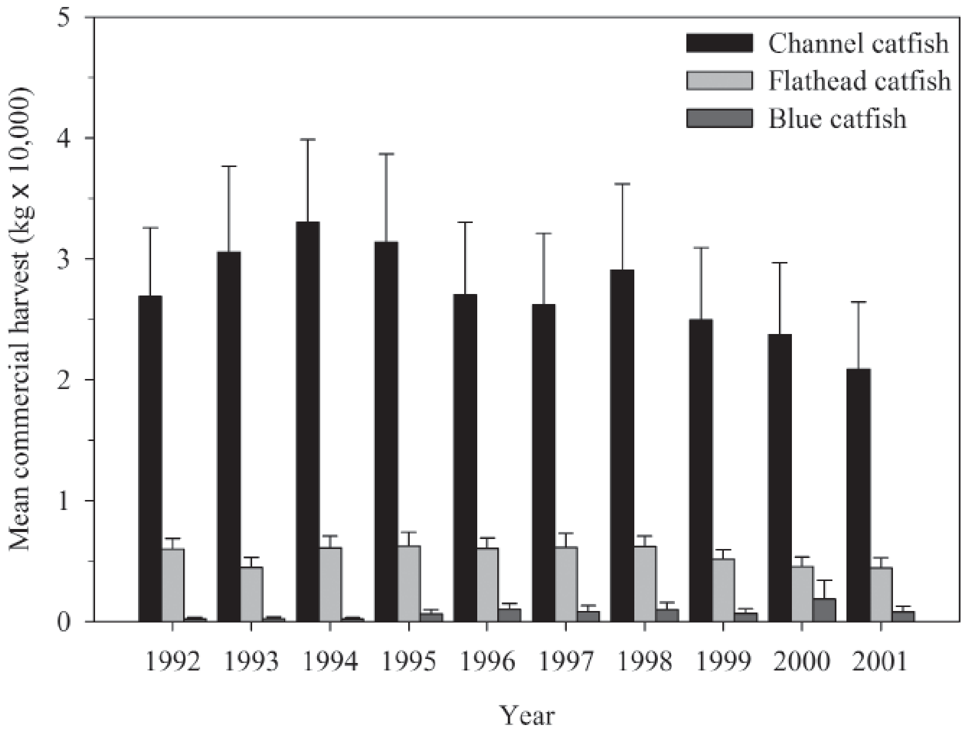

FIGURE 6. Mean commercial harvest by pool of nonbullhead ictalurid species in the upper Mississippi River from 1992 to 2001. Error bars represent 1 SE.

of submerged and free-floating macrophytes in the UMR, having 20–25% areal coverage by submerged and free-floating macrophytes (Peck and Smart 1986). Likewise, most bullheads commercially harvested between 1953 and 1986 were from Pool 9 (i.e., 56.1%). Furthermore, declining harvest weight and loss of large areas of submerged vegetation occurred simultaneously in the late 1980s and early 1990s. From 1987 to 1989, a reduction in submerged aquatic macrophytes was observed. Although mechanisms associated with the decline are unknown, low discharge and high nutrients likely led to high algal blooms that competed with macrophytes for nutrients and reduced light penetration (Moore et al. 2010). The drought was followed by a record flood in 1993, which exacerbated the stresses (e.g., low water clarity, high current velocity, and increased deposition: Kimber et al. 2001) on both submerged and emergent plant species in many areas (Spink and Rogers 1996; Moore et al. 2010). Affected species included yellow lotus *Nelumbo lutea*, sago pondweed *Potamogeton pectinatus*, river bulrush *S. fluviatilis*, and many woody species (Spink and Rogers 1996). Wild celery actually increased after the flood and spread to new areas. Much of the aquatic vegetation, both native and nonnative, recovered within a few years, but fishery-independent estimates of bullhead abundance remained low until the mid-2000s (Irons, unpublished data).

Nonbullhead ictalurid commercial harvest fluctuated over time, likely in response to a temporal progression of factors. The peak exhibited in 1958 coincided with emergence of a new bait type (i.e., soybean *Glycine max* cake). During the 1950s, soybean meal was found to be both edible and conducive to weight gain in cultured channel catfish (Shell 1967). The meal was further developed as both fish feed and cake bait, achieving widespread use in the commercial fishing industry by the late 1950s. Soybean cake has been shown to significantly increase channel catfish catches in single and tandem hoop nets (Pierce et al. 1981; Flammang and Schultz 2007) but to repel flathead catfish (Pierce et al. 1981). Despite some differences among species, soybean cake may have led to record catches through its effectiveness and novelty as a bait type.

In the 1960s, 1970s, and early 1980s, NBI harvest declined throughout the UMR. Reduced harvest

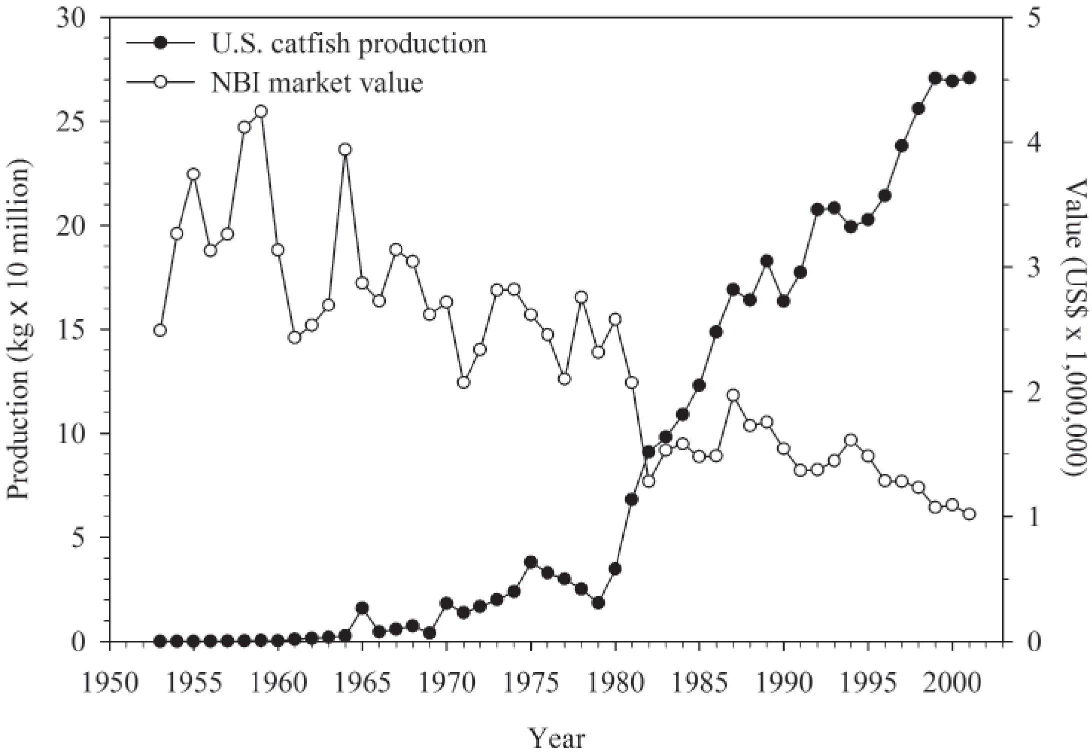

FIGURE 7. Total U.S. channel catfish production and inflation-adjusted total market value of nonbullhead ictalurids harvested in the upper Mississippi River from 1953 to 2001.

of NBI was likely due to recruitment overfishing, possibly facilitated by the new, highly effective soybean cake bait. Slipke et al. (2002) demonstrated that the spawning potential ratio (a ratio of the number of eggs produced in an exploited population to that produced by an unexploited population) of channel catfish in the UMR fell below 10% prior to 1984, due to high exploitation of immature channel catfish. Before Iowa adopted the minimum length regulations suggested by the UMRCC, channel catfish could be harvested once they reached 330 mm. Helms (1975) found that 90% of female channel catfish were sexually immature and the other 10% had not reached their full egg production potential by the time they reached 330 mm in UMR. In contrast, 50% of female channel catfish were mature at 381 mm and were, collectively, capable of producing 10 times more eggs (Helms 1975). Prior to 1984, recruitment overfishing of channel catfish in the UMR led to continually decreasing yields (Slipke et al. 2002). Two years after Iowa adopted the minimum length regulations in 1984, total channel catfish harvest weight more than doubled (Pitlo 1997). Furthermore, catch of age-0 channel catfish in Pool 14 increased, suggesting enhanced recruitment associated with regulation changes (Pitlo 1997). Because more than 72% of NBI harvest was from Pools 9–19 (i.e., Iowa waters), positive effects of the regulation change in 1984 were reflected in overall UMR harvest trends. After 1984, recruitment overfishing was no longer an issue in the UMR channel catfish fishery (Slipke et al. 2002).

Other potential factors affecting commercial catfish harvest were likely associated with decreased demand for wild-caught catfish. By 1970, fishing limitations or fish consumption advisories based on mercury levels had been established in 19 states, including Minnesota and Wisconsin (Kleinert and Degurse 1972). Soon after, in 1972, fish contaminated with polychlorinated biphenyls (PCBs) in the UMR were first reported in Pool 8 by the Wisconsin Department of Natural Resources (Degurse and Ruhland 1972). These fish contained PCB levels exceeding limits established by the U.S. Food and Drug Administration, stimulating extensive news coverage and an embargo on commercially harvested fish flesh from Pool 8 (Pitlo 1997).

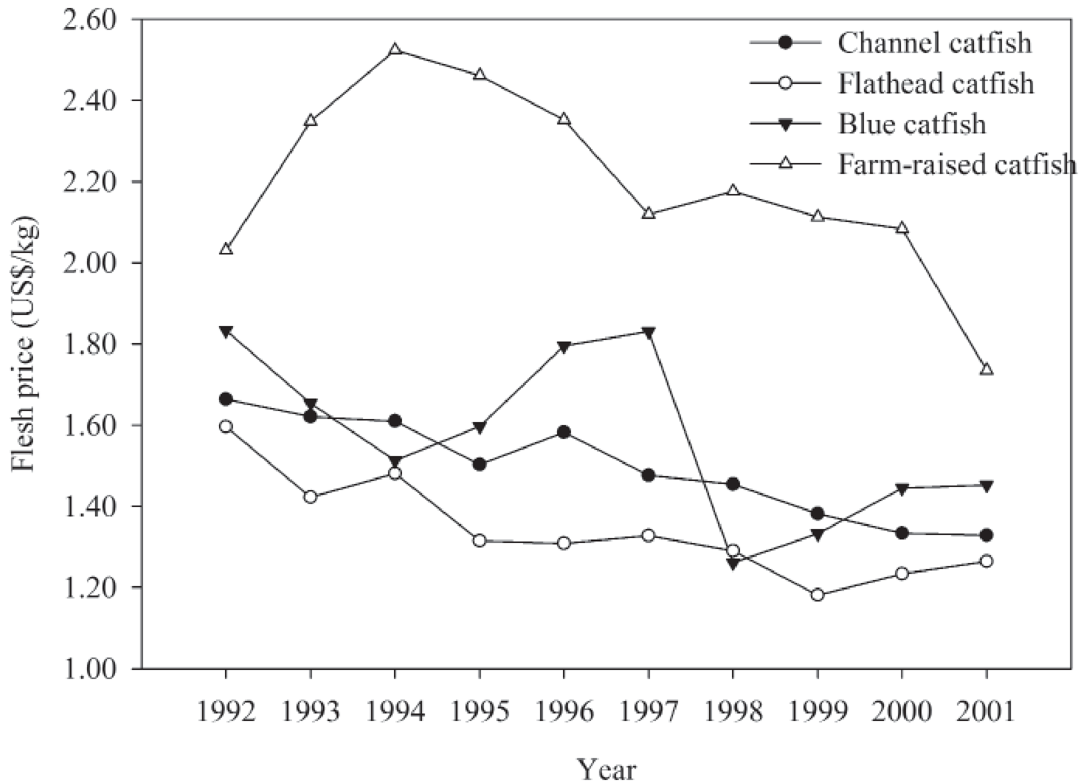

FIGURE 8. Mean inflation-adjusted flesh prices of catfish harvested in the upper Mississippi River or cultured in the United States from 1953 to 2001.

Passage of the Clean Water Act in 1972 and the Toxic Substances Control Act in 1976 were quickly followed by bans and controls on many contaminants in the UMR. Despite reduced contaminant inputs into the river following the acts, elevated levels of PCBs and other chemicals were found both in fish (Rostad et al. 1995) and in the environment, particularly downstream of large metropolitan areas (Balogh et al. 1999; Wiener and Sandheinrich 2010). Since the 1970s, health advisories and safe consumption limits have been established by every state in the UMR for PCBs, mercury, and other contaminants. The issue of contaminated fish flesh was readily answered by the aquaculture industry, which could produce fish safe for consumption. Cultured catfish tissues had lower levels of PCBs and other polychlorinated chemicals than wild-caught catfish tissues from the Mississippi River (Scott et al. 2009). Concerns for public health, therefore, may have partially stimulated the market shift to cultured catfish.

Aquaculture grew quickly during the 1960s following development of efficient feed (Dupree 1982) and was recognized as an industry in 1974. At the time, aquaculture was relatively profitable, with flesh prices far exceeding production costs (Dillard and Waldrop 1983). According to Dupree (1982), the industry primarily focused on propagation of channel catfish for several reasons. Channel catfish were capable of tolerating crowded conditions and extensive handling, and they accepted pelleted feed. Additionally, their flesh was relatively odorless, could be controlled for off-flavors, and was uncontaminated when fish were raised under controlled conditions. Fillets were of a consistent size and supply was available throughout the year. Blue catfish, despite their large size, were not preferred because they were more difficult to spawn, grew more slowly at large sizes, and were more susceptible to disease during fry and fingerling stages. Flathead catfish, though prized for their flavor, required more intensive management and money to culture due to their piscivory. Bullheads were more susceptible to disease and their flesh was comparatively low in value. Cultured channel catfish, therefore, provided direct market competition for wild-caught channel catfish. Similar appropriation of the market share by cultured fish was demonstrated for salmonids by Asche et al. (2005), who found that imported, cultured, and wild salmon *Oncorhynchus* spp. stocks competed in the same market in Japan; increased production of salmon was a primary factor in decreasing prices for wild salmon.

As the catfish aquaculture industry expanded, distinction between cultured and wild-caught catfish became increasingly important (Kinnucan and Venkateswaran 1990). One of the primary factors affecting consumer attitudes toward catfish was knowledge of whether the product was cultured or wild-caught. The other primary factor was perception of flavor, a quality that can be closely monitored in aquaculture. Furthermore, commercial pathways of cultured and wild-caught catfish became nearly mutually exclusive. As demonstrated by Sullivan and Hunt (1984), cultured catfish were sold almost exclusively to processors and subsequently distributed as value-added products (i.e., products that have been made more valuable through processing). Wild-caught catfish, in contrast, were sold directly to consumers and, to a lesser extent, to secondary markets (e.g., restaurants and grocery stores). Portions of the catfish market that depend on product safety and consistency (i.e., processors and secondary distributors) are now primarily sustained by cultured catfish.

The aquaculture industry grew exponentially in the 1980s and 1990s, producing more than 250 million kg of catfish for commercial sale. Increase in availability of high-quality catfish created an excess supply, driving prices down for both wild-caught and cultured catfish. With this supply, it is likely that bullheads experienced a complete loss of the market share, thus explaining the rapid decline in commercial harvest during the 1990s. However, the aquaculture industry is limited in the extent to which it can compete with commercial fishermen by its operating costs. Profitability has fluctuated over time with feed costs, particularly those of corn *Zea mays*, soybean, and Gulf menhaden *Brevoortia patronus* (Buguk et al. 2003). Primarily due to high feed prices, catfish production costs have exceeded average market values numerous times since the 1980s (Dasgupta and Engle 2007). Since flathead catfish propagation requires even greater capital due to feeding preferences, it is possible that flathead catfish have remained in a niche market almost entirely supplied by commercial fishermen (Jackson 1999). By 2001, the flesh price of cultured catfish had yet to fall below that of any wild-caught catfish species sold in the UMR. As discussed by Muir and Young (1998), aquaculture can strongly influence market share, but it is unlikely that the industry will fully supplant commercial fishing.

In conclusion, commercial harvest of ictalurid catfish in the impounded reaches of the UMR varied spatially and temporally. Spatial distributions in harvest of both bullheads and NBI were distinct from patterns in abundance and were fairly stable from 1953 to 2001. Temporal variations in harvest weight and market value likely occurred for numerous reasons. Early declines were associated with habitat loss and overexploitation while later declines were likely related to a loss of market share driven by aquaculture production. Despite lower harvest weights, ictalurid catfish have consistently maintained their share of the total commercial harvest in the UMR (i.e., approximately 16% of the total harvest weight and 42% of the total market value). Therefore, changes observed in commercial catfish harvest may be indicative of broader trends in commercial fishing in the UMR.

Acknowledgments

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