CHAPTER 12

Fishes

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The Upper Mississippi and Illinois Rivers are central to the cultural heritage of North America. They have been important sources for subsistence, commerce, recreation, and even the subject of American literature. Throughout the rivers' short history of development and resource exploitation, the ecosystem has been managed for seemingly conflicting uses. Modification of the hydrology of the Upper Mississippi River System (UMRS) and conversion of its floodplain to other uses has had an impact on fish habitat in many ways. Despite the great historic importance of the rivers and their fishes, information critical to fisheries management is scarce. The available data and literature reviewed here must be extrapolated and interpreted with caution.

Fisheries management on the UMRS is critical because, among biotic resources, fishes support the greatest number of commercial and recreational uses. In 1982, UMRS fisheries provided more than 8.5 million activity days of sport fishing that generated more than $150 million ($234 million in 1995 dollars) in direct expenditures (Fremling et al. 1989). In a 1990 recreational-use survey, fishing accounted for almost 29 percent of reported activity, providing economic benefits of almost $350 million in 1990 dollars (USACE 1993). The value of commercial fisheries between 1978 and 1991 was set at between $2 and $2.4 million annually (Upper Mississippi River Conservation Committee [UMRCC], Rock Island, Illinois, 1978–1991 Annual Reports). These figures suggest that a decline in prey, sport, or commercial fishes of the UMRS would be detrimental to recreational and regional economies. As a result, it is important to detect negative population trends as they occur so remedial actions can be considered.

Surveying Upper Mississippi River System Fish Populations

The five UMRS States and Federal agencies have monitored the fish populations to varying degrees since surveys began in the late 1800s on the Illinois River. However, historically these surveys lacked consistent sampling standards needed to interpret their results together.

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The State of Minnesota has continuous annual survey data for Lake Pepin sauger and walleye populations that extend back to 1965. Illinois has been electrofishing consistently at 33 permanent stations along 581 miles (935 km) on the Mississippi River since 1976 and intermittently at 27 stations on the Illinois River since 1957. Iowa has sampled target species since 1985 in three pools and conducted management-oriented research. Over the decades, Wisconsin and Missouri have focused most of their efforts on management-oriented research. A commercial fish catch database has been maintained by the UMRCC since the 1950s. Prior commercial fish data also are available.

Fishery managers have long recognized the need for comprehensive standardized data collection. In 1990, the Long Term Resource Monitoring Program (LTRMP) began highly standardized monitoring in six intensively studied segments of the UMRS. Increased consensus over monitoring needs and better cooperation among State and Federal agencies eventually will provide sound information for better systemic management on the UMRS.

Species Numbers and Diversity

The Mississippi is special among large rivers of the temperate zones in that it supports an unusually large number of fish species. At least 260 freshwater species have been reported from the Mississippi River Basin.

The fishes of the Mississippi River are an extraordinary biological resource. The Mississippi is special among large rivers of the temperate zones in that it supports an unusually large number of fish species. At least 260 freshwater species have been reported from the Upper Mississippi River Basin (Fremling et al. 1989). For comparison, based on data from Welcomme (1979), the UMRS supports approximately as many fish species as the Paranà River of tropical South America, which drains a similarly large basin, and far more species than the temperate Volga or Danube Rivers in Europe. Historically, approximately 150 species of fish have been reported from the UMRS (Fremling et al. 1989; Pitlo et al. 1995). Although many species are quite rare and 60 species are occasional strays from adjoining tributaries, this diversity stands in stark contrast to Midwestern lakes, which often contain fewer than 15 species. This exceptional diversity of fishes makes the Mississippi River one of the nation's greatest ecological treasures.

The presence of so many fish species can be attributed to two circumstances. First, the Mississippi River system is physically complex with a wide range of aquatic areas (i.e., channels, backwater lakes) that in turn provide a wide array of habitats for fishes (Welcomme 1979). The Mississippi River supports many relatively recent fish species such as shiners, redhorses, darters, and sunfishes (e.g., bluegill, pumpkinseed, green sunfish) whose presence dates back 30 million years or less. Many of these are habitat specialists that require particular conditions (Fremling et al. 1989). For example, black basses, crappies, and sunfishes probably originated in floodplain drainage systems (Cavender 1986; Cross et al. 1986) and, to thrive in the UMRS, require lake-like backwaters. Second, the general north–south orientation of the Mississippi River provided a corridor for escape and recolonization during glacial advances and retreats (Hynes 1970). This fact no doubt allowed many fish species to persist through the glacial advances. Very ancient species such as sturgeons, paddlefish, gars, bowfin, some minnows, and buffalo fishes (Figure 12-1; Miller 1965) still can be found in the Upper Mississippi.

Despite the continued presence of many fish species, their abundance, size, and distribution may have changed as a result of human activity. For example, after navigation dams were constructed, Fremling and Claflin (1984) reported increased abundance of lentic species (bluegills, largemouth bass). Conversely, fish movement of many species throughout the system has been impeded by the same dams.

Current Status

The LTRMP provides key data that document patterns in the number of fish species (species richness) in the UMRS. During the first five years of the program, 127 species were documented using standardized monitoring. That figure is a minimal estimate because some rare fish are extremely difficult to detect.

Fish species richness tends to vary

between the northern and southern reaches of the river (Figure 12-2). Pool 8 in the northern reach had the highest species richness, closely followed by Pool 4, also in the northern sector. While species richness was slightly greater in the northern reaches, the four other study areas had similar species richness. Habitat patterns in Pool 8 consist of a diverse mix of floodplain features that include mazes of braided side channels and backwaters. In contrast, channel and flood management strategies in the lower pooled reaches and particularly the Unimpounded

Figure 12-1. **The paddlefish is an ancient species that has persisted in the Upper Mississippi River System (Source: National Marine Fisheries Service, Woods Hole, Massachusetts).**

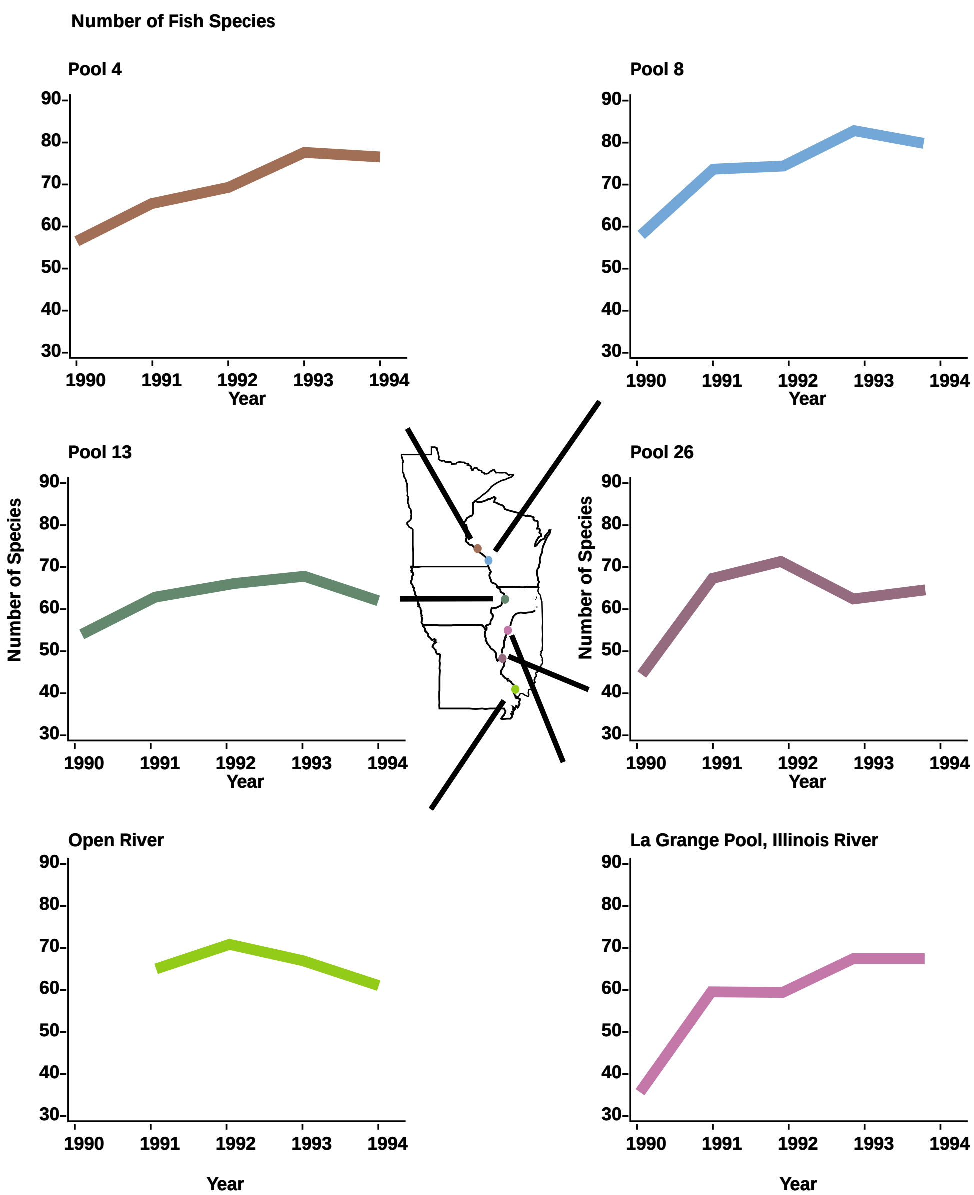


Figure 12-2. **Long Term Resource Monitoring Program sampling indicates that the northern part of the Mississippi River tends to support slightly more fish species than does the Unimpounded Reach or La Grange Pool of the Illinois River. Apparent increasing trends in species numbers are produced by increasing sampling effort in most study reaches and should not be interpreted as a real increase in the numbers of fish species present.**

Figure 12-3. **This young shovelnose sturgeon displays the unique bony scales and bottom dwelling habits of sturgeons (Source U.S. Fish and Wildlife Service, Onalaska, Wisconsin).**

Figure 12-4. **This 6-foot sturgeon caught near Muscatine, Iowa, shows the size lake sturgeon once achieved in the Upper Mississippi River System. Such large specimens are currently very rare in the waterway (Source: Musser Public Library, Muscatine, Iowa).**

Reach from St. Louis, Missouri, to Cairo, Illinois, have caused the loss of side-channel and backwater areas. The greater physical complexity of the Upper Impounded Reach of the UMRS may explain the higher species richness. This north–south variance in species richness also suggests that the key to maintaining this unusual biological resource may be to preserve the physical complexity of the river.

No evidence of a recent decline in species richness exists (Figure 12-2), and overall, little evidence to suggest a substantial net loss of species in the system since the 1800s. However, human alterations including management for commercial navigation, flood control, municipal and industrial waste, and agriculture have had consequences for the distribution and abundance of particular species.

Spatial Distribution of Selected Riverine Species

Riverine fishes usually occur in main-channel and side-channel habitats. They are streamlined in shape (e.g., walleye, white bass) or exhibit bottom-dwelling behavior (e.g., sturgeons, buffalo fishes, catfishes) that shelters them from the fastest flow in the channel. Many riverine species are economically important or serve as indicators of change in the system.

Shovelnose (Figure 12-3), pallid, and lake sturgeon are characteristic of the deep channels of large rivers. Pallid sturgeon once were important to commercial fisheries because of their large size compared to shovelnose sturgeon. This species now is rare and listed as endangered by Iowa, Illinois, Missouri, and the U. S. Fish and Wildlife Service (Table 12-1; Pitlo et al. 1995; Duyvejonck 1996). Only three pallid sturgeon have been collected by the LTRMP since 1989 and those all in the Unimpounded Reach.

Lake sturgeon, once abundant in the river (Figure 12-4), have been present but uncommon in LTRMP samples. Presently they are protected or sufficiently rare to merit special concern in all five UMRS states (Table 12-1; Johnson, 1987; Pitlo et al. 1995; Duyvejonck 1996). Missouri recently initiated a lake sturgeon stocking program in an effort to increase their abundance.

The shovelnose sturgeon is the most abundant of sturgeon species. It is commercially and recreationally fished in some states but listed as a species of concern in others. Although catch rates are low, the LTRMP has on average detected shovelnose in all study reaches except La Grange Pool of the Illinois River (Figure 12-5). Total catch data suggests the abundance of this species might be increasing in much of the Upper Mississippi River.

Two riverine species, sauger and wall-

Table 12-1. **Fish listed by Federal and Upper Mississippi River System State agencies as threatened, endangered, or species of special concern in the Mississippi River main stem (Source: Duyvejonck 1996).**

Fish Species	Federal	MN	WI	IA	IL	MO
Alabama shad						R
Alligator gar					T	R
American eel			R			
Bigeye shiner					E	
Blacknose shiner				T	E	R
Blue sucker		SC	T			WL
Blue catfish		SC				
Bluntnose darter		SC	E	E		
Brown bullhead						R
Burbot				T		
Central mudminnow						E
Chestnut lamprey				T		
Crystal darter		SC	E			E
Flathead chub						E
Freckled madtom				E		
Ghost shiner			EX			WL
Goldeye			E			
Grass pickerel				T		
Gravel chub		SC	E			
Greater redhorse			T		E	
Highfin carpsucker					R	
Iowa darter					E	
Lake sturgeon		SC	R	E	E	E
Longear sunfish			T			
Mississippi silvery minnow						WL
Mooneye						R
Mud darter			SC			
Northern pike						R
Orangethroat darter				T		
Ozark minnow			T			
Paddlefish		SC	T			WL
Pallid shiner		SC	E	R	E	EX
Pallid sturgeon	E			E	E	E
Pearl dace				E		
Pirate perch				SC		
Pugnose minnow		SC	SC	SC		WL
Pugnose shiner			SC	E	E	
Redfin shiner			T			
River darter						WL
River redhorse		R	T		T	
Shovelnose sturgeon		SC				
Sicklefin chub	1					R
Silver jaw minnow						WL
Skipjack herring			E			
Speckled chub			T			
Starhead topminnow			E			
Sturgeon chub	1				E	R
Trout-perch				R		R
Weed shiner			SC	E		
Western sand darter			SC	T	E	WL
Yellow base		SC				

Key: 1 = Federal candidate species, E = endangered, EX = extirpated from state, R = rare, SC = special concern, T = threatened, WL = watch list

Figure 12-5. **Total catch-per-unit-effort + 1 (catch + 1) of shovelnose sturgeon in Long Term Resource Monitoring Program study reaches between 1990 and 1994 increased gradually as sampling effort increased, except in La Grange Pool on the Illinois River where sturgeon were not detected. Reduced catches during 1993 were due to reduced sampling efforts and probable fish redistribution during extreme flooding. Note the logarithmic scale on the left axis of each graph does not start with 0.**

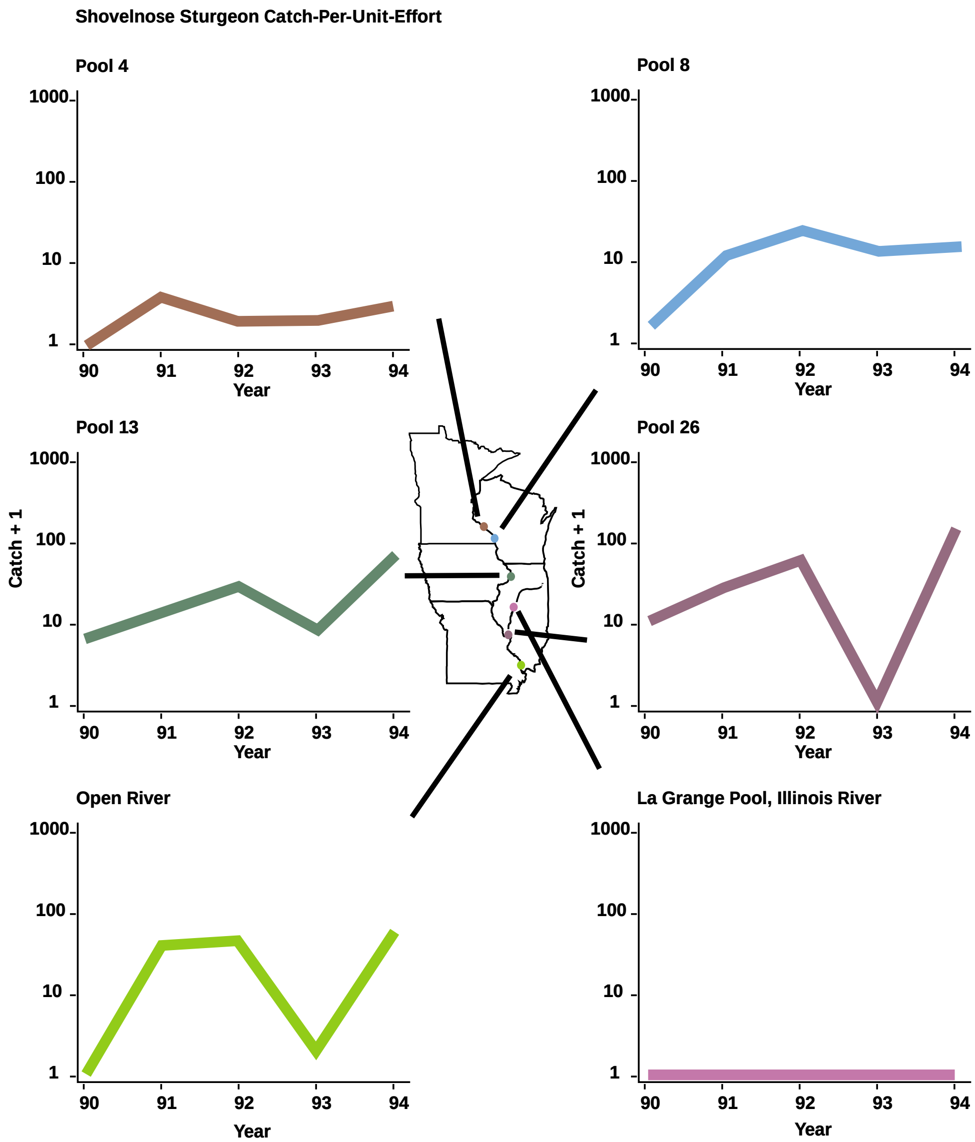


Figure12-6. **The walleye is a popular gamefish found in channel habitats. (Source: U. S. Fish and Wildlife Service, Onalaska, Wisconsin).**

eye, are highly prized by anglers and support important recreational fisheries in the Upper Mississippi River, particularly in riverine channels. The larger walleye (Figure 12-6) is less tolerant of turbidity (Pflieger 1975) and confines itself to the river's northern pools. Sauger, distributed throughout the UMRS, are most abundant in flowing channels, particularly along wing dams and in the tailwaters below the locks and dams. The abundance of sauger is much the same among LTRMP study reaches (except in the Unimpounded Reach) and increased substantially during

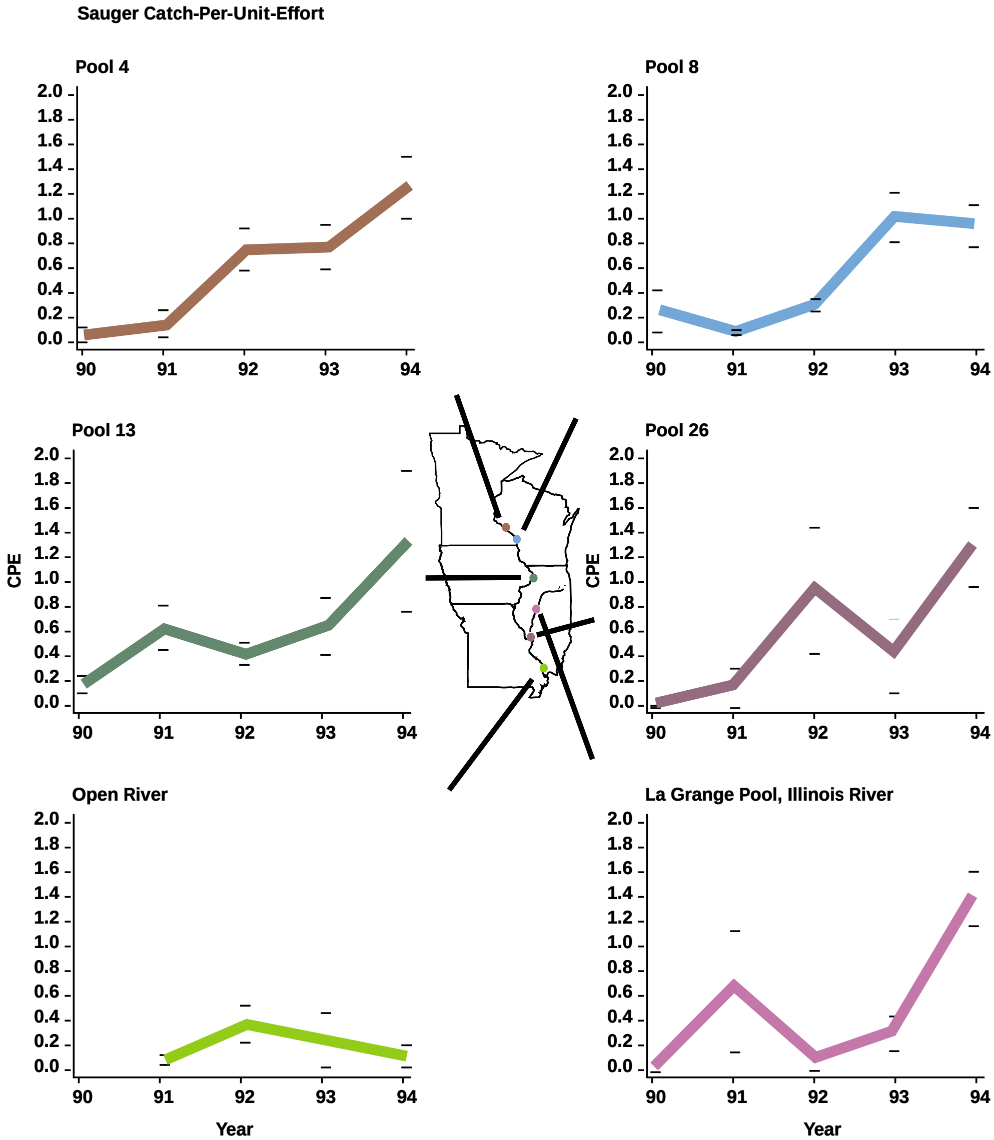


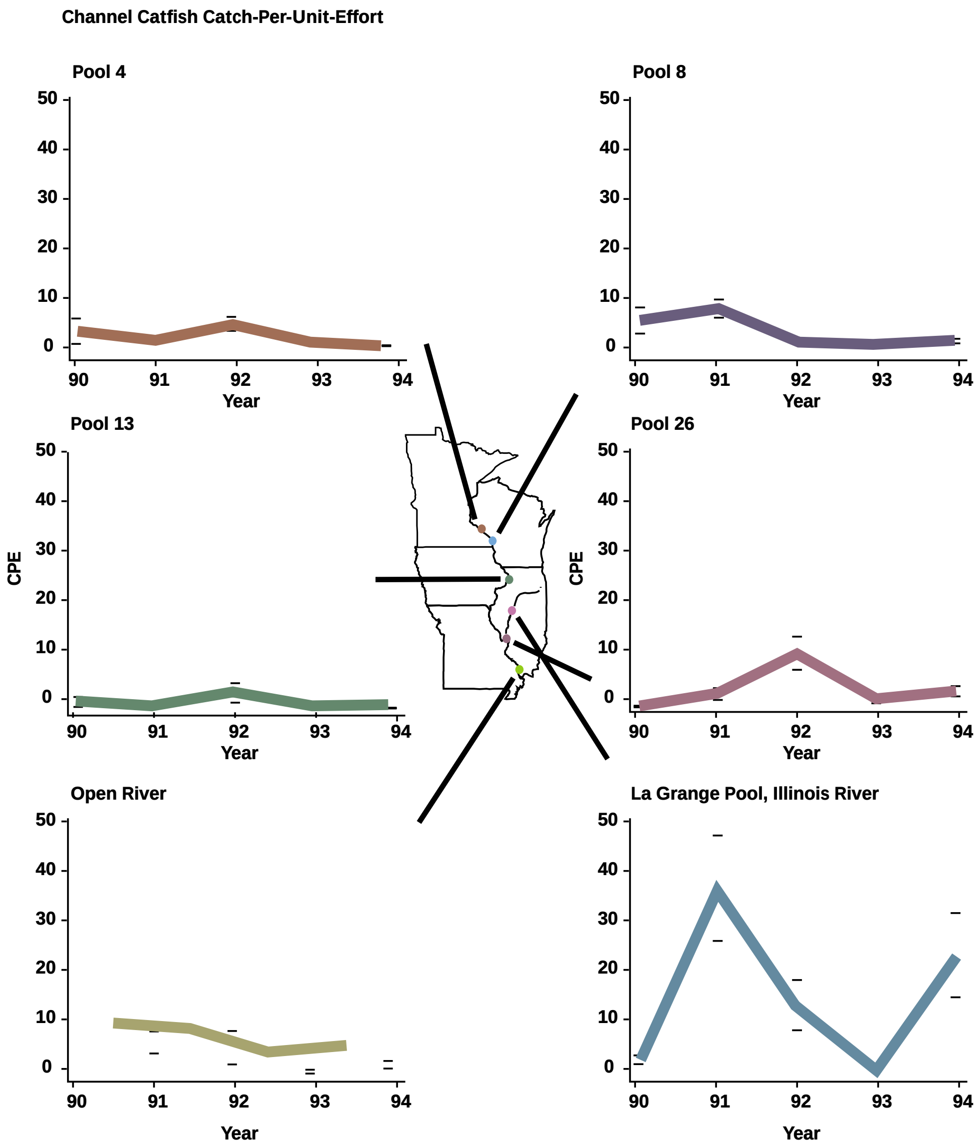
Figure 12-7. **Catch-per-unit-effort (CPE) is the average number of fish captured in a 15-minute electrofishing sample, and is an index of abundance. Sauger CPE has been similar among the Long Term Resource Monitoring Program study reaches except in the Open River (Unimpounded Reach). Apparent abundance of the popular gamefish increased steadily through the sampling period.**

the period from 1990 to 1994 (Figure 12-7).

Consistently rated among the four most-abundant commercial species, catfishes also rate high among anglers (Figure 12-8). Many species of catfish live in the UMRS; some (madtoms) are found in swift, flowing habitats while others (channel catfish) are more widely distributed in channel and backwater habitats. The channel catfish is the most abundant species, but many anglers actively seek the larger flathead catfish and blue catfish. The LTRMP sampling shows channel catfish populations have remained generally steady throughout the UMRS (Figure 12-9).

Figure 12-8. **Channel catfish are among the most common species caught on the Upper Mississippi River System (Source: Richard Whitney, Leavenworth, Washington).**

Figure 12-9. **Catch-per-unit-effort for Long Term Resource Monitoring Program hoop net sampling shows channel catfish abundance evenly distributed and populations maintained at a steady level throughout the Upper Mississippi River System. For hoopnets, CPE is the number of fish captured per net per day. Wide fluctuations in abundance from La Grange Pool are attributed to low-water sampling when fish become concentrated in channel areas; some catches exceeded 1,500 young-of-the-year and 1+ aged fish.**



Wide fluctuations in abundance in La Grange Pool are attributed to low-water sampling when fish become concentrated in channel areas and the fact that some catches exceeded 1,500 young-of-the-year and 1+ aged fish (Kevin Irons, Illinois Natural History Survey, Havana, Illinois, personal communication).

Smallmouth buffalo (Figure 12-10) are another important riverine species that together with other buffalo species, rank among the top four commercial species (Duyvejonck 1996). These members of the sucker family live and feed near the bottom of the main and side channels, consuming a variety of macroinvertebrates. Becker (1983) suggests this species may require flooded terrestrial areas for spawning. The abundance of smallmouth buffalo, as measured by hoop netting, showed no statistically significant trends nor differences among LTRMP study reaches. However, catch rates increased during 1994 in Pools 8, 13, and 26 of the Mississippi River and La Grange Pool of the Illinois River, probably in response to extreme flooding the previous summer.

White bass are a recreationally important schooling predator (Figure 12-11). In the Mississippi River drainage they occur from central Minnesota to the Gulf of Mexico (Scott and Crossman 1973; Pflieger 1975). The LTRMP electrofishing does not indicate any strong spatial or temporal trends, but the species is slightly more abundant in the lower three Mississippi River study reaches (Gutreuter 1997).

The blue sucker, a once-important commercial fish found in fast-flowing reaches (Carlander 1954), now is a species of concern in three UMRS states (Table 12-1; Johnson 1987; Pitlo et al. 1995; Duyvejonck 1996). This striking bluish-colored riverine fish (Figure 12-12) is adapted to life in deep and swift channels. Blue suckers persist in the Upper Mississippi River and have been detected in all LTRMP study reaches except La Grange Pool of the Illinois River. The decline from harvestable stocks to the present rare status may indicate an important change in habitat conditions, probably related to navigation improvements.

Importance of Backwater Habitats

Many fishes that depend on lake-like backwaters (especially black bass, crappie, and sunfish) are ecologically and economically important. Bluegills (Figure 12-13) are prized by anglers and also represent this important ecological component of the UMRS. The LTRMP data suggest that the abundance of bluegills in Pools 4, 8, and 26

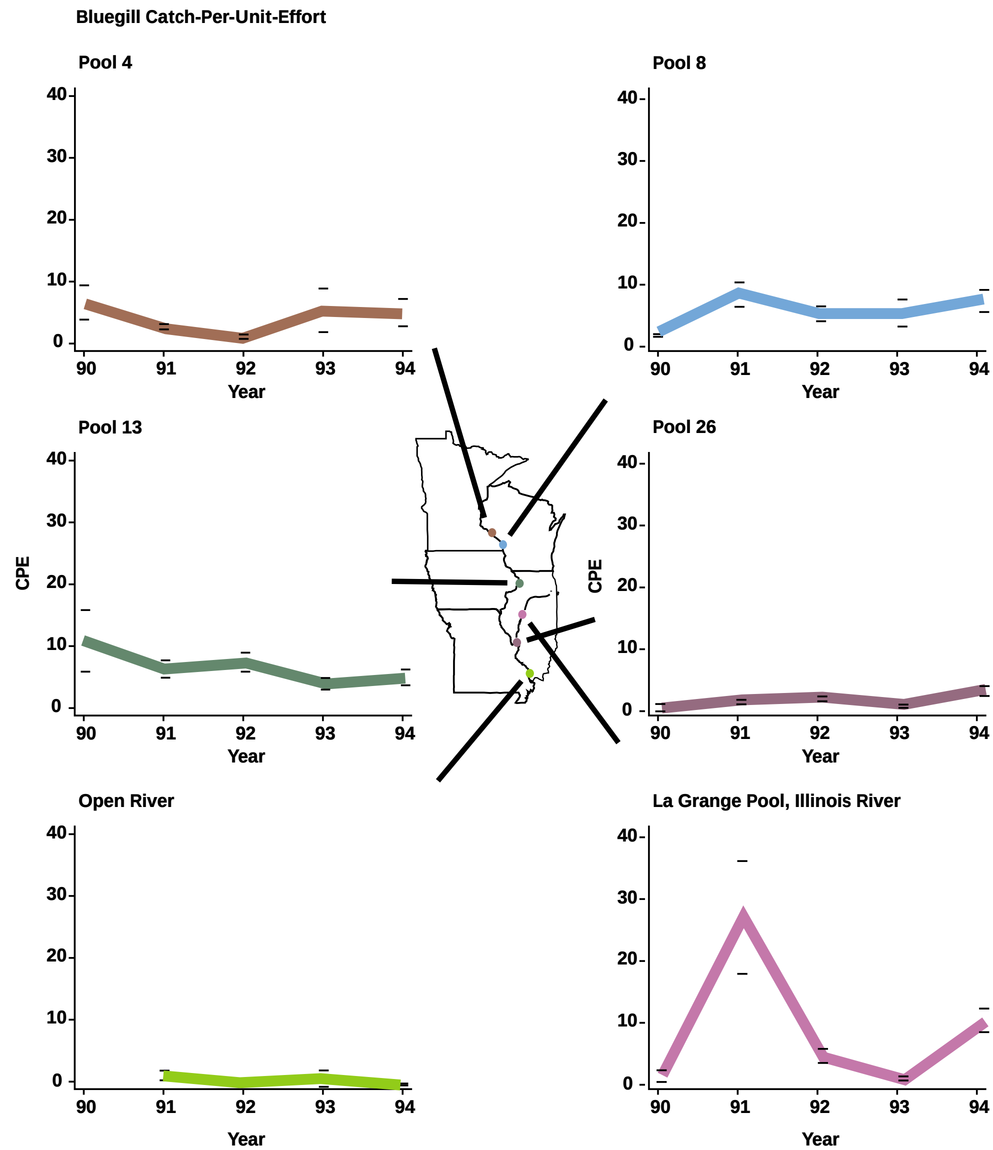
Figure 12-10. **The smallmouth buffalo is an important commercial species (Source: Charles Purkett, Jefferson, Missouri).**

Figure 12-11. **White bass are channel-dwelling game fish (Source: William Pflieger, Ashland, Missouri).**

Figure 12-12. **Blue suckers (young-of-the-year shown above) once were plentiful on the river but now are rare because of channel modifications (Source Mike Peterson, Missouri Department of Conservation, Cape Girardeau, Missouri).**

Figure 12-13. **The bluegill is one of the most popular sport fish on the Upper Mississippi River System (Source: New Hampshire Department of Inland Fisheries, Concord, New Hampshire).**

Figure 12-14. **Catch-per-unit-effort (CPE) from Long Term Resource Monitoring Program electrofishing data suggests bluegill abundance in Pools 4, 8, and 26 of the Mississippi River and La Grange Pool of the Illinois River either are without obvious trend or have increased from 1990 to 1994. (Electrofishing CPE measures the number of fish captured in 15 minutes of sampling effort.) Data further indicates evidence of a decline in abundance in Pool 13 and the Open River (Unimpounded Reach). Differences in abundance among these six study reaches suggest that habitat conditions may be more important than recent trends. However, mean relative bluegill abundance from the Open River study reach typically is less than one-third of the values from the other reaches; abundance also tends to be lower in Pool 26 than in Pools 4, 8, and 13. All Illinois River centrachid species show large year classes in 1991.**



of the Mississippi River and La Grange Pool of the Illinois River is without obvious trend or has increased from 1990 to 1994. There is, however, evidence of a population decline in Pool 13 and the Unimpounded Reach (Figure 12-14).

Differences in abundance among the six LTRMP study reaches suggest that local habitat conditions may be more important than recent trends. The mean relative abundance of bluegills from the Unimpounded Reach typically has been less than one-third of the values from the other study reaches. Abundance also tends to be lower in Pool 26 than in Pools 4, 8, and 13. Patterns of abundance among study reaches for largemouth bass (Figure 12-15), black crappie (Figure 12-16), and white crappie are similar to that for bluegill (Gutreuter 1997). Year classes of these four species were particularly strong during 1991 and 1994 in La Grange Pool on the Illinois River (Figures 12-14 to 12-16). The extent of spring flooding is a suspected mechanism that influences reproduction and growth (Paul Raibley, Illinois Natural History Survey, Havana, Illinois, personal communication), but the relationship has not undergone rigorous testing.

This pattern of abundance contrasts

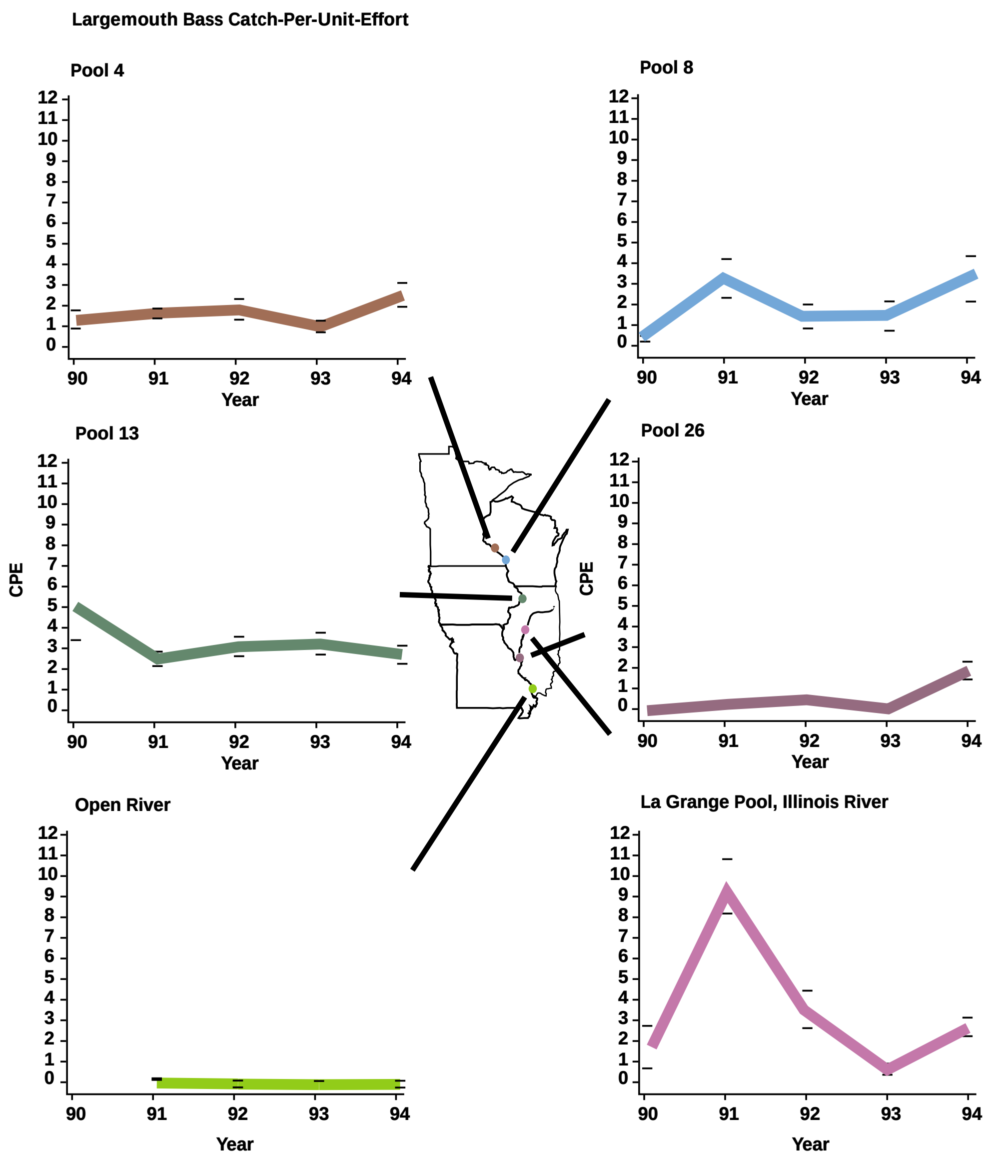


Figure 12-15. **Long Term Resource Monitoring Program (LTRMP) electrofishing data suggests abundances of largemouth bass are without obvious trend from 1990 to 1994. (Electrofishing CPE measures the number of fish captured in 15 minutes of sampling effort). However, for most centrarchids, differences in abundance among the six LTRMP study reaches suggest that habitat conditions may be more important than recent trends. Mean relative abundance of largemouth bass from the Pool 26 study reach was 2 to 3 times lower than the upstream reaches and few were captured in the Open River (Unimpounded Reach).**

starkly with these species' natural range; the Unimpounded Reach is near the center of their range and Pools 4 and 8 are relatively near the northern-range limit. All other factors being equal, greater abundance should be found in the Unimpounded Reach reach than in the northern-most reaches; however, all other factors are not equal. For example, important differences exist among LTRMP study reaches in the proportions of backwater aquatic areas in the floodplain (Table 12-2). Excluding permanently impounded areas immediately above the dams, backwaters constitute larger fractions of the floodplain in La Grange Pool of the Illinois River and Pools 4, 8, and 13 of the Mississippi River than in Pool 26 and especially in the Unimpounded Reach. The LTRMP data provide circumstantial evidence that the abundance of important centrarchids in some areas of the Upper Mississippi may be limited by the availability of suitable backwater habitat. Water-level fluctuations also may contribute to the patterns of abundance of these backwater-dependent species. Such fluctuations tend to be greatest in the Unimpounded Reach and least in Pool 8 (Burkhardt et al. 1997), and tend to increase from Pool 2 to Pool

Figure 12-16. **Catch-per-unit-effort (CPE) from Long Term Resource Monitoring Program electrofishing data suggests that the abundance of black crappie is without obvious temporal trend from 1990 to 1994. (Electrofishing CPE measures the number of fish captured in 15 minutes of sampling effort.) Significant regional differences are evident. Pool 4 near the species' northern range limit Pool 26, and the Open River (Unimpounded Reach) with few backwaters have much lower catch rates than other reaches.**

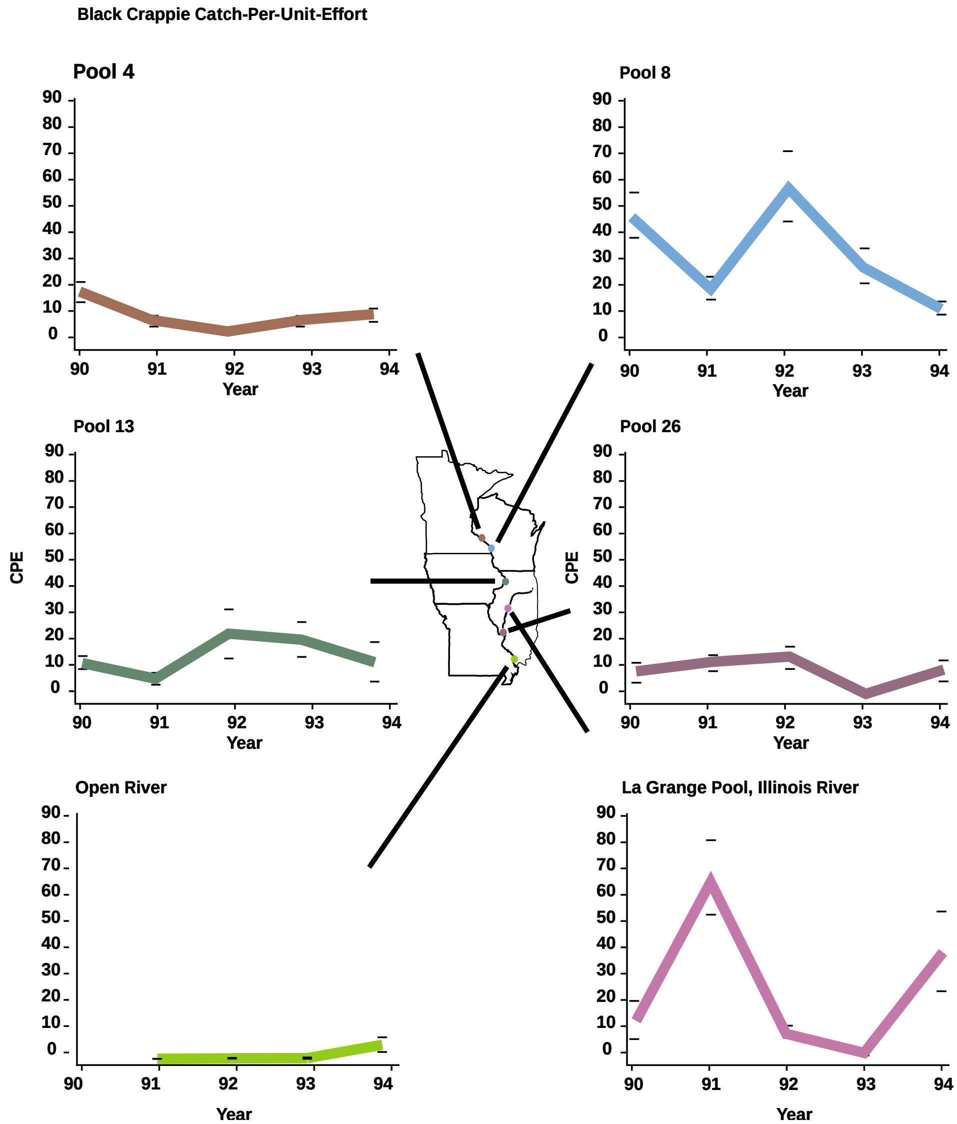


Figure 12-17. **The gizzard shad is an abundant prey species (Source: American Fisheries Society).**

26 (Wlosinski and Hill 1995). This means the abundance of these backwater-dependent species is inversely related to water-level fluctuations. However, water-level fluctuations and geographic latitude are comparable in Pool 26 and La Grange Pool of the Illinois River (Burkhardt et al. 1997), suggesting this factor alone cannot explain abundance of these species. More research is needed to assess the importance of available backwaters, water-level fluctuations, and other critical features of habitat. In addition, cost-effective ways to maintain and improve habitat quantity and quality must be identified.

Table 12-2. **Key features of the floodplain and aquatic area compositions (in ha) of the Long Term Resource Monitoring Program study reaches. Aquatic area is that portion of the floodplain which is inundated at normal water elevations.**

		Floodplain composition (%)			Aquatic area composition (%)	
Study reach	**Floodplain area**	**Open water**	**Aquatic vegetation**	**Agriculture**	**Contiguous backwater***	**Main channel**
Pool 4	28,358	50.5	10.0	12.1	21.3	10.5
Pool 8	19,068	40.1	14.4	0.9	30.6	14.2
Pool 13	35,528	29.7	8.6	27.9	28.5	24.7
Pool 26	51,688	13.4	1.4	65.4	17.3	54.4
Unimpounded Reach	105,244	9.9	0.6	71.5	0.0	79.0
La Grange Pool, Illinois River	89,554	15.7	2.2	59.6	52.2	21.3

*Total area fitting criteria (Wilcox 1993) excluding impounded areas and tributary delta lake (Lake Pepin, Pool 4); this area excludes all secondary and tertiary channels.

Prey Species

Gizzard shad and emerald shiners are two important prey species in the UMRS. Bertrand (1995) cited studies reporting that shad (Figure 12-17) composed 62 percent of the food (by volume) in largemouth bass stomachs, 73 percent in white crappie, 76 percent in black crappie, and 55 percent in sauger. The LTRMP data for gizzard shad show significantly higher abundance of gizzard shad in the Pool 26, Unimpounded, and La Grange Pool reaches, especially during the 1993 flood year. The LTRMP data show that emerald shiners are somewhat more abundant in northern reaches and overall abundance declined slightly from 1990 through 1994. A consistent pattern of greater numbers in the pooled reaches versus open river reaches is evident through time (Forbes and Richardson 1920; Bertrand 1995).

Exotic Species

Exotic (nonnative) species helped shape the current conditions of Mississippi River fisheries. The common carp, native to rivers of Europe and Asia, was first detected in the Mississippi River in 1883 (Figure 12-18; Cole 1905). Presently this is the most important exotic species in the system, comprising most of the commercial harvest (Kline and Golden 1979; Fremling et al. 1989) and being the dominant species in the Upper Mississippi (Gutreuter 1992). Coinciding with the dramatic increase in the abundance of common carp, commercial catches of native buffalo fishes, which are ecologically similar, declined by approximately 50 percent (Kline and Golden 1979). Abundance of common carp in all LTRMP study reaches increased markedly over the period of 1990 to 1994, but this species tended to be less abundant in the Unimpounded Reach than elsewhere (Figure 12-19, following page).

Figure 12-18. **The common carp has become the most common fish in commercial catches since its introduction in the late 1800s (Source: New Hampshire Department of Inland Fisheries, Concord, New Hampshire).**

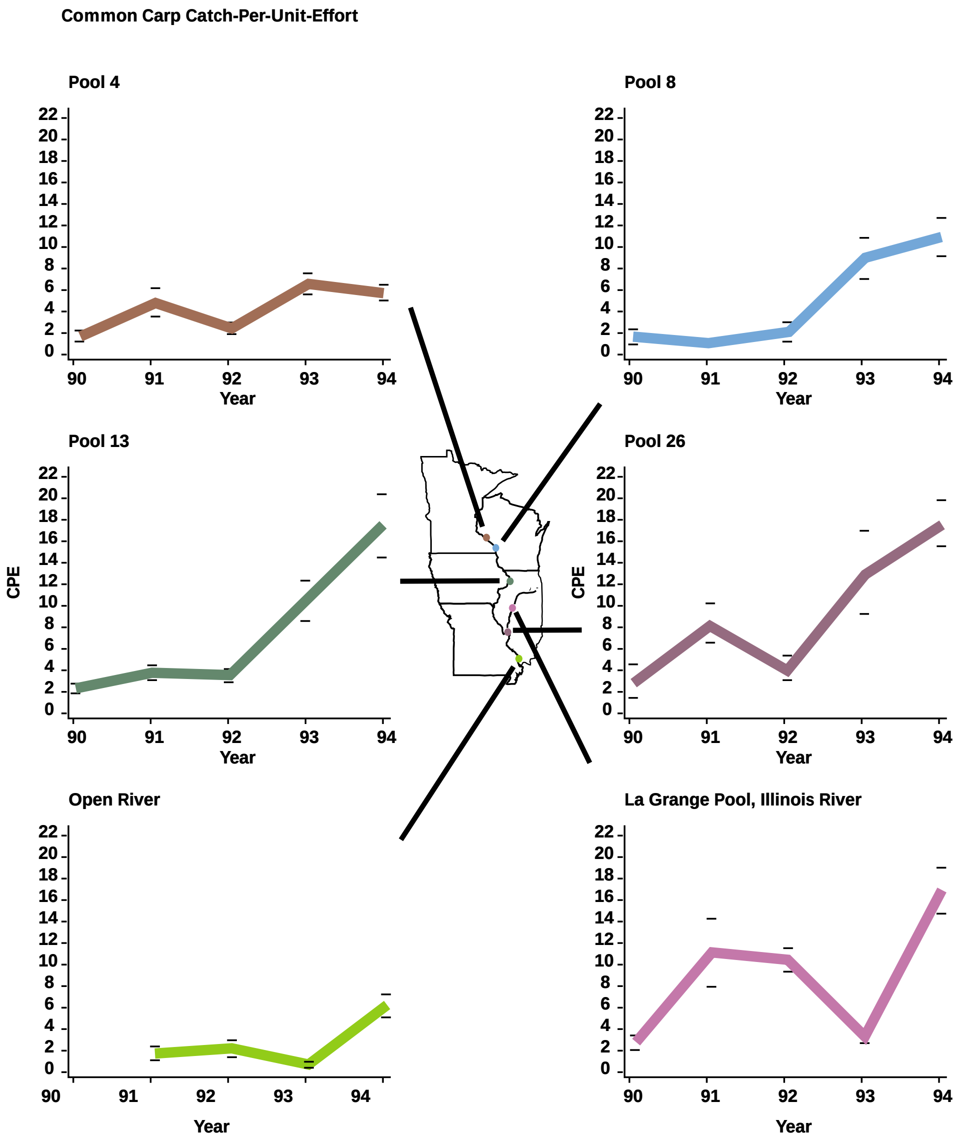


Figure 12-19. **Abundance of common carp as illustrated by catch-per-unit-effort (CPE) in all Long Term Resource Monitoring Program study reaches increased markedly over the period of 1990 to 1994, but this species tends to be less abundant in the Open River (Unimpounded Reach) than elsewhere. (Electrofishing CPE measures the number of fish captured in 15 minutes of sampling effort).**

Other large members of the minnow family invaded the Mississippi River more recently. The bighead carp is native to eastern Europe and Asia and was introduced into North America by aquaculturalists. The LTRMP first detected this species in Pool 26 during 1991 and in the Unimpounded Reach during 1992 (Tucker et al. 1996). As of 1996, the LTRMP had not detected this species elsewhere. Although bighead carp were present in LTRMP catches from 1990 through 1994 (Gutreuter 1997), sampling gear used by the LTRMP is not effective in capturing this species. Commercial fishers report that bighead carp have become common since 1992 and often are found in close association with paddlefish (Fred Cronin, LTRMP Field Station, Illinois Natural History Survey, Alton, Illinois, personal communication). It should be noted that the potential increased abundance of bighead carp could be detrimental to native fish species because this exotic plankton feeder competes with larval fishes and the adults of some native species that rely on zooplankton for food.

Another exotic species, grass carp, is a large herbivore of the minnow family intentionally imported from Asia in 1963 (Pflieger

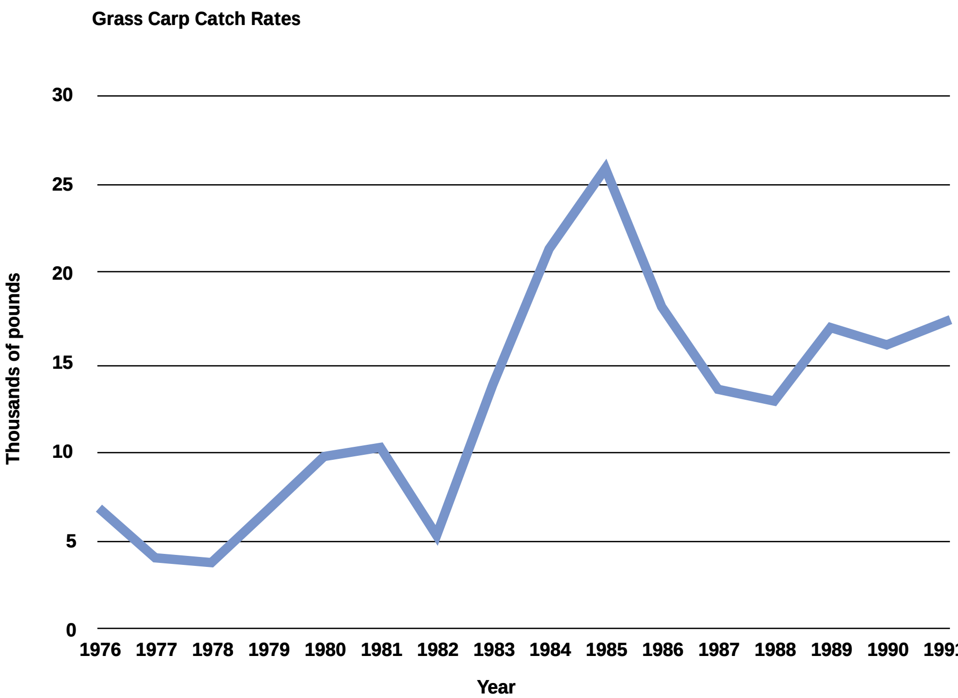


Figure 12-20. **Commercial catch rates of the recently introduced grass carp have increased significantly since 1976, with a peak harvest in Iowa of over 25,000 pounds (11,340 kg) in 1985. Reproduction has been detected in both the Mississippi and Illinois Rivers (Source: John Pitlo, Iowa Department of Natural Resources, Bellevue, Iowa).**

1975) to control nuisance aquatic vegetation. Grass carp soon escaped into the Mississippi River and spread throughout the system. Gravid specimens have been captured and reproduction documented (Raibley et al. 1995). Like bighead carp, their abundance is not high and fewer than 30 fish are captured throughout the LTRMP per year. However, the commercial catch has increased significantly since 1976, with a 1985 peak harvest of over 25,000 pounds (11,340 kg) in Iowa (Figure 12-20; John Pitlo, Iowa Department of Natural Resources, Bellevue, Iowa, personal communication).

The round goby is the most recently identified exotic fish to threaten the Mississippi River. This 8-inch (20-cm) species is native to the Black and Caspian Seas of Asia and the rivers that drain into them. The round goby was unintentionally introduced into the Great Lakes, probably from the ballast water of a transoceanic ship, and first discovered in Lake St. Clair near Detroit, Michigan, in 1990. This species currently is common in the Upper Illinois Waterway (Pam Thiel, U.S. Fish and Wildlife Service, Onalaska, Wisconsin, personal communication). Round gobies pose a substantial threat because they are aggressive and highly territorial, displacing native species from their habitats and eating their eggs. They also have a high reproductive potential and tolerate extreme water-quality conditions.

Endangered Species

"The only Federally listed endangered species in the UMRS is the pallid sturgeon (USFWS 1993) which also is listed by Iowa, Illinois, and Missouri (Table 12-1). The U.S. Fish and Wildlife Service has further considered the following species as candidates for listing: lake sturgeon, paddlefish, sicklefin chub, blue sucker, and the crystal darter. Each of the five states adjoining the Upper Mississippi River also list species considered threatened, endangered, rare, or of special concern within their jurisdictional boundaries (Table 12-1). This can be attributed to the geographic location of a given state, which may lie on the fringes of the natural range of a given species, while the species as a whole may be relatively numerous on a regional or national basis" (Source: Pitlo et al. 1995).

The only Federally listed endangered species in the UMRS is the pallid sturgeon.

Change Over Time

Fishes of the Upper Mississippi River have long been important to the peoples who inhabit the Midwest, including pre-Columbian mound builders (Ward 1903) of the Marion and Mississippian cultures (Hoops 1993). These peoples carved effigies of Mississippi River fishes, indicating the importance of this natural resource (Calvin 1893). Father Marquette, the Jesuit explorer of the 1670s reported the existence of "monstrous fish," including one that struck a canoe violently. Father Anastasius Douay, who traveled with La Salle in 1687, wrote that the rivers of the Mississippi Basin were so full of fish that members of the expedition were able to capture them with their bare hands. Thomas Jefferson foresaw the eventual importance of the Mississippi River when he wrote, "The Mississippi will be one of the principal channels of future commerce for the country westward of the Allegheny [and] yields perch, trout, gar, pike, mullets, herrings, carp, spatula fish of fifty pound weight, catfish of one hundred pounds weight, buffalo fish, and sturgeon" (Jefferson 1854).

Fishes of the Upper Mississippi River have long been important to the peoples who inhabit the Midwest, including pre-Columbian mound builders of the Marion and Mississippian cultures.

Commercial fishing has been important to residents of the Mississippi River Basin at least since the mid-1800s. Commercial fishing was well established in Quincy, Illinois, by 1869 (Redmond 1869), and J. P. Walton (1893) reported on the abundance of buffalo fish near Muscatine Island in 1842. However, navigation—not fisheries—has been the primary goal for management of the Mississippi River. The U.S. Army Corps of Engineers has been responsible for alterations to the Mississippi River to support navigation since the first channel surveys were authorized in 1824. Commercial fisheries of the Upper Mississippi River likely were changed by these navigation improvements and other anthropogenic influences. The existence of such long-term changes is based on anecdotal or circumstantial evidence because commercial catches were not recorded systemically until 1953 when the UMRCC coordinated the effort (UMRCC 1953–1995). Fishes of the Upper Mississippi River System were not monitored using standardized methods until the advent of the Long Term Resource Monitoring Program sampling in 1990 (Gutreuter 1997).

Anecdotally, we know the blue sucker once was an important commercial species in fast-flowing areas of the Mississippi River but virtually disappeared by 1926. This species also was believed to be abundant in the Keokuk Rapids. Catches were reported to dwindle, however, after about 1910 and completion of the Keokuk Dam (now Lock and Dam 19) in 1913 (Carlander 1954).

The system of locks and dams above St. Louis, Missouri, also had consequences for other fishes, particularly the skipjack herring. The skipjack herring is a highly mobile species once persistent in all reaches of the Mississippi River except the headwaters. Presently this species persists only in the lower reaches (Fremling et al. 1989). Skipjack herring were reported to be abundant during the 1860s in Lake Pepin, a natural lake formed by the delta at the confluence of the Chippewa and Mississippi Rivers in what is now Pool 4 (Carlander 1954). More recently, Becker (1983) listed skipjack herring as extinct from Wisconsin waters, attributing the decline of this species to the locks and dams. Other mobile riverine fishes that may have been affected adversely by the locks and dams (particularly the Keokuk Dam) include sturgeons, paddlefish, and American eel (Duyvejonck 1996).

More recent data also indicate that the dams impede the movement of fishes. Wlosinski and Maracek (unpublished data) compiled information from 126 different telemetry and mark/recapture studies to determine the impact of navigation dams on fish movement between pools. They found that 87 percent of the total 5,253 fish recaptured did not move from the pool where they were captured, 8 percent moved upriver, and 5 percent moved downriver (Figure 12-21). No black crappie, white crappie, bluegill, northern pike, or common carp were found outside the original pool. Species that showed interpool movement included channel catfish, freshwater drum, flathead catfish, largemouth bass, paddle-fish, sauger, shovelnose sturgeon, small-mouth bass, walleye, and white bass. Most fish moved through dams during open-river conditions when head differentials were less than 1 foot (0.3 m). Skipjack herring reinvaded the uppermost pools of the Mississippi River during the Flood of 1993 (Figure 12-22, following page), when dam gates were held wide open and the river attained free-flowing conditions that allowed upriver passage through the dams. This demonstrates that although the locks and dams have altered the Upper Mississippi River, highly mobile fish like skipjack herring can exploit the occasional opportunity to move upriver.

Impounded aquatic areas immediately above the locks and dams superficially resemble storage reservoirs and are included in the LTRMP definition of backwaters (Wilcox 1993). This has led to speculation that impoundment has benefited backwater-dependent species like the centrarchids (Fremling and Claflin 1984). However, these areas do not seem to function as lake-like backwaters. Impounded areas typically are shallow environments strongly influenced by wind and waves. Recent studies indicate that sediments in impounded areas are similar to sediment in the channel borders (Rogala 1996) and do not resemble the fine sediments in deep backwaters. Similarly, fish communities in impounded areas resemble those in main-channel border areas and tend to support low relative abundances of back-water-dependent species like the centrarchids (Gutreuter 1992). Creation of a 9-foot (2.7-m) navigation channel by combined use of dams and channel alignment (wing dams and revetments) no doubt helped prevent the loss of many backwaters that would have resulted if channel alignment alone was used to support navigation in those same reaches. However, any notion that impoundment will have long-term benefits to backwater-dependent species above and beyond presettlement baseline conditions is questionable.

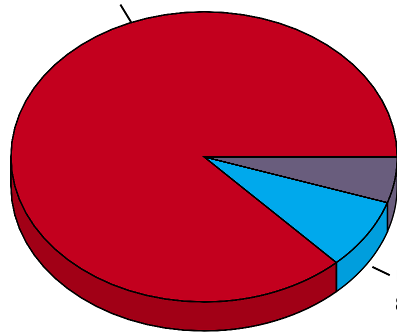


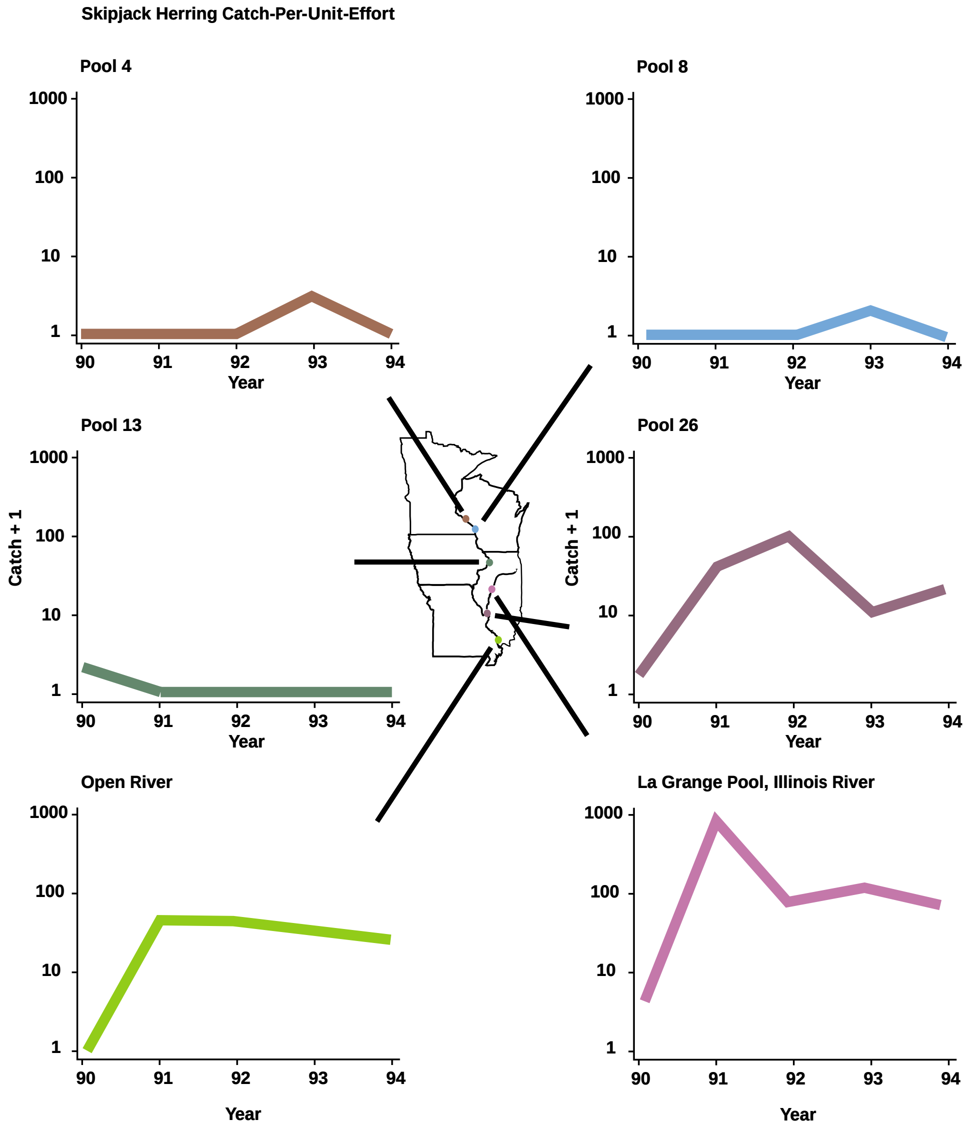
Figure 12-21. **Telemetry and mark/recapture studies used to assess the impact of navigation dams on fish movement between pools showed 87 percent of fish recaptured stayed in the pool where they were captured, 8 percent moved upriver, and 5 percent downriver. (Source: Joseph H. Wlosinski, USGS Environmental Management Technical Center, Onalaska, Wisconsin).**

Trends in Riverine Fishes

Long-term data have been collected in State-sponsored sampling in Minnesota and Illinois. Data collected in Minnesota between 1965 and 1995 show that Lake Pepin walleye populations appear relatively stable through time but sauger populations fluctuate widely (Stevens 1995). Several strong year classes apparently persisted between the late 1960s and mid-1970s, but the mechanisms that control year-class strength are not known.

Illinois' long-term sampling since 1976 indicates that channel catfish populations have increased through time (Figure 12-23, see page 19). Much of the statewide increase was due to significant increases in the Unimpounded Reach; populations in the pooled reaches showed slight increases (Bertrand 1995). Bertrand (1995) suggests that response to commercial size limits initiated in 1976 helped increase the abundance of "quality-sized" fish.

Figure 12-22. **The migratory species skipjack herring catch-per-unit-effort + 1 (catch + 1) reinvaded the uppermost pools of the Mississippi River during the Flood of 1993 when the Lock and Dam 19 gates were held wide open and the river attained free-flowing conditions that allowed upriver passage through this historic obstacle.**



Many biotic and abiotic factors affect year-class reproductive success and in rivers, water-level fluctuations may be important.

Smallmouth buffalo in Illinois waters did not show a strong trend through time, but a strong year class apparently detected by LTRMP sampling in 1994 was observed after extreme flooding in 1993 (Bertrand 1995), as might be expected from their spawning requirements.

Long-term trends in Illinois white bass populations show generally increasing abundance, but the trend is not significant (Bertrand 1995). Large numbers of fish captured in 1993 were small fish that represented a strong cohort that declined during the subsequent winter of 1993–94 (Bertrand 1995).

Relative abundance of common carp decreased between 1976 and 1986 then remained stable until 1993; they have since increased twofold (Bertrand 1995). As reflected by LTRMP data, extreme flooding in 1993 coincided with increased abundance.

Trends in Backwater Fishes

Long-term data from Illinois (Bertrand 1995) show increasing bluegill populations in the 1980s and a slight drop in the 1990s (Figure 12-24). Bluegills were consistently more abundant in the pooled reaches than in the Unimpounded Reach. Many biotic and abiotic factors affect year-class repro-

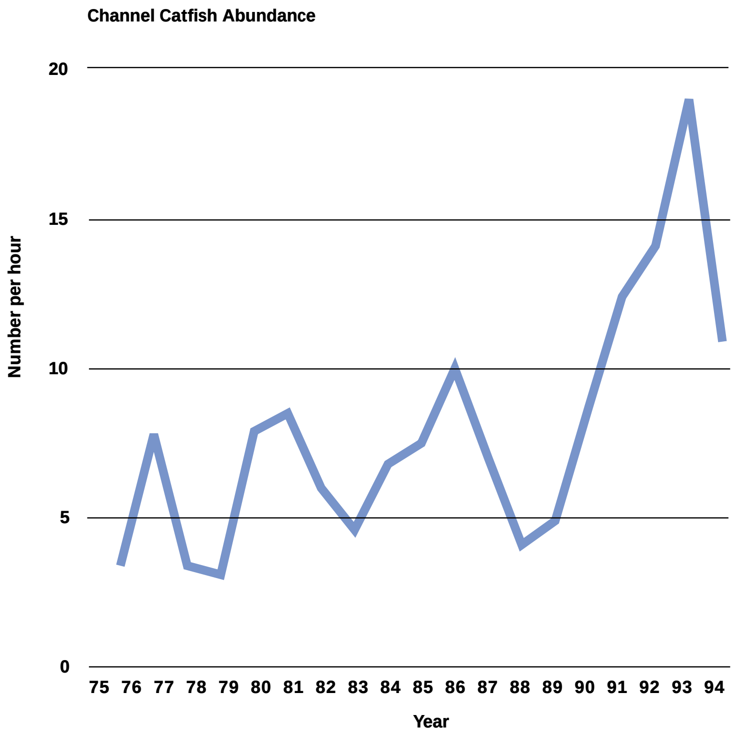


Figure 12-23. **Relative abundance of channel catfish from sites distributed along the Mississippi River bordering Illinois show an increasing trend in species abundance (catch-per-unit-effort number per hour) with large increases in the late 1980s and early 1990s. Much of the increase was due to higher catches in the Unimpounded Reach (Source: Bertrand 1995).**

ductive success and in rivers, water-level fluctuations may be important (Welcomme 1979; Junk et al. 1989). For bluegills (and other centrarchids), water-level changes may strand nests or expose small fish to predators or, in winter, eliminate temperature refuges. The two most abundant cohorts were produced in low-flow years, when water levels were relatively stable (Bertrand 1995). Theiling et al. (1996) attribute changes within Pool 26 centrarchid abundance to the presence or absence of lower pool drawdowns, flow regimes, and plant abundance.

Since 1976, largemouth bass abundance has increased in Illinois waters of the pooled reaches of the Mississippi River (Figure 12-25, following page), but they are missing from the Unimpounded Reach (Bertrand 1995). Spawning requirements are similar to bluegill and telemetry studies show that largemouth bass will abandon their nests because of rapidly falling water levels (Pitlo 1992). Overwintering habitat also may be important. Pitlo (1992) suggests

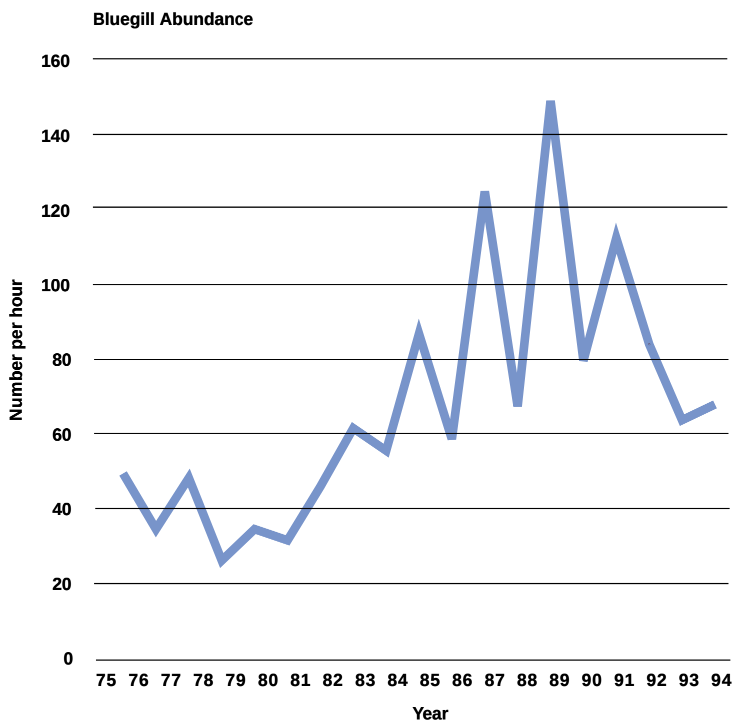


Figure 12-24. **Relative abundance of bluegills (catch-per-unit-effort per hour) from the Mississippi River bordering Illinois has tended to increase since the early 1980s. Bluegills were consistently more abundant in pooled reaches than in the Unimpounded Reach where increased populations were detected later (Source: Bertrand 1995).**

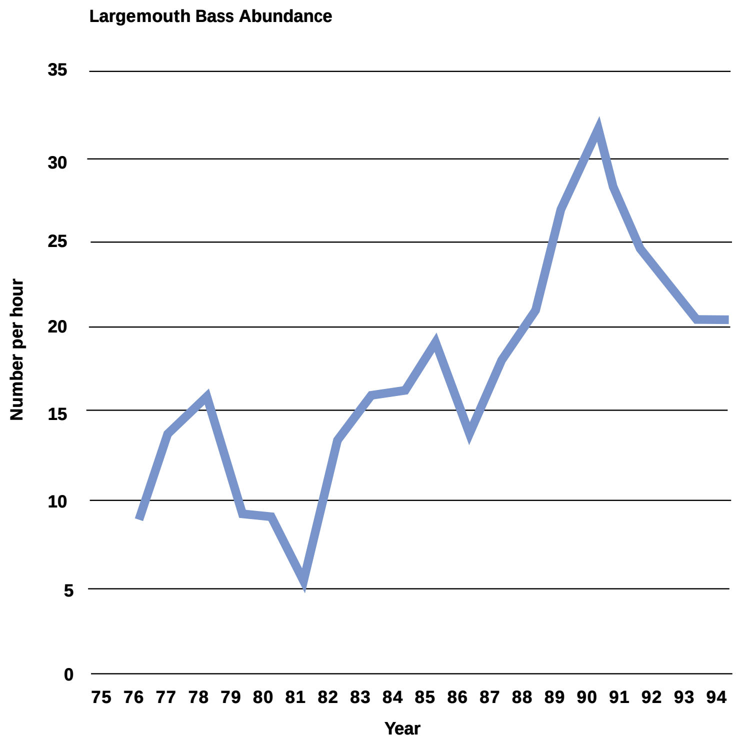


Figure 12-25. **Long-term largemouth bass populations (catch-per-unit-effort per hour) have increased similar to bluegill but they are missing from the Unimpounded Reach (Source: Bertrand 1995).**

that energy expended during fall flooding may consume energy reserves necessary for overwinter survival. Bertrand (1995) attributes some of the increase in largemouth bass populations in Illinois to the presence of stable water levels during winter.

Trends for black and white crappie populations seem to differ (Bertrand 1995). Numbers of black crappie have fluctuated without obvious trend since 1976 (Figure 12-26). White crappie, conversely, were abundant during 1976 and 1977, but their numbers decreased by almost two-thirds in 1978 and remain at less than one-half their abundance two years earlier (Bertrand 1995).

Trends in Prey Species

There is no obvious trend in abundance of gizzard shad and emerald shiners in the Mississippi River bordering the State of Illinois (Bertrand 1995). Both species exhibit strong and weak year classes, but the mechanisms that control prey species are unknown.

Trends in Illinois River Fishes

The Illinois River has been surveyed at fixed sample sites since 1963 (Sparks and Lerczak 1993; Lerczak et al. 1994). Trends in fish populations differed in the upper, middle, and lower river reaches, with the Upper Illinois River showing the greatest improvements. In 1963, pollution tolerant habitat generalists (common carp and goldfish) represented over 60 percent of the catch (Sparks and Lerczak 1993). By 1992, goldfish and carp were relatively rare (about 5 to 10 percent of the catch) and many new species were encountered. Lower Illinois River reaches did not show the degree of degradation seen in the Upper Illinois River in 1963, but improvements in fish community diversity were detected in 1992. Abundance of common carp declined in both reaches and the number of important gamefish species increased. Abatement of industrial and municipal pollution has resulted in many improvements in the upper river, but growth in fish populations in the middle and lower reaches continues to be limited by factors that relate to high sedimentation rates and the resultant habitat degradation (Sparks and Lerczak 1993).

Discussion and Information Needs

The fishes of the Upper Mississippi River System are an exceptional biological resource, not just for the recreation and commerce they support but because this diverse fauna is so unique among temperate rivers. Human activity has had an impact on fish communities in some river reaches, but overall fish biodiversity has been remarkably persistent and resilient in the face of multiple competing uses of the UMRS. Despite the long history and importance of the UMRS, little is known of the ecological processes that maintain this richness. The combination of research and monitoring efforts of the LTRMP partnership offers the opportunity to learn how to manage this national treasure better. It also may provide a key to maintaining exceptional biological resources in the presence of other uses of large rivers.

Many important but unanswered questions remain. For example, research indicates that relatively warm, calm water found in deeper backwaters may be crucial to the overwinter survival of many fish species (Bodensteiner and Sheehan 1988; Bodensteiner et al. 1990; Sheehan et al. 1990; Pitlo 1992; Gent et al. 1995). Spatial patterns in the abundance of backwater-dependent fishes such as the bluegill are consistent with the conjecture that backwaters limit these species in the open river. We need to know whether the availability of overwintering habitat is limiting, to what extent sediment deposition threatens this habitat, and what cost-effective management options might be developed. This task requires identifying critical features of habitat, including effects of water-level fluctuations. Developing that knowledge requires additional experimental manipulation of backwaters, monitoring, and analysis. Development of geographic information systems modeling tools and increased availability of bathymetric data are beneficial and needed to identify probable overwinter fish habitat (see Chapter 7).

A second concern is loss of the islands that create physical complexity in the floodplain. Islands are being eroded by wind and waves in the reservoir-like impounded portions of some navigation pools (see Chapter 4). One solution being tested in Pool 8 is the use of "seed islands," small, relatively inexpensive rock barriers constructed in areas of high sediment transport. Sediment should be naturally deposited behind these seed islands, allowing larger islands to build up and recreate physical complexity. Knowing how fishes respond to this increased physical complexity will help managers focus their management and restoration efforts.

A third issue is the need to better understand the cumulative effects of navigation management on fishes. Studies that estimate the numbers of fish killed by entrainment through the propellers of commercial towboats are under way. However, we know little about how the present channel management infrastructure (i.e., dams, wing dikes, armored banks) has had a significant cumulative effect on fishes and their habitat. Routine navigation channel maintenance operations might be changed to provide both valuable navigation benefits and improved habitat availability.

Another consideration is that little is known about the importance of the main channel as fish habitat, primarily because this area is difficult to sample effectively. Quantitative trawling being used in ongoing studies of navigation effects holds great potential to change that. Initial results show higher-than-expected fish abundance and diversity (24 species), as well as a high occurrence of species of concern such as lake sturgeon. Gizzard shad, freshwater drum, channel catfish, and smallmouth buffalo

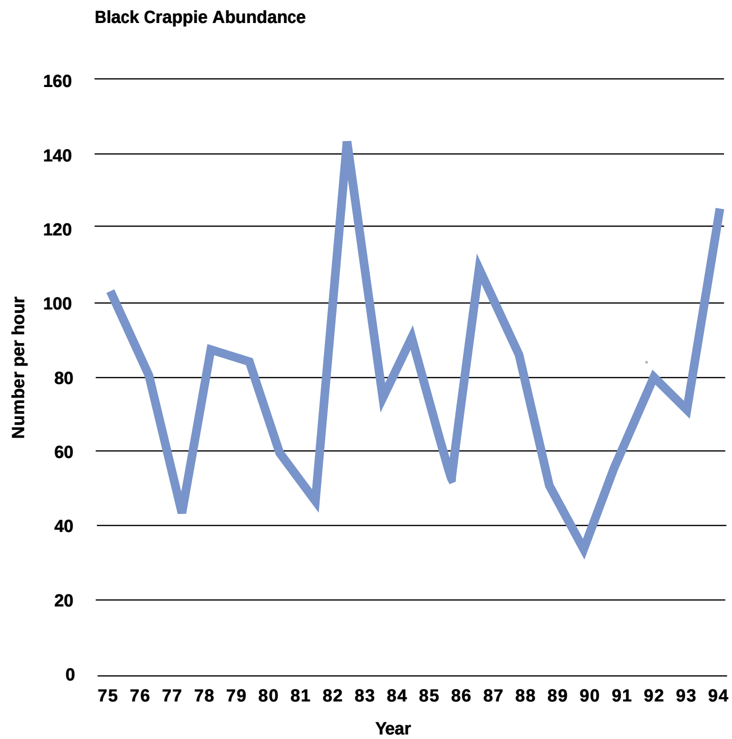


Figure 12-26. **Long-term black crappie populations have fluctuated without obvious trends (Source: Bertrand 1995).**

have been caught throughout the length of the navigation channel in Pool 26. Species found in the impounded part of the navigation channel include blue catfish and bigmouth buffalo. Species found in the upper riverine portion of the navigation channel in Pool 26 include sturgeons, blue suckers, and shorthead redhorse, which are characteristic inhabitants of high-current velocities. The Illinois River main channel supports high abundances of fish, but lacks the high species diversity found in the Mississippi River. This preliminary information enhances the need to know more about use of the main navigation channel by fishes.

We need to learn more about the major factors that influence reproduction and recruitment and those that influence the food web of the Upper Mississippi River.

Finally, we know too little about the basic processes that fuel fish production. We need to learn more about the major factors that influence reproduction and recruitment and those that influence the food web of the Upper Mississippi River. For example, river ecologists have long held that the seasonal cycle of flooding is responsible for high biological productivity in floodplain rivers (Starrett and Friz 1965). Most recently this idea was articulated as the "flood-pulse" concept of Junk et al. (1989). Although this concept is appealing, it encompasses too much to serve as a scientific hypothesis. Therefore it is important to identify and examine specific aspects of the flood-pulse idea because the system of dams in the Upper Mississippi River Basin alters the seasonal patterns of water-level fluctuation (Theiling 1996). Preliminary LTRMP studies suggest that certain fishes grew significantly faster during the warm-season Flood of 1993 than during years of typical spring water elevations (Bartels 1995). Further it was found that some fishes grew significantly more slowly during the low-flow year of 1989 (Bartels 1995). Long-term data from Illinois indicate that largemouth bass and bluegill can produce large year classes during low-flow, stable-water years, while channel catfish, smallmouth buffalo, white bass, black crappie, emerald shiners, freshwater drum, and common carp produce large year classes in response to seasonal flooding (Bertrand 1995). Refinement of our knowledge of basic fish reproduction processes will be critical to the assessment of, for example, the costs and benefits of alternative water-level management strategies.

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References

Bartels, A. D. 1995. Growth of selected fishes in Navigation Pool 8 of the Upper Mississippi River: A test of the flood-pulse concept. M.S. thesis submitted to the faculty of the graduate school of the University of Wisconsin-La Crosse, December 1995. Reprinted by U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, January 1997. LTRMP 97-R001. 63 pp. (NTIS #PB97-144117)

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1052 pp.

Bertrand, B. A. 1995. Illinois monitoring of Mississippi River fish 1976–1994. Illinois Department of Natural Resources, Springfield, Illinois. F-67-R-9 Study 102 Job 102.3.

Bodensteiner, L. R., and R. Sheehan. 1988. Implications of backwater habitat management strategies to fish populations. Pages 60–65 *in* Proceedings of the Forty-Fourth Annual Meeting of the Upper Mississippi River Conservation Committee, March 8–10, 1988, Peoria, Illinois.

Bodensteiner, L. R., W. M. Lewis, and R. J. Sheehan. 1990. Differences in the physical environment of the Upper Mississippi River as a factor in overwinter survival of fish. Pages 109–117 *in* Proceedings of the Restoration of Midwestern Stream Habitat Symposium, Dec. 3–5, 1990, Minneapolis, Minnesota. Sponsored by the North Central Division of the American Fisheries Society.

Burkhardt, R. W., S. Gutreuter, M. Stopyro, A. Bartels, E. Kramer, M. C. Bowler, F. A. Cronin, D. W. Soergel, M. D. Petersen, D. P. Herzog, K. S. Irons, T. M. O'Hara, K. Douglas Blodgett, and P. T. Raibley. 1997. 1996 Annual Status Report: A summary of fish data in six reaches of the Upper Mississippi River System. U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, August 1997. LTRMP 97–P011. 15 pp. + Chapters 1–6 (NTIS #PB97–206387)

Calvin, S. 1893. Pages 30–53 *in* Prehistoric Iowa. Iowa Historical Lectures. Iowa Historical Society, Iowa City.

Carlander, H. B. 1954. A history of fish and fishing in the Upper Mississippi River. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 96 pp.

Cavender, T. M. 1986. Review of the fossil history of North American freshwater fishes. Pages 699–724 *in* C. H. Hocutt, and E. O. Wiley, editors. The zoogeography of North American freshwater fishes. John Wiley and Sons, New York.

Cole, L. J. 1905. The German carp in the United States: U.S. Bureau of Fisheries Report for 1904.

Cross, F. B., R. L. Mayden, and J. D. Stewart. 1986. Fishes in the western Mississippi basin (Missouri, Arkansas, and Red Rivers). Pages 367–411 *in* C. H. Hocutt, and E. O. Wiley, editors. The zoogeography of North American freshwater fishes. John Wiley and Sons, New York.

Duyvejonck, J. 1996. Ecological trends of selected fauna in the Upper Mississippi River. Pages 41–48 *in* D. L. Galat, and A. G. Frazier, editors. Overview of river-floodplain ecology in the Upper Mississippi River Basin, Volume 3 of J. A. Kelmelis, editor, Science for floodplain management into the 21st century. U.S. Government Printing Office, Washington, D.C.

Forbes, S. A., and R. E. Richardson. 1920. The fishes of Illinois. State of Illinois, Natural History Survey Division, Champaign.

Fremling, C. R. and T. O. Claflin. 1984. Ecological history of the Upper Mississippi River. Pages 5–24 *in* J. G. Wiener, R. V. Anderson, and D. R. McConville, editors. Contaminants in the Upper Mississippi River. Butterworth Publishers, Stoneham, Massachusetts.

Fremling, C. R., J. L. Rasmussen, R. E. Sparks, S. P. Cobb, C. F. Bryan, and T. O. Claflin. 1989. Mississippi River fisheries: A case history. Pages 309–351 *in* D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106, Ottawa, Ontario.

Gent, R., J. Pitlo, and T. Boland. 1995. Largemouth bass response to habitat and water quality rehabilitation on a backwater of the Upper Mississippi River. North American Journal of Fisheries Management 15:784–793.

Gutreuter, S. 1992. Systemic features of fisheries of the Upper Mississippi River System, 1990 fisheries component annual report. U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin, October 1992. EMTC 92–T001. 42 pp. (NTIS # PB93126431)

Gutreuter, S. 1997. Fish monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990–1994.

U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, November 1997. LTRMP 97–T004. 78 pp. + Appendix (NTIS #PB98–116981)

Hoops, R. 1993. A river of grain: The evolution of commercial navigation on the Upper Mississippi River. College of Agriculture and Life Sciences Research Report, University of Wisconsin, Madison. 125 pp.

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press, Ontario. 555 pp.

Jefferson, T. 1854. Notes on Virginia. Writings of Thomas Jefferson, Volume VIII. Taylor and Maury, Washington, D.C.

Johnson, J. E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, Maryland. 42 pp.

Junk, W. L., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river floodplain systems. Pages 110–127 *in* D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication in Fisheries and Aquatic Sciences 106. Ottawa, Ontario.

Kline, D. R., and J. L. Golden. 1979. Analysis of the Upper Mississippi River commercial fishery. Pages 82–117 *in* J. L. Rasmussen, editor. A compendium of fishery information on the Upper Mississippi River, 2nd Edition. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Lerczac, T. V., R. E. Sparks, and K. D. Blodgett. 1994. The long term Illinois River fish population monitoring program. Illinois Natural History Survey, Center for Aquatic Ecology, Champaign, Illinois. Aquatic Ecology Technical Report 94/5. 105 pp.

Miller, R. R. 1965. Quaternary freshwater fishes of North America. Pages 569–581 *in* H. E. Wright, Jr., and D. G. Frey, editors. The Quaternary of the United States. Princeton University Press, New Jersey.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City, Missouri. 343 pp.

Pitlo, J. 1992. Federal aid to fish restoration completion report: Mississippi River investigations, Project No. F–109–R. Iowa Department of Natural Resources, Bellevue, Iowa.

Pitlo, J., A. Van Vooren, and J. Rasmussen. 1995. Distribution and abundance of Upper Mississippi River fishes. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 20 pp.

Raibley, P. T., K. D. Blodgett, and R. E. Sparks. 1995. Evidence of grass carp (*Ctenopharyngodon idella*) reproduction in the Illinois and Upper Mississippi Rivers. Journal of Freshwater Ecology 10:65–74.

Redmond, P. H. 1869. History of Quincy and its men of mark; or, facts and figures exhibiting its advantages and resources, manufactures and commerce. Heirs and Russell, Quincy, Illinois.

Rogala, J. T. 1996. Surficial sediment characteristics in Pools 4 and 8, Upper Mississippi River. U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, November 1996. LTRMP 96–T006.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa, Ontario. 966 pp.

Sheehan, R. J., W. M. Lewis, and L. R. Bodensteiner. 1990. Winter habitat requirements and overwintering of riverine fishes. Federal Aid in Sport Fish Restoration, Final Report for Project F–79–R, Illinois Department of Conservation, Springfield, Illinois. 86 pp.

Sparks, R. E., and T. V. Lerczak. 1993. Recent trends in the Illinois River indicated by fish populations. Illinois Natural History Survey Center for Aquatic Ecology Technical Report 93/16. 34 pp.

Starrett, W. C., and A. W. Friz. 1965. A biological investigation of the fishes of Lake Chautauqua, Illinois. Illinois Natural History Survey Bulletin Volume 29, Article 1. Illinois Natural History Survey, Urbana, Illinois.

Stevens, A. 1995. Completion Report: Lake Pepin 1995. Minnesota Department of Natural Resources Division of Fish and Wildlife, Section of Fisheries. F-29-R(P)-15.

Theiling, C. H. 1996. An ecological overview of the Upper Mississippi River system: Implications for postflood recovery and ecosystem management. Pages 3–28 *in* D. L. Galat, and A. G. Frazier, editors. Overview of river floodplain ecology in the Upper Mississippi River Basin, Volume 3 of J. A. Kelmelis, editor. Science for floodplain management into the 21st century. U.S. Government Printing Office, Washington, D.C.

Theiling, C. H., R. J. Maher, and R. E. Sparks. 1996. Effects of variable annual hydrology on a river regulated for navigation: Pool 26, Upper Mississippi River System. Journal of Freshwater Ecology 11:101–114.

Tucker, J. K., F. A. Cronin, R. A. Hrabik, M. D. Peterson, and D. P. Herzog. 1996. The bighead carp (*Hypophthalmichthys nobilis*) in the Mississippi River. Journal of Freshwater Ecology 11:241–243.

UMRCC (Upper Mississippi River Conservation Committee)1953–1995. Web site. Available at http://www.Mississippi-River.com/UMRC.

USACE (U.S. Army Corp of Engineers). 1993. Economic impacts of recreation on the Upper Mississippi River System: Economic impacts report. Final Version, March 1993, U.S. Army Corps of Engineers, St. Paul District, Planning Division. 31 pp. + Appendixes.

USFWS (U.S. Fish and Wildlife Service). 1993. Endangered, threatened, and proposed species in Fish and Wildlife Service Region III. Minneapolis-St. Paul, Minnesota.

Walton, J. P. 1893. Scraps of Muscatine history. Manuscript [reported by H. B. Carlander (1954); unseen by author].

Ward, D. L. 1903. Historical anthropological possibilities in Iowa. Iowa Journal of History and Politics 1:46–76.

Welcomme, R. L. 1979. Fisheries ecology of floodplain rivers. Longman, London, United Kingdom. 317 pp.

Wilcox, D. B. 1993. An aquatic habitat classification system for the Upper Mississippi River System. U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin. EMTC 93–T003. 9 pp. + Appendix A.

Wlosinski, J. H., and L. Hill. 1995. Analysis of water level management on the Upper Mississippi River. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, May 1995. LTRMP 95–T001. 43 pp. (NTIS # PB96–141411)