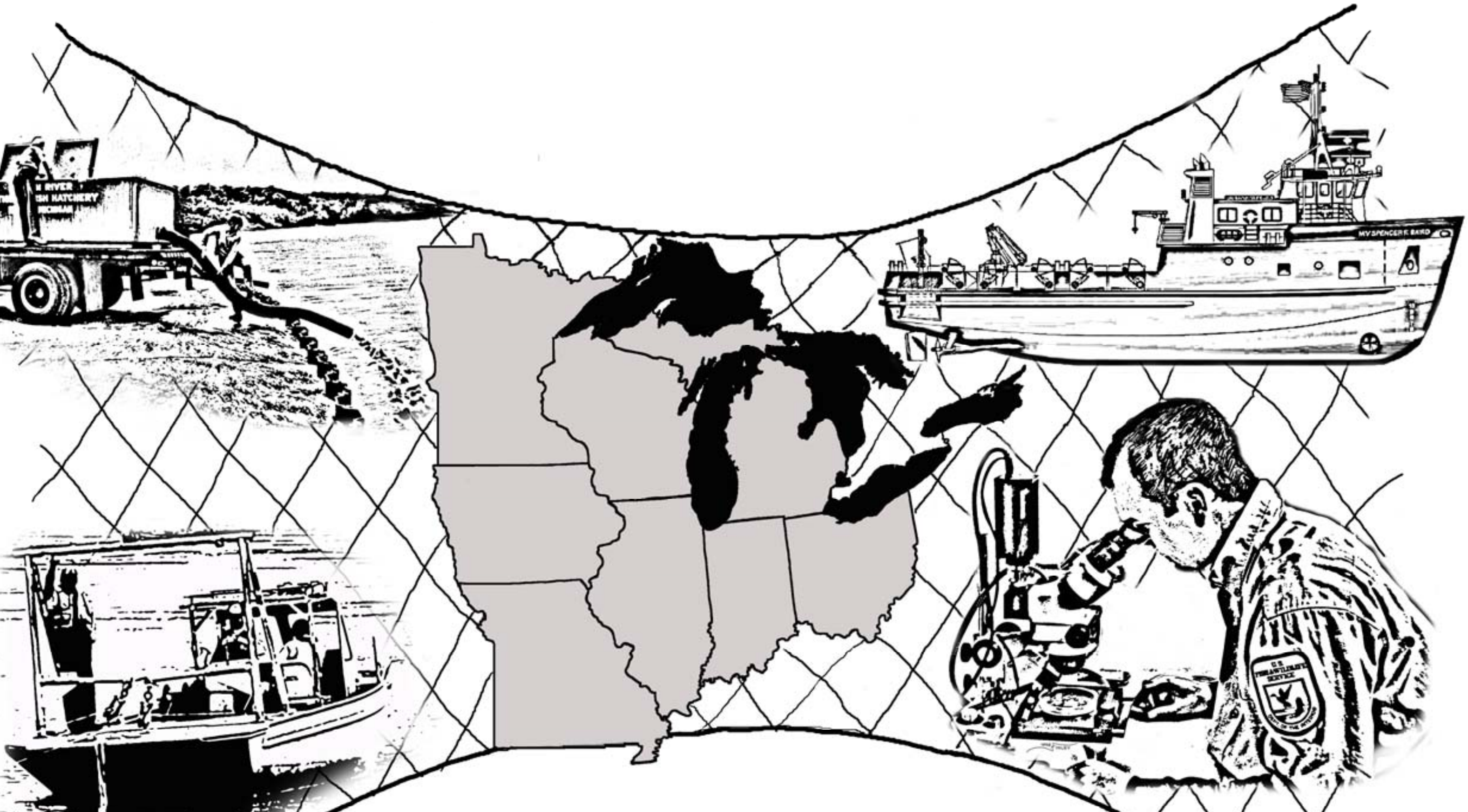
U.S. Fish & Wildlife Service

Region 3 Fisheries Data Series Report

FDS-2007-4

Fisheries Monitoring at Harlow Island, Middle Mississippi River 2005-2007



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U.S. Fish and Wildlife Service
Great Lakes-Big Rivers Region
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September 2007

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Suggested Citation

Caswell, N., N. Richards, and M. Mangan. 2007. Fisheries Monitoring at Harlow Island, Middle Mississippi River 2005-2007. Region 3 Fisheries Data Series Report FDS-2007-4, U.S. Fish and Wildlife Service, Carterville National Fish and Wildlife Conservation Office, Marion, Illinois.

Abstract

Modification of the Middle Mississippi River for navigation purposes has changed many of the natural functions of the river system. Backwater restoration is critical to increasing the habitat and flow diversity of the Middle Mississippi River. The Harlow Island remnant side channel (HIRSC) was one of the first areas selected for restoration planning. This side channel is currently a backwater that has experienced excessive sedimentation, and is connected to the Mississippi River only during extreme high-water periods. Our objective was to compare the fish community at the HIRSC before and after restoration, while comparing community changes at a control site to factor out any system-wide changes. A borrow ditch in the Wilkinson Island backwater complex was selected to serve as the control site. This site did not hold water continually throughout 2005. A new control site, the lower end of Tower Island Chute, was selected in 2006, but by late summer it also dried up. No control site was sampled in 2007. We caught 7,437 fish representing 29 species at Wilkinson Island, and 9,235 fish representing 14 species at Tower Island. At the HIRSC, we captured 18,437 fish representing 36 species between June 2005 and September 2007. A flood occurred following the April 2007 sampling, and that event resulted in a change in the community. We collected species that were not present in samples collected before the flood. Conversely, seven species that were previously captured were absent in samples collected after the flood. Most species showed an increase in the numbers of young fish after the flood of April 2007. Many species in the HIRSC, especially silver carp *Hypophthalmichthys molitrix*, were undersized or in poor condition. Restoration of the HIRSC should ensure that it is deep enough to hold water except during a severe drought. The HIRSC should flood with greater regularity, and it should contain high-quality habitat for a wide variety of native fishes.

Introduction

Modification of the Upper Mississippi River for navigation purposes began as early as the 1820's. The Rivers and Harbors Act of 1930 authorized the U.S. Army Corps of Engineers to begin construction of lock and dam structures to maintain a 9-ft (2.75-m) deep navigation channel from St. Paul, Minnesota, to St. Louis, Missouri (O'Donnell and Galat 2007). The current Upper Mississippi River System includes 37 lock-and-dam structures and thousands of river channelization structures to maintain a 9-ft (2.75-m) navigation channel (USGS 2007). As a result, many of the natural functions of the system have degraded, principally because modifications have altered water level and flow regimes (Bayley 1995).

Important habitats that have been lost due to the homogenization of the Mississippi River includes backwater and off-channel areas. Those areas were once flushed and scoured on a regular basis, but are now subject to continuous sedimentation (Gent et al. 1995). The importance of backwater areas was best described by Bade (1980) and Pitlo (1992), who noted that backwaters provide prime habitat, including wintering habitat, for all life stages of native fish. For example, Shaeffer and Nickum (1986) found backwaters contained higher densities of larval fish than were found in main channel habitats, indicating that backwaters were more productive. Shaeffer and Nickum (1986) concluded that: 1) backwater areas were important nursery areas for larval and juvenile fishes, 2) downstream main channel sites benefitted from backwater areas, and 3) loss of these habitats would be detrimental to the Mississippi River as a whole.

Improved habitat and increased flow diversity is critical to the Upper Mississippi River. The U.S. Army Corps of Engineers (USACOE) identified the need to conduct ecosystem restoration while improving navigation. Therefore, the USACOE initiated a series of planning efforts for three river reaches. As part of that effort, an interagency team was formed to evaluate restoration needs and opportunities, and identify intial monitoring needs for the portion of the Mississippi River between river mile 128 and 164 (the Harlow Reach). That team felt the intial focus of monitoring should be on the Harlow Island sub-area within the Harlow Reach. It was likely one of the first areas where detailed project planning would occur in the future.

Within the Harlow Island sub-area is the Harlow Island remnant side channel (HIRSC). This area is connected to the Mississippi River only during extreme high-water periods, so the fish community is replenished infrequently. Restoration of habitat connectivity that was fragmented by navigation system construction and floodplain development would provide habitat diversity that is required by riverine fishes to complete their life cycles. In addition, the general consensus of river fisheries biologists is that by restoring access opportunities for all species, native species will be better able to compete with nonnative species (Bade 1980).

Our objective was to compare the fish community at the HIRSC before and after restoration, while comparing community changes within a control site to factor out any system-wide changes.

Study Area

Two Middle Mississippi River backwater areas were selected for study. The HIRSC (River Mile [RM]142.7 – RM141.7) will undergo restoration to improve habitat conditions. The HIRSC is divided into two sections of approximately equal length connected by a narrow ditch (Figure 1). Water was present in the ditch throughout the sampling season, so we treated both sections as a single unit. A rock closing structure is still present near the lower end of the upstream section of the HIRSC. We did not measure average depth throughout this backwater, but depths were typically less than 1 m. In addition, there was approximately 1 m of soft, uncompacted sediment throughout the backwater. This backwater was unique in that it held sufficient water to support many fish throughout the drought conditions of 2005, while many other backwaters dried up.

The control backwater selected for study in 2005 was a borrow ditch in the Wilkinson Island backwater complex (RM95.0 – RM88.0). This backwater was used as a control site to assess possible systemic changes that may not be the result of habitat restoration at the HIRSC. We selected this backwater because its size and shape were similar to the HIRSC (Figure 2). Depths in this backwater ranged from over 1 m when sampling began to almost zero when it dried out. Unlike the HIRSC, this backwater contained only 20-30 cm of uncompacted soft sediment lining the bottom. Although a levee borrow ditch is not the same as a remnant side channel, this borrow ditch is connected to the river on a regular basis. Like many backwaters along the Middle Mississippi River, however, this borrow ditch dried up almost completely during the initial 2005 sampling season.

The Wilkinson Island control site did not hold water continually throughout 2005, so a different control site was selected in 2006. The second control site was located at the lower end of Tower Island Chute (RM 76.5; Figure 3). Tower Island Chute is a remnant side channel that was disconnected from the river by a levee. However, the lower end of the chute is riverward of the levee and is connected to the river during high water. This site was typically less than 1 m in depth, and contained some woody debris. Like the HIRSC, this site had approximately 1 m of soft, uncompacted sediments. Interviews with land owners indicated that this site held water year round, but by late summer of 2006, it had almost completely dried out.

Methods

The original design for this project was based on the Before-After Control-Impact (BACI) analysis described by Stewart-Oaten et al. (1986). This analysis allows the examination of the effects of large-scale, unreplicated experiments. A given parameter is measured at “impact” and “control” sites repeatedly through time. Changes at the impact site are tested for significance by comparing the differences between control and impact sites before and after the event, which in this case will be the restoration activities.

We started with the Wilkinson Island backwater as the control site in 2005, believing that it would be hydrologically similar to the HIRSC. The Wilkinson Island backwater was completely dry by the third sample. In 2006 we selected the lower end of the Tower Island Chute as an alternate control site. This control site also dried up just a few months into the sampling period. The HIRSC always retained enough water to support large numbers of fish, although it’s area was greatly reduced by late 2006. For 2007, an additional control backwater was not selected, and the BACI analysis is no longer an option. This is more fully addressed in the discussion.

We made 14 trips to the HIRSC between June 2005 and September 2007. The Wilkinson Island borrow ditch was sampled twice (June and August 2005) before it dried out. The Tower Island Chute was sampled four times between February and August 2006, when it dried out. Sampling gears used in each backwater included daytime AC electrofishing and mini-fyke nets. We used a 5000-W, 3-phase AC generator (Multi-Quip Model GDP 5000H) wired to a boat-mounted electrofishing system. We typically used 5-10 amps of AC power. Electrodes were three, 0.95-cm diameter x 1-m galvanized steel cables suspended from fiberglass booms mounted on each side of the bow. If the circuit breaker on the generator tripped repeatedly, the electrode wires were wrapped once around the boom and taped to reduce the surface area of the electrodes that contacted the water. One person dipped fish during each electrofishing run. Mini-fyke nets (frames 0.6 m high x 1.2 m wide, 0.6-m diameter hoops, 3-mm mesh, 4.5 m long x 0.6 m high lead) were also set.

We planned four units of effort per gear per trip in each backwater. Four 15-minute electrofishing runs would generally cover the entire area of each backwater when it was full. Potential net sites were spaced 100 m apart on the shoreline of each backwater and marked with a global positioning system. Net locations were randomly chosen each month from these potential sites.

Water quality parameters were measured during each sampling trip in the lower pool of the HIRSC. Water temperature (°C), dissolved oxygen (DO; mg/L), and pH were measured to the nearest 0.1. Whereas, specific conductance (µS/cm) and turbidity (NTU) were measured exactly as it read on the meter.

Figure 1.—Aerial photograph of the Harlow Island remnant side channel of the Middle Mississippi River. The site is outlined in red. Blue lines indicate the area where water typically backs up into the side channel. Photo credit: U.S. Army Corps of Engineers – St. Louis District.

Figure 2.―Aerial photograph of the Wilkinson Island borrow ditch on the Middle Mississippi River, the control site used in 2005. The site is outlined in red. Photo credit: Google Earth.

Catches were summarized for each backwater, and length-frequency distributions were prepared. We aged a small sample (N=11) of silver carp *Hypophthalmichthys molitrix* that were captured in the HIRSC in November 2006. Fish were aged by examining a cross-section of the leading pectoral fin ray cut with an Isomet low-speed saw. Species richness was calculated for the HIRSC and plotted against the river hydrograph for the study period. Although HIRSC did not dry up, the upper half of the HIRSC could only be electrofished during periods of high water (June-August 2005, April-June 2006, and May-July 2007), and some of these periods reduced our sampling effort. Therefore, species richness was corrected to account for variable effort. For each sampling trip, we used the number of species caught per net, plus the number of additional or new species captured per 15-min electrofishing sample.

Figure 3.―Aerial photograph of the lower end of Tower Island Chute on the Middle Mississippi River, the control site used in 2006. The site is outlined in red. Photo credit: Google Earth.

Results

Wilkinson Island

Water temperature was high at Wilkinson Island (Table 1). Dissolved oxygen was sufficient to support fish, but declined as the backwater began to dry out. A total of 7,437 fish representing 29 species and 14 taxonomic families were collected at Wilkinson Island (Table 2). Electrofishing accounted for only 8% (N=567) of the total catch there. Mini-fyke nets were responsible for the remaining catch (N=6,870), and most of these were small-bodied and young-of-year (YOY) fishes.

The Wilkinson Island backwater samples included 4,981 YOY *Hypophthalmichthys* spp. (20-70 mm total length), which was 67% of the total catch. A subsample of 1,152 fish was identified to species and all were silver carp. Other abundant species or genera included gizzard shad *Dorosoma cepedianum* (N=663), mosquitofish *Gambusia affinis* (N=355), orangespotted sunfish *Lepomis humilis* (N=207), freshwater drum *Aplodinotus grunniens* (N=199), and *Lepomis* spp. (N=772). Subsequent *Lepomis* spp. captures included bluegill *Lepomis macrochirus* (N=61), as well as green sunfish *L. cyanellus* and warmouth *L. gulosus* in low abundances.

Tower Island

Water temperatures at the Tower Island Chute reached 33.9^{o}C in June 2006, which was higher than any temperature recorded at the HIRSC (Table 1). However, all other temperature measurements at Tower Island were lower than those taken in the same month at HIRSC. Catches of all species except mosquitofish and shortnose gar *Lepisosteus platostomus* were low or non-existent during the June and August trip. Unlike Wilkinson Island, however, DO concentrations were high, averaging 12.6 mg/L, during all four trips combined. Mean pH (9.2) at the Tower Island Chute was somewhat higher than the other two backwaters. A total of 9,235 fish, representing 14 species, were captured in all samples at Tower Island Chute (Table 3). The most common species was mosquitofish, which constituted 94% (N=8,706) of the total sample. Other abundant species included orangespotted sunfish (N=460), and shortnose gar (N=33). No other species were represented by more than eight individuals in the composite Tower Island samples. Unlike the Wilkinson Island backwater, neither common carp *Cyprinus carpio* nor Asian carps were abundant in this backwater. Several silver carps were observed jumping during electrofishing surveys, but only one was captured. We did not capture large quantities of YOY or older silver carp as we did in the other backwaters. Some adults were captured, but they were few. When sampling began in this backwater in February 2006, we observed large numbers of large fish bones along the shoreline. We believe the lack of large fish in this backwater was the result of a fish kill at an unknown time. The elevation of this backwater was probably more similar to Harlow Island than Wilkinson Island because it had obviously not been inundated for some time before our February 2006 start date.

Harlow Island

Water quality measurements at the HIRSC were similar (except for higher pH at Tower Island) to the two control backwaters (Table 1). The average water temperature was high (22.9^{o}C) for all trips. Only two trips were taken during the winter months (November – February), so the average temperature for our samples is probably higher than the actual average temperature for this backwater. Dissolved oxygen concentrations were often high at the HIRSC, with the highest readings in February 2006 (15.5 mg/L). Turbidity measurements were lowest (76 NTU) shortly after the April 2007 flood.

Table 1.—Results of water quality measurements at the Harlow Island, Wilkinson Island, and Tower Island backwaters of the Middle Mississippi River during 2005-2007.

Backwater	Month-year	Turbidity (NTU)	Conductivity (µS/cm)	Temperature (^oC)	Dissolved Oxygen (mg/L)	pH
Harlow Island						
	Jun-05	238	482	33.3	9.0	7.7
	Aug-05		437	30.3	6.2	7.9
	Sep-05		390	30.4	7.2	8.2
	Oct-05		349	21.9	10.2	8.3
	Feb-06	118	306	8.1	15.5	
	Apr-06	308	337	21.1	10.7	8.6
	Jun-06	446	334	32.2	5.8	8.0
	Aug-06	793	309	30.4	12.2	9.2
	Oct-06	823	375	10.3	12.5	8.7
	Jan-07	346	440	8.0	7.7	
	Apr-07		530	17.8		
	May-07	76	486	25.3	5.6	8.7
	Jul-07	117	567	29.1	6.9	7.3
	Sep-07	390	426	22.6	7.6	8.3
	Mean	366	412	22.9	9.0	8.3
Wilkinson Island						
	Jun-05		404	35.5	8.5	8.0
	Aug-05	38	430	29.4	5.3	8.4
	Mean	38	417	32.5	6.9	8.2
Tower Island						
	Feb-06	123	237	7.0	14.4	9.5
	Apr-06	164	304	20.3	7.2	8.6
	Jun-06	650	246	33.9	14.0	9.1
	Aug-06		270	27.5	14.6	9.5
	Mean	312	264	22.2	12.6	9.2

Table 2. —Relative abundance of fishes in the Wilkinson Island borrow ditch of the Middle Mississippi River during 2005.

Family	Common Name, Scientific Name	Number captured		
		June	August	Total
Amiidae				
	Bowfin *Amia calva*		3	3
Atherinidae				
	Brook silverside *Labidesthes sicculus*	1	6	7
Catostomidae				
	Bigmouth buffalo *Ictiobus cyprinellus*	1		1
	Quillback *Carpiodes cyprinus*	5		5
	River carpsucker *Carpiodes carpio*	1	1	2
	Shorthead redhorse *Moxostoma macrolepidotum*		1	1
	Ictiobus spp.	6		6
Centrarchidae				
	Black crappie *Pomoxis nigromaculatus*	1	3	4
	Bluegill *Lepomis macrochirus*	1	60	61
	Green sunfish *Lepomis cyanellus*	3	3	6
	Largemouth bass *Micropterus salmoides*	4	3	7
	Orangespotted sunfish *Lepomis humilis*	12	195	207
	Warmouth *Lepomis gulosus*	1	1	2
	White crappie *Pomoxis annularis*	2	4	6
	Lepomis spp.	772		772
	Pomoxis spp.	9		9
Clupeidae				
	Gizzard shad *Dorosoma cepedianum*	518	145	663
	Skipjack herring *Alosa chrysochloris*	1		1
Cyprinodontidae				
	Blackstripe topminnow *Fundulus notatus*	2	3	5
Cyprinidae		5		5
	Common carp *Cyprinus carpio*	11	4	15
	Emerald shiner *Notropis atherinoides*	1	1	2
	Grass carp *Ctenopharyngodon idella*	7	47	54
	River shiner Notropis blennius		8	8
	Silverband shiner *Notropis shumardi*		2	2
	Silver carp *Hypophthalmichthys molitrix*		1,152	1,152
	Hypophthalmicths spp.	3,829		3,829
Ictaluridae				
	Channel catfish *Ictalurus punctatus*		3	3
Hiodontidae				
	Goldeye *Hiodon alosoides*		2	2
Lepisosteidae				
	Longnose gar *Lepisosteus osseus*	1	1	2
Percichthyidae				
	White bass *Morone chrysops*		36	36
Percidae				
	Sauger *Sander canadensis*	3	1	4
Poecilliidae				
	Mosquitofish *Gambusia affinis*	156	199	355
Sciaenidae				
	Freshwater drum *Aplodinotus grunniens*	70	129	199
Total		5,423	2,013	7,436

Table 3. ―Relative abundance of fishes in the lower end of Tower Island Chute of the Middle Mississippi River during 2006.

		Number captured				
Family	Common Name, Scientific Name	Feb	Apr	Jun	Aug	Total
Amiidae						
	Bowfin *Amia calva*		4	3		7
Atherinidae						
	Inland silversides *Menidia beryllina*	1	1			2
Catostomidae						
	Bigmouth buffalo *Ictiobus cyprinellus*	1	1	1		3
Centrarchidae						
	Bluegill *Lepomis macrochirus*	2				2
	Green sunfish *Lepomis cyanellus*	1	1			2
	Orangespotted sunfish *Lepomis humilis*	370	131		2	503
	Warmouth *Lepomis gulosus*	1				1
	White crappie *Pomoxis annularis*	2	3			5
Cyprinidae						
	Common carp *Cyprinus carpio*	1	7			8
	Red shiner *Cyprinella lutrensis*	1				1
	Silver carp *Hypophthalmichthys molitrix*		1			1
Lepisosteidae						
	Shortnose gar *Lepisosteus platostomus*		6	16	11	33
	Spotted gar *Lepisosteus oculatus*		4			4
Poecilliidae						
	Mosquitofish *Gambusia affinis*	8,021	103	45	537	8,706
Total		8,401	262	65	550	9,278

We captured 18,437 fish representing 36 species between June 2005 and September 2007. Electrofishing accounted for only 7.7% (N=1,410) of the total catch, while mini-fyke nets captured 92.3% (N=17,023) of the total (Table 4). Mosquitofish were the dominant small-bodied species at the HIRSC. Mosquitofish constituted for 76% (N=14,079) of the total catch, and most (11,497) of these were captured during October 2006. The next most abundant species were gizzard shad (N=1,108), silver carp (N=381), orangespotted sunfish (N=328), bluegill (N=145), and common carp (N=133).

Fish captures by trip were relatively consistent through 2005 (Table 5). Totals ranged from 492 fish (12 species) in October 2005 to 979 fish (15 species) in September 2005. Catches from February 2006 through April 2007 were lower, ranging from 60 fish (5 species; no electrofishing) in August 2006 to 167 fish (9 species) in April 2007. The only exception during this period was during October 2006 when we captured 11,497 mosquitofish and one longnose gar *Lepisosteus osseus*.

The HIRSC was flooded just after the April 2007 sample. Catches in the post-flood samples (May – September 2007) were dominated by *Dorosoma* spp. (N=1,626), the subfamily Ictiobinae (buffalos and carpsuckers; N=979), and mosquitofish (N=441). Many YOY *Dorosoma* spp. and Ictiobinae captured during this time were not identified to species. In all, we captured 11 species after the flood that were not captured before the flood (Tables 4-5), including the ozark minnow *Notropis nubilus* and central stoneroller *Campostoma anomalum*. Bowfin *Amia calva*, paddlefish *Polyodon spathula*, and all of the ictalurid species were only captured before the flood.

Length-frequency distributions were prepared for several of the most abundant species captured at the HIRSC. Most of these species showed an increase in the numbers of young fish after the flood of April 2007. Common carp size structure before and after the flood did not visibly change (Figure 4). However, many common carp observed before the flood were thin and believed to be in generally poor condition. Although bluegill size structure did not change greatly, the number of young fish substantially increased (Figure 5). Most of the post-flood catch was of shad YOY that were not identified to species and the abundance of those fish was substantially greater before the flood. Most of the fish, representing the subfamily Ictiobinae, collected after the flood were YOY, so they could not be identified to species (Figure 7).

Perhaps the most interesting information collected on any species in the HIRSC was that for silver carp. Similar to other species, their size distribution shifted toward smaller fish after the flood (Figure 8). However, the most remarkable thing was their abundance and slow growth. Although they were not the most abundant fish in the sample, anecdotal information suggests that they were the most abundant large fish in the backwater. On our first trip in June 2005, we drove the boat back and forth in the lower section of the backwater for about 20 min. During that time more than 80 silver carp that had jumped into the boat. We observed large numbers of bones from fish (we believe many were silver carp) that died after the upper section dried out in 2006. However, we still captured more than 125 silver carp in our next two samples (January and April 2007) before the flood.

The silver carp collected at the HIRSC in 2005 averaged 345 mm in total length, and that mean length changed little during the subsequent two years (Figure 9). Age assessment of 10 silver carp captured in late November 2006 indicated that they were from the 2000 year class.

Species richness (i.e., number of species represented) at the HIRSC also produced interesting results. When species richness for each trip (except for August and October 2006, when electrofishing could not be completed due to the low water level) was plotted against the Chester, Illinois daily gauge data for the Mississippi River, we observed an increase from 13 species in April 2007 to 22 species in May 2007 immediately after the flood. A decline in the number of species was observed for subsequent samples. However, when separated by gear and adjusted for effort, species richness does not show the same magnitude of change.

We plotted the species-per-unit-effort (SPUE) separately for each gear. The electrofishing SPUE did not show any obvious pattern, but the netting SPUE appeared to follow a pattern similar to the hydrograph (Figure 10). This was probably due to increased depth (>0.2 m) at Harlow Island in response to rain events, which allowed us to set our nets in deeper water where they were more efficient than when they were set at depths of only a few centimeters. We also plotted the SPUE for both gears combined and corrected for unique species, and did not observe any discernable pattern or increase in relation to the flood (Figure 11). Regardless of whether species richness is adjusted for effort or not, the overall sample produced 26 species before the flood and 31 species after the flood.

Table 4.—Relative abundance of fishes in electrofishing (EF) and mini-fyke netting (MF) collections at the Harlow Island remnant side channel of the Middle Mississippi River, 2005-2007.

Family	Common Name, Scientific Name	Number Captured: Pre-Flood EF	Pre-Flood MF	Pre-Flood Totals	Post-Flood EF	Post-Flood MF	Post-Flood Totals	Total
Amiidae								
	Bowfin *Amia calva* [a]	4	3	7				7
Catostomidae								
	Bigmouth buffalo *Ictiobus cyprinellus*	74	10	84	8		8	92
	Black buffalo *Ictiobus niger*	1		1	7		7	8
	Quillback *Carpiodes cyprinus* [a]	1		1				
	River carpsucker *Carpoides carpio* [b]				20		20	20
	Smallmouth buffalo *Ictiobus bubalus*	26		26	6		6	32
	Ictiobinae					932	932	932
	Ictiobus spp.					6	6	6
Centrarchidae								
	Black crappie *Pomoxis nigromaculatus*	8	3	11	2		2	13
	Bluegill *Lepomis macrochirus*	6	15	21	5	119	124	145
	Green sunfish *Lepomis cyanellus*	13		13	1	35	36	49
	Largemouth bass *Micropterus salmoides*	1	1	2	1		1	3
	Longear sunfish *Lepomis megalotis* [b]				1		1	1
	Orangespotted sunfish *Lepomis humilis*	19	179	198	4	126	130	328
	Warmouth *Lepomis gulosus*	2		2		11	11	13
	White crappie *Pomoxis annularis*	10	13	23	2	6	8	31
	Lepomis spp.		1	1				1
	Pomoxis spp.		1	1				1
Clupeidae								
	Gizzard shad *Dorosoma cepedianum*	69	201	270	440	398	838	1108
	Dorosoma spp.					788	788	788
Cyprinidae								
	Bighead carp *Hypophthalmichthys nobilis*	14		14	1	3	4	18
	Central stoneroller *Campostoma anomalum* [b]					1	1	1
	Common carp *Cyprinus carpio*	96	5	101	26	6	32	133
	Emerald shiner *Notropis atherinoides*					3	3	3
	Grass carp *Ctenopharyngodon idella* [a]	6		6				6
	Ozark minnow *Notropis nubilus* [b]					1	1	1
	Sand shiner *Notropis stramineus* [b]				1		1	1
	Silver carp *Hypophthalmichthys molitrix*	351	2	353	24	4	28	381
	Hypophthalmichthys spp.					11	11	11
Hiodontidae								
	Goldeye *Hiodon alosoides* [b]				4	1	5	5
	Mooneye *Hiodon tergisus* [b]					1	1	1
Ictaluridae								
	Channel catfish *Ictalurus punctatus* [a]	19		19				19
	Flathead catfish *Pylodictis olivaris* [a]	2		2				2
	Yellow bullhead *Ameiurus natalis* [a]		1	1				

[a] Indicates species that was only captured prior to the flood of April 2007.
[b] Indicates species that was only captured after the flood of April 2007.

Table 4 continued.―Relative abundance of fishes in electrofishing (EF) and mini-fyke netting (MF) collections at the Harlow Island remnant side channel of the Middle Mississippi River, 2005-2007.

		Number Captured						
		Pre-Flood			Post-Flood			
Family	Common Name, Scientific Name	EF	MF	Total	EF	MF	Total	Total
Lepisosteidae								
	Longnose gar *Lepisosteus osseus*	5	6	11	1		1	12
	Shortnose gar *Lepisosteus platostomus*	15	46	61	9	11	20	81
	Spotted gar *Lepisosteus oculatus*		2	2		1	1	3
Percichthyidae								
	White bass *Morone chrysops* [b]				1		1	1
Percidae								
	Logperch *Percina caprodes* [b]					1	1	1
	River darter *Percina shumardi* [b]					1	1	1
	Sauger *Sander canadensis* [b]				20	6	26	26
Poecilliidae								
	Mosquitofish *Gambusia affinis*	11	13,627	13,638	7	434	441	14,079
Polyodontidae								
	Paddlefish *Polyodon spathula* [a]	1		1				
Sciaenidae								
	Freshwater drum *Aplodinotus grunniens*	48		48	21	1	22	70
Total		802	14,116	14,918	612	2,907	3,519	18,437

[a] Indicates species that was only captured prior to the flood of April 2007.
[b] Indicates species that was only captured after the flood of April 2007.

Table 5.—Relative abundance of fishes collected during each trip to the Harlow Island remnant side channel in 2005-2007.

Family	Common Name, Scientific Name	2005 Jun	2005 Aug	2005 Sep	2005 Oct	2006 Feb	2006 Apr	2006 Jun	2006 Aug	2006 Oct	2007 Jan	2007 Apr	2007 May	2007 Jul	2007 Sep	Total
		Number captured														
Amiidae																
	Bowfin *Amia calva* [a]						2	1	1		1	2				7
Catostomidae																
	Bigmouth buffalo *Ictiobus cyprinellus*	3	8	5	5	14	8	11			21	9	8			92
	Black buffalo *Ictiobus niger*											1		3	4	8
	Quillback *Carpiodes cyprinus* [a]					1										1
	River carpsucker *Carpoides carpio* [b]												1	17	2	20
	Smallmouth buffalo *Ictiobus bubalus*	3	4	1	3	2	6	2			1	4	1		5	32
	Ictiobinae												932			932
	Ictiobus spp.												6			6
Centrarchidae																
	Black crappie *Pomoxis nigromaculatus*	1				5	3	2						2		13
	Bluegill *Lepomis macrochirus*	18	2	1										34	90	145
	Green sunfish *Lepomis cyanellus*		13										1	1	34	49
	Largemouth bass *Micropterus salmoides*			1		1								1		3
	Longear sunfish *Lepomis megalotis* [b]													1		1
	Orangespotted sunfish *Lepomis humilis*	4	34	115	5	30	5	3	2				1	12	117	328
	Warmouth *Lepomis gulosus*					2								3	8	13
	White crappie *Pomoxis annularis*	3	6	3	1	8		1			1		6		2	31
	Lepomis spp.	1														1
	Pomoxis spp.	1														1
Clupeidae																
	Gizzard shad *Dorosoma cepedianum*	221	8	10	4	2	3	22					31	458	349	1,108
	Dorosoma spp.												788			788
Cyprinidae																
	Bighead carp *Hypophthalmichthys nobilis*	2			1	3					4	4	1		3	18
	Central Stoneroller *Campostoma anomalum* [b]												1			1
	Common carp *Cyprinus carpio*	2	7	7	3	17	15	11			25	14	8	13	11	133
	Emerald shiner *Notropis atherinoides*												3			3
	Grass carp *Ctenopharyngodon idella*					2	3					1				6
	Ozark Minnow *Notropis nubilus* [b]												1			1
	Sand shiner *Notropis stramineus* [b]														1	1
	Silver carp *Hypophthalmichthys molitrix*	53	26	27	46	2	58	12			63	66	6	18	4	381
	Hypophthalmichthys spp.												11			11
Hiodontidae																
	Goldeye *Hiodon alosoides* [b]												2	3		5
	Mooneye *Hiodon tergisus* [b]													1		1

[a] Indicates species that was only captured prior to the flood of April 2007.
[b] Indicates species that was only captured after the flood of April 2007.

Table 5 continued.—Relative abundance of fishes collected during each trip to the Harlow Island remnant side channel in 2005-2007.

		Number captured															Total
		2005				2006					2007						
Family	Common Name, Scientific Name	Jun	Aug	Sep	Oct	Feb	Apr	Jun	Aug	Oct	Jan	Apr	May	Jul	Sep		
Ictaluridae																	
	Channel catfish *Ictalurus punctatus* [a]		2	1	5	7	3					1					19
	Flathead catfish *Pylodictis olivaris* [a]				1							1					2
	Yellow bullhead *Ameiurus natalis* [a]			1													1
Lepisosteidae																	
	Longnose gar *Lepisosteus osseus*	2	1	1			1		3	1		2			1		12
	Shortnose gar *Lepisosteus platostomus*	11	7	6		1	6	2	3		8	17	9	9	2		81
	Spotted gar *Lepisosteus oculatus*		2										1				3
Percichthyidae																	
	White bass *Morone chrysops* [b]												1				1
Percidae																	
	Logperch *Percina caprodes* [b]												1				1
	River Darter *Percina shumardi* [b]												1				1
	Sauger *Sander canadensis* [b]												6	20			26
Poecilliidae																	
	Mosquitofish *Gambusia affinis*	290	500	799	414	7	7	15	51	11,497	43	15	10	95	336		14,079
Polyodontidae																	
	Paddlefish *Polyodon spathula* [a]							1									1
Sciaenidae																	
	Freshwater drum *Aplodinotus grunniens*	12	15	1	4	9	4	3					4	8	10		70
Total		627	635	979	492	113	124	86	60	11,498	167	137	1,841	699	979		18,437

[a] Indicates species that was only captured prior to the flood of April 2007.
[b] Indicates species that was only captured after the flood of April 2007.

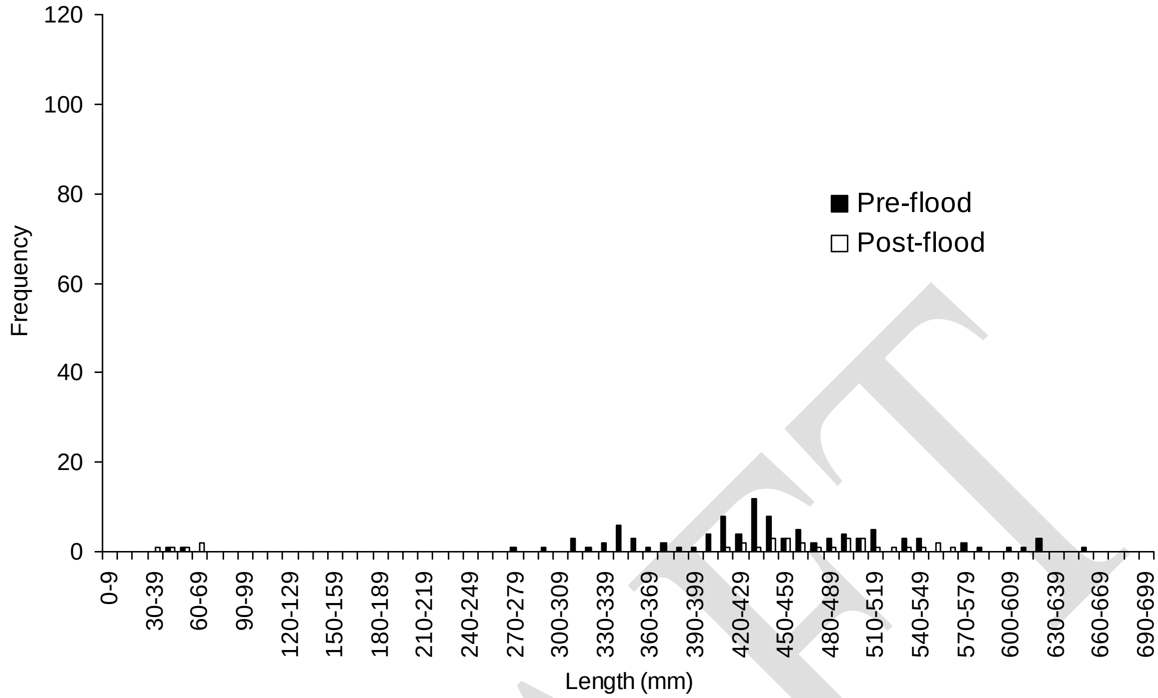

Figure 4.―Length-frequency distribution for common carp *Cyprinus carpio* captured at Harlow Island before (N=100) and after (N=32) the flood of April 2007.

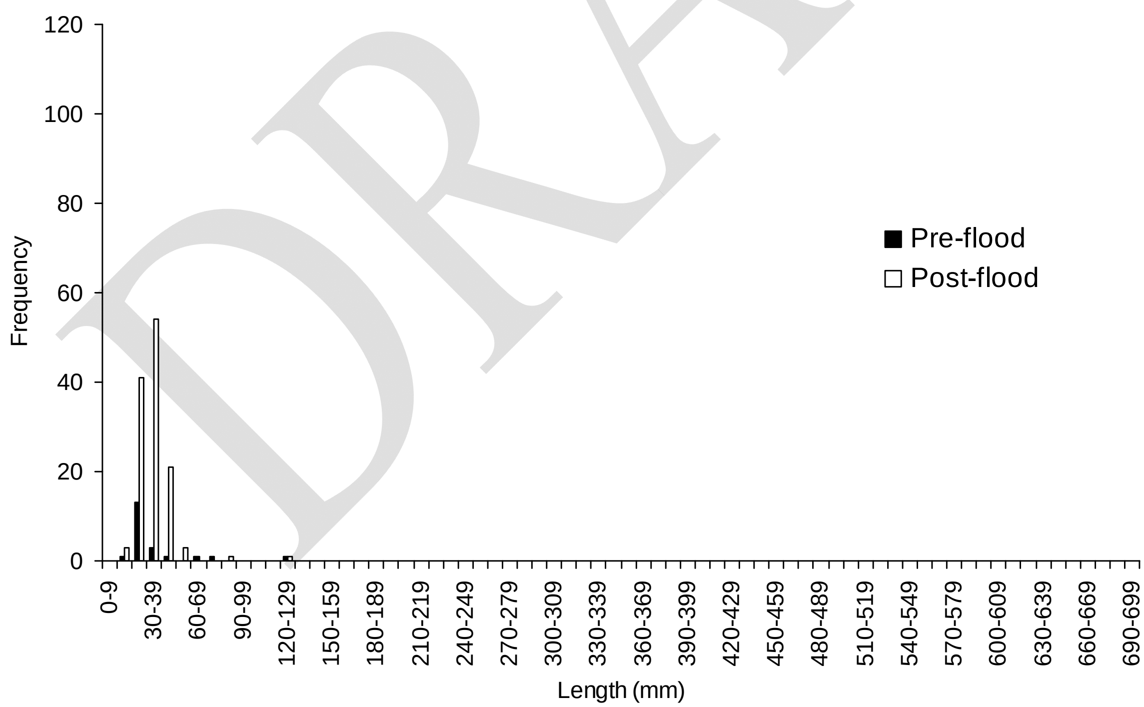

Figure 5.―Length-frequency distribution for bluegill *Lepomis macrochirus* captured at Harlow Island before (N=21) and after (N=124) the flood of April 2007.

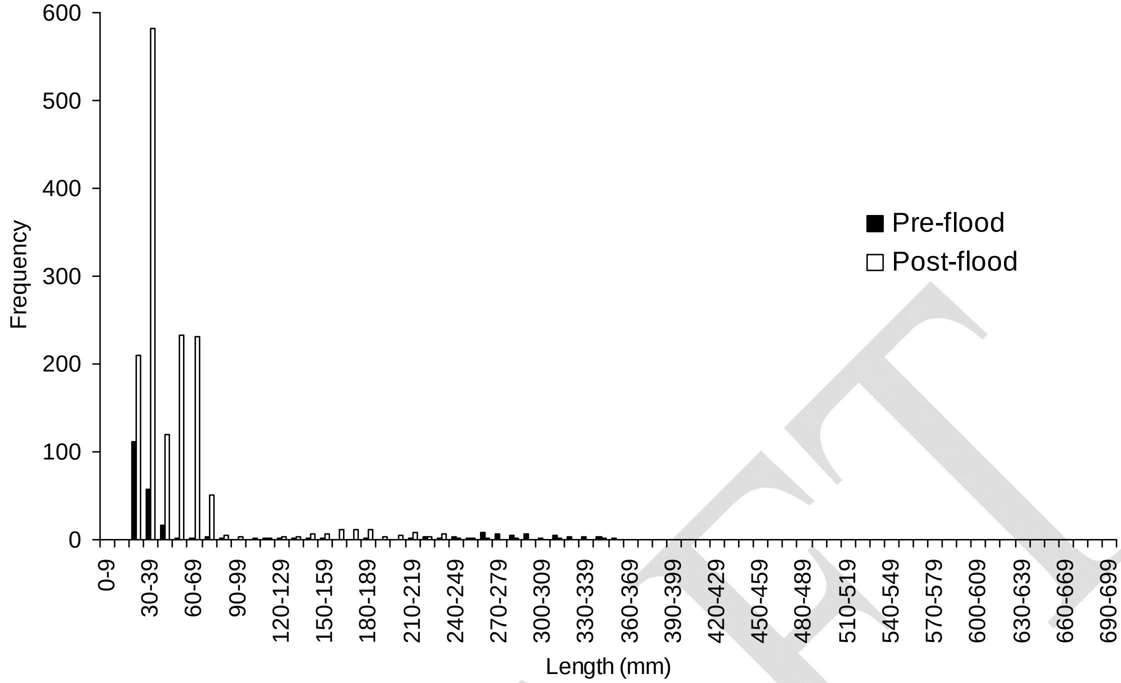

Figure 6.―Length-frequency distribution for *Dorosoma* spp. captured at Harlow Island before (N=261) and after (N=1,527) the flood of April 2007.

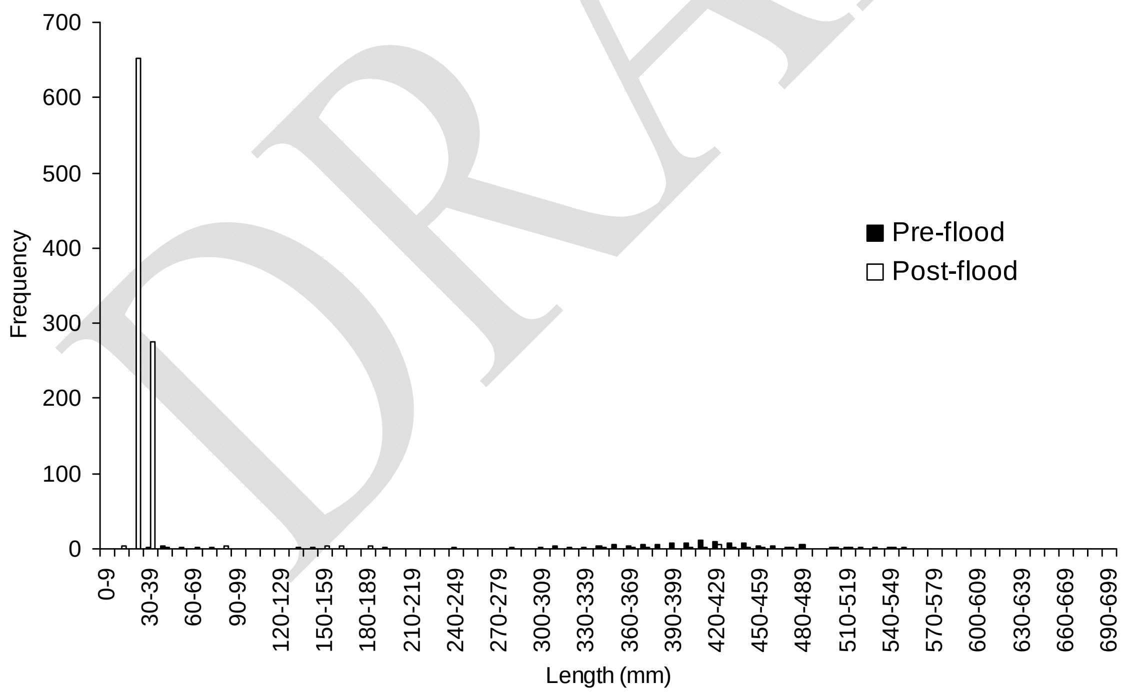

Figure 7.―Length-frequency distribution for subfamily Ictiobinae captured at Harlow Island before (N=112) and after (N=973) the flood of April 2007.

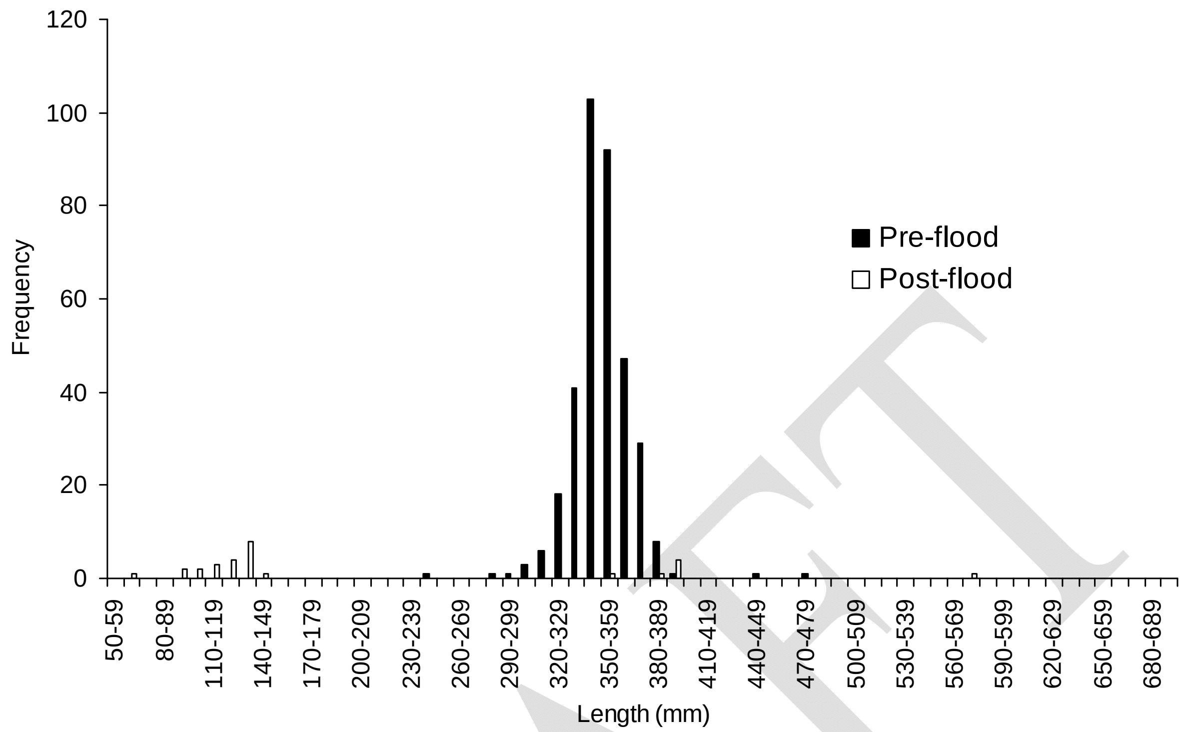

Figure 8.—Length-frequency distribution for silver carp *Hypophthalmichthys molitrix* captured at Harlow Island before (N=353) and after (N=28) the flood of April 2007.

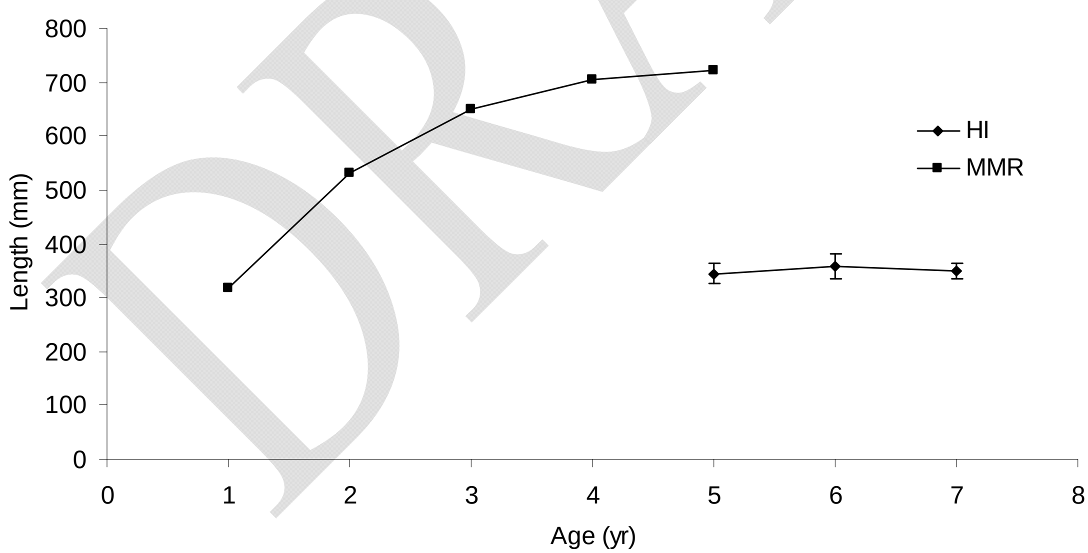

Figure 9.—Length-at-age data for silver carp *Hypophthalmichthys molitrix* captured at Harlow Island (HI) along with back-calculated length-at-age data for silver carp from the Middle Mississippi River (MMR; Williamson and Garvey 2005). Both data sets are for fish from the 2000 year class. Error bars for the HI data are +/-1 standard deviation.

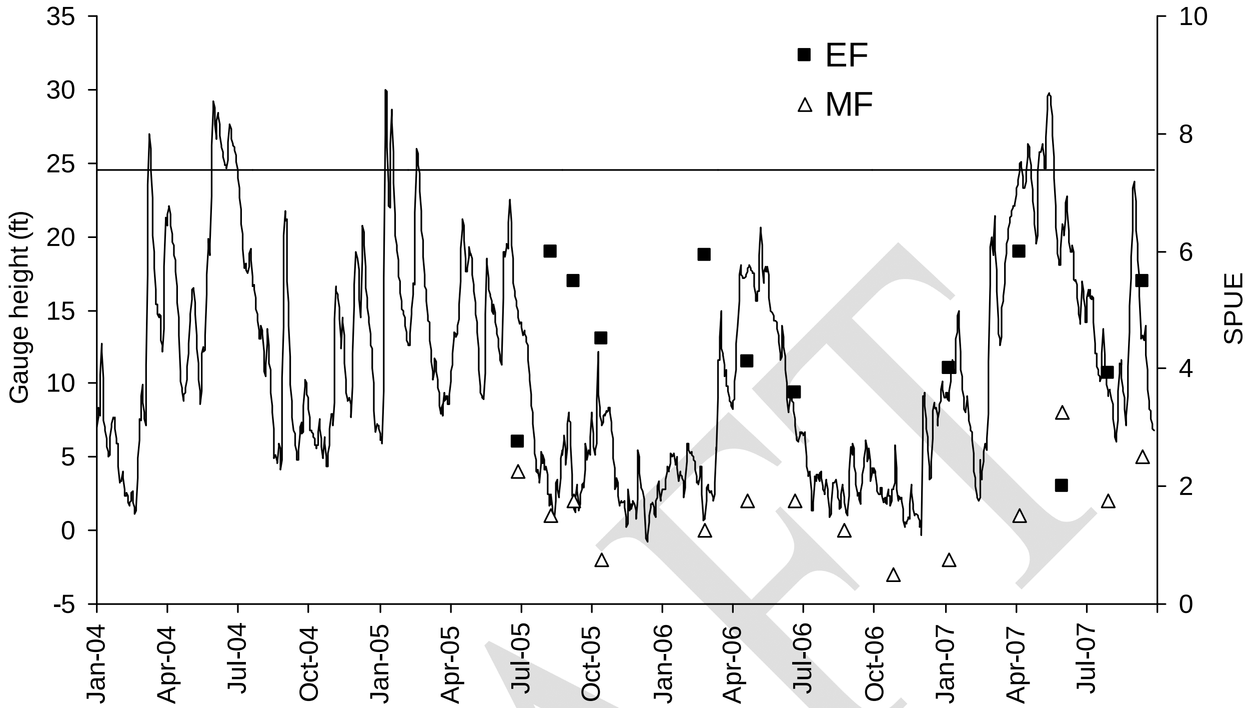

Figure 10.―Species-per-unit-effort (SPUE) for samples taken with electrofishing (EF) and mini-fyke netting (MF) at Harlow Island in 2005-2007, and daily gauge height (ft) at the U.S. Army Corps of Engineers gauging station on the Mississippi River at Chester, Illinois during 2004-2007. The solid horizontal line indicates the approximate gauge height (24.5 ft) at which the Harlow Island remnant side channel is connected to the river.

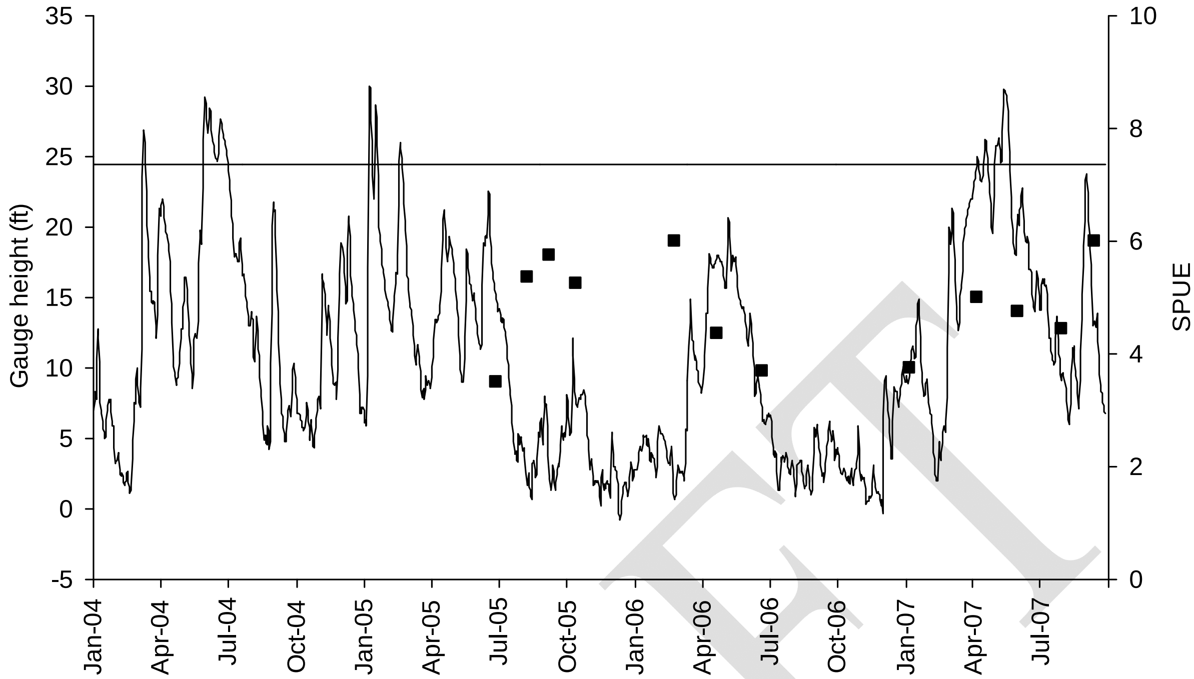

Figure 11.—Combined species-per-unit-effort (SPUE) corrected for unique species captured by electrofishing for samples taken at Harlow Island in 2005-2007, and daily gauge height (ft) at the U.S. Army Corps of Engineers gauging station on the Mississippi River at Chester, Illinois during 2004-2007. The solid horizontal line indicates the approximate gauge height (24.5 ft) at which the Harlow Island remnant side channel is connected to the river.

Discussion

Periodic flooding and drying is a natural occurrence in floodplain ecosystems (Bayley 1995). This would have to be taken into account in any study of floodplain backwaters. Ideally, we would have used multiple control sites for this study, but that was not financially feasible from the beginning. If our design included several control sites and one or more retained water during the study, then we might have been able to draw additional conclusions. Underwood (1994) stated that multiple control sites in a BACI design allows the use of averages for those control sites rather than relying on data for only one. This helps to prevent normal or random ecological variation at one site but not the other from being characterized as a change attributable to the impact. We also anticipated multiple flood events at the HIRSC, but there was only one. Although we ended the pre-project monitoring without a control site, we learned a considerable amount about the fish community at the HIRSC during an extended low-water period, and during and following the single flood event. After the flood species richness increased slightly, species composition changed, and relative abundance of YOY increased substantially for some species.

More frequent flooding and higher quality habitat would probably create a healthier backwater at the HIRSC. The Wilkinson Island borrow ditch was inundated by the river (possibly several times) during the spring of 2005. We believe that this backwater is flooded more frequently and at a lower river stage than the HIRSC. Most of the species we captured at Wilkinson Island were those that are present throughout the river system (e.g., gars, catfishes, and freshwater drum) or species common to floodplain lakes such as crappies and sunfishes (Miranda 2005). However, we also captured species at Wilkinson Island that we only captured at the HIRSC after the flood in April 2007. These species included the emerald shiner *Notropis atherinoides*, goldeye *Hiodon alosoides*, and sauger *Sander canadensis*.

Flood pulses are the driving force for river-floodplain systems (Junk et al. 1989). Periodic floods enhance productivity and maintain diversity in river systems (Bayley 1995). Influxes of YOY of many species into backwaters during floods show that the backwaters are important in the life cycle of riverine fishes. Junk et al. (1989) stated that the timing and duration of floods is critical to species that gain access to the floodplain for feeding and spawning. Spawning by many species takes place at the beginning of, or during, a flood, resulting in timely colonization of the floodplain for feeding or shelter. We documented backwater use by relatively large numbers of YOY Ictiobinae and *Dorosoma* spp. at the HIRSC, and large numbers of YOY *Hypophthalmichthys* spp. (a nonnative species) at Wilkinson Island. Junk et al. (1989) also stated that recruitment is usually poor when the flood recedes too soon during the warm growing season. When this occurs, many fish are stranded in the floodplain, and may die when conditions become unfavorable, as we witnessed at all three of our backwater study sites. An increase in the frequency and duration of floods at the HIRSC would probably lead to this backwater providing a greater benefit to native species.

Improvements in the physical habitat at the HIRSC are also needed. Removal or compaction of the soft sediments will improve fish habitat. Studies have demonstrated that periodic drawdowns and dewatering of lakes can improve the condition of the littoral substrate, aquatic vegetation, macroinvertebrate production, and overall fish community (Wegner and Williams 1974: Moyer et al. 1995). Periodic drying of the HIRSC will probably continue to occur naturally, but compaction or removal of the sediments will also help to increase depth and habitat diversity. Additional flow through this remnant side channel during floods would also help to periodically scour soft sediments that may accumulate.

Increased depth in the HIRSC may also lead to lower average temperature. The temperature averaged 22.9^{o}C, but temperatures as high as 33.3^{o}C were recorded. High average temperatures may give non native species a competitive edge. Silver carp tolerate a wide range of temperatures (16-40 ^{o}C; Kolar et al. 2007). Lower temperatures may make this backwater habitable by a wider range of species than we captured during the pre-flood period. The dissolved oxygen levels were also relatively high at the HIRSC, so high primary production is occurring there. This may be the reason that this backwater was capable of supporting such large numbers of silver carp and other fish. The silver carp we captured survived from a year class that Garvey et al. (2007) documented as a dominant year class in the Mississippi River, so their great abundance in the HIRSC is not astonishing. However, they were grossly undersized (Williamson and Garvey 2005), and anecdotal evidence suggests that some of the native species at the HIRSC also suffered from below-average growth rates. We did not weigh fish, but many including bigmouth buffalo *Ictiobus cyprinellus* and common carp appeared to be in poor condition. The conditions we saw at Harlow Island may not be conducive to fish growth in crowded conditions, but they were certainly capable of supporting large numbers of fish.

We believe that restoration of the HIRSC should ensure that this backwater is deep enough to hold water, except during a severe drought. HIRSC should flood with greater regularity, and it should contain high-quality habitat for a range of native fishes. At this point, we probably should plan for the presence of non native fish species because we will not be able to create a habitat that will exclude invasive carps while allowing access by native species. However, we can provide habitat that will potentially have greater benefit to native species already present.

Finally, even though we believe that more frequent flooding would help improve conditions at the HIRSC, the fact is that *it does* flood more frequently. The problems we faced during this project were exacerbated by the fact that we were sampling the HIRSC during the longest, flood-free period in the last 10 years (Figure 12). Based on the hydrograph for the Mississippi River at Chester, Illinois, we do not believe that the Harlow Island side channel was inundated between late February 2005 and early April 2007, a period of more than two years. Even if we conduct post-project monitoring, it is improbable that we would have water conditions similar to pre-project monitoring. Because environmental conditions may be so different during post-project monitoring, we may not be able to attribute any population and fish community changes to the restoration. We could, however, characterize post-project fish population and community structure, and relate them to other "healthy" backwaters in the system.

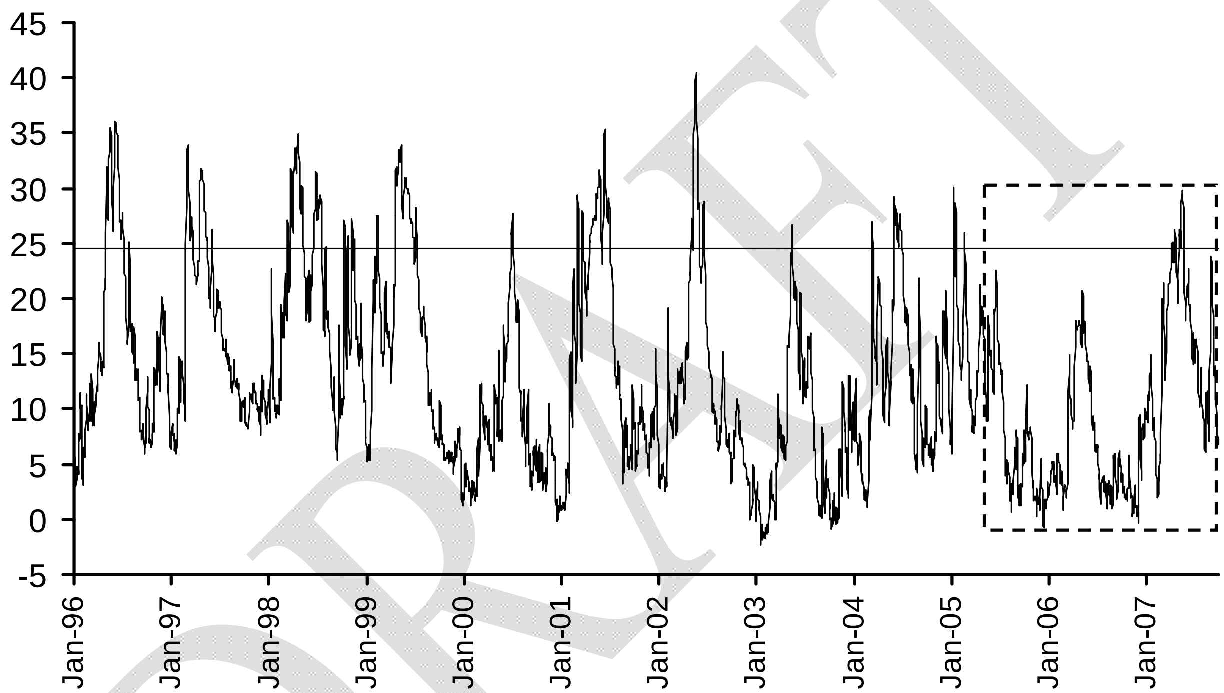

Figure 12.—Daily gauge height (ft) at the U.S. Army Corps of Engineers gauging station on the Mississippi River at Chester, Illinois during 1996-2007. The dashed box indicates the approximate time period in which pre-project samples were taken at Harlow Island in 2005-2007. The solid horizontal line indicates the approximate gauge height (24.5 ft) at which the Harlow Island remnant side channel is connected to the river.

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