MELVIN PRICE LOCKS AND DAM

UPPER MISSISSIPPI RIVER BASIN
MISSISSIPPI RIVER MISSOURI AND ILLINOIS

PROGRESS REPORT 2000

DESIGN MEMORANDUM NO. 24
AVOID AND MINIMIZE MEASURES

US Army Corps of Engineers
St. Louis District

"Good engineering enhances the environment"

JUNE 2001

Cover photo

Shovelnose sturgeon collected during biological monitoring at Dike 53.0L. Physical and biological sampling is being conducted at this site to assess changes at the site caused by changing the configuration of the dike into a weir. As constructed, the dike extended into the navigation channel and was considered a navigation hazard. Through coordination with regional resource agencies, an agreement was made to lower the last 300 ft. of the dike to –15 ft. (create a weir) while leaving the rest of the dike intact. Pre-modification bathymetry, velocity, hydroacoustic fisheries data, and fish sampling were completed at the site on January 20, 2000. Fish sampling was conducted in cooperation with the Missouri Department of Conservation, Cape Girardeau LTRMP field station. One hundred and twenty six fish were collected. The collection was dominated by shovelnose sturgeon but also included paddlefish, blue catfish, sauger, and goldeye. The results of this work are in Appendix H. Post-modification monitoring at this site is scheduled for 2001.

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2000 PROGRESS REPORT

MELVIN PRICE LOCKS AND DAM
MISSISSIPPI RIVER - MISSOURI AND ILLINOIS

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Avoid and Minimize
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Executive Summary

The St. Louis District agreed to establish an Avoid and Minimize Program (A&M) in 1992 to reduce possible environmental impacts of increased navigation traffic due to construction of a second lock at Melvin Price Locks and Dam. Full scale implementation of the program began in 1996. Expenditures in the program total roughly $1 million a year. Direction of the program is coordinated through the A&M team, which consists of state, federal and private partners in both natural resources and industry. Each year, a progress report detailing A&M activities during the past year is released.

Construction efforts in 2000 were focused on Pool 24. In 1993 the A&M program constructed three chevron dikes at river mile 289. The original design called for the placement of five chevron dikes at the site. In 2000 the A&M Program issued a contract for the construction of the final two chevrons. Due to abnormally lower water levels in 2000 the new chevrons could not be constructed. Further on site inspection has resulted in the determination that, due to flow and depth limitations, only 1 chevron dike can be constructed. Plans now call for that structure to be completed in 2001.

Biological monitoring work continued on the chevron dike fields in Pools 24 and 25. Those results are showing that fish are using the structures as over-wintering and nursery habitat. Five new species were documented in association with the Pool 25 multiple roundpoint structures (MRS) in 2000. Prior years collections have included the blue sucker, an uncommon species in the Mississippi River. A study detailing fish use of off-bankline revetment found that it was providing valuable backwater habitat. Forty-seven species of fish have been collected in association with off-bankline revetment in Pool 24.

Work to assess and improve fish passage at Lock and Dam 25 continued in 2000. Results from 1999 showed that fish movement through the dam gates occurs almost exculsively during open river conditions. Monitoring efforts in 2000 focused on creating hydraulic conditions to extend or create open river conditions outside of the natural period of open river. Gate manipulation work during the summer found that extending the period of open river is possible, but that velocities increased in gate bay 17. Fish movement data was inconclusive. Changes in gate operations did not appear to affect tow traffic.

Pre-construction survey and fish sampling of a dike modification site in the middle river (river mile 53.0) was completed. The dike, which extended into the navigation channel, was modified by lowering the last 300 ft. of the dike to -15 ft. below the water (creating a weir). Prior to construction the site was considered an excellent over-wintering location for fishes. Fish sampling resulted in the collection of 126 fish behind the dike. The collection was dominated by shovelnose sturgeon but also included paddlefish, blue catfish, sauger, and goldeye. Post-modification monitoring at this site is scheduled for 2001.

Two reports on the monitoring of effects of Environmental Pool Management (EPM) in Pool 25 were completed in 2000. It should be pointed out that both studies took place during what would be considered extreme years for EPM and water regulation.

The report on waterfowl food production found that a number of species of plants, including smartweed and chufa, responded to the drawdowns and that seed production was higher than those documented at other intensively managed moist soil impoundments. Conversion of seed biomass to potential waterfowl use days revealed an abundance of available forage. Avian use surveys found waterfowl spent the majority of time foraging in the shallow water areas where vegetation was produced by EPM. The occurrence of young trees in EPM created vegetation was also documented. The report concluded that varying the EPM regime could provide the greatest long term benefits to plant and invertebrate production, but that more research is needed.

The report on fish use of vegetation produced by EPM found that fish numbers were not higher in vegetated areas than in non-vegetated areas, though those findings were susceptible to the high variability associated with a low number of samples and sites. Low dissolved oxygen rates were noted at three of the four vegetated sites. The importance of the edge habitat between the vegetated and non-vegetated areas was documented. The stranding of fishes was noted at several locations. Stranding and low dissolved oxygen rates were likely a function of summer pool water levels, which were low for an unusually long period, and outside the normal guidelines for EPM. Early spring sampling found that the residual vegetation produced by EPM was used by over 27 species of fish, with most larval or juvenile fish. Additional work is needed to help establish what impact varying the EPM regime from year to year has on fish.

2000 was the fifth year of the Middle Mississippi River pallid sturgeon habitat use study. Based on the tracking work, pallid sturgeon continue to show a positive selection for areas in the main channel border, downstream of island tips, between wing dams, and the tips of wing dams. Pallid sturgeon show a negative selection of areas in the main channel, downstream of wing dams and upstream of wing dams. Pallid sturgeon show no selection, negative or positive, for bendway weirs. Based on these results, future St. Louis District projects in the open river will give consideration to the creation or protection of these types of habitats and the importance they may play in the recovery of the species.

A report documenting the 1995 bendway weir blast sampling survey at Price's Bend was completed in 2000. This report showed that blast sampling was an effective means of sampling in the extreme conditions seen in bendway weir fields and documented the differences in catch efficiency by gear type under those conditions. Twelve species and 217 fish were collected during the blast survey.

In November 2000, a meeting was held to coordinate the placement of wood structures in the Mississippi River. This meeting was in response to requests from our A&M partner agencies who have long requested that the St. Louis District explore ways to incorporate woody structure into our Operation and Maintenance Program on the Mississippi River. It was decided initially that two different types of structures would be placed. Four sites were selected for placement, with construction to take place in 2001.

The A&M prototype mooring buoy below Lock and Dam 25 was replaced in 2000. The new buoy was designed to replace the prototype buoy, which was placed in 1998. The new buoy corrected the design deficiencies of the original buoy. The original buoy was returned to the District Service Base where it will be modified based on the new design. Plans call for that buoy to be placed below Lock and Dam 22, if a suitable site can be located.

A vision document for middle Mississippi River side channel restoration was completed in 2000. This document serves as a guide for side-channel conservation and restoration work in middle Mississippi River. The condition and physical attributes of every side-channel in the middle Mississippi River is outlined, as are the potential actions needed for rehabilitation. A multi-agency committee of A&M team members created the document, and while not a product of the A&M program, will be used by the A&M program as we undertake future side channel work.

The 2001 A&M budget is expected to be $1 million. Proposed construction activities in 2001 include construction of the chevron dike in Pool 24 and placement of the wood structures. Monitoring work will include continued sampling at the chevron dike and multiple roundpoint structures, new sampling behind the bullnose dikes, continued tracking of pallid sturgeon in relation to Corps training structures, and post-modification monitoring at dike 53.0. Further testing of gate manipulation scenarios at Lock and Dam 25 will occur in 2001. Monitoring of the effects of changing the Environmental Pool Management regime will also continue. Plans also call for a generic side-channel micro-model to be created to assist in planning future side-channel restoration and enhancement work.

Avoid and Minimize
Environmental Impacts Program
St. Louis District - Mississippi Valley Division
2000 Progress Report

In October 1992, the St. Louis District issued Design Memorandum No. 24, "Avoid and Minimize Measures, Melvin Price Locks and Dams, Upper Mississippi River - Missouri and Illinois". The document was developed as a commitment made in the 1988 Record of Decision attached to the Melvin Price Locks and Dam Environmental Impact Statement for the Second Lock. St. Louis District set aside funds from 1989 to 1995 to implement eight elements recommended by the study team. Implementations of measures in that part of the program were detailed in the 1995 Progress Report. In fiscal year 1996, O&M funds were received to begin full-scale implementation of recommended measures. The planning and implementation team consists of staff from the US Army Corps of Engineers-St. Louis District, U.S. Fish and Wildlife Service-Rock Island (FWS), Illinois Department of Natural Resources (IDNR), Missouri Department of Conservation (MDOC), River Industry Action Committee (RIAC), and the Long Term Resource Monitoring Station (LTRM/MDOC) at Cape Girardeau, Mo. Each group contributes staff time to plan and attend meetings and collect data as part of a monitoring program. This team meets at least once a year to discuss ongoing work and plan future work. Outside of these meetings the St. Louis District routinely corresponds with the team to coordinate monitoring and solicit ideas and input.

The A&M program has produced a yearly progress report since 1995. This report details project activities over the past year and describes expected activities in the upcoming year. Many of the activities occur over several years. Copies of the previous years' reports, and Design Memorandum No. 24, are available from the St. Louis District.

2000 A&M Program Activities

A&M 1. **2000 Construction.** Construction efforts in 2000 were focused on Pool 24. In 1993 the A&M program constructed three chevron dikes at RM 289.0. These chevrons were placed to hold dredge material, control main channel and side channel deposition, and improve habitat diversity. These structures have proven to be excellent habitat for both fish and macroinvertebrates. The original design called for the placement of five chevron dikes at the site. In 2000 the A&M program issued a contract for the construction of the final two chevrons, which were to be placed between the existing structures, and the construction of a notched closing structure behind South Fritz Island, just below the chevrons. However, due to abnormally lower water levels in 2000 the new chevrons and notched dike could not be constructed. Further on site inspection has resulted in the determination that, due to flow and depth limitations, only 1 chevron dike can be constructed. Plans now call for that structure to be completed in 2001.

A&M 2. **Chevron Dike Monitoring.** The A&M program has constructed three sets of chevron dikes. The first set was constructed in 1993 at river mile 289 in Pool 24, near Cottonwood Island. This set of three dikes was constructed in 1993 as an alternative to constructing a closing rock structure, to maintain the existing flow split in that reach, and as a placement site for dredge disposal. In 1998, three chevron dikes were constructed at river mile 266, in Pool 25. These dikes were placed to focus main channel flow. In 1998 a single chevron dike was constructed at river mile 250, also to focus river flows. Future work calls for the placement of four additional dikes at the river mile 250 site, construction of an additional dike at river mile 289, and construction of a set of chevron dikes at river mile 226, in Pool 26. Since construction, biological monitoring has taken place at the chevrons dike fields at river mile 289 and at river mile 266.

Pool 24, River Mile 289 Biological Monitoring. The Illinois Department of Natural Resources (IDNR) has sampled the set of three chevron dikes located in Pool 24, near Cottonwood Island (river mile 289), since they were constructed in 1993. The site was sampled four times in 2000. Analysis of the entire data set shows that fish are using the chevron dikes and that catch rates inside the chevron dikes are more than double catch rates outside of the dikes. Catch rates inside of the chevron dikes were higher than those in nearby Drift Slough. Over 48 species have been found in association with the chevron dikes. The inside of the chevron dikes appear to be providing favorable nursery habitat to young-of-the-year and juvenile fishes, including white bass, smallmouth buffalo, largemouth bass, and bluegill. The outside of the chevron dikes are providing excellent habitat for a variety of fishes including channel catfish, flathead catfish, common carp, minnows, and shiners. A detailed summary of the IDNR fish sampling efforts in available in Appendix A.

Pool 25, River Mile 266 Biological Monitoring. The A&M program has constructed three chevron dikes in Pool 25 of the Mississippi River (river mile 266). One complete and one partial dike were constructed in June 1998. In March 1999 the partial dike was completed and one additional chevron dike was constructed. The three chevron dikes at river mile 266 were surveyed in August 1999, December 1999, and September 2000. A winter sample was scheduled for late 2000 but ice formation in Pool 25 made it impossible to sample the site. During each trip bathymetry, velocity, and hydroacoustic fisheries data was collected.

Fish were found in association with the chevron dikes during all three sampling trips. The upper and middle dikes showed a marked increase in fish density in the December sample. These increased concentrations are likely due to the fact that fish are using the structures as over-wintering habitat. Both dikes provide the deep holes and low velocities that fish seek out during the winter. The lower dike had no over-wintering fish and held very few fish during any of our sampling trips. This lack of fish may be due to the configuration of that dike and/or when it was constructed. The configuration of that dike (the riverside leg is much shorter than the bankside leg) does not provide the refuge from river flows that the other dikes appear too. Having been constructed one year later than the upper two chevron dikes, the lower chevron dike has had only two high water event to create a scour hole behind the dike. The lower dike is also built higher than the other dikes. Consequently, depths behind the lower chevron dike are shallower than behind either of the upper two chevron dikes. While lower than the December sample, the August and September samples showed that fish were using all three of the chevron dikes. The density data from September 2000 (pooled conditions) was similar to that seen at open river in August 1999. Detailed results are available in Appendix A.

Monitoring at the site will continue in 2001. Presently a summer and a winter sample are scheduled. In addition to hydroacoustic monitoring, gill nets will be set to determine species composition behind the dikes.

A&M 3. **Multiple Roundpoint Structure Monitoring.** In 1998, the A&M Program constructed a multiple round point structure (MRS) in Pool 25 (river mile 265.7L). This innovative training structure consists of 6 separate round rock points, or cones, on 100 ft centers extending from the bank in a fashion similar to a wing dike. The round point structure was developed to function as a wing dike and appears at the water surface to be a heavily notched wing dike. Each of the six points stands alone and is not connected to the other points.

The multiple round point structure has been monitored since construction for both fish use and bathymetric changes. Electro-fish sampling has been conducted by the Illinois Department of Natural Resources at the site since 1998. The structure was sampled four times in 2000. Five new species were collected in 2000, bringing the number of species collected to 21. New species collected in 2000 were the mooneye, spotfin shiner, river shiner, sand shiner, and bullhead minnow. Gizzard shad, emerald shiners, carp, freshwater drum, and flathead catfish continue making up the majority of the collected fish. On every sampling occasion prior to 2000, blue sucker were collected. Collection of the blue suckers is of interest because the species is uncommon in the Mississippi River and is a species of concern with resource agencies. No blue suckers were collected in 2000. The Illinois report concluded that the structure was providing useful and valuable habitat (Appendix B). Bathymetric surveys have shown that the MRS have increased diversity at the site through a series of individual scour holes that have been created directly below and downstream of the MRS. The area was all shallow sand wave habitat prior to construction.

A&M 4. **Off-bankline Revetment Monitoring.** From 1991 to 1995 the Illinois Department of Natural Resources (IDNR) conducted fish sampling on the Gosline Island off-bankline revetment (OBR) in Pool 24. In 2000, the St. Louis District asked the IDNR to prepare a report on that work to help aid the A&M program in assessing the impacts of off-bankline revetment and to help evaluate and plan future work. The results of the IDNR work showed that the Gosline Island off-bankline revetment, placed in the mid-1980s, was providing valuable habitat for a variety of fishes. For the study five sites were sampled; the outside rock of the OBR, the inside rock of the OBR, the natural bankline behind the OBR, and two control sites (a main channel border site with conventional revetment and a side channel border site). Electrofishing catch rates were highest along the natural bankline inside the OBR, followed by the inside rock, side channel border, and outside rock. Catch rates were lowest at the main channel border site. A total of forty-eight species of fish were collected during sampling, with 47 species associated with the OBR habitats. The number of species collected was highest along the inside rock (38), natural bankline (34), and outside rock (32). Ten species were collected only inside the OBR. Seven species of centrachids (sunfish and bass species generally considered off-channel fishes) were collected inside the OBR. The IDNR report stated that the OBR was providing excellent habitat for quality sized catfish and from the species composition and number of young of the year fish present, that the inside of the OBR appears to be providing backwater habitat in a reach where such habitat is limited. A copy of the IDNR report is available in Appendix C.

A&M 5. **Effects of Environmental Pool Management on Fish and Wildlife.** The St. Louis District has employed Environmental Pool Management (EPM) since 1994. EPM resulted from operational changes in the way the navigation pools are regulated after high water events. What results is a large crop of vegetation in the lower ends of Pools 24, 25,and 26. This vegetation becomes available to fish, aquatic insects, and migratory birds as water levels rise. The District is exploring ways to further enhance EPM but lacks basic information on fish and migratory bird use of the EPM created vegetation. In 2000, Southern Illinois University-Carbondale completed two studies to determine the response of waterfowl, aquatic invertebrates, fish and water quality to wetland vegetation produced by EPM (Appendix D).

It needs to be noted that the hydraulic regime during these studies was extreme compared to EPM in past years. High water during much of the drawdown kept water levels about two feet lower than the target EPM elevation and for much longer than what had been experienced in other years. This resulted in a greater vegetative response than in other years and the extended dewatering of areas that typically would not have been exposed for such a long time.

5A. Effects of Water Level Management on Waterfowl and Waterfowl Food Production in Pool 25, Upper Mississippi River. The objectives of this study were to characterize the plant community associated with water level management and estimate seed biomass production, quantify the aquatic invertebrate population response to increased vegetation production, and characterize the spring migratory waterfowl use of habitats produced by water level management.

Fifteen genera of plants were documented during the study, with smartweeds, barnyard grasses, and sedges occurring most frequently. Seed production levels produced by EPM were substantially higher than those documented at other intensively managed moist soil impoundments on the UMR. These high seed counts result in high quality habitat and abundant food availability for migrating waterfowl. Little zonation in plant species distribution with elevation suggests relatively uniform availability of food resources in the study area. Seed biomass estimates were converted into potential waterfowl use days. These results showed that even with substantial loss of seed biomass, there was an abundance of plant food available to waterfowl. Cottonwood, maple, and willow trees have also started to occur at many of the sampling locations. The presence of these species may be an unwanted consequence of EPM. By varying the way EPM is implemented every year, prevention of tree species establishment may be possible.

Invertebrate samples collected in 1998 and 1999 were compared to see if differences in relative abundance exist between plots and years. Significant differences were found between years, with 1998 having higher invertebrate diversity and abundance. This may be a result of frequent water spikes in the 1998 EPM effort, which could have allowed invertebrates stranded in isolated pools to survive the drawdown, and replenished soil moisture allowing drought resistant species to survive in the soil. Diversity was higher in vegetated plots than in devegetated plots. No significant increase in density was seen between plots, though the authors cautioned that more study was needed to fully understand the invertebrate dynamics in pool 25.

Over 170,000 waterfowl use days were recorded each year in the study area during the spring migration. Waterfowl were using the vegetated areas with over 94% of all waterfowl occurring in those areas with vegetation. Greater than 98% of these birds were dabbling ducks, consisting mainly of mallards, pintail, and teal.

The results of this study have shown that EPM is producing a community of annual moist soil plants that in turn are producing a large quantity of seeds known to be important to waterfowl and other migratory birds. The organic matter produced by EPM contributes to the overall energy budget of the river. having benefits both inside and outside of the project area. Additional research needs to be conducted on the relationship of macroinvertebrate densities and EPM and how varying the EPM regime affects plant growth, and consequently waterfowl distribution within the study area. Evidence is suggesting that a varying the way EPM is implemented between pools and between years may provide the greatest long-term benefit to the resource.

5B. Fish and Water Quality Responses to Vegetation Produced via Environmental Pool Management Pool 25, Mississippi River. The objectives of this study were to examine fish use of EPM created vegetated areas versus similar non-vegetated areas. determine the benefit of residual vegetation to young fishes, and monitor the effect of vegetation on water quality and zooplankton.

Four sites in Pool 25 were sampled after the 1999 summer pool drawdown (29 June to 12 August). Vegetated and non-vegetated areas were sampled at each site from late August to middle October. Substantial numbers of fish were found in the vegetated areas but fish abundance and diversity were not statically significantly higher in the vegetated plots. The high variability associated with a small number of samples and sites may have been the cause. The greatest difference between vegetated and non-vegetated areas was seen at the Turner Island site. At this site the vegetation was accessible to fishes that typically use flowing water habitat. This area provided nursery habitat for young channel shiners, spotfin shiners, and river shiners.

The results showed the occurrence of low dissolved oxygen (DO) at three of the four sites. Low DO values were probably caused by decomposition of vegetation and low atmospheric mixing. Backwater sites were dominated by fish like the common carp and mosquitofish, which are tolerant of low oxygen levels. Results also indicated that fish may be excluded from using the internal portions of large expanses of dense emergent vegetation because of the low DO.

While the backwater sites had the greatest DO problems, the highest diversity of fish collected was in a backwater along the vegetation/devegetated interface. This edge habitat likely attracted edge-dwelling fish. Increasing this edge habitat in dense vegetation stands, like those created in 1999, would likely benefit fish through the creation of habitat and the alleviation of low DO conditions.

Residual vegetation from the 1998 EPM effort was sampled in the spring of 1999. This vegetation consisted of dead stalks of smartweed. This vegetation, which at some sites formed a dense underwater network, provided cover in areas that would otherwise have been barren, and likely provided food for fish through increased invertebrate abundance. Uncommon fishes like the blue sucker, mooneye, silver chub and slenderhead darters were collected in association with the residual vegetation. Overall 28 species were collected in the residual vegetation, with most being late larval or early juvenile fish. The results indicate that these areas are providing valuable nursery and rearing habitat for young fish.

The hydraulic regime in 1999 was extreme compared to EPM in past years. High water during much of the drawdown kept water levels about two feet lower than the target EPM elevation and for much longer than what had been experienced in other years. This resulted in a greater vegetative response than in other years and the extended dewatering of areas that typically would not have been exposed for such a long time. This was seen in the presence of exposed mussel beds and isolated backwaters. The elevation at which many of these areas became exposed or isolated was 431, 1 ft below the lowest target elevation (432) established for EPM. The authors suggested that alternating the EPM regime to compensate for the negative impacts of a previous years drawdown should be explored.

Data from 2000, during which water levels were intentionally held on the higher end of the EPM range, are presently being analyzed. Future work will focus on the analysis of the zooplankton data, invertebrate data collection. the establishment of new sites, and further evaluation of the timing, duration and depth of EPM drawdowns.

A&M 6. **Fish Passage Improvement at Lock and Dam 25.** The A&M program began a project in 1999 to monitor fish movement through the dam gates at Lock and Dam 25. This work was undertaken to assess the possibility of conditional gate management and or structural alternatives to enhance the ability of fish to move between pools. The issue of inhibiting fish passage has long been one of concern with the Corps state and federal partner agencies. The 1999 results showed that fish were moving through the dam at open river. Movement opportunities outside of open river are probably very limited. All monitoring work is being conducted in the last gate bay (17) in the succession. This tainter gate bay is located on the Illinois end of the lock and dam structure and has some properties that make it more conducive to fish movement then other gate bays. Monitoring efforts in 2000 were to focus on creating hydraulic conditions to extend or create open river conditions outside of the natural period of open river.

Spring rains and snow melt within the basin fuel the increase in spring flows seen on the Mississippi River. In 2000, the increase in spring flows was not enough to create open river conditions on the Mississippi River. This was caused by abnormally low levels of rain and the lack of snow in the basin. Because of these circumstances Lock and Dam 25 did not have a spring open river event. In June of 2000, Lock and Dam 25 did finally reach open river conditions. To test whether open river conditions could be extended, it was decided that as the Lock and Dam 25 staff returned Pool 25 to a pooled condition, some gates would be left completely out of the water. To compensate for those gates, other gates would be lowered into the water further than normal. Changes in velocity, fish movement, and adverse impacts to tows using Lock and Dam 25 were all recorded. This test was conducted on 10 July. The last five gates (13-17) were all held out of the water while the other 12 gates were lowered into the water. As flows decreased during the day those 12 gates were lowered while gates 13-17 remained out of the water. Eventually gates 13, 14, and 15 were also lowered. Within 10 hours of the initial gate movements, all 17 gates had to be lowered into the water to maintain pool.

Fish movement did not change due to altering in the gate settings. This is in large part due to the fact that there was minimal fish movement prior to 10 July and on 10 July. Sampling on 29 June found a fish movement rate of .12 fish per minute. Open river conditions occurred very late in 2000 and likely occurred after the conditions (water temperature was already 80°F) that cue spawning migrations in many fishes. Lock and Dam 25 went to open river on 9 June, which also allowed an excellent opportunity for fish movement prior to 29 June.

Some concern was expressed that the gate manipulations would create changes in flow patterns that could affect tows entering and exiting the lock. Tow pilots were polled as they left Lock and Dam 25 and none reported experiencing problems.

Velocities did change during the test. Two benchmarks were examined, the percent of flows below 4 foot per second (fps) and the percent of flows below 2 fps. These numbers were based on examination of fish prolonged swimming speed. Most fish species can traverse flows less than 2 fps. As flows rise above 2 fps the number of fish species that appear to be able to pass decreases. Four fps is the upper end of swimming speeds for Mississippi River fish. At the start of the test over 35% of the flows were below 4 fps and 5% were below 2 fps. As gates were lowered into the water these percentages continued to drop. Near the end of the test, but prior to placement of gates 16 and 17 in the water, less than 13% of the flows were below 4 fps and less than 1% were below 2 fps. By comparison, on 29 June, during open river conditions, 89% of the flows were below 4 fps and 42% were below 2 fps.

The results of this study, to date, have shown that fish do move through Lock and Dam 25 but movement appears to be limited to periods of open river. Manipulating the gates to extend the period of open river is possible, but as originally tested also increased velocities in gate bay 17. Fish movement data is inconclusive. Changes in gate operations do not appear to affect tow traffic. Work in the spring of 2001 will include manipulating gates as Lock and Dam 25 is heading towards open river (versus coming out of open river like in 2000). Testing at that time should coincide with spring fish movement and should give a better indication of the true effects of gate manipulation on fish movement. A study report will also be completed in 2001.

A&M 7. **Middle Mississippi River Pallid Sturgeon Habitat Use Project.** In 2000, the A&M program continued for the fifth year to fund Southern Illinois University-Carbondale, Cooperative Fisheries Research Laboratory to monitor the relationship between river training structures and the federally listed endangered pallid sturgeon, and to collect life history information. Efforts in 2000 focused on collecting and implanting new fish, tracking existing fish, and continuing observation of a purported sturgeon spawning site near Chester, Illinois.

Unfortunately, no additional pallid sturgeon were obtained from commercial fishermen and implanted with sonic transmitters during year five. Two pallid sturgeon were collected but not implanted with transmitters, due to their small size. Tracking continued in 2000 on two fish implanted in 1999, one of which was identified as a female with eggs when originally captured.

A total of 195 relocations of the study fish have been made from 13 November 1995 to 31 December 2000. Most of the tracking effort was made between RM 81 and 151 in order to maximize relocations. The study fish were located in the main channel habitat for 38% of all relocations. Main channel border and between wing dam habitat were used by the fish 27% and 14% percent of all relocations respectively. Twenty-five percent of all the relocations were in some way associated with river training structures. When water temperatures were below 4°C. the sturgeon were found in association with current-disruption structures more often than during the study as a whole (12% of the time compared to 9%), however the main channel was still used most often (48%). Main channel and main channel border habitat were used 82% of the time once water temperatures exceeded 4°C.

Habitat availability analysis indicates that the study area was approximately 64% main channel, 11% main channel border, 1% downstream island tips, and the other 24% of habitat types being related to river training structures. The sturgeon showed positive selection for, in rank order: main channel border, down stream of island tips, between wing dams, and the tips of wing dams. The fish showed a negative selection for, in rank order, main channel, down stream of wing dams, and upstream of wing dams. Seasonal trend work showed that the study fish generally moved downstream in the winter, upstream during the late summer and fall, and had variable movements in the spring and summer. Fifty-five substrate samples taken at the points where sturgeon were relocated indicated that the fish were most commonly found over sand (81%), and occasionally over sand/gravel (9%) and mud/silt (5.5%).

Spawning site work in 2000 expanded sampling work completed in 1999. The site was sampled twice in 1999, and consisted of sand, very course sand, gravel, and pebbles. In the spring of 2000, the site was sampled on three occasions with a benthic egg dredge. No eggs of any kind were collected. In addition, trammel nets were drifted through the area during each sampling trip. No pallid sturgeon were collected and shovelnose sturgeon made up the majority of the catch (59%). The St. Louis District was scheduled to collect bathymetric, velocity, substrate, and hydroacoustic fisheries data at the site, but shallow water depths during the spring in 2000 did not allow the survey boat access to the site. That work is now scheduled for spring 2001.

The results of this study indicate that pallid sturgeon may have a preference for the types of habitats and conditions created along the main channel border, downstream of island tips, and between wings dams. Based on these results, future St. Louis District projects in the open river (including the A&M program) will give consideration to the creation or protection of these types of habitats and the importance they may play in the recovery of the species. Restoration or creation of these types of habitats will increase habitat diversity in the open river. Increased habitat diversity will in turn benefit many species, including the pallid sturgeon.

Southern Illinois University-Carbondale also completed a supplemental report which specifically addressed pallid sturgeon use of reaches with bendway weirs. This report looked at pallid sturgeon use of the Kaskaskia and St. Genevieve bendway weir fields. Those two fields were within the area (river miles 94-123) that accounted for over 70% of all pallid sturgeon relocations. Within that 30 mile area, bendway weir reaches comprised about 10% of the available habitat. Pallid sturgeon relocations were found in association with bendway weir habitat 8% of the time. Based on those results it does not appear that pallid sturgeon select for or against bendway weir habitat.

More detailed results of the pallid sturgeon work is available in Appendix E.

A&M 8. **Bendway Weir Fisheries Survey Report.** Since 1990, the St. Louis District has installed twenty bendway weir fields in the Mississippi River. Hydroacoustic fisheries work has shown that fish are using the weir fields but determining species composition was impossible. In 1995, the St. Louis District, in an effort to determine what species are found in association with bendway weirs, conducted a high explosive fisheries survey at the Price's Towhead bendway weir field. In 2000, the final report on that work was completed. A total of 217 fish was captured using blast fishing at the Price's Towhead site, representing 12 different species. Freshwater drum dominated the catch, followed by gizzard shad, and blue catfish. Species composition differed by capture method. Four species, shovelnose sturgeon, skipjack herring, stonecat and freckled madtom, were collected only in the mid-water catch nets. Two species, carp and smallmouth buffalo, were collected only in the surface collections. Species specific catch efficiency varied greatly by sampling gear. Conventional fish collection techniques (e.g., trotlines, gill nets, and hoop nets) were ineffective capture methods in the bendway weir field when compared with the blast fishing. In fact, the most numerically abundant species taken by explosives (freshwater drum) was not taken by conventional sampling techniques. The complete report is located in Appendix F.

A&M 9. **Wood Structure and the O&M Progam on the Open River.** The A&M program partner agencies have long requested that the St. Louis District explore ways to incorporate wood structures into our Operation and Maintenance Program on the Mississippi River. The potential environmental benefits of the District incorporating woody structures into its O&M program include increased habitat diversity and increased organic matter in the river. In November 2000, a meeting was held between the Corps, Illinois Department of Natural Resources and the USFWS to determine how and where to place woody structure. It was decided initially that two different types of structures would be prepared, wood bundles and a modified pile dike structure. The logs to be used for the project came courtesy of the Westvaco Corporation. Actual design and placement of the structures will be determined onsite by what is feasible and safe.

The first work site will be in the dike field between dikes 164.9 and 165.1. This site will serve as the testing site to determine what is practical when driving logs. Once it has been established what is feasible, the crew will move downstream and place an unrooted dike at about river mile 163.8R near the head of the sandbar. This site was chosen because placement here would likely collect debris and push flow around the backside of the sandbar, helping to isolate the sandbar from the bank. Two sites were also selected for the placement of log bundles. Log bundles will be placed behind an L-dike at river mile 165.5R and a wing dike at river mile 157.3L.

Pre-construction monitoring will include bathymetric, velocity, hydroacoustic fish, and substrate surveys of the proposed sites. Post construction monitoring will also include bathymetric, velocity, hydroacoustic fish, and substrate surveys, as well as macroinvertebrate and fisheries collection. The structures will be monitored and evaluated for their value as river training devices. Construction will take place in 2001. Monitoring will also begin in 2001. The results of the November meeting are in Appendix G.

<u>A&M 10</u>. **Mooring Buoy Replacement at Lock and Dam 25.** The District replaced the mooring buoy below Lock and Dam 25 in 2000. The original buoy installed was a prototype designed by the Corps, based upon input from the navigation industry and constructed by them at no charge to the District. The location below the dam facilitated alignment with the lock for tows using the buoy on their way upstream. The tow captains experienced and reported several problems with the buoy as it was designed. First and foremost, it had a tendency to turn over, thus being unavailable for use. Second, it vacillated severely in the current created by high flows and was therefore unsafe for use during those conditions. The prototype design was modified to correct the original design problems. Major design changes included a deeper and longer keel and a longer buoy. The height was also increased to make access to the buoy easier for deck hands attempting to tie-off from empty barges. A new buoy was constructed, based upon the modified design, with shared funding from the Maritime Administration and the A&M program. The new buoy was transported from Bollinger Ship Yard in New Orleans to the Service Base in St. Louis by the navigation industry. The new buoy was placed in late September. Preliminary indications are that the new buoy is functioning much better than the original.

The prototype buoy was removed from Lock and Dam 25 when the new buoy was installed and transported to the District Service Base. Present plans are to modify the buoy at the Service Base, based upon the new design, and deploy it along the left descending bank below the lock at Lock and Dam 22. The Corps is working with our partners in the towing industry and Missouri Department of Conservation to find a suitable on-bank mooring location. Modification and installation of the buoy and bank anchor will be accomplished utilizing A&M funds, hopefully in 2001.

<u>A&M 11</u>. **Wing Dike Modification Pre-project monitoring, Dike 53.0L.** In January of 2000 the Corp collected pre-modification multi-beam bathymetry, velocity, and hydroacoustic fisheries data at an existing dike located at river mile 53. As constructed, the dike extended 600 ft. into the river and had an elevation of +15 ft. LWRP (310.48). The dike, which extended into the navigation channel and was considered a

navigation hazard, was scheduled for modification during the summer of 2000. Several modification alternatives were discussed, including (1) removing the last 300 ft. of the dike, (2) lowering the entire dike down to –15 ft. (creating a weir), or (3) lowering the last 300 ft. of the dike to –15 ft. while leaving the rest of the dike intact. Through coordination with regional resource agencies, the decision was made to implement option 3. The dike was modified in August 2000.

Results of the pre-modification bathymetric survey showed the presence of two holes below the dike. One hole extended behind and riverward of the tip of the dike. The second hole, which appeared to have been created by the plunging action of water overtopping the dike, was located outward from the toe of the dike. The hydroacoustic analysis found an average density of 835 fish per acre at the site. The data showed fish using the entire area behind the dike, with the majority of the fish using the inside hole.

To complement the Corps work, the Missouri Department of Conservation set four experimental gill nets below the dike. Each 300-ft. net was set on the bottom. Two nets were set in the inner hole, perpendicular to the bank, one net was set perpendicular to the dike on the ridge between the two holes, and one net was set perpendicular to the tip of the dike. Ninety-one fish were collected in the inside hole. The collection was dominated by shovelnose sturgeon but also included paddlefish, blue catfish, sauger, and goldeye. Twenty-five fish (all sturgeon) were collected on the ridge between the two holes. One appeared to be a shovelnose sturgeon/pallid sturgeon cross. Ten fish were collected in the net set off the dike tip. This area likely had flows higher than either of the other net set locations. That set included paddlefish, blue catfish, and shovelnose sturgeon. Post-modification monitoring at this site is scheduled for 2001. The results of the pre-construction work are in Appendix H.

<u>A&M 12</u>. **MMR Side Channel Document** In 2000 the St. Louis District completed a vision document for the middle Mississippi River side channels. This document, formed by a multi-agency committee composed of the A&M team members, creates a vision for side-channel conservation and restoration work in middle Mississippi River. Long term goals established by the team included providing over-wintering habitat every 5-7 miles, providing off channel habitat every 5-7 miles, maintaining connectivity and small craft access to the side channel areas, and providing improved public access to river resources. The condition and physical attributes of all 31 side channels in the middle Mississippi River are outlined in the document, as are the initial proposed actions required for rehabilitation and enhancement. The document, located in Appendix I, was not a product of the A&M program.

FY 2001 A&M Program

The FY 2001 A&M budget is $1 million. This figure is in line with previous years' budgets but is less than the $1.5 million per year requested in Design Memorandum No. 24. At this time, the program is expected to be extended until 2007 to offset the annual differences in funding. Proposed construction activities in 2001 include completion of the chevron dike above Cottonwood Island (river mile 289) and construction of the wood structures in the middle Mississippi River. Biological monitoring work will include continued sampling at the chevron dike and multiple roundpoint structures, new sampling behind the bullnose dikes, continued tracking of pallid sturgeon in relation to Corps training structures, and post-modification monitoring at dike 53.0. Further testing of gate manipulation scenarios at Lock and Dam 25 will occur in 2001. Monitoring of the effects of changing the Environmental Pool Management regime will also continue. Plans also call for a generic side-channel micro-model to be created to assist in planning future side-channel improvement work.

Avoid & Minimize Team

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Appendices

Appendix A.

2000 Summary Report on Pool 26 Chevron Dike Hydroacoustic Fisheries Sampling – U.S. Army Corps of Engineers, St. Louis District

Cottonwood Island Chevron Dike Fisheries Evaluation Update – Illinois Department of Natural Resources

Appendix B.

Multiple Round Point Structures Preliminary Fisheries Evaluation – Illinois Department of Natural Resources

Appendix C.

Gosline Island Off-bankline Revetment Fisheries Evaluation Update – Illinois Department of Natural Resources

Appendix D.

Environmental Pool Management

Evaluation of Environmental Pool Management on Pool 25, Mississippi River. Southern Illinois University – Carbondale, Cooperative Wildlife Research Laboratory.

Fish and Water Quality Responses to Vegetation Produced via Environmental Pool Management Pool 25, Mississippi River. Southern Illinois University – Carbondale, Fisheries and Illinois Aquaculture Center and Department of Zoology

Appendix E.

2000 Progress Report – Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University – Carbondale, Fisheries Research Laboratory and Department of Zoology.

Middle Mississippi River Pallid Sturgeon Habitat Use Project: Supplemental Report on Bendway-Weir Field Use by Pallid Sturgeon. Southern Illinois University – Carbondale, Fisheries Research Laboratory and Department of Zoology.

Appendix F.

Draft Report: The Use of High Explosives to Conduct a Fisheries Study at a Bendway Weir Field on the Mississippi River - U.S. Army Corps of Engineers, St. Louis District and Missouri Department of Conservation

Appendix G.

Wood Structure Meeting Summary, November 2000 - U.S. Army Corps of Engineers, St. Louis District.

Appendix H.

Dike 53 Physical and Biological Monitoring Trip Report - U.S. Army Corps of Engineers, St. Louis District.

Appendix I.

Middle Mississippi River Side Channel Vision - U.S. Army Corps of Engineers, St. Louis District.

Appendix A.

2000 Summary Report on Pool 26 Chevron Dike Hydroacoustic Fisheries Sampling – U.S. Army Corps of Engineers, St. Louis District.

Cottonwood Island Chevron Dike Fisheries Evaluation Update – Illinois Department of Natural Resources

2000 Summary Report
Chevron Dike Hydroacoustic Fisheries Sampling

US Army Corps of Engineers, St. Louis District
Avoid and Minimize Program

Background: Three chevron dikes have been constructed in Pool 25 of the Mississippi River (M.R.M. 266.0R). Two of these dikes were constructed in June 1998. One was constructed in March 1999. These innovative channel training structures were built under the St. Louis District's Avoid and Minimize program. At this location the three chevron dikes, which look like "V's or U's" with the apex pointing upstream, were built in a downstream line and act to deflect flow towards the channel. During high flow a deep hole is scoured in the area behind the chevron dike's apex. The slack-water area that forms behinds the structures, outside of high flow conditions, creates a unique habitat. Previous fish sampling work on chevron dikes in Pool 24 (Atwood 2000) found that a variety of fishes are using this habitat.

Sampling to Date: The three chevron dikes at 266.0 were sampled once in 2000, on 7 September. A winter 2000 sample was planned but due to icy conditions during most of the winter we were unable to access the site. The chevrons were previously sampled on 4 August 1999 and 13 December 1999. Information on each sampling trip follows.

4 August 1999

All three chevron dikes were sampled. Water temperature was 27.2°C. Pool 25 was at open river but the chevron dikes were not overtopped. The MV Boyer was used to collect bathymetry, velocity, and hydroacoustic fisheries data. Transects were run upstream from the bottom of the chevron dike to the apex. Three transects were run inside of both the top and middle dikes. Four transects were run inside of the lower chevron dike. Depths behind the top and middle chevron dikes exceeded 11 meters. Depths behind the lower chevron dike exceeded 7 meters. Analysis of the hydroacoustic data found similar fish densities behind all three dikes. Densities ranged from 325 fish per acre behind the top chevron dike to 406 fish per acre behind the lower chevron dike. The density behind the middle chevron dike was 402 fish per acre. Because Pool 25 was at open river, it is likely that these dikes were providing some refuge to fish from the higher velocities associated with open river.

13 December 1999

All three chevron dikes were sampled. Water temperature was 5°C. Pool 25 was at normal pool conditions. The MV Boyer collected bathymetry, velocity, and hydroacoustic fisheries data. At each chevron dike, the same transects lines run on 4 August were run on 13 December. In addition, one transect was run across the back end of each chevron dike and one transect was run around the outside of the lower and upper chevron dikes. Two additional transects were run inside both the top and middle chevron dikes. Depths behind the top and middle chevron dikes exceeded 9 meters. Depths behind the lower chevron dike exceeded 4 meters. Fish densities between the three dikes varied greatly. No fish were found using the lower weir. Fish densities per acre were 1,828 and 2590 for the upper and middle chevron dikes respectively. No fish were found on the transects run across the end of each chevron dike. One fish was found on the transect around the outside of the lower chevron dike. No fish were found around the outside of the upper chevron. Transects and fish locations for all three dikes are included at the end of the report.

7 September 2000

All three chevron dikes were sampled. Water temperature was 24.8°C. Pool 25 was at normal pool conditions. The MV Boyer was used to collect bathymetry, velocity, and hydroacoustic fisheries data. Transects were run upstream from the bottom of the chevron dike to the apex. Four transects were run inside of each the three dikes. Depths behind the top and middle chevron dikes exceeded 8 meters. Depths behind the lower chevron dike did not exceed 5 meters. Analysis of the hydroacoustic data found similar fish densities behind the upper and middle dikes (490 and 317 fish per acre). Fish density behind the lower chevron was very low (52 fish per acre). Densities during this sample were similar to those collected during the August 1999 sample.

Table 1. Chevron sampling data

	Sample date	Max. depth meters	Fish density #/acre	Water temp. °C	Pool conditions
Upper Chevron inside	8-4-99	11	325	27.2	Open river
Upper Chevron inside	12-13-99	9	1823	5	Normal pool (winter)
Upper Chevron inside	9-7-00	9	490	24.8	Normal pool
Middle Chevron inside	8-4-99	11	402	27.2	Open river
Middle Chevron inside	12-13-99	9	2590	5	Normal pool (winter)
Middle Chevron inside	9-7-00	8	317	24.8	Normal pool
Lower Chevron inside	8-4-99	7	406	27.2	Open river
Lower Chevron inside	12-13-99	4	0	5	Normal pool (winter)
Lower Chevron inside	9-7-00	5	52	24.8	Normal pool

Conclusions: Fish were using the chevron dikes during all sampling trips. The upper and middle dikes showed a marked increase in density from the August and September samples to the December sample. These increased concentrations are likely due to the fact that fish are using the structures as over-wintering locations. Both dikes provide the deep holes and low velocities that fish seek out during the winter. The lower dike had no over-wintering fish and held very few fish during any of our sampling trips. This lack of fish may be due to the configuration of that dike and/or when it was constructed. The configuration of that dike (the riverside leg is much shorter than the bankside leg) does not provide the refuge from river flows that the other dikes appear too. Having been constructed one year later than the upper two chevron dikes, the lower chevron dike has had only two high water event to create a scour hole behind the dike. Consequently, depths behind the lower chevron dike are shallower than behind either of the upper two chevron dikes.

While lower than the December sample, the August and September samples showed that fish were using all three of the chevron dikes. The density data from September 2000 (pooled conditions) was similar to that seen at open river in August 1999. Additional data during these two conditions would help determine if fish are using chevron dikes as a refuge from rising flows outside of the over-wintering season. Based on the results from Atwood (2000) you would expect fish to be using the dikes year round.

Monitoring at the site will continue in 2001. Presently a summer and a winter sample are scheduled. In addition to hydroacoustic monitoring, gill nets will be set to determine species composition behind the dike.

References:

Atwood, E.R. 2000. Cottonwood Island Dike Fisheries Evaluation Update. Prepared for U.S. Army Corps of Engineers, St. Louis District. 18 pp.

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Cottonwood Island Chevron Dike
Fisheries Evaluation Update

Prepared for:
U.S. Army Corps of Engineers
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May 2001

Introduction

The Illinois Department of Natural Resources. Division of Fisheries. Boundary Rivers Program. with assistance from the St. Louis District. Corps of Engineers. has conducted fish sampling with A.C. electrofishing (EF) on the Cottonwood Island chevron dikes since October 1993. Three chevrons were constructed by the St. Louis District in the October 1993. The chevrons were constructed as an alternative to constructing a rock closing structure between the upper ends of Sand Bar Island and North Fritz Island. between river miles 290 and 289. Construction of two more chevrons at this location is planned. The chevrons were constructed to increase the proportion of the flow going down the main channel with the goal of reducing the amount of maintenance dredging needed in this river reach.

Methods

The upstream and downstream most chevrons have been sampled. along with a small backwater slough at Drift Island as a control stations. In 1998 two additional control stations (Head of Bay Island and main channel border along Cottonwood Island, adjacent to the upper chevron) were sampled to evaluate them for possible inclusion in the study. The dates of sampling for these sites. as well as EF time period for each site are shown in Table 1.

The electrofishing unit used in this study consists of a 230 volt. 4000 watt. 3 phase A.C. generator which energizes 3 steel cable electrodes (5/8") suspended from 3 booms projecting off the bow of the boat (18' welded aluminum boat). The electrodes are approximately 5' apart. project about 6' off the bow and extend into the water about 4' in depth. thus creating an electric field with an approximate diameter of 10' and reaching a depth of about 6'. Typically 6 - 10 amperes of current are generated within this field. The sampling is conducted by a two person crew. one stationed in the bow of the boat to dip stunned fish with a long handled dip net from the water and into a oxygenated live well. and one operating the motor. Typically. two EF runs are conducted at each chevron. one along the outside of the chevron and one within the inside of the chevron. Rough sketches of the study area and typical chevron sampling runs are attached.

After each EF run the fish are identified to species. weighed and measured. checked for abnormalities and disease. then returned live to the river. Fishes too small to identify in the field are preserved and returned to the lab for processing. Data are tabulated on standard field sheets and later entered into the Department's fisheries database (Fisheries Analysis System). Voucher specimens were sent to the Department of Zoology at Southern Illinois University. Carbondale for preservation and storage.

Results and Discussion

A total of 8815 fishes representing 56 species have been collected during 1329 minutes of electrofishing (99.49 fish/15 ef min). When these data are summarized by habitat type (inside.

outside. Drift Island Slough and Head of Bay Island) over all sampling periods (Table 2), the highest catch rate was observed inside the chevrons (152.23 fish/15 min EF), followed by Drift Island Slough (104.50 fish/15 min EF), outside the chevrons (70.22 fish/15 min EF) and Head of Bay Island (68.57 fish/15 min EF). The number of species collected was also highest inside the chevrons (42 species) [Table 2], followed by Drift Island Slough (38 species), outside the chevrons (30 species) and Head of Bay Island (27 species). Forty nine of the 56 species collected have been collected at the chevrons (inside and outside combined). Table 3 summerizes fish collections from all sites sampled to date.

When the number of species collected at each station are compared (Figure 1), the highest species richness was observed from inside the upper chevron (39 species) followed by Drift Island Slough (38 species), upper outside (29 species), lower inside (28 species), Head of Bay Island (27 species) and lower outside (19 species). When catch rates for each site (over all sampling periods) are compared, the upper inside chevron is higher than all other sites with 159.40 fish/15 min EF, followed by lower inside (130.94 fish/15 min) and Drift Island Slough (104.50 fish/15 min) [Figure 2]. Although some of the difference in catch rates and species richness can be explained by variable sampling effort among stations, and differences in electrofishing efficiency among stations, these data suggest that the habitat types created inside the chevron dikes are holding more individual fishes and more fish species than either the habitat immediately outside of the chevrons or nearby side channel and backwater habitats.

A similar picture emerges when the catch rates of selected individual fish species at each station are compared. The catch rates for gizzard shad (Figure 3) and bullhead minnow (Figure 5) were higher inside chevrons than elsewhere. The catch rate for smallmouth buffalo was highest in the slough followed by inside lower and inside upper (Figure 6). The catch rates for channel catfish (Figure 7) and flathead catfish (Figure 8), however, were highest on the outside of the chevrons. The largemouth bass catch rates were highest in the slough, and slightly higher inside the two chevrons than outside (Figure 9). The bluegill catch rate in the slough habitat was much higher than elsewhere, but was higher inside chevrons than outside (Figure 10).

An examination of the length frequencies of selected fishes collected from the vicinity of the chevrons and Drift Island Slough helps illustrate the similarities and differences in the fish populations inhabitating these habitat types. For instance, although smallmouth buffalo densities associated with the chevrons appear to be considerably less than those in Drift Island Slough, the size range observed for this species is slightly greater in the vicinity of the chevrons than in the slough. This may indicate the nursery habitat provided by the chevron and slough habitats are similar in quality for this species (Figures 11, 12 and 13).

The channel catfish catch rate was more than three times higher along the outside of the chevrons than inside (Table 2), suggesting higher densities outside. The channel catfish catch rate at Drift Island Slough is similar to that observed inside. The size structure of channel catfish collected at Drift Island Slough, and inside and outside the chevrons indicates similar sized fishes are utilizing these areas (Figures 14, 15 and 16). The catch rate data coupled with the length frequency data suggests that adult fish are residing most often outside the chevrons and occasionally move into the inside. The purpose of such movement is unknown. but at least two possibilities exist. Channel catfish use the inside as a temporary resting place from high current velocities experienced on outside. and they are utilizing the slighty higher density of forage fishes and slighter different macroinvertebrate assemblage (Ecological Specialists, Inc 1997) found inside the chevrons.

Unlike the channel catfish. the catch rate for white bass on the inside was 2.5 times that on the outside and the observed size distribution of these fishes between these habitats is markedly different. The majority of white bass found inside were young of the year fishes. while most of those fish collected on the outside of the chevrons were one year or older, suggesting the interior habitat is providing valuable nursery habitat for young white bass.

Largemouth bass and bluegill densities also appear to be higher in Drift Island Slough than inside chevrons and the size structure in these habitats is similar (Figures 17, 18, 19 and 20), probably indicating the chevrons are providing favorable juvenile and adult habitat conditions.

Conclusion

The data collected thus far in this evaluation strongly suggest that chevron dikes are providing useful and valuable habitat for a variety of riverine fishes. The outside of chevrons have been shown to provide excellent habitat for quality sized channel catfish, flathead catfish, common carp and a variety of minnows and shiners. Smallmouth bass. uncommon within this river reach. have also been collected along the outside of chevrons. From the species composition and the number of young of the year fishes present, the inside of chevrons appear to be providing backwater type habitat (at appropriate water levels) in a reach of river where such habitat is limited.

Table 1. Sampling dates and electrofishing effort for Cottonwood Island chevron dike study.

Sampling date	Station name	Electrofishing effort (min)
14-Oct-93	Upper Chevron Outside	9
02-Aug-95	Upper Chevron Outside	14
12-Sep-95	Upper Chevron Outside	16
11-Oct-95	Upper Chevron Outside	14
14-Aug-96	Upper Chevron Outside	15
09-Sep-96	Upper Chevron Outside	15
06-Oct-96	Upper Chevron Outside	15
16-Jul-97	Upper Chevron Outside	10
26-Sep-97	Upper Chevron Outside	15
12-Jun-98	Upper Chevron Outside	20
17-Aug-98	Upper Chevron Outside	15
14-Oct-98	Upper Chevron Outside	15
26-Aug-99	Upper Chevron Outside	15
23-Sep-99	Upper Chevron Outside	12
22-May-00	Upper Chevron Outside	12
29-Aug-00	Upper Chevron Outside	15
29-Sep-00	Upper Chevron Outside	15
18-Oct-00	Upper Chevron Outside	15
14-Oct-93	Upper Chevron Inside	9
02-Aug-95	Upper Chevron Inside	14
12-Sep-95	Upper Chevron Inside	16
11-Oct-95	Upper Chevron Inside	14
14-Aug-96	Upper Chevron Inside	15
09-Sep-96	Upper Chevron Inside	15
06-Oct-96	Upper Chevron Inside	15
16-Jul-97	Upper Chevron Inside	10
26-Sep-97	Upper Chevron Inside	15
12-Jun-98	Upper Chevron Inside	15
17-Aug-98	Upper Chevron Inside	15
14-Oct-98	Upper Chevron Inside	15
26-Aug-99	Upper Chevron Inside	15
23-Sep-99	Upper Chevron Inside	12
22-May-00	Upper Chevron Inside	12
29-Aug-00	Upper Chevron Inside	15
29-Sep-00	Upper Chevron Inside	15
18-Oct-00	Upper Chevron Inside	15
14-Oct-93	Lower Chevron Outside	9
12-Sep-95	Lower Chevron Outside	16
14-Aug-96	Lower Chevron Outside	15
09-Sep-96	Lower Chevron Outside	15
08-Oct-96	Lower Chevron Outside	15
16-Jul-97	Lower Chevron Outside	15
17-Aug-98	Lower Chevron Outside	15
14-Oct-93	Lower Chevron Inside	9
12-Sep-95	Lower Chevron Inside	16
14-Aug-96	Lower Chevron Inside	15
16-Jul-97	Lower Chevron Inside	15
12-Jun-98	Lower Chevron Inside	15
17-Aug-98	Lower Chevron Inside	15
14-Oct-98	Head of Bay Island	20
26-Aug-99	Head of Bay Island	15
23-Sep-99	Head of Bay Island	20
22-May-00	Head of Bay Island	20
29-Sep-00	Head of Bay Island	15
18-Oct-00	Head of Bay Island	15
21-Jul-95	Drift Island Slough	30
21-Jul-95	Drift Island Slough	30
12-Aug-96	Drift Island Slough	30
12-Aug-96	Drift Island Slough	30
09-Sep-96	Drift Island Slough	15
08-Oct-96	Drift Island Slough	15
04-Aug-97	Drift Island Slough	30
04-Aug-97	Drift Island Slough	30
06-Aug-98	Drift Island Slough	30
06-Aug-98	Drift Island Slough	30
25-Aug-99	Drift Island Slough	30
25-Aug-99	Drift Island Slough	30
29-Aug-00	Drift Island Slough	30
29-Aug-00	Drift Island Slough	30
12-Jun-98	Cottonwood MCB	20
	Total effort to date	1209

Table 2. Composition of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes study area, 1993 - 2000.

	Chevron Inside		Chevron Outside		Chevron total		Head of Bay Is.		Drift Is. Slough		All Stations	
sampling effort (min)	337		357		764		105		390		1188	
Species	N	N/15min	N	N/15min	N	N/15min	N	N/15min	N	N/15min	N	N/15min
Shortnose gar	5	0.22			5	0.09	2	0.29	3	0.12	10	0.13
Longnose gar									5	0.19	5	0.06
Bowfin									25	0.96	25	0.32
American eel			2	0.08	2	0.04					2	0.03
Skipjack herring	1	0.04			1	0.02	1	0.14			2	0.03
Gizzard shad	795	35.39	166	6.97	961	15.02	14	2.00	294	11.31	1269	16.01
Threadfin shad	2	0.09			2	0.04					2	0.03
Mooneye			3	0.13	3	0.05					3	0.04
Bighead carp	1	0.04			1	0.02			1	0.04	2	0.03
Silver carp									1	0.04	1	0.01
Goldfish	1	0.04			1	0.02					1	0.01
Carp	44	1.96	108	4.54	152	0.83	49	7.00	125	4.81	326	4.11
Carp x Goldfish									1	0.04	1	0.01
Central stoneroller			1	0.04	1	0.02	1	0.14			2	0.03
Suckermouth minnow	5	0.22			5	0.09					5	0.06
Silver chub	7	0.31	11	0.46	18	0.13			12	0.46	30	0.38
Spotfin shiner	126	5.61	263	11.05	389	2.38	47	6.71	3	0.12	439	5.54
Red shiner	14	0.62	44	1.85	58	0.26	32	4.57			90	1.14
Emerald shiner	677	30.13	1037	43.57	1714	12.79	156	22.29	4	0.15	1874	23.64
Silverband shiner	1	0.04			1	0.02					1	0.01
River shiner	48	2.14	32	1.34	80	0.91					80	1.01
Bigmouth shiner			1	0.04	1	0.02					1	0.01
Sand shiner	7	0.31	17	0.71	24	0.13					24	0.30
Channel shiner	83	3.69	36	1.51	119	1.57	11	1.57	1	0.04	131	1.65
Spottail shiner	4	0.18			4	0.08					4	0.05
Shiner spp.	13	0.58			13	0.25					13	0.16
Bluntnose minnow	4	0.18	5	0.21	9	0.08			1	0.04	10	0.13
Bullhead minnow	526	23.41	56	2.35	582	9.94	14	2.00	51	1.96	647	8.16
Bigmouth buffalo	18	0.80			18	0.34	13	1.86	114	4.38	145	1.83
Smallmouth buffalo	60	2.67	25	1.05	85	1.13	2	0.29	253	9.73	340	4.29
Black buffalo	1	0.04			1	0.02	2	0.29	11	0.42	14	0.18
Carpsucker spp	14	0.62			14	0.26					14	0.18
Quillback	14	0.62			14	0.26			1	0.04	15	0.19
River carpsucker	105	4.67	1	0.04	106	1.98			19	0.73	125	1.58
Highfin carpsucker	1	0.04			1	0.02					1	0.01
Spotted sucker									2	0.08	2	0.03
Shorthead redhorse	4	0.18	9	0.38	13	0.08	4	0.57	4	0.15	21	0.26
Golden redhorse	3	0.13			3	0.06	1	0.14			4	0.05
Channel catfish	32	1.42	110	4.62	142	0.60	19	2.71	43	1.65	204	2.57
Flathead catfish	5	0.22	105	4.41	110	0.09	5	0.71	33	1.27	148	1.87
Freckled madtom			1	0.04	1	0.02	1	0.14			2	0.03
Mosquitofish	23	1.02			23	0.43	1	0.14	45	1.73	69	0.87
Brook silverside	2	0.09			2	0.04			1	0.04	3	0.04
White bass	32	1.42	14	0.59	46	0.60	5	0.71	3	0.12	54	0.68
Yellow bass			1	0.04	1	0.02					1	0.01
Black crappie	5	0.22			5	0.09	13	1.86	121	4.65	139	1.75
White crappie	2	0.09			2	0.04	1	0.14	46	1.77	49	0.62
Largemouth bass	40	1.78	8	0.34	48	0.76	4	0.57	112	4.31	164	2.07
Smallmouth bass			7	0.29	7	0.13					7	0.09
Warmouth	1	0.04			1	0.02			11	0.42	12	0.15
Green sunfish	105	4.67	13	0.55	118	1.98	2	0.29	6	0.23	126	1.59
Bluegill	282	12.55	26	1.09	308	5.33	58	8.29	980	37.69	1346	16.98
Redear sunfish									1	0.04	1	0.01
Bluegill x Green sunfish	1	0.04			1	0.02					1	0.01
Orangespotted sunfish	119	5.30	2	0.08	121	2.25	5	0.71	294	11.31	420	5.30
Walleye									1	0.04	1	0.01
Sauger	3	0.13			3	0.06			2	0.08	5	0.06
Logperch	1	0.04	1	0.04	2	0.02			2	0.08	4	0.05
Mud darter									2	0.08	2	0.03
Freshwater drum	183	8.15	53	2.23	236	3.46	17	2.43	83	3.19	336	4.24
Total number fish collected	3420	152.23	2158	90.67	5578	64.81	480	68.57	2717	104.50	8775	110.70
Number of species collected	42		30		49		27		38		56	

Table 3. Summary of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes study area, 1993 - 2000.

	Chevrons				Control sites			
	Lower inside	Lower outside	Upper inside	Upper outside	Head of Bay Is.	MCB	Drift Is. Slough	All Stations
sampling effort (min)	85	100	252	257	105	20	390	1209
Species								
Shortnose gar			5		2		3	10
Longnose gar							5	5
Bowfin							25	25
American eel				2				2
Skipjack herring			1		1			2
Gizzard shad	215	41	580	125	14	5	294	1274
Threadfin shad	1		1					2
Mooneye				3				3
Bighead carp	1						1	2
Silver carp							1	1
Goldfish			1					1
Carp	7	27	37	81	49	4	125	330
Carp x Goldfish							1	1
Central stoneroller				1	1			2
Suckermouth minnow	3		2					5
Silver chub		2	7	9			12	30
Spotfin shiner	52	57	74	206	47	3	3	442
Red shiner	1	5	13	39	32			90
Emerald shiner	119	194	558	843	156	3	4	1877
Silverband shiner	1							1
River shiner	20	13	28	19		2		82
Bigmouth shiner				1				1
Sand shiner		1	7	16				24
Channel shiner	5	8	78	28	11	2	1	133
Spottail shiner			4					4
Shiner spp.			13					13
Bluntnose minnow	1		3	5			1	10
Bullhead minnow	114	7	412	49	14	1	51	648
Bigmouth buffalo	10		8		13		114	145
Smallmouth buffalo	27	8	33	17	2	2	253	342
Black buffalo	1				2		11	14
Carpsucker spp.			14					14
Quillback	5		9			1	1	16
River carpsucker	30		75	1		3	19	128
Highfin carpsucker			1					1
Spotted sucker							2	2
Shorthead redhorse		4	4	5	4	5	4	26
Golden redhorse	1		2		1	1		5
Channel catfish	8	56	24	54	19	2	43	206
Flathead catfish	3	27	2	78	5		33	148
Freckled madtom				1	1			2
Mosquitofish			23		1		45	69
Brook silverside			2				1	3
White bass	14	5	18	9	5	1	3	55
Yellow bass		1						1
Black crappie	3		2		13		121	139
White crappie			2		1		46	49
Largemouth bass	11		29	8	4		112	164
Smallmouth bass		1		6				7
Warmouth			1				11	12
Green sunfish	4		101	13	2		6	126
Bluegill	23	4	259	22	58	1	980	1347
Redear sunfish							1	1
Bluegill x Green sunfish			1					1
Orangespotted sunfish	23		96	2	5		294	420
Walleye							1	1
Sauger			3				2	5
Logperch			1	1			2	4
Mud darter							2	2
Freshwater drum	39	18	144	35	17	4	83	340
Total number fish collected	742	479	2678	1679	480	40	2717	8815
Number of species collected	28	19	39	29	27	16	38	56

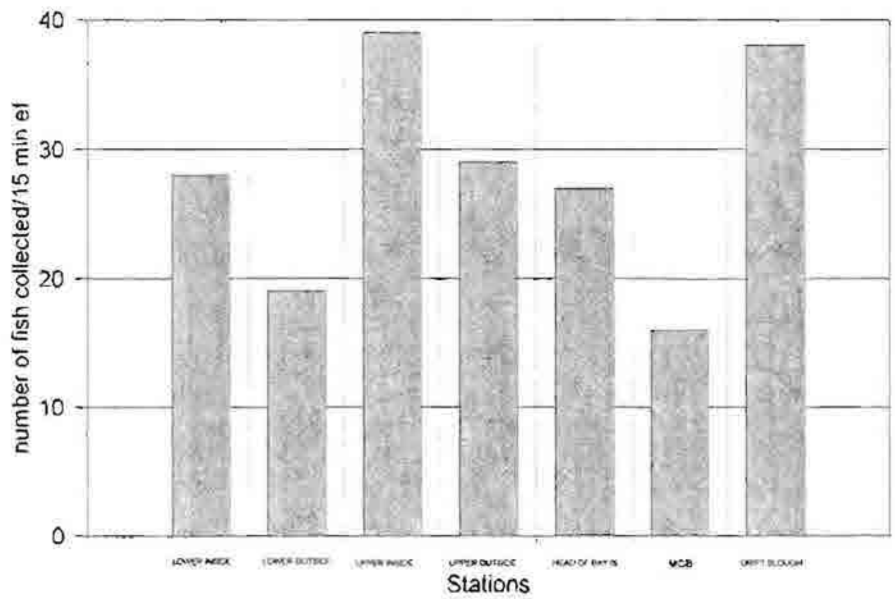


Figure 1 Total number of fish species collected with electrofishing at Cottonwood Island chevron dikes study area.

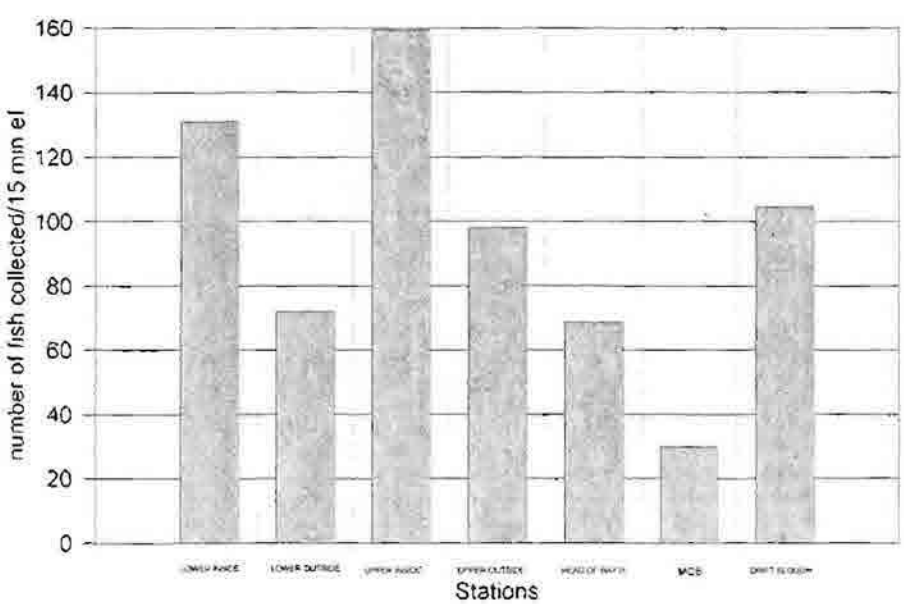


Figure 2. Total number of fish collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area.

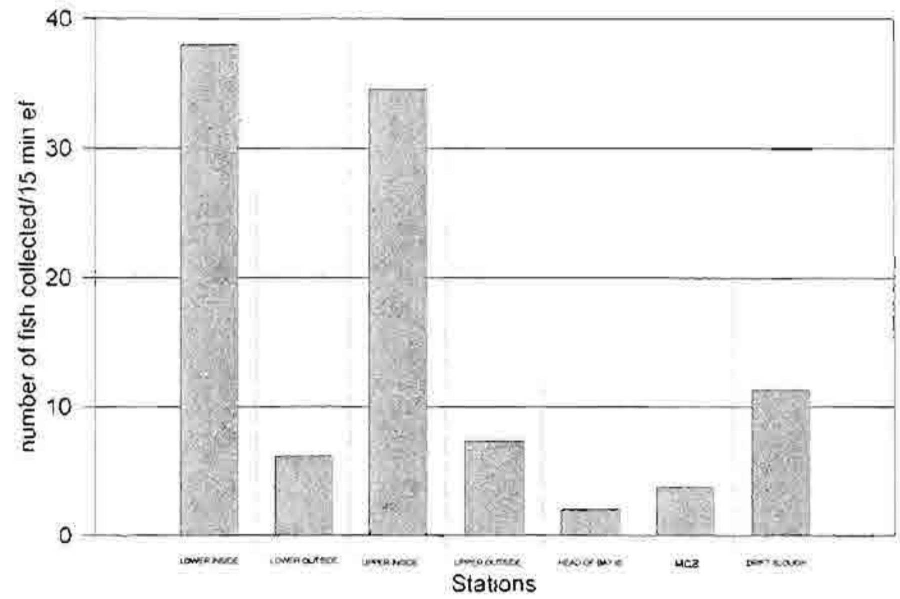


Figure 3 Total number of gizzard shad collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area

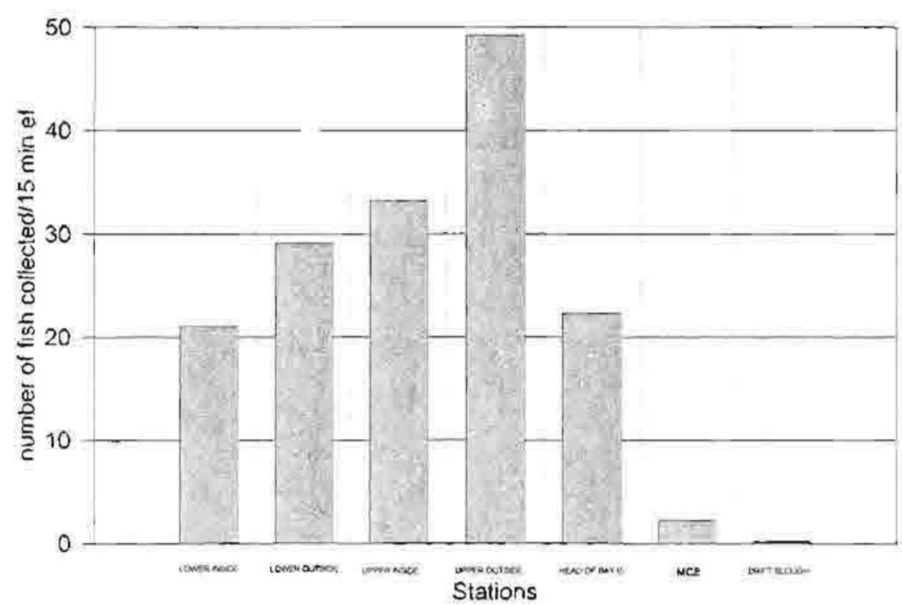


Figure 4 Total number of emerald shiner collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area

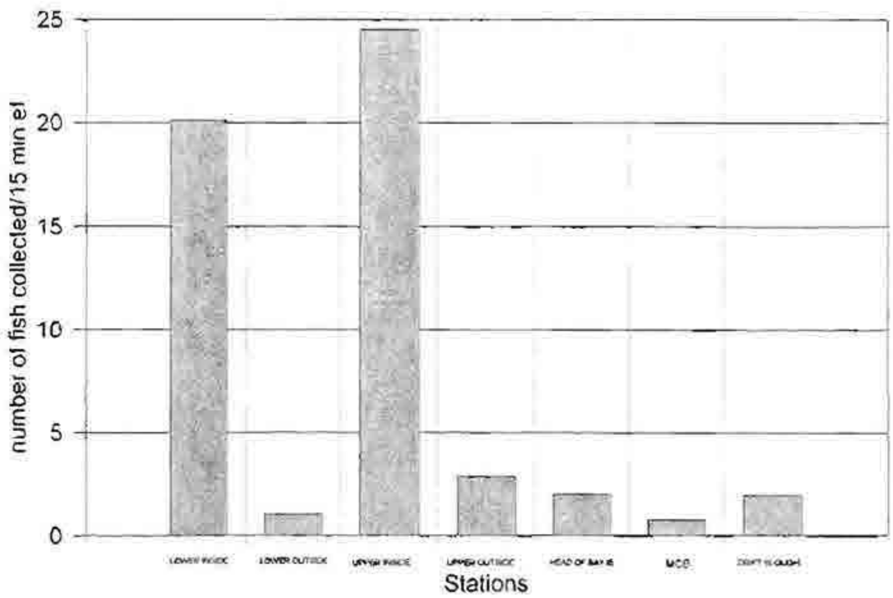


Figure 5. Total number of bullhead minnow collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area

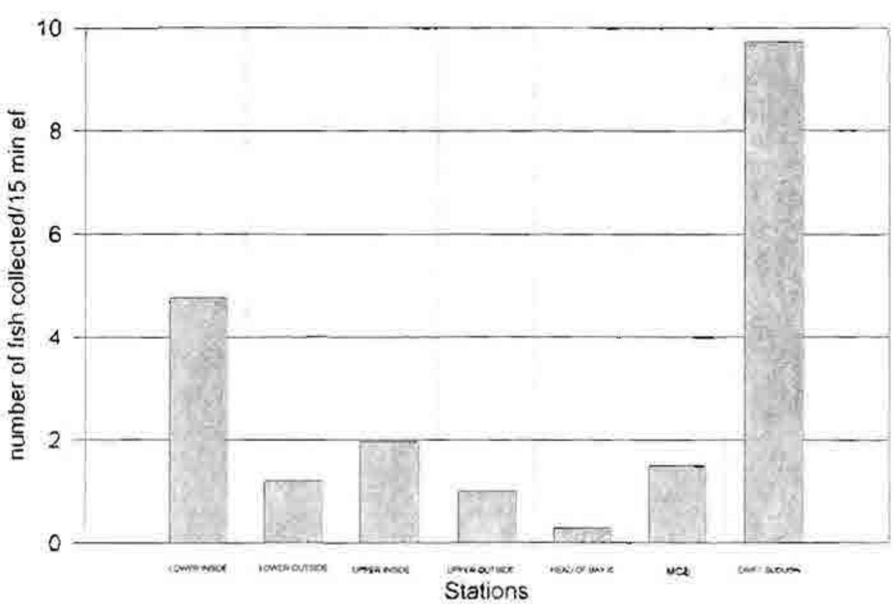


Figure 6. Total number of smallmouth buffalo collected per 15 min of electrofishing at Cottonwood Islar chevron dikes study area

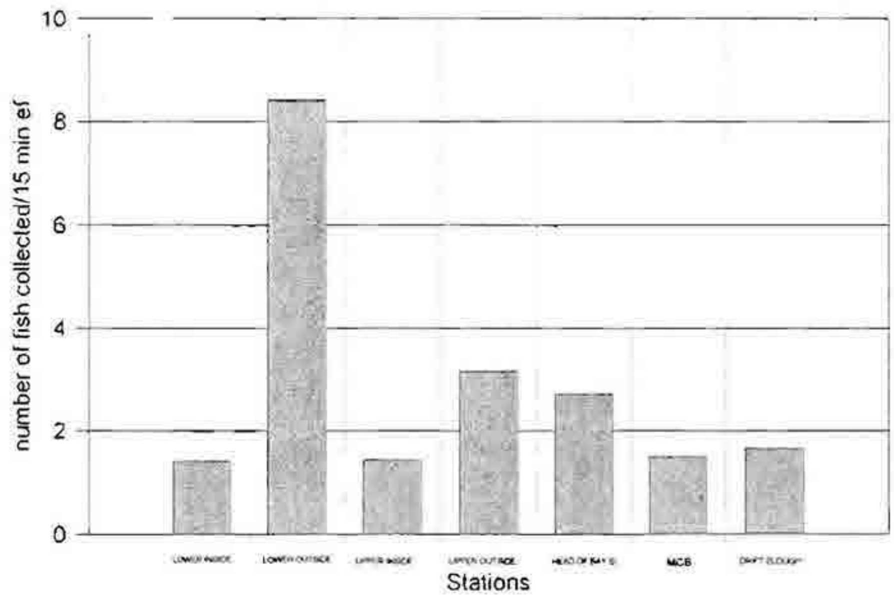


Figure 7. Total number of channel catfish collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area.

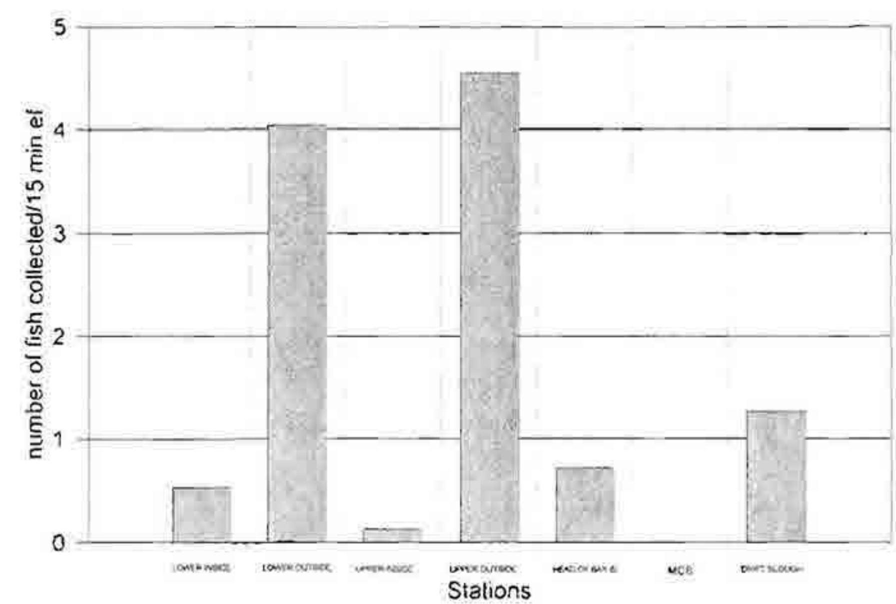


Figure 8. Total number of flathead catfish collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area.

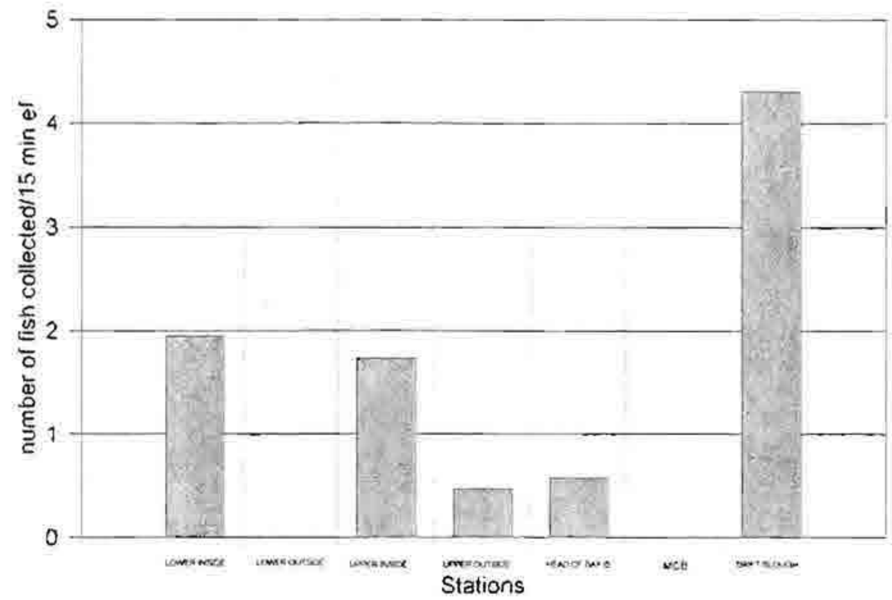


Figure 9. Total number of largemouth bass collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area

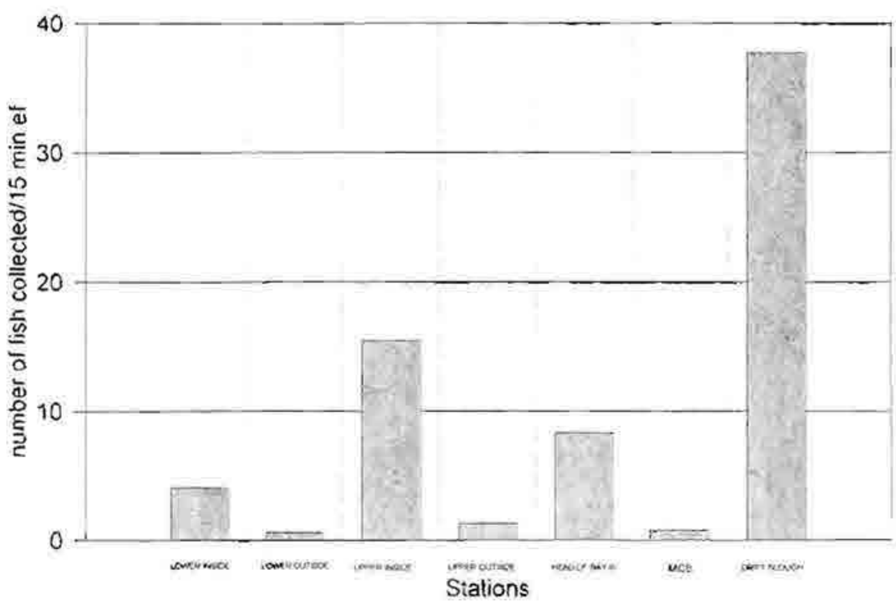


Figure 10 Total number of bluegill collected per 15 min of electrofishing at Cottonwood Island chevron dikes study area.

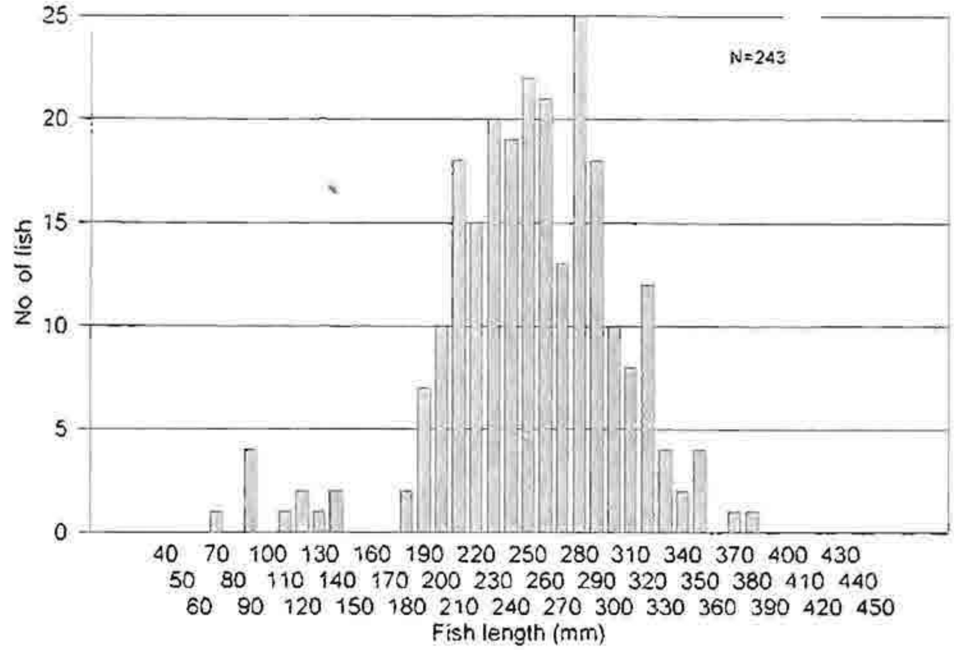


Figure 11 Length frequency of smallmouth buffalo collected at Drift Island Slough, 1993-2000

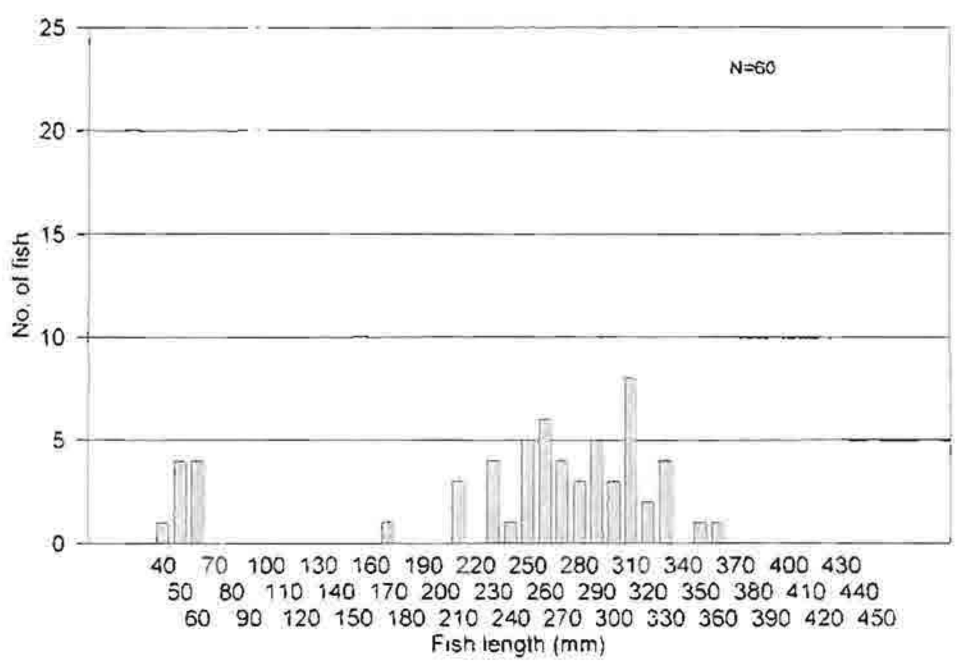


Figure 12 Length frequency of smallmouth buffalo collected inside Cottonwood Island Chevron dikes 1993-2000.

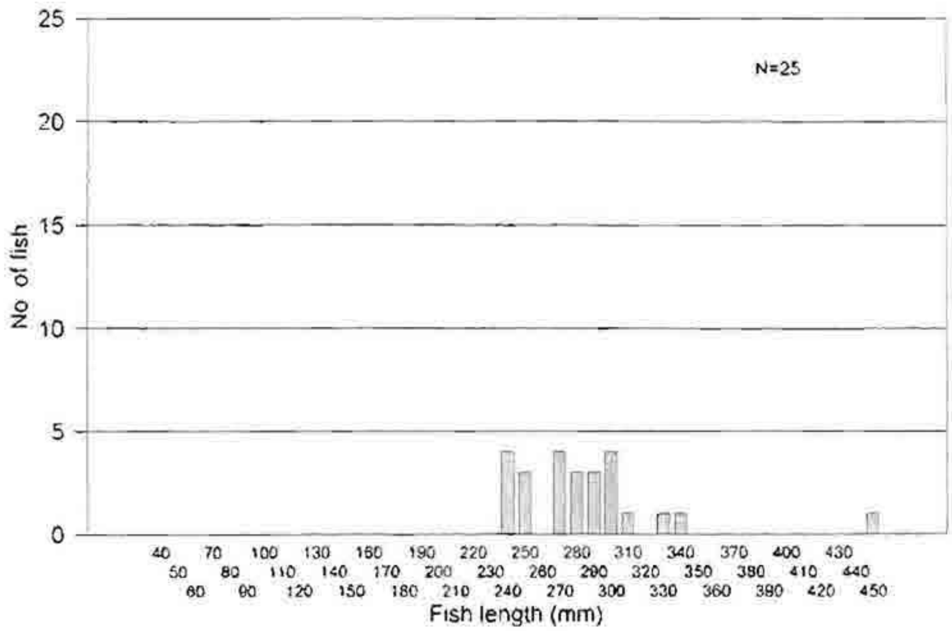


Figure 13. Length frequency of smallmouth buffalo collected outside Cottonwood Island Chevron dikes, 1993 -2000

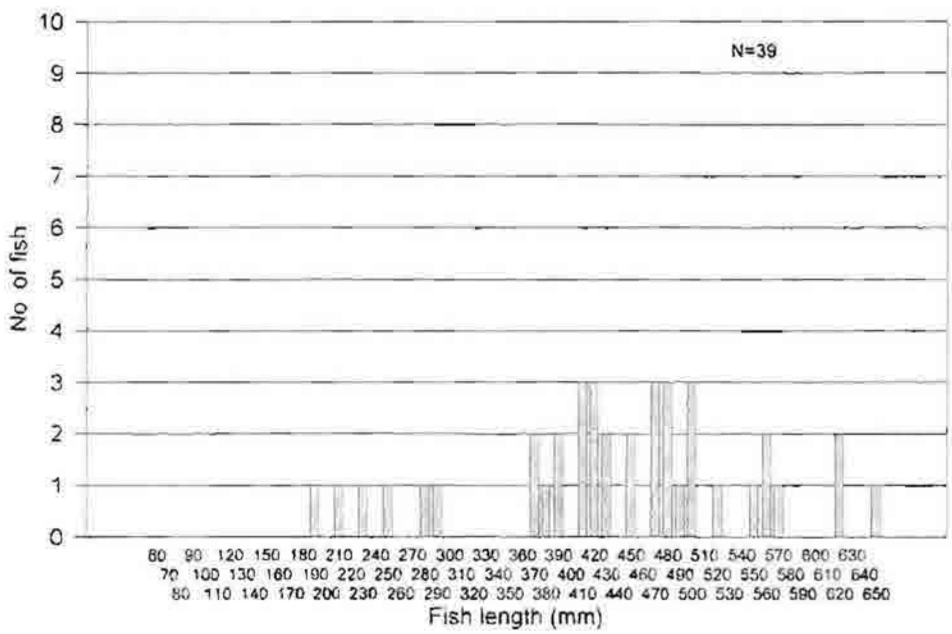


Figure 14. Length frequency of channel catfish collected at Drift Island Slough, 1993 -2000

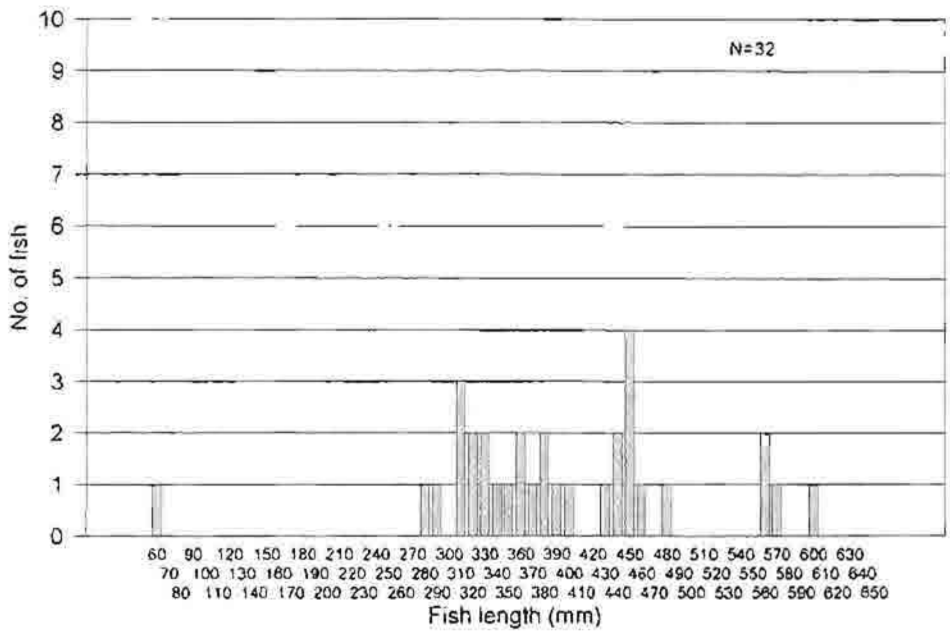


Figure 15 Length frequency of channel catfish collected inside Cottonwood Island Chevron dikes, 1993 -2000.

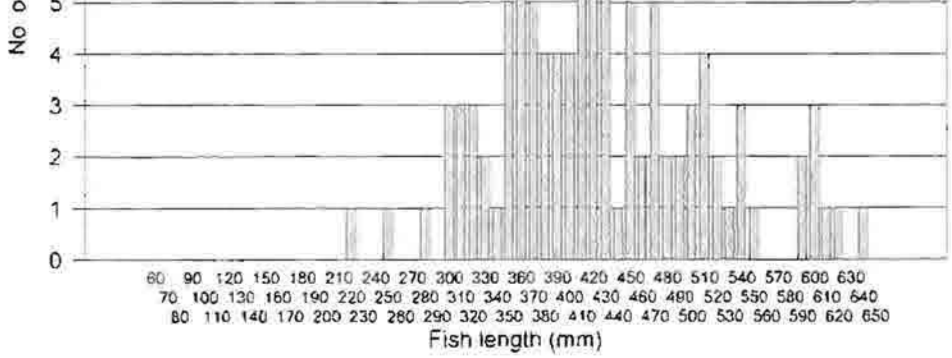


Figure 16 Length frequency of channel catfish collected outside Cottonwood Island Chevron dikes 1993 -2000

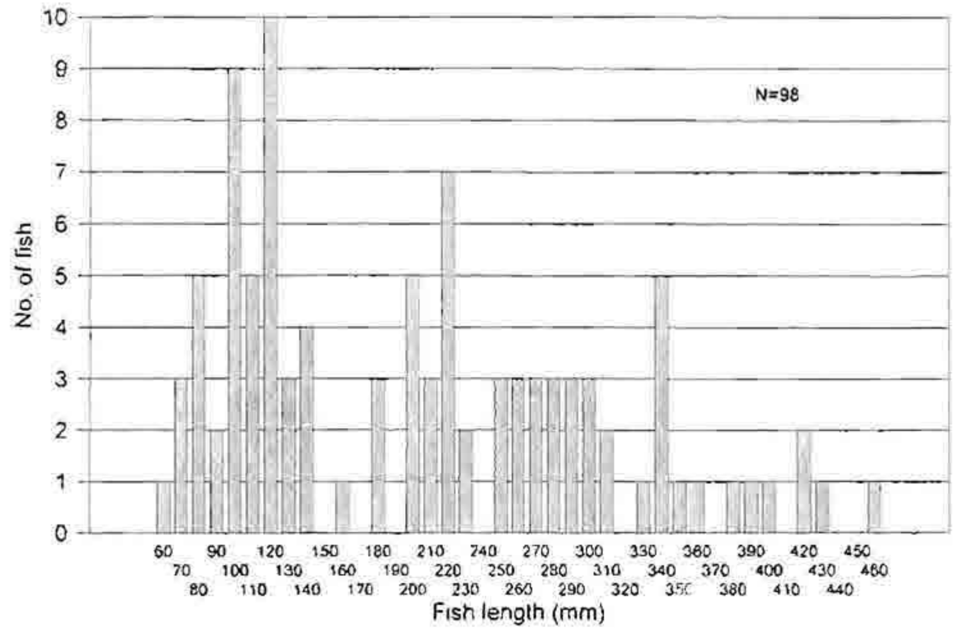


Figure 17. Length frequency of largemouth bass collected Drift Island Slough, 1993 -2000

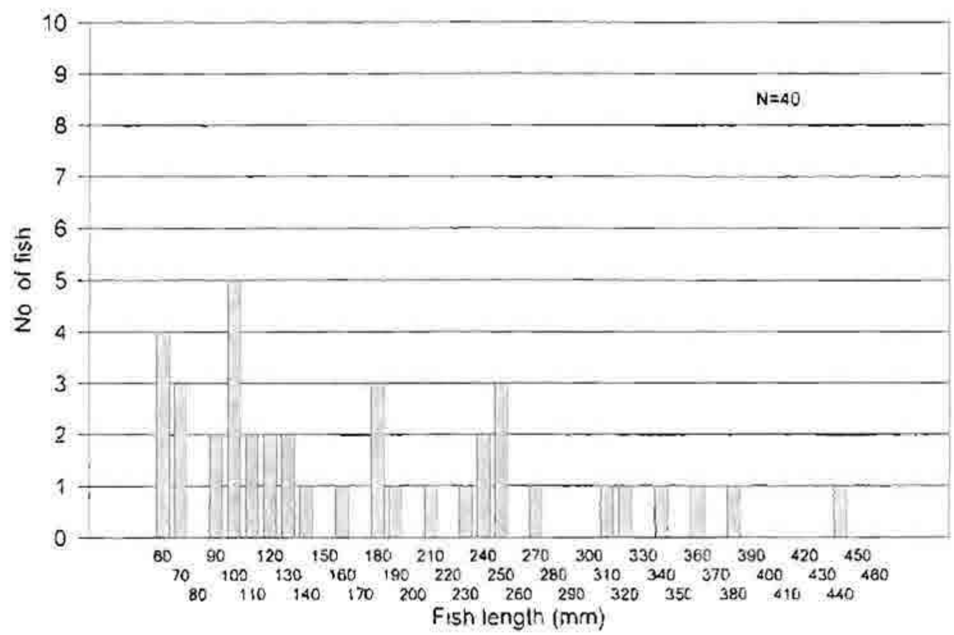


Figure 18 Length frequency of largemouth bass collected inside Cottonwood Island Chevron dikes, 1993 -2000

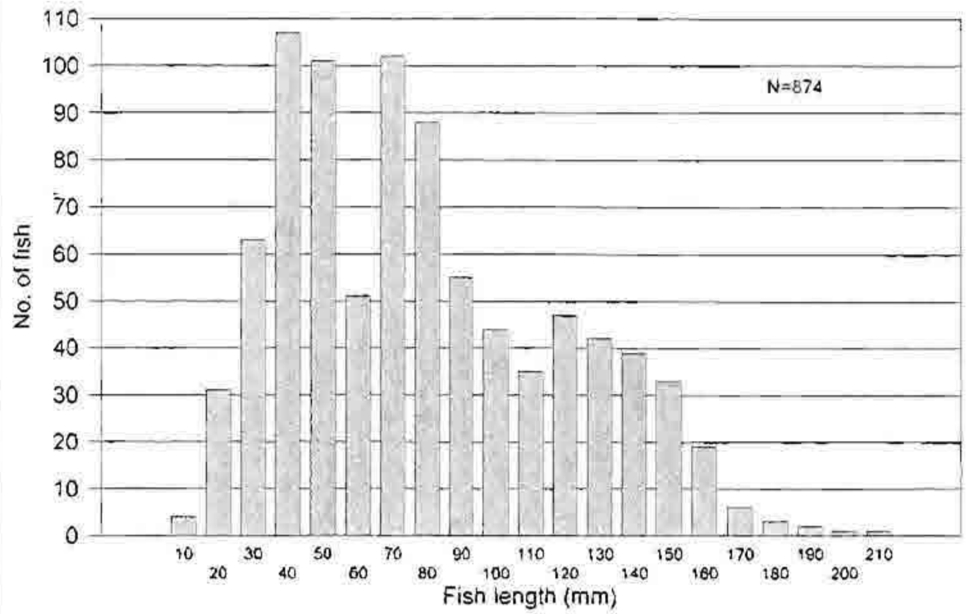


Figure 19. Length frequency of bluegill collected at Drift Island Slough, 1993 - 2000

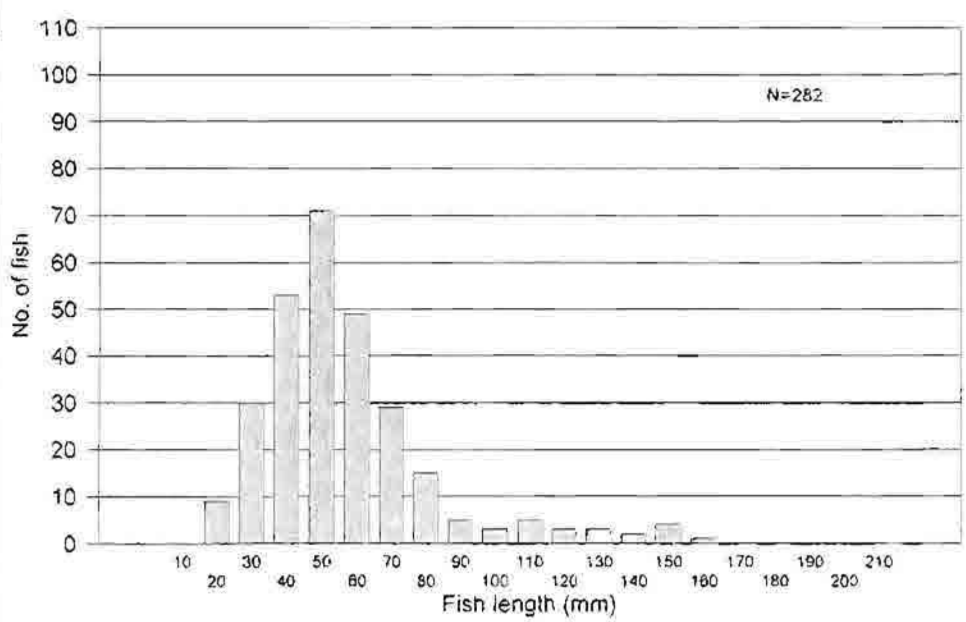
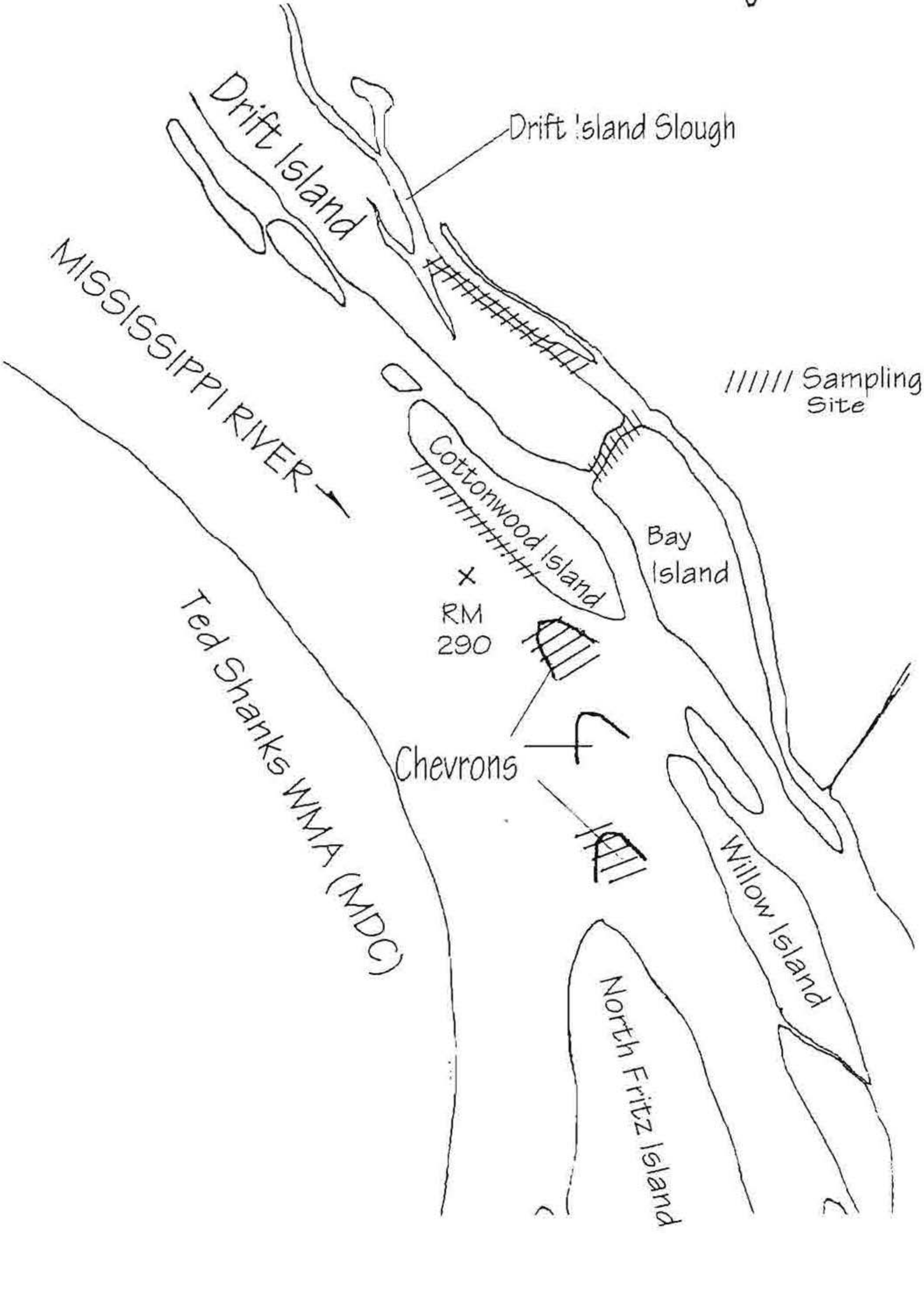
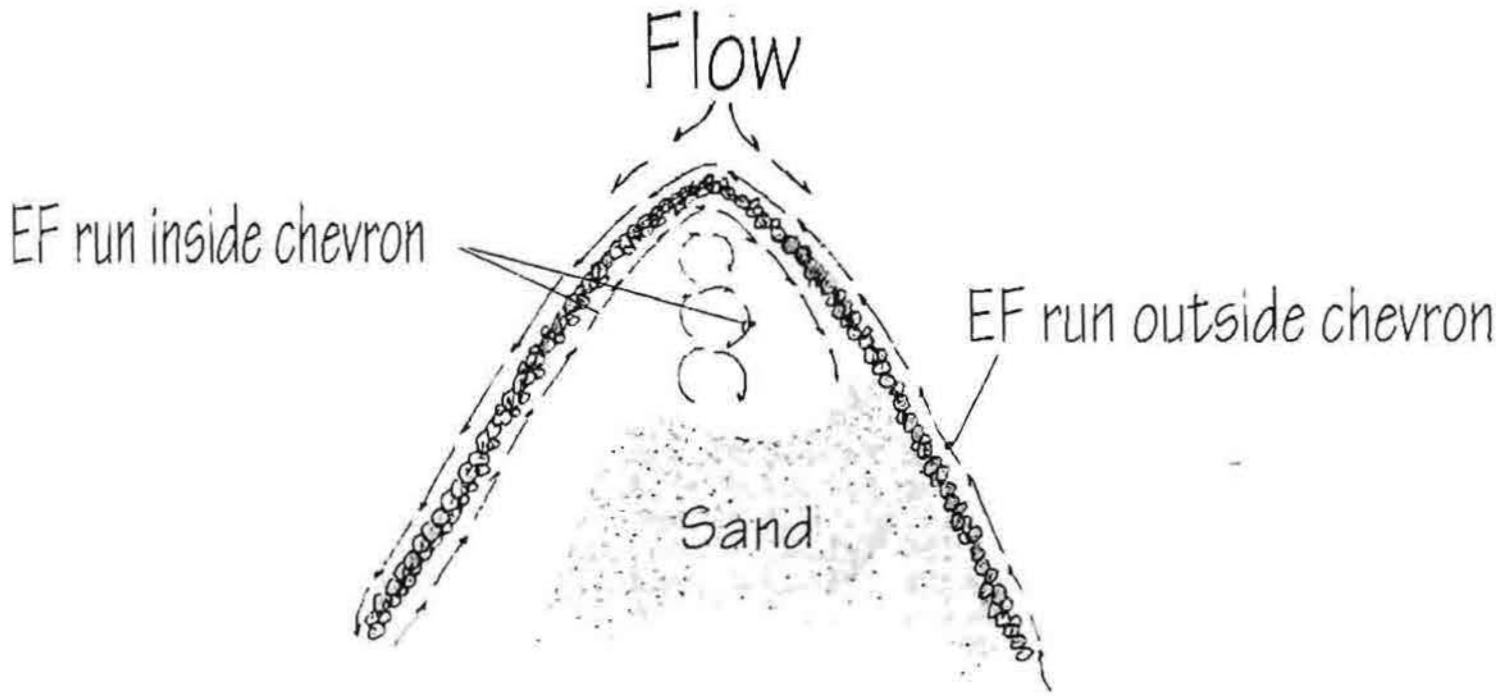


Figure 20 Length frequency of bluegill collected inside Cottonwood Island Chevron dikes, 1993 - 2000

Cottonwood Island Chevron Dike Study Area



Typical Chevron Electrofishing Runs



Appendix B.

Multiple Round Point Structures Preliminary Fisheries Evaluation – Illinois Department of Natural Resources

Multiple Round Point Structures
Preliminary Fisheries Evaluation

Prepared for:
U.S. Army Corps of Engineers
St.Louis District

Prepared by:
Elmer R. Atwood
Illinois Department of Natural Resources
Fisheries Division
Boundary River Program

May 2001

Introduction

The Illinois Department of Natural Resources, Division of Fisheries. Boundary Rivers Program has collected eight fish samples with A.C. electrofishing (EF) at the Multiple Round Point Structures constructed by the St. Louis District. Corps of Engineers at Mississippi River mile 256.6L. since August 1998 (164 min). The sampling was conducted in order to obtain information on the composition of fishes utilizing these structures.

Methods

The electrofishing (ef) unit and the sampling methodology used in this sampling effort is the same as that used in the chevron dike study. Each sampling run involved electrofishing around each of the six round points and collecting all fish stunned within the range of the dip net and circling around below and between structures to capture stunned fishes initially out of range.

Results and Discussion

A total of 690 fish (63.11 fish/15min ef). representing 21 species were collected on the eight sampling runs (164 minutes total) [Table 1 and Table 2]. Emerald shiner. gizzard shad and flathead catfish exhibited the highest overall catch rates, followed by carp, freshwater drum and channel catfish (Table 2). Emerald shiner, channel catfish, flathead catfish and freshwater drum were collected at each sampling trip, carp and shorthead redhorse were collected on 7 of 8 trips (Table 3).

A notable species collected in this effort is the blue sucker. This big river species is uncommonly collected in the Mississippi River and is considered a species of special concern by state and federal natural resources agencies. The collection of a blue sucker on 4 of 8 sampling runs may indicate that these fishes are seeking the habitat conditions provided by these structures.

The length frequency distributions of the flathead and channel catfishes collected thus far indicate that both young of year and older individuals of these species are utilizing these structures. Length and weight data for channel catfish. flathead catfish and blue sucker are attached.

Conclusion

The data collected thus far in this evaluation suggest that multiple round point structures are providing useful and valuable habitat for a variety of riverine fishes. Collection of blue suckers may indicate these structures are providing a unique habitat type (riffle-like). once more common in the river.

Table 1. Sampling dates and electrofishing effort for Pool 25 Multiple Round Point Structures, 1998-2000.

Sampling date	Electrofishing effort (min)
18-Aug-99	22
15-Oct-98	15
07-Sep-99	20
22-Sep-99	30
23-May-2000	15
28-Aug-2000	20
26-Sep-2000	20
17-Oct-2000	22
Total	164

Table 2. Composition of fishes collected with A.C. electrofishing at Pool 25 Multiple Round Point Structures, 1998-2000 (164 total minutes ef).

Species	Number	No./15min ef
Gizzard shad	88	8.05
Mooneye	1	0.09
Carp	32	2.93
Spotfin shiner	9	0.82
Red shiner	3	0.27
Bullhead minnow	2	0.18
Emerald shiner	388	35.49
River shiner	2	0.18
Sand shiner	2	0.18
Channel shiner	13	1.19
Smallmouth buffalo	6	0.55
Blue sucker	9	0.82
Shorthead redhorse	15	1.37
Channel catfish	23	2.10
Flathead catfish	57	5.21
Stonecat	2	0.18
White bass	1	0.09
Green sunfish	7	0.64
Bluegill	1	0.09
Slenderhead darter	1	0.09
Freshwater drum	28	2.56
Total number	690	63.11
Total number species	21	

Table 3. Composition of fishes collected with A.C. electrofishing at Pool 25 Multiple Round Point Structures, 1998 - 2000.

Species	Aug 98	Oct 98	Sep 99	Sep 99	May 00	Aug 00	Sep 00	Oct 00	Total no.	Frequency of occurrence
sampling effort (min)	22	15	20	30	15	20	20	22	164	
Gizzard shad	22	30	[illegible]	5	17			13	88	6
Mooneye						1			1	1
Carp	3		5	12	3	6	1	2	32	7
Spotfin shiner					1	5	3		9	3
Red shiner			1			1		1	3	3
Bullhead minnow							1	1	2	2
Emerald shiner	41	8	31	1	1	87	55	164	388	8
River shiner								2	2	1
Sand shiner						1		1	2	2
Channel shiner				4	1	1	2	5	13	5
Smallmouth buffalo	2	2	2						6	3
Blue sucker	1	1	6	1					9	4
Shorthead redhorse	2	3	2	3		3	1	1	15	7
Channel catfish	5	3	3	3	4	3	1	1	23	8
Flathead catfish	14	5	13	5	2	11	4	3	57	8
Stonecat			1			1			2	2
White bass				1					1	1
Green sunfish			2			3		2	7	3
Bluegill			1						1	1
Slenderhead darter			1						1	1
Freshwater drum	2	3	4	1	1	3	12	2	28	8
Totals	92	55	73	36	30	125	80	198	690	8
Total no. spp	9	8	14	10	8	13	9	13	21	

MRPS length and weight data for selected fishes

Channel catfish

N	TL(mm)	WT(g)
1	67	
1	67	
1	81	
1	83	
1	87	
1	90	
1	98	10
1	99	
1	103	
1	110	15
1	300	195
1	317	305
1	356	360
1	385	460
1	388	455
1	400	510
1	421	600
1	426	575
1	447	855
1	494	1240
1	539	1225
1	555	1860
1	678	3200

Flathead catfish

N	TL(mm)	WT(g)
1	43	
1	54	
1	60	
1	75	
1	77	
1	85	
1	88	
1	90	
1	92	
1	96	
1	96	
1	96	10
1	107	10
1	110	20
1	113	20
1	125	20
1	125	30
1	160	50
1	165	50
1	175	55
1	178	56
1	178	50
1	181	60
1	182	70
1	182	60
1	183	65
1	186	70
1	190	90
1	191	50
1	193	70
1	196	85
1	201	75
1	201	90
1	202	80
1	204	95
1	206	65
1	210	120
1	214	100
1	216	95
1	222	130
1	227	125
1	230	155
1	231	125
1	231	105
1	259	170
1	266	220
1	266	180
1	282	250
1	285	240
1	297	255
1	310	300
1	315	330
1	315	325
1	352	440
1	353	525
1	399	675
1	420	775

Blue sucker

N	TL(mm)	WT(g)
1	150	
1	160	
1	500	1030
1	520	1240
1	527	1125
1	557	1775
1	615	2100
1	658	3300
1	664	2900

Appendix C.

Gosline Island Off-bankline Revetment Fisheries Evaluation Update – Illinois Department of Natural Resources

Gosline Island Off-bankline Revetment
Fisheries Evaluation Update

Prepared for:
U.S. Army Corps of Engineers
St.Louis District

Prepared by:
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Illinois Department of Natural Resources
Fisheries Division
Boundary Rivers Program

February 2001

Introduction

The Illinois Department of Natural Resources, Division of Fisheries, Boundary Rivers Program conducted fish sampling with A.C. electrofishing (EF) on the Gosline Island Off-bankline Revetment (OBR) between July 1991 and September 1995 to evaluate possible fisheries benefits of this type of structure. This report presents a brief overview of the results of the study.

Methods

The Gosline Island OBR is located between approximate Mississippi River miles 289.0 and 279.8 along the left descending bank of the navigaiton channel. In 1991 three electrofishing sampling stations were established for this evaluation: Gosline Inside Rock, Gosline Outside Rock and a main channel borbor (MCB) control site. Electrofishing runs at Gosline Inside Rock were made along the inside surface of the Gosline Island OBR (i.e. along the rock surface between the island and the OBR). Electrofishing runs at Gosline Outside Rock were made along the outside surface of the OBR. Electrofishing runs at the MCB control site were made along a conventional rock revetment, with rock similar in size to that at the OBR, located along the right descending bank between approximate river miles 277.0 and 276.0. In 1992 a station along the island's natural bankline inside the Gosline Island OBR was added and in 1994 a side channel border (SCB) control site along the Illinois shoreline opposite Gosline Island between approximate river miles 280.5 and 279.8. The dates of sampling and electrofishing effort for these sites are presented in Table 1.

The electrofishing unit used in this study consists of a 230 volt, 4000 watt, 3 phase A.C. generator which energizes 3 steel cable electrodes (5/8") suspended from 3 booms projecting off the bow of the boat (18' welded aluminum boat). The electrodes are approximately 5' apart, project about 6' off the bow and project into the water about 4' in depth, thus creating an electric field with an approximate diameter of 10' and reaching a depth of about 6'. Typically 6 - 10 amperes of current are generated within this field. The sampling is conducted by a two person crew, one stationed in the bow of the boat to dip stunned fish with a long handled dip net from the water and into a oxygenated live well, and one operating the motor. Typically, two EF runs were conducted at each station. Rough sketches of the study area and typical OBR sampling runs are attached.

After each EF run the fish are identified to species, weighed and measured, checked for abnormalities and disease, then returned live to the river. Fishes too small to identify in the field are preserved and returned to the lab for processing. Data are tabulated on standard field sheets and later entered into the Department's fisheries database (Fisheries Analysis System).

Results and Discussion

A total of 9685 fishes representing 48 species and 2 hybrids have been collected during 1889 minutes of electrofishing (76.91 fish/15 ef min). When these data are summarized by habitat type (MCB control, inside rock, inside natural, outside rock and SC Control) over all fish species and sampling periods (Table 2), the highest catch rate was observed along the natural bankline inside the OBR (97.94 fish/15 min EF), followed by inside rock (94.25 fish/15 min EF) and side channel border control (83.42 fish/15 min EF). The catch rate at outside rock (62.52 fish/15 min EF) was slightly higher than the catch rate at MCB control (52.90 fish/15 min EF). These data suggest that the habitat types created inside the OBR are holding more individual fishes and more fish species than either the habitat immediately outside the OBR or at the control sites. It should be noted, however, that the higher catch rates observed on the inside of the OBR may be the result of greater electrofishing efficiency in the shallow, confined conditions on the inside.

The number of species collected was also highest along the inside rocks (38 species) [Table 2], followed by inside natural (34 species) and outside rock (32 species). The number of species collected at the MCB and SC control sites was 25 and 27, respectively. When observed as a single habitat unit, with OBR habitats inside and outside viewed as an interacting, integrated whole, we notice that of the 48 species collected so far in this study, 47 are associated with the OBR.

The catch rates for gizzard shad, bullhead minnow, smallmouth buffalo, black crappie, white crappie and bluegill were higher inside OBR than elsewhere. The following species were collected only inside OBR: shortnose gar, bowfin, goldeye, northern pike, golden shiner, silverband shiner, sand shiner, blackstripe topminnow, mosquitofish and orangespotted sunfish. The catch rates for channel catfish, flathead catfish and smallmouth were highest on the outside rock of the OBR. River darter, logperch and fantail darter were collected only along the outside rock (Table 2).

Conclusion

The data collected thus far in this evaluation strongly suggest that off-bankline revetments are providing useful and valuable habitat for a variety of riverine fishes. The outside of the OBR provide excellent habitat for quality sized channel catfish, flathead catfish, common carp and a variety of minnows and shiners. From the species composition and the number of young of the year fishes present, the inside of OBR appear to be providing backwater type habitat (at appropriate water levels) in a reach of river where such habitat is limited.

Table 1. Sampling dates and electrofishing effort for Gosline Island Off-bankline Revetment study.

Station Name	Sampling date	E.F. effort (min)
Gosline Inside Rock	11-Jul-91	15
Gosline Inside Rock	5-Aug-91	15
Gosline Inside Rock	10-Sep-91	15
Gosline Inside Rock	15-Oct-91	15
Gosline Inside Rock	20-Nov-91	15
Gosline Inside Rock	11-Dec-91	15
Gosline Inside Rock	20-Apr-92	15
Gosline Inside Rock	12-May-92	15
Gosline Inside Rock	8-Jun-92	15
Gosline Inside Rock	21-Jul-92	15
Gosline Inside Rock	17-Aug-92	15
Gosline Inside Rock	23-Sep-92	15
Gosline Inside Rock	13-Oct-93	3
Gosline Inside Rock	13-Oct-93	15
Gosline Inside Rock	10-May-94	15
Gosline Inside Rock	10-May-94	30
Gosline Inside Rock	15-Jun-94	7.5
Gosline Inside Rock	6-Jul-94	10
Gosline Inside Rock	16-Aug-94	10
Gosline Inside Rock	14-Sep-94	15
Gosline Inside Rock	5-Oct-94	10
Gosline Inside Rock	6-Jul-95	10
Gosline Inside Rock	1-Aug-95	7.5
Gosline Inside Rock	11-Sep-95	5
Gosline Inside Rock	11-Sep-95	10
Gosline MC Control	11-Jul-91	15
Gosline MC Control	5-Aug-91	15
Gosline MC Control	10-Sep-91	15
Gosline MC Control	15-Oct-91	15
Gosline MC Control	20-Nov-91	15
Gosline MC Control	11-Dec-91	15
Gosline MC Control	8-Jun-92	15
Gosline MC Control	21-Jul-92	15
Gosline MC Control	17-Aug-92	15
Gosline MC Control	23-Sep-92	15
Gosline MC Control	13-Oct-93	3
Gosline MC Control	13-Oct-93	15
Gosline MC Control	15-Jun-94	7.5
Gosline MC Control	16-Aug-94	10
Gosline MC Control	14-Sep-94	15
Gosline MC Control	5-Oct-94	10
Gosline MC Control	6-Jul-95	10
Gosline MC Control	11-Sep-95	15
Gosline Outside	11-Jul-91	15
Gosline Outside	5-Aug-91	15
Gosline Outside	10-Sep-91	15
Gosline Outside	15-Oct-91	15
Gosline Outside	20-Nov-91	15
Gosline Outside	11-Dec-91	15
Gosline Outside	12-May-92	15
Gosline Outside	8-Jun-92	15
Gosline Outside	21-Jul-92	15
Gosline Outside	17-Aug-92	15
Gosline Outside	23-Sep-92	15
Gosline Outside	13-Oct-93	3
Gosline Outside	13-Oct-93	15
Gosline Outside	15-Jun-94	7.5
Gosline Outside	6-Jul-94	10
Gosline Outside	16-Aug-94	10
Gosline Outside	14-Sep-94	15
Gosline Outside	5-Oct-94	10
Gosline Outside	6-Jul-95	10
Gosline Outside	1-Aug-95	7.5
Gosline Outside	11-Sep-95	15
Gosline Inside Natural	20-Apr-92	15
Gosline Inside Natural	14-Oct-92	30
Gosline Inside Natural	12-Apr-94	20
Gosline Inside Natural	15-Jun-94	15
Gosline Inside Natural	6-Jul-94	10
Gosline Inside Natural	16-Aug-94	10
Gosline Inside Natural	14-Sep-94	15
Gosline Inside Natural	5-Oct-94	10
Gosline Inside Natural	6-Jul-95	10
Gosline Inside Natural	1-Aug-95	7.5
Gosline Inside Natural	11-Sep-95	15
Gosline SC Control	15-Jun-94	7.5
Gosline SC Control	6-Jul-94	10
Gosline SC Control	16-Aug-94	10
Gosline SC Control	14-Sep-94	15
Gosline SC Control	5-Oct-94	10
Gosline SC Control	6-Jul-95	10
Gosline SC Control	1-Aug-95	15
Gosline SC Control	11-Sep-95	15
Gosline Natural Control	12-Apr-94	20

Table 2. Composition of fishes collected with A.C. boat electrofishing @ Gosline Island OBR. (number of fish/15min sampling).

Species	WCS Control	Inside Rock	Inside Natural	Outside Rock	SC Control	Totals
Sampling effort (min)	408	593	270	488	130	1889
Shortnose gar		0.08	0.22			0.06
Bowfin			0.06			0.01
American eel	0.04			0.06		0.02
Gizzard shad	14.82	34.25	22.22	18.81	7.27	22.49
Goldeye		0.05				0.02
Mooneye	0.29	0.08				0.09
Northern pike			0.06			0.01
Goldfish		0.13	0.11		0.12	0.06
Carp	3.05	5.06	6.67	3.97	7.96	4.77
Carp x Goldfish hybrid	0.04					0.01
Golden shiner		0.05	0.06			0.02
Silver chub	0.33	0.05	0.06	0.28		0.17
Spotfin shiner	0.59	1.16	3.00	0.71	2.19	1.25
Red shiner		0.15	0.17	0.18	0.12	0.13
Emerald shiner	6.14	5.49	8.00	9.28	9.69	7.26
Silverband shiner		0.03				0.01
River shiner		0.13	0.39		0.12	0.10
Sand shiner		0.08				0.02
Channel shiner		0.03	0.11	0.09	0.12	0.06
Shiner species		0.05				0.02
Bullhead minnow	0.29	1.57	6.00	0.80	0.69	1.67
Bigmouth buffalo	0.11	0.18	0.67	0.06	0.23	0.21
Smallmouth buffalo	1.14	2.61	3.22	0.71	2.88	1.91
Black buffalo		0.18	0.39	0.03	0.23	0.13
Quillback		0.08	0.06		0.12	0.04
River carpsucker	0.11	1.47	0.33	0.28	2.54	0.78
Shorthead redhorse		0.18		0.12		0.09
Golden redhorse				0.03		0.01
Channel catfish	2.65	4.30	0.94	4.61	4.50	3.56
Flathead catfish	0.66	0.28	0.06	2.67	2.31	1.09
Blackstripe topminnow		0.08	0.17			0.05
Mosquitofish		0.18	0.83			0.17
Brook silverside	0.04	0.08	0.11	0.06		0.06
White bass	1.14	0.58	0.50	0.43	1.73	0.73
Yellow bass	0.04	0.10		0.03		0.05
Black crappie	0.22	1.42	6.44	0.09	0.92	1.50
White crappie	0.04	0.35	4.06	0.03	0.12	0.71
Largemouth bass	1.47	4.38	4.06	2.89	6.35	3.45
Smallmouth bass	0.11	0.10		0.28	0.12	0.13
Warmouth					0.12	0.01
Green sunfish	0.44	2.76	0.67	0.46	4.62	1.49
Bluegill	3.79	14.14	18.33	5.75	9.69	10.03
Orangespotted sunfish		0.18	1.06			0.21
Bluegill x Green sunfish hybrid		0.03		0.03	0.23	0.03
Walleye	0.04		0.39	0.03		0.07
Sauger	0.15	0.23	0.28		0.23	0.16
River darter				0.03		0.01
Slenderhead darter				0.03	0.46	0.04
Logperch				0.03		0.01
Fantail darter				0.03		0.01
Freshwater drum	15.18	11.99	8.28	9.62	17.77	11.93
Total	52.90	94.25	97.94	62.52	83.42	76.91
No. species	25	38	34	32	27	48

Table 3. Composition of fishes collected with A.C. boat electrofishing @ Gosline Island OBR. (total number collected)

Species	MCB Control	Inside Rock	Inside Natural	Outside Rock	SC Control	Totals
Sampling effort (min)	408	593	270	488	130	1889
Shortnose gar		3	4			7
Bowfin			1			1
American eel	1			2		3
Gizzard shad	403	1354	400	612	63	2832
Goldeye		2				2
Mooneye	8	3				11
Northern pike			1			1
Goldfish		5	2		1	8
Carp	83	200	120	129	69	601
Carp x Goldfish hybrid	1					1
Golden shiner		2	1			3
Silver chub	9	2	1	9		21
Spotfin shiner	16	46	54	23	19	158
Red shiner		6	3	6	1	16
Emerald shiner	167	217	144	302	84	914
Silverband shiner		1				1
River shiner		5	7		1	13
Sand shiner		3				3
Channel shiner		1	2	3	1	7
Shiner species		2				2
Bullhead minnow	8	62	108	26	6	210
Bigmouth buffalo	3	7	12	2	2	26
Smallmouth buffalo	31	103	58	23	25	240
Black buffalo		7	7	1	2	17
Quillback		3	1		1	5
River carpsucker	3	58	6	9	22	98
Shorthead redhorse		7		4		11
Golden redhorse				1		1
Channel catfish	72	170	17	150	39	448
Flathead catfish	18	11	1	87	20	137
Blackstripe topminnow		3	3			6
Mosquitofish		7	15			22
Brook silverside	1	3	2	2		8
White bass	31	23	9	14	15	92
Yellow bass	1	4		1		6
Black crappie	6	56	116	3	8	189
White crappie	1	14	73	1	1	90
Largemouth bass	40	173	73	94	55	435
Smallmouth bass	3	4		9	1	17
Warmouth					1	1
Green sunfish	12	109	12	15	40	188
Bluegill	103	559	330	187	84	1263
Orangespotted sunfish		7	19			26
Bluegill x Green sunfish hybrid		1		1	2	4
Walleye	1		7	1		9
Sauger	4	9	5		2	20
River darter				1		1
Slenderhead darter				1	4	5
Logperch				1		1
Fantail darter				1		1
Freshwater drum	413	474	149	313	154	1503
Total	1439	3726	1763	2034	723	9685
No. species	25	38	34	32	27	48

Appendix D.

Environmental Pool Management

Evaluation of Environmental Pool Management on Pool 25, Mississippi River. Southern Illinois University – Carbondale, Cooperative Wildlife Research Laboratory.

Fish and Water Quality Responses to Vegetation Produced via Environmental Pool Management Pool 25, Mississippi River. Southern Illinois University – Carbondale, Fisheries and Illinois Aquaculture Center and Department of Zoology

PROJECT FINAL REPORT TO:

U.S. ARMY CORPS OF ENGINEERS,
ST. LOUIS DISTRICT

STUDY TITLE:

Evaluation of Environmental Pool Management on Pool 25, Mississippi River

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Abstract: Since 1994, the U.S. Army Corps of Engineers (USACE) has been conducting a habitat enhancement program on Pool 25, Mississippi River to improve the quality and quantity of riverine-wetland habitat available to fish and waterfowl. Environmental Pool Management (EPM) promotes moist-soil plant growth by stabilizing water levels during the growing season to prevent vegetation from being inundated prior to becoming established. Although EPM is similar to moist-soil management, this wetland management technique has never been evaluated in a large, regulated river. We used plant and invertebrate community response, as well as waterfowl surveys and behavioral observations, to evaluate the utility of conducting moist-soil management in the Mississippi River to enhance habitat available to migrating waterfowl. Following stabilized water levels 1 m below full pool for 60 days in 1999, we characterized a plant community dominated by moist-soil plants. *Polygonum*, *Echinochloa*, and *Cyperus* occurred in >75% of sample plots. Most plant taxa were relatively well-distributed across the study area. Seed biomass production was estimated at 2,484 kg/ha. A paired-plot experiment, where vegetation growth was controlled in 1 plot, was conducted to quantify invertebrate diversity and density response to the presence of vegetation. Invertebrate diversity was significantly higher in vegetated plots than devegetated plots. Nektonic and benthic invertebrate density responded inconsistently among study sites. Spring waterfowl surveys were dominated by dabbling ducks (>94%), and most birds were observed in vegetated habitats (>98%). The most common species were mallards (*Anas platyrhynchos*) and northern pintails (*A. acuta*). Behavioral observations indicated dabbling ducks using vegetated habitat spent 25-57 % of their diurnal time-activity budget feeding. Mallards spent the least time feeding, 31%, whereas northern pintails spent the most time feeding, 45%. Based on short-term data, EPM has the same effectiveness for producing vegetated habitats beneficial to migrating waterfowl in a large, regulated river that moist-soil management has in traditional shallow impoundments. Results are based on one or two years of data: therefore, additional research and monitoring are recommended to ensure goals of EPM continue to be met over a broader range of hydrologic conditions. Finally, we suggest options for varying the implementation of EPM to improve long-term performance, encompass a more regional view, or consider a more diverse aquatic ecosystem.

INTRODUCTION

In 1994, the USACE and Missouri Department of Conservation (MDC) developed a water level management plan to enhance fish and wildlife habitat along the Upper Mississippi River by increasing wetland habitat quantity and quality while maintaining the navigation channel. The plan, called Environmental Pool Management (EPM), attempted to increase the production of aquatic macrophytes in Pools 24, 25, and 26 by stabilizing water levels 0.2-1.0 m below full pool to expose extensive areas of mudflats during the growing season. Pool levels were stabilized at lower levels ≥30 days to allow plant germination and growth then gradually (<6 cm/day) restored to full pool to prevent vegetation from being over-flooded. One specific goal of EPM was to improve habitat for migratory waterbirds, particularly waterfowl.

While many habitat restoration and enhancement projects profess benefits to migratory birds, few assessments of restoration include birds as a criterion. Evaluation studies assess the success of projects in meeting specific goals and provide information that may help fine-tune projects. Waterfowl can be a good indicator for evaluating restoration and enhancement projects because there is generally some historic data available for both local and continental populations (Toth and Anderson 1998). Additionally, the composition of a waterbird community can reflect the abundance of food resources within a floodplain (Kingsford and Porter 1994). An increase in aquatic vegetation can provide direct benefits to waterfowl by producing foods like seeds and tubers (Bellrose 1941) as well as indirect benefits by increasing aquatic macroinvertebrate populations (Kadlec 1962, Harris and Marshall 1963, Voigts 1976, Murkin et al. 1982, Murkin and Kadlec 1986).

Invertebrates are an essential component of all aquatic systems. They serve as an intermediate between primary producers and higher trophic levels and are an important food source for numerous aquatic-related vertebrates (Harris et al. 1995). Health of aquatic ecosystems is commonly gauged by the richness and abundance of invertebrates (Harris et al. 1995, Rosenberg and Resh 1992). As the fluctuating hydrograph of the historic river system stabilized following dam construction there was likely a shift in invertebrate taxa (Merritt and Cummins 1996); therefore, as system structure begins to change again, it is plausible that another associated shift in taxa could occur. Although it is commonly accepted that aquatic macroinvertebrate populations are influenced by the amount of vegetation in a wetland, very little is reported on invertebrate-vegetation dynamics in riverine systems with regulated flow.

Environmental Pool Management is based on sound wetland management principles; however, these principles have rarely been applied to pools of a large, regulated river. Initial investigations estimated EPM generated 320-400 ha of emergent vegetation at 10-100 stems/m² on mudflats exposed in Pool 25 between 1994-1996 (Wlosinski et al. unpublished data). Seven plant genera commonly recognized as waterfowl foods were the most common. However, macrophyte species composition in an impoundment will change over time (Fredrickson and Taylor 1982) resulting in fluctuations in types and amounts of direct and indirect benefits to wildlife. Therefore, it is important to determine if EPM continues to enhance growth of macrophyte species providing beneficial resources to migrating waterfowl. Furthermore, no evaluation of the food resources resulting from EPM has been conducted. Finally, no data have been collected to evaluate if migrating waterfowl are responding to EPM. The goal of this study was to evaluate the use of moist-soil management for improving habitat available to migrating waterfowl on Pool 25, Mississippi River.

OBJECTIVES

1. Characterize the plant community response to EPM and estimate seed biomass production.
2. Quantify the aquatic macroinvertebrate population response to increased vegetation produced by EPM.
3. Characterize the response of spring migrating waterfowl to habitat produced by EPM.

STUDY AREA

The study was conducted in the lower reach of Pool 25, a 32-mile stretch of the Mississippi River between Lock and Dam 25 (river mile 241.4) and Lock and Dam 24 (river mile 273.4, Fig. 1). Normal pool level is maintained at 434 ft National Geodetic Vertical Datum (NGVD) at Lock and Dam 25 by the USACE and minimum water surface elevation is 429.7 ft NGVD (Wlosinski 1996, Patrick 1998). Pool 25 contains a mosaic of habitats including bottomland forest, backwater lake, side channel, backwater, and cropland (U.S. Army Corps of Engineers 1996). Four hundred sixteen vertebrate species have been recorded in the floodplain habitat of Pools 24-26 (Terpening et al. 1975).

Specific study sites were located in the backwater slough at Jim Crow Island, the downstream, side-channel tip at Turner Island, and within the backwater lake of the Batchtown State Fish and Waterfowl Management Area, hereafter referred to as Batchtown. Earlier work indicated water drawdowns resulted in increased macrophyte abundance at all 3 sites (Wlosinski et al., unpublished data). All study sites are hunted for waterfowl through controlled drawing of established hunting blind sites (U.S. Army Corps of Engineers 1996).

METHODS

Plants

Community Response.--We characterized plant community response using 16 transects, oriented perpendicular to the shoreline. One transect was located at Jim Crow, 1 at Turner, and the remainder were in Batchtown. Along each transect, sample stations were located at elevations corresponding to 5, 20, 35, 50, and 75-cm below full pool. At each elevation, sample sites were located by gently tossing a 0.5-m^2 sampling frame on the ground. We recorded number of stems and percent cover for each species present inside the sampling frame. Samples were collected during 24-25 July and 13 August 1999, beginning approximately 3 weeks after pool level reached minimum water surface elevation. Nomenclature for plant species followed Mohlenbrock (1986).

We used frequency of occurrence and percent cover to describe changes in community structure along the elevation gradient (Daubenmire 1959). We used a Kruskal-Wallis nonparametric analysis of variance (ANOVA) to test for differences in percent cover related to elevation. When the ANOVA indicated differences occurred, we used a nonparametric Bonnferoni-type multiple comparison with unequal sample sizes to identify differences among means (Analytical Software 1996). Individual species of woody plants did not occur frequently enough for a species-specific analysis. However, because woody-species encroachment at higher elevations could be a concern for management, we combined eastern cottonwood (*Populus deltoides*), willow (*Salix* spp.), and silver maple (*Acer saccharinum*) into a single "woody species" category for analysis.

Seed Biomass.--We estimated seed biomass of *Polygonum lapathifolium*, *Cyperus erythrorhizos*, *Leptochloa panicoides*, *Leersia oryzoides*, *Echinochloa crusgalli*, and *E. muricata* at Jim Crow Island and Batchtown using techniques developed by Laubahn and Fredrickson (1992). This technique uses regression equations for these particular plant species or a group of 2 or 3 species, which is the case for *Echinochloa*, to estimate seed biomass from plant and seed head dimensions. Samples were collected on 3, 10, and 11 September 1999, beginning approximately 3 weeks after normal pool elevation was resumed and after the dominant species could be differentiated and had set seed. Data were collected from 252 25x25-cm plots located randomly along transects oriented perpendicular to the shoreline. Number of stems and seed heads were recorded for each plant species rooted within the sampling frame. A representative plant for each species within the sampling column was chosen for measuring seed head and plant dimensions. We measured the straightened height of the plant (m), height of the seed head (cm) along the rachis from the lowest rachilla to the top of the straightened seed head, and base diameter of the seed head (cm) along the lowest seed producing rachilla (Laubahn and Fredrickson 1992).

Invertebrates

We conducted an experiment to test if macroinvertebrate diversity and density was attributable to increased macrophyte production associated with EPM. We established 4 sets of paired-plots on the study area, 1 set each at Jim Crow and Turner and 2 sets at Batchtown (Fig. 1). Each plot was 400 m^2 and plots within each pair were spaced at least 10 m apart.

We collected nektonic and benthic samples during 3-4 October 1998 from 9 points within each plot at the Jim Crow and Turner sites. A drop in pool water level during 10-11 October 1998 (Fig. 2) and the onset of the 1998 waterfowl hunting season precluded us from collecting samples at the 2 Batchtown locations. Nektonic samples were collected by passing a D-frame sweep net 5 times through a vertical column of water, including the detritus layer overlaying the sediment, contained by a 40-cm diameter stovepipe sampler. Following each sweep, the contents of the net were rinsed with water into a U.S. Standard 30 mesh bucket sieve. All sweeps for 1 sample location were stored in a single plastic zipper-lock freezer bag and preserved with 80% ethyl alcohol until processed in the lab. One benthic sample was collected at each sampling point using a 196.35-cm^3 core sampler (Swanson 1983). Benthic samples were rinsed and stored by the same methods as nektonic samples.

In summer 1999, one plot from each pair was randomly assigned to remain vegetated (control) or to be devegetated (treatment). Treatment plots and a 3-5 m buffer around the plot were treated with Rodeo®, a commercial, non-persistent, aquatic herbicide, beginning 2 weeks after soils were exposed. Plots and buffer areas were treated every 2 weeks until water level returned to full pool. By preventing vegetation establishment within the devegetated plots we attempted to simulate substrate conditions prior to EPM (i.e. no management). Vegetated plots represented current habitat conditions. Nektonic and benthic invertebrate samples were collected at all 4 sites during 2 October 1999 following methods used during 1998.

In the lab, samples were stained with rose bengal for at least 24 hours to facilitate processing (Mason and Yevich 1967). Samples were drained of the alcohol, rinsed with water in a U.S. Standard 30 mesh sieve, then sorted under a magnifying lamp. Identification and taxonomic classification of macroinvertebrates followed Pennak (1989) and Merritt and Cummins (1996). Annelids were identified to class, Crustaceans to order or family, and Molluscs and Insects to family. This taxonomic resolution is generally adequate to determine trophic functional group (Cummins 1973) and the number of taxa identified was a crude indicator of species diversity.

Invertebrate diversity was calculated using the Shannon index of diversity (H'). Differences in invertebrate diversity was calculated for site-specific plot comparisons using a modified t-test (Zar 1996). For the Jim Crow and Turner sites, 3-factor ANOVA was used to test for a difference in the mean density of all invertebrate taxa, including site, year, and treatment as explanatory variables in the model. We tested for treatment effects at Jim Crow and Turner separately using 2-factor ANOVA with year and treatment as explanatory variables and the interaction term as an indicator response by invertebrates to the treatment. Because data were available for Batchtown only in 1999, these data were analyzed using a separate ANOVA that included site and treatment as explanatory variables. When ANOVA indicated differences occurred, we used Least Significant Difference multiple comparison to identify differences between specific means. When necessary, data were log(x + 1) transformed to meet assumptions of normality and stabilize variance. We predicted that if EPM caused an increase in macroinvertebrate diversity and density, devegetated plots would have significantly lower density and diversity than vegetated plots during 1999.

Waterfowl

We counted waterfowl during the 1999 and 2000 spring migration by conducting weekly ground surveys. All side channel and backwater areas south of Hausgen Island (Fig. 1) were surveyed beginning the last week in February and ending after the first week in April. Surveys were conducted from the bow of a boat except the slough on Jim Crow Island and the impounded areas of Turner Island, which were surveyed on foot. We recorded total number, species, and habitat (whether waterfowl were in vegetation or open water) for all species of ducks and geese observed during each survey.

For the 6 week survey period, we report the number of waterfowl-use days for dabbling ducks, diving ducks, and Canada geese (*Branta canadensis*). Waterfowl-use days were calculated by multiplying the mean waterfowl count of 2 consecutive surveys by the number of days between surveys then summing all means over the 6 week survey period. To test for guild-specific differences in waterfowl-use days between habitats, we used a two-tailed Mann-Whitney U-test with Normal Approximation and Continuity Correction.

Using aerial survey data provided by Illinois Natural History Survey (INHS), we compared waterfowl abundance during spring migration before vs. after implementation of EPM. Three years of data were available for spring migration before EPM (1992-94) and six years of data were used for post EPM (1995-2000). For each year, we summed all waterfowl recorded during the INHS spring survey period that typically began in mid February and ended mid to late April and tested for differences pre- vs. post-EPM using single factor ANOVA. We performed analyses on the most common taxa separately (mallards, northern pintails, northern shoveler [*Anas clypeata*], and American green-winged teal [*A. crecca carolinensis*]) as well as all dabblers combined, and mergansers. Because continental waterfowl populations also fluctuated during these years, we included breeding population estimates for each species or combination of species as a covariate in each analysis. Continental population estimates were from survey strata 20-50 of the spring breeding population survey (U.S. Fish and Wildlife Service 2000). We used estimates from the May following the spring surveys as this likely was the best estimate of population size during spring migration.

We conducted behavioral observations to construct time-activity budgets of waterfowl during spring migration. Observations were conducted between sunrise and sunset (Central Standard Time) from duck blinds located throughout the study area using a 20-60x spotting scope. Individuals were selected for observation by aiming the spotting scope at the center of a flock and selecting the bird in the center of the field of view. Focal individuals were observed for 15-30 minutes with behavior recorded at 10-sec intervals. If the original bird swam out of view, before the end of the 30-min session, the observation was adjusted to the nearest neighbor of the same species and sex as the focal-individual (Losito et al. 1989). Behavioral categories included: feeding, comfort (preening, drinking, wing flapping, head shaking), locomotion (swimming, flying), agonistic (chasing, biting), courtship (including copulation), loafing (inactive and resting), and alert. All data were dictated into a portable microcassette recorder then sequentially transcribed to data sheets.

We compared species-specific sex and year differences in time-activity budgets using a 2-tailed Mann-Whitney *U*-test with Normal Approximation and Continuity Correction. Differences in specific behaviors between species was tested using Kruskal-Wallis nonparametric ANOVA and a Bonnferoni-type nonparametric multiple comparison (Analytical Software 1996). All data are presented as non-transformed means (±1 SE) and results of statistical analyses were considered significant at $P < 0.05$.

RESULTS

Plants

Community Composition.–Fifteen genera of plants were recorded from all plots. *Polygonum*, *Echinochloa*, and *Cyperus* were the most common plant genera encountered, occurring in 93.2%, 79.5%, and 76.7% of plots, respectively (Table 1). Mean number of genera per plot did not vary with elevation ($F_{4,68} = 1.40$, $P = 0.244$). Mean stem density (stems/m^2) was highest for *Cyperus* and *Polygonum* (89.2 ± 20.8 stems/m^2 and 41.4 ± 5.8 stems/m^2, respectively; Table 2). Mean stem density of woody species was 1.9 ± 0.5 stems/m^2.

Mean percent cover was independent of elevation for all plants except *Polygonum* and *Ipomea purpurea* ($F_{4,68} = 2.650$, $P = 0.041$ and $F_{4,68} = 3.360$, $P = 0.014$, respectively; Table 3).

Percent cover of *Polygonum* was significantly lower at the 75-cm elevation than the 50-cm elevation ($Zcv = 2.81$, $P < 0.05$) but not at the other elevations. Although mean percent cover of *Ipomea purpurea* was significantly related to elevation, post hoc multiple comparison revealed no significant differences between specified elevations ($Zcv = 2.81$, $P > 0.05$), suggesting the overall result was not very strong.

Seed Biomass.--Seed biomass data was collected for 5 moist-soil plant groups (Table 4). Estimated mean seed biomass for all locations was 2.496 kg/ha and was comprised mainly of *Cyperus erythrorhizos* (1.223 kg/ha) and *Polygonum lapathifolium* (1.084 kg/ha). Total seed biomass production per ha was generally higher at Batchtown than at Jim Crow, as were genera-specific seed production; although *Leptochloa panicoides* had higher seed biomass production at Jim Crow than at Batchtown (Table 4).

Invertebrates

Diversity.--Sixty-one taxa were collected from nektonic and benthic samples during this study, 52 in 1998 and 37 in 1999 (Appendix A). The combination of species richness and abundance resulted in an overall Shannon diversity index value of $H_{max}' = 1.79$. Predators were the dominant trophic group, represented by 31 different taxa, followed by scavengers, 7 taxa: shredders, 6 taxa: collectors and filterers, 5 taxa each; scrapers, 4 taxa; and parasites and borers, 1 taxon each. During 1998, 44 different taxa were collected at Jim Crow and 39 different taxa were collected at Turner (Table 5): diversity did not differ between plots at either site ($t_{2, 2654} = 0.69$, $P = 0.494$ and $t_{2, 2595} = 1.88$, $P = 0.062$, respectively, Table 6).

Following vegetation control in 1999, 21 taxa were collected at Jim Crow, 18 at Turner, 22 at Batchtown West, and 26 at Batchtown East (Table 5). Ten taxa collected in 1998 were not collected in 1999, including 8 predator taxa and 2 collector taxa (Appendix A). Diversity of taxa was higher in the vegetated plots at Jim Crow ($t_{2,\ 127.1}$ = 4.96, P < 0.001), Turner ($t_{2,\ 48.7}$ = 4.49, P < 0.001), Batchtown West ($t_{2,\ 86.5}$ = 6.74, P < 0.001), and Batchtown East ($t_{2,\ 121.0}$ = 3.12, P < 0.002, Table 6). Predators and scavengers were the trophic group found less often in the devegetated plots.

Nektonic Macroinvertebrate Density.-- In 1998, prior to the devegetation experiment, mean invertebrate density in all vegetated plots (n = 4) was 11.0 ± 1.2 individuals/m^2. Density of invertebrates was higher at Jim Crow than Turner ($F_{1,36}$ = 14.41, P < 0.001), but invertebrate density in vegetated plots did not differ from plots scheduled to be devegetated for either Jim Crow ($F_{1,16}$ = 0.03, P = 0.857) or Turner ($F_{1,16}$ = 1.11, P = 0.307, Table 7). Oligochaeta was the most common taxa, 4.2 ± 0.8 individuals/m^2, followed by Physidae, 2.8 ± 0.4 individuals/m^2, and Corixidae, 1.3 ± 0.3 individuals/m^2.

Following vegetation control in 1999, mean invertebrate density in all vegetated plots (n = 4, including the 2 Batchtown sites) was 2.5 ± 0.3 individuals/m^2, lower than in 1998 ($F_{1,76}$ = 74.88, P < 0.001). Invertebrate density in vegetated plots did not differ between Jim Crow and Turner; however, invertebrate density at Batchtown West was significantly lower than Jim Crow, and invertebrate density at Batchtown East was significantly lower than all other sites ($F_{3,32}$ = 12.66, P < 0.001, Table 7). The most common taxa included oligochaetes, 0.6 ± 0.1 individuals/m^2, corixids 0.5 ± 0.1 individuals/m^2, and Chironomidae, 0.4 ± 0.1 individuals/m^2.

For Jim Crow and Turner, there was a significant site by year by treatment interaction ($F_{1,64}$ = 21.89, P < 0.001, Fig. 3), indicating there was not a consistent response by aquatic macroinvertebrates to vegetation removal. At Turner, the vegetated plot had higher invertebrate density than the devegetated plot ($F_{1,16} = 16.13$, $P = 0.001$), but invertebrate density was higher in the devegetated plot at Jim Crow ($F_{1,16} = 23.40$, $P < 0.001$, Fig. 3). We detected no difference in invertebrate density between treatment and control plots at either Batchtown West ($F_{1,16} = 3.65$, $P = 0.074$) or Batchtown East ($F_{1,16} = 2.45$, $P = 0.137$, Fig. 3) in 1999.

In an effort to understand the differences in invertebrate response to presence of vegetation, at each site we conducted taxon-specific analyses for the most common invertebrate taxa collected; oligochaetes, chironomids, and corixids. We did not detect a treatment effect for oligochaete or corixid density at either Turner ($F_{1,32} = 3.57$, $P = 0.068$ and $F_{1,32} = 1.34$, $P = 0.256$, respectively) or Jim Crow ($F_{1,32} = 0.77$, $P = 0.387$ and $F_{1,32} = 1.34$, $P = 0.255$, respectively). Density for both taxa did not differ significantly between plots at Batchtown West ($F_{1,16} = 0.14$, $P = 0.715$ and $F_{1,16} = 0.08$, $P = 0.779$, respectively), but corixid density was higher in the vegetated plot at Batchtown East ($F_{1,16} = 7.21$, $P < 0.016$) whereas oligochaete density was similar between plots ($F_{1,16} = 2.65$, $P = 0.123$, Table 8). There was no detectable treatment effect on chironomid density at Turner ($F_{1,32} = 3.19$, $P = 0.084$), but at Jim Crow chironomid density increased in the devegetated plot ($F_{1,32} = 55.41$, $P < 0.001$, Table 8) following vegetation removal. Chironomid density was similar between plots at Batchtown West ($F_{1,16} = 2.65$, $P = 0.123$), but higher in the devegetated plot at Batchtown East ($F_{1,16} = 13.97$, $P = 0.002$, Table 8).

Finally, we removed chironomids, oligochaetes, and corixids from the model to test for a treatment effect on the remaining invertebrate taxa and we detected no treatment effect at Jim Crow ($F_{1,32} = 0.40$, $P = 0.531$), but invertebrate density was lower in the devegetated plot at Turner ($F_{1,32} = 16.96$, $P < 0.001$, Table 8). Invertebrate density was greater in the vegetated plot at Batchtown West ($F_{1,16} = 20.62$, $P < 0.001$) but did not differ between plots at Batchtown East ($F_{1,16} = 0.21$, $P = 0.656$, Table 8).

Benthic Macroinvertebrate Density.--In 1998, mean benthic invertebrate density in all vegetated plots ($n = 4$) was 270.9 ± 43.6 individuals/m^2. In contrast to the nektonic samples, density of invertebrates was higher at Turner than Jim Crow ($F_{1,32} = 25.53$, $P < 0.001$). Invertebrate density in vegetated plots and plots assigned to be devegetated did not differ at either Jim Crow ($F_{1,16} = 2.21$, $P = 0.157$) or Turner ($F_{1,16} = 3.16$, $P = 0.094$, Table 7). Oligochaetes were most abundant (253.5 ± 43.9 individuals/m^2) followed by physids (9.6 ± 1.5 individuals/m^2).

In 1999, mean benthic invertebrate density for vegetated plots ($n = 4$) including the Batchtown sites was 72.7 ± 12.7 individuals/m^2, lower than in 1998 ($F_{1,70} = 37.83$, $P < 0.001$). Unlike the site-specific variation in the nektonic samples collected in 1999, benthic invertebrate density in vegetated plots did not differ between the 4 sites ($F_{3,32} = 0.40$, $P < 0.756$, Table 7). Abundant taxa included oligochaetes (63.3 ± 12.5 individuals/m^2) and physids (3.4 ± 1.1 individuals/m^2).

Following the devegetation experiment there was a significant site by year by treatment interaction ($F_{1,64} = 9.31$, $P < 0.003$, Fig. 4) for Jim Crow and Turner, suggesting there was not a consistent treatment effect among sites. Benthic invertebrate density did not differ between plots at Turner ($F_{1,16} = 0.11$, $P = 0.748$), but was higher in the devegetated plot at Jim Crow ($F_{1,16} = 11.49$, $P = 0.004$, Fig. 4). Separate analyses showed density did not differ between plots at either Batchtown West ($F_{1,16} = 0.77$, $P = 0.393$) or Batchtown East ($F_{1,16} = 0.97$, $P = 0.338$, Fig. 4).

Similar to the nektonic samples, we conducted taxon-specific analyses for the most common taxa. There was no detectable treatment effect for oligochaete or chironomid density at Turner ($F_{1,32}$ = 0.88, P = 0.354 and $F_{1,32}$ = 1.78, P = 0.192, respectively, Table 9), but density for both taxa increased in the devegetated plot Jim Crow ($F_{1,32}$ = 10.03, P = 0.003 and $F_{1,32}$ = 6.33, P = 0.017, respectively, Table 9). Density of oligochaetes and chironomids was similar between plots at Batchtown East ($F_{1,16}$ = 3.03, P = 0.101 and $F_{1,16}$ = 1.23, P = 0.284, respectively), whereas at Batchtown West density of oligochaetes did not differ between plots ($F_{1,16}$ = 0.64, P = 0.437), but chironomid density was higher in the devegetated plot ($F_{1,16}$ = 5.72, P = 0.030, Table 9). We did not detect a treatment effect for physid density at either Jim Crow ($F_{1,32}$ = 4.08, P = 0.052) or Turner ($F_{1,32}$ = 0.58, P = 0.453, Table 9) and density was similar between plots at both Batchtown West ($F_{1,16}$ = 0.00, P = 1.000) and Batchtown East ($F_{1,16}$ = 0.02, P = 0.896, Table 9). Finally, we removed these taxa from the model, but did not detect a significant treatment effect for the remaining taxa at both Jim Crow ($F_{1,32}$ = 0.02, P = 0.877) and Turner ($F_{1,32}$ = 1.53, P = 0.225). Benthic invertebrate density of the remaining taxa did not differ between plots at either Batchtown West ($F_{1,16}$ = 0.02, P = 0.889) or Batchtown East ($F_{1,16}$ = 2.99, P = 0.103, Table 9).

Waterfowl

Surveys.--Lower Pool 25 supported 227,182 and 185,870 duck use-days and 1,244 and 385 Canada goose use-days during the 6-week ground survey period in spring 1999 and 2000, respectively. Peak number of waterfowl surveyed (16,277) in 1999 occurred on 7 March (Fig. 5) and was dominated by mallards (7,980) and northern pintails (7,800). Peak Canada goose numbers was highest on 27 February (227, Fig. 6). During 2000, peak number of waterfowl (13,167) occurred on 4 March (Fig. 5) and was principally mallards (6,420), northern pintails

(3,584), and American green-winged teal (1,718). Peak number of Canada geese (21) occurred on 31 March (Fig. 6). During both years, surveys were dominated by dabbling ducks (Table 10). Species-specific abundance is summarized in Appendix B. After controlling for continental population size, we detected no difference in waterfowl abundance for any species or species group in the INHS aerial survey data (P's > 0.21, Table 11).

Dabbling ducks and Canada geese were more abundant in vegetated habitats ($Z = 3.32$, $P < 0.001$ and $Z = 1.99$, $P = 0.046$, respectively), while diving ducks were more common in open water habitats ($Z = 3.38$, $P < 0.001$, Table 10). During spring 1999, 94.0% of all ducks counted were in vegetated habitats; during spring 2000, ducks in vegetated habitats made up 89.3% of all ducks surveyed and were mainly dabbling ducks (99.2%). Dabbling ducks totaled 23.2% of all ducks surveyed in open water in 2000.

Behavior.--During 2 spring seasons, we observed American green-winged teal for 28.2 h, mallards for 55.2 h, and northern pintails for 37.2 h (Table 12). American green-winged teal showed no annual differences in time engaged in locomotion ($Z = 1.43$, $P = 0.154$), courtship ($Z = 0.20$, $P = 0.840$), or comfort ($Z = 0.95$, $P = 0.341$). Foraging effort was less during 1999 than 2000 ($Z = 3.19$, $P = 0.001$). Conversely, more time was spent loafing in 1999 than in 2000 ($Z = 2.36$, $P = 0.019$, Fig. 7). Female American green-winged teal spent more time feeding than males ($Z = 2.49$, $P = 0.013$), whereas males spent more time in comfort activities ($Z = 2.78$, $P = 0.005$, Table 12). Males also spent more time engaged in locomotion ($Z = 2.05$, $P = 0.041$) and aggressive encounters ($Z = 2.96$, $P = 0.007$). Neither mallards nor northern pintails differed in time activity budgets between years (Fig. 7). Proportion of time spent in each activity did not differ between sexes for either species (Table 12).

DISCUSSION

Plants

One of the goals of EPM was to increase the production of plant foods important for migratory waterfowl, using moist-soil management. While moist-soil vegetation dynamics are well documented in seasonally flooded, shallow impoundments (Fredrickson and Taylor 1982, Merendino 1989, Lane and Jensen 1999), this is one of the few quantitative assessments to document that moist-soil management has the same utility in a large, regulated river. We recorded 15 taxa of moist-soil plants, 10 more taxa than reported in a previous study (Wlosinski et al. unpublished data), including 3 genera of woody plant species and common cocklebur (*Xanthium strumarium*). Unlike Wlosinski et al., we did not record *Panicum* or *Setaria*. Percent occurrence was comparable between studies for most genera, except we encountered *Polygonum* twice as frequently (93.2%) and *Amaranthus* half as often (16.4%).

Species occurrence differences between our study and previous data (Wlosinski et al. unpublished data) may be due to several factors. First, Wlosinski et al. report data collected in Pools 24-26. Thus, although *Panicum* and *Setaria* occurred in 15 and 10% of their plots, respectively, they may not have been present within samples collected in Pool 25. Second, study sites within Pool 25 were not identical between studies. We did not sample vegetation at Stag Island (as reported by Wlosinski et al.), but sampled extensively (12 transects) throughout Batchtown. Third, the difference in number of taxa reported could be related to dewatering rate. Drawdowns in both 1995 and 1996 commenced following a 3-day dewatering, whereas drawdown commenced after a 13-day dewatering in 1999 (Fig. 8). Slower dewatering often leads to greater diversity, especially in mid to late growing season (Fredrickson and Taylor 1982, Lane and Jensen 1999). Fourth, perennial species commonly increase in an impoundment when it has been under moist-soil management for more than 4 years. The occurrence of woody species in our sample may indicate successional changes in the plant community since Wlosinski et al. collected data in 1996. Lastly, we sampled more plots across a greater elevational range; therefore, we had a greater probability of detecting relatively rare species.

Trees and perennial herbaceous plants occurred throughout the study area. It seems unlikely that trees would become established at the lower elevations, however, these species may survive at the higher sites. This is not necessarily detrimental because some herbaceous perennials can produce a large abundance of seeds readily consumed by waterfowl (Fredrickson and Taylor 1982) and leaf litter from trees can provide valuable nutrients for aquatic macroinvertebrates, which are food for fish and waterfowl. However, establishment of trees may cause a decline in early succession annuals through shading. Furthermore, trees may increase sediment deposition during high water flows, leading to increased siltation rates.

We failed to detect substantial differences in plant species composition with elevation in the pool. Uniformity in plant distribution may be a response to a fast dewatering event. Water levels in the pool went from full pool to 75 cm below full pool in 13 days; however, 60 cm of this drop occurred in 6 days (Fig. 8). Stands of similar vegetation are generally produced when water is removed from an area in a few days (Fredrickson and Taylor 1982, Lane and Jensen 1999). We did find that *Ipomea purpurea*, *Xanthium strumarium*, and *Amaranthus rudis* occurred more frequently at higher elevations (Table 1), but only *Ipomea purpurea* is considered a dry soil species. In general, soils dried considerably following dewatering in 1999. Water levels stabilized 60 cm below our lowest sample elevation in 1999, which permitted soils to dry enough to support *Bidens* spp., a moist-soil plant species that prefers drier soils, at our lowest sampling elevation.

Another explanation for uniform plant distribution, for at least *Polygonum*, *Echinochloa*, and *Cyperus*, is that we did not differentiate between species within these genera. Vegetation sampling occurred several weeks after germination, a period when identifying moist-soil plant species is difficult; therefore, a decision was made during data collection to identify plants to genus when speciation was not possible. Zonation may have occurred within a particular genus, but our data does not allow us to make that distinction.

An assumption of EPM was that increased moist-soil vegetation would result in a higher production of waterfowl food in the form of seeds. Data support this assumption; we estimated seed production in lower Pool 25 was 2,496 kg/ha during 1999. While intensively managed moist soil impoundments in the UMR can consistently produce 1,344 kg/ha of seeds (Reid et al. 1989), reported seed biomass estimates have ranged from 364 kg/ha in Louisiana (Davis et al. 1961) to 2,920 kg/ha in Missouri (Fredrickson and Taylor 1982). Of the taxa we sampled, *Cyperus erythrorhizos* had the highest overall seed biomass (1,223 kg/ha) which was higher than values reported by other studies. *Cyperus erythrorhizos* seed biomass was reported at 670 kg/ha in the Illinois River Valley, (Low and Bellrose 1944) and *Cyperus* seed biomass was reported as high as 900 kg/ha in southeast Missouri (Fredrickson and Taylor 1982); although, there was no distinction of a particular species. Our estimate of seed biomass estimate for *Polygonum lapathifolium* (1,084 kg/ha) was comparable to others (Low and Bellrose 1944, Fredrickson and Taylor 1982). *Echinochloa* spp. seed biomass (106.7 kg/ha) was considerably lower than estimates of 2,920 kg/ha reported for the Illinois River floodplain (Low and Bellrose 1944) or 1,550 kg/ha reported for southeast Missouri (Fredrickson and Taylor 1982).

We only estimated seed biomass and did not consider other edible plant parts, such as tubers. *Cyperus esculentus* is not considered an important seed producer, investing more energy in tuber production for reproduction (Kelley 1990). In fact, 85% of the belowground biomass of chufa can be tubers which can contribute 360 kg/ha of food (Kelley 1990). While this value is lower than some of our seed biomass estimates, a measure of tuber biomass produced by EPM would help provide a more accurate calculation of waterfowl carrying capacity.

The availability of plant foods is an important determinant of habitat quality on areas managed for migrating waterfowl (Bellrose and Crompton 1979). To provide a measure of the functional value of the seed produced, we converted our seed biomass estimates into waterfowl use days using the following equation from Reinecke et al. (1989):

{[Seed biomass (g/ha) · ME (kcal/g)]/DEE (kcal/day) = waterfowl use-day/ha}

where ME equals metabolizable energy of the food for waterfowl and DEE equals daily energy expenditure for a duck (Table 13). For example, *Echinochloa* has an ME value of 2.82 kcal/g for pintails (Table 13, Hoffman and Bookhout 1985), and the DEE for a pintail is 243 kcal/day (Prince 1979). Thus, the seed produced by *Echinochloa* on one hectare of Pool 25 (107 kg/ha) could support 1,242 PUD [(107,000 g/ha × 2.82 kcal/g)/243 kcal/day]. Multiplying this estimate by the estimated 320-400 ha of vegetation produced by EPM (Wlosinski et al. unpublished data) indicates that *Echinochloa* could support 397,440-496,800 PUD. However, such calculations over estimate carrying capacity because all seeds produced are not available to waterfowl. Some seeds are eaten by other birds, seeds may fall into deep water where they are not available to many species, drift away during flow events, or lose energy value due to deterioration following inundation. *Echinochloa* mass declines 43-57% after 90 days of inundation (Neely 1956). Even assuming substantial loss of seed biomass to these sources, biomass available to waterfowl was substantial.

Invertebrates

We documented significant between year differences in the aquatic macroinvertebrate community. Both invertebrate diversity and abundance were higher at Jim Crow and Turner during 1998 than 1999. Differences were not a result of the total number of days between reflooding and sampling. In fact, sample sites were flooded 5 days longer in 1999 than 1998. Differences may have been caused by differences in hydroperiod between years (Fig. 9). During 1998, the total number of days recorded below full pool was greater than 1999, but water level spikes occurred on several occasions, including one event in July when water levels exceeded full pool. Anecdotal reports suggest most of the vegetation that had established prior to this peak died (K. Dalrymple, Missouri Department of Conservation, personal communication). This high water event was followed by another period of drawdown and vegetation regrowth before water levels rose to full pool. In contrast, during 1999 water levels were relatively stable for 54 days during July and August. Aquatic macroinvertebrates vary considerably in their ability to survive dry conditions (Wiggins et al. 1980). The more frequent water level spikes in 1998 may have allowed invertebrates stranded in isolated pools to survive the drawdown and replenished soil moisture, thus increasing the length of time that drought resistant invertebrates were able to survive in the soil (M. Whiles, Southern Illinois University at Carbondale, personal communication). In contrast, the 54-day drawdown during the hottest months of the year (July -

August) in 1999 may have decreased the survivability of some taxa. Alternately, primary production (i.e. food for invertebrates) may have been higher in 1998 either due to favorable soil moisture levels caused by the "irrigation events" or the 2 germination events that occurred before and after the July high water event. Furthermore, the senescence of the first vegetative growth may have contributed a supply of detritus biomass earlier during reflood in 1998. This detritus input may have provided additional structure and food resources to aquatic macroinvertebrates, thereby allowing for a more rapid recolonization or quicker production.

Aquatic plant communities greatly influence invertebrate communities (Westlake 1975, Voigts 1976, Korschgen 1989). An assumption behind EPM was that increased vegetation would provide direct benefits to invertebrates in the form of food and cover (Atwood et al. 1996), which would benefit fish and birds that feed on invertebrates. Presumably these benefits would be measured as an increase in aquatic macroinvertebrate diversity and abundance. Although there was considerable annual variation in diversity and density, we found invertebrate diversity was higher in vegetated vs. devegetated plots at all sites sampled in 1999 (Table 6). The number of predator, shredder, and scavenger taxa seemed most influenced by the presence of vegetation. Most of the predators we collected in the vegetation are classified as climbers or clingers and those in devegetated areas are mostly swimmers (Merritt and Cummins 1996). Therefore, aquatic macroinvertebrate predator diversity appears to have increased when vegetation created suitable habitats for these taxa. Although trophic dynamics of invertebrates in floodplain systems has been largely unstudied (Smock 1999); presumably, predator taxa was influenced by prey base. However, at 3 of the 4 sites sampled in 1999, invertebrates were not more abundant in vegetated habitat. How the more diverse predator community could contribute to our failure to detect differences in invertebrate density between vegetated vs. devegetated plots is unclear.

In contrast to diversity, the relationship between invertebrate density and vegetation was inconsistent among our study sites. Our data suggest that EPM does not consistently result in increased macroinvertebrate abundance for waterfowl and fish during fall. Invertebrate abundance is influenced by a variety of abiotic and biotic factors. We initially thought the response by invertebrates to the presence of vegetation (signal) would be strong enough to overcome variability in other explanatory factors (noise). However, it is apparent that invertebrate community dynamics within Pool 25 are more complex and need further study before any definitive conclusions are reached. Some taxa would likely not respond to vegetation but rather components in the litter and soil. We did not quantify the amount, depth, or type of litter on the soil surface, therefore, we cannot speculate whether differences in litter occurred between plots. Additionally, litter-dependent taxa may have been influenced by detrital inputs associated with vegetation production occurring along plot periphery, and the results we obtained were effected by the size of the treatment plots. Finally, increases in predators (either fish or invertebrate predators) may have decreased prey species abundance in vegetated areas.

The taxonomic resolution we chose for invertebrate identification may have complicated our analyses for both nektonic and benthic samples. Wrubleski (1989) found chironomid distribution in vegetated versus devegetated areas was partitioned by subfamilies. Chironominae were more abundant in areas where aquatic macrophytes were removed than adjacent vegetated areas; Orthocladiinae were more abundant in vegetated areas and Tanypodinae demonstrated no difference between habitats. Had we used a finer taxonomic resolution it is possible we might have found taxa-specific responses. However, finer resolution would not have altered our conclusions about overall invertebrate abundance as a food source for waterfowl.

Waterfowl

The goal of EPM to increase macrophyte abundance was, in part, an attempt to increase the quality of river habitats for migrating waterfowl. By increasing the quality of foraging areas in Pool 25, waterfowl can more easily meet physiological and behavioral demands during migration, such as building endogenous reserves and pair formation (Fredrickson and Drobney 1979) and/or provide those resources for a larger population, which can lead to increased duckling recruitment on breeding areas. To meet nutritional demands during migration, waterfowl feed on plant foods such as seeds and tubers that are high in carbohydrates and more easily converted to fat and invertebrates that provides ample protein for individuals undergoing molt (Ricklefs 1974, Anderson and Low 1976, Murkin and Kadlec 1986, Korschgen 1989, Reid et al. 1989).

Our ground surveys during spring migration recorded >185,000 waterfowl use-days (Table 10), but analysis of pre- vs. post-EPM aerial survey data did not detect increased waterfowl populations during spring in years following implementation of EPM. This should not be viewed as evidence that waterfowl have not benefitted from EPM. First, many factors influence spring population size at a specific site, including many that act away from the site of interest. Second, spring/summer hydroperiod during 1992-2000 varied considerably. Constraints imposed by river flow meant that EPM was not implemented in a uniform manner during all years. Furthermore, hydroperiod during one pre-EPM year (1992) may have permitted moist soil plant growth, which may explain the large waterfowl numbers surveyed during spring of 1993 (Table 11). Given such strong interannual variability and limited years available for comparison, it is not surprising we could not detect differences in waterfowl abundance.

Because distribution of migratory birds is influenced by many factors, abundance is not always an adequate measure of habitat quality (Van Horne 1983), rather parameters that characterize the functional response of waterfowl may be more useful. On our study area, >94% of all waterfowl occurred in vegetated areas and >98% of these birds were dabbling ducks that spent from 25-57% of their diurnal time foraging (Fig. 7). Although we do not have diet data, the most common dabbling ducks in our surveys (mallard, pintail, and teal) feed extensively on the seeds of plants recorded during plant surveys. Foraging effort was consistent with data collected at other spring migration areas (Gruenhagen 1987, Smietanski 1994). These data suggest habitats created by EPM are providing quality habitat for waterfowl. However, it should be noted that dabbling ducks require shallow water for foraging, and vegetated areas closely correspond with shallow water areas. Thus, we can not unambiguously relate behavior to vegetation production. Behavioral data from shallow, open water habitats would considerably strengthen the link between vegetation production and waterfowl behavior.

CONCLUSIONS AND RECOMMENDATIONS

Our data confirm that EPM has produced a community of early successional, annual moist soil plants that has increased the production of seeds known to be important waterfowl foods. The presence of woody species at many sample locations suggests encroachment by woody perennials in higher sites in Pool 25 may result if EPM continues. If prevention of tree species establishment is desirable, the USACE may want to consider not using EPM in all years in all pools. Interspersing years of full pool and EPM may reduce germination of seeds or lower the survival of young trees. Our data do not indicate an increase in the aquatic macroinvertebrate food resource for waterfowl as a result of EPM, but additional research is necessary to confirm this result. However, invertebrates have inherent value and invertebrate communities are increasingly being used to evaluate the success of habitat restoration and enhancement and ecosystem health (Rosenberg and Resh 1992, Merritt et al. 1999, O'Malley 1999). Our data indicate invertebrate diversity was enhanced by EPM. Furthermore, plant production in shallow water areas may have more than site-specific benefits to the invertebrate community. Course and fine particulate organic matter created by decomposing vegetation and flushed from shallow water, vegetated areas will contribute to the overall energy budget of the river, potentially benefitting pelagic invertebrate taxa and species that prey upon them.

We did not detect an overall increase in waterfowl abundance after EPM. However, habitat selection by migratory birds like waterfowl is influenced by many biotic and abiotic factors; thus, efforts to establish a causal link between habitat management actions and population size can be difficult. Because of this, estimates of food availability become a surrogate and sometimes preferred measure of success. Based on this criteria, EPM substantially increased the quantity of moist-soil seed produced in Pool 25 for waterfowl.

As with any attempt at habitat enhancement or restoration, long-term monitoring is essential to ensure management goals continue to be met. Our evaluation is based on 1 year of data for plants, and 2 years of data for invertebrates and waterfowl, and therefore, may not reflect periodic fluctuations in these particular communities. Plant community composition will likely change as sedimentation slowly fills backwater areas, or if successional changes in community composition occur. Further invertebrate investigations should be conducted that include additional study sites and more of the annual cycle. Our conclusions are based on fall abundance: consequently, results may not be similar in spring or additional research may help identify mechanisms preventing invertebrate taxa from increasing. Studies of invertebrate biomass or production may provide additional insight into EPM's influence on the aquatic macroinvertebrate community (Benke et al 1984). We documented heavy use of vegetated areas by foraging ducks, additional research is needed to link this behavior specifically to vegetation production. Spring 2001 represents a unique opportunity to learn about vegetation-waterfowl dynamics and EPM. Water levels remained mostly at full pool during the 2000 growing season preventing plant establishment over large areas. Thus, unlike previous years, shallow water habitats devoid of vegetation are available for study. Comparison of bird distribution and behavior in 2001 with 1999 and 2000 could contribute valuable data towards understanding waterfowl response.

Finally, the USACE should investigate the feasability of varying the timing and duration of EPM. While we recognize that implementation of EPM is constrained by hydrologic factors largely outside of USACE control, the long term benefits of EPM will be maximized if EPM is not implemented in the same way every year. Such options should include the possibility of not implementing EPM in all years. If Pools 24-26 can be manipulated separately, these pools could be managed as a wetland complex, with the goal of providing all habitats somewhere within the complex each year, without having to provide them in every pool. Given the difficulty of controlling water levels, this may be logistically more feasible than trying to micromanage water levels in a single pool. Discussions should also consider the impacts of implementing EPM at different elevations. What are the impacts of holding water at 430 vs. 432 ft? How might a short duration rise in water levels affect plant growth. The answers to these questions will likely vary depending on the taxa considered. If more fine tuned water management is not feasible, we at least advocate continued investigations that take advantage of the naturally variable hydrodperiod. Such studies will provide critical information that can be used to confirm patterns identified in this study, provide a better understanding of how this variability effects the Pool 25 system, and suggest ways to use EPM that continues to benefit both waterfowl and other wetland dependent taxa.

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Table 1. Percent occurrence of plant taxa along an elevation gradient (cm) relative to full pool (434.0 ft. NGVD), on transects (n = 16) oriented perpendicular to the shoreline, in Pool 25, Mississippi River, during summer 1999.

Taxa	Elevation below full pool					Overall
	5	20	35	50	75	
Polygonum[a]	100.0	94.0	94.0	100.0	75.0	93.2
Echinochloa[b]	81.3	87.5	75.0	84.6	66.7	79.5
Cyperus[c]	75.0	62.5	81.3	92.3	75.0	76.7
Rorippa islandica	31.3	31.3	37.5	61.5	33.3	38.4
Woody plants[d]	25.0	18.8	18.8	38.5	33.3	26.0
Leptochloa panicoides	31.3	12.5	37.5	15.4	16.7	23.3
Lindernia dubia	18.8	12.5	12.5	38.5	41.7	23.3
Leersia oryzoides	25.0	25.0	18.8	15.4	16.7	20.6
Amaranthus rudis	37.5	12.5	12.5	15.4	0.0	16.4
Xanthium strumarium	18.8	18.8	12.5	0.0	0.0	11.0

Table 1. Continued.

Taxa	Elevation below full pool 5	20	35	50	75	Overall
Ipomea purpureo	25.0	6.3	0.0	0.0	0.0	6.9
Eragrostis hypnoides	0.0	0.0	6.3	7.7	8.3	4.1
Bidens spp.	6.3	6.3	0.0	0.0	8.3	4.1

[a]Includes *Polygonum lapathifolium* and *P. pennsylvanicum*

[b]Includes *Echinochloa crusgalli* and *E. muricata*

[c]Includes *Cyperus esculentus* and *C. erythrorhizos*

[d]Includes *Populus* spp., *Acer* spp., and *Salix* spp.

Table 2. Stem density [$\bar{x}$ stems/m^2 (SE)] of plant taxa along an elevation gradient (cm) relative to full pool (434.0 ft. NGVD), on transects (n = 16) oriented perpendicular to the shoreline in Pool 25, Mississippi River, during summer 1999.

	Elevation below full pool					
Taxa	5	20	35	50	75	Overall
Polygonum[a]	19.3 (3.5)	35.0 (7.5)	45.0 (10.4)	84.9 (23.9)	27.7 (7.2)	41.4 (5.8)
Echinochloa[b]	35.5 (12.3)	50.0 (13.0)	46.8 (14.0)	20.6 (7.8)	7.7 (2.9)	34.0 (5.4)
Cyperus[c]	23.8 (6.1)	71.5 (40.8)	127.3 (48.2)	158.8 (80.7)	74.0 (32.3)	89.2 (20.8)
Rorippa islandica	5.0 (3.0)	2.8 (1.3)	4.8 (2.8)	4.3 (1.2)	2.7 (1.7)	3.9 (1.0)
Woody plants[d]	2.0 (1.3)	1.5 (1.0)	1.0 (0.6)	3.1 (1.4)	2.0 (0.9)	1.9 (0.5)
Leptochloa panicoides	2.3 (1.0)	30.5 (30.0)	3.0 (1.3)	34.5 (32.2)	2.7 (2.3)	14.4 (8.7)
Lindernia dubia	7.0 (3.9)	6.5 (4.8)	3.5 (2.5)	4.0 (2.0)	14.0 (7.5)	6.7 (1.9)
Leersia oryzoides	2.8 (2.0)	2.8 (1.6)	1.5 (0.9)	2.8 (2.0)	1.3 (1.0)	2.2 (0.7)
Amaranthus rudis	2.8 (1.3)	3.3 (3.0)	0.5 (0.3)	1.5 (1.2)	0.0 (0.0)	1.7 (0.7)
Xanthium strumarium	1.3 (0.7)	1.0 (0.6)	0.8 (0.5)	0.0 (0.0)	0.0 (0.0)	0.7 (0.2)

Table 2. Continued.

	Elevation below full pool					
Taxa	5	20	35	50	75	Overall
Ipomea purpurea	1.5 (0.7)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.2)
Eragrostis hypnoides	0.0 (0.0)	0.0 (0.0)	1.5 (1.5)	0.6 (0.6)	1.0 (1.0)	0.6 (0.4)
Bidens spp.	0.3 (0.3)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.3 (0.3)	0.2 (0.1)

[a]Includes *Polygonum lapathifolium* and *P. pennsylvanicum*

[b]Includes *Echinochloa crusgalli* and *E. muricata*

[c]Includes *Cyperus esculentus* and *C. erythrorhizos*

[d]Includes *Populus* spp., *Acer* spp., and *Salix* spp.

Table 3. Percent cover [$\bar{x}$ % (SE)] and results of Kruskal-Wallis test (*H*) for differences in percent cover related to elevation, of plant taxa along an elevation gradient (cm) relative to full pool (434.0 ft. NGVD) in Pool 25, Mississippi River, during summer 1999. Transects ($n = 16$) were oriented perpendicular to the shoreline. Kruskal-Wallis statistics were considered significant when $P < 0.05$ and are identified with boldface type.

	Elevation below full pool							
Taxa	5	20	35	50	75	Overall	*H*	*P*
Ipomea purpurea	4.4 (2.1)	0.6 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.1 (0.5)	11.36	**0.023**
Polygonum[a]	15.0 (9.5)	17.8 (3.4)	23.8 (4.7)	26.2 (6.2)	8.8 (2.1)	18.5 (1.9)	10.99	**0.027**
Echinochloa[b]	22.8 (6.5)	23.8 (5.7)	18.8 (4.4)	15.0 (6.7)	6.3 (2.1)	18.0 (2.5)	7.56	0.109
Cyperus[c]	12.2 (3.5)	20.0 (8.0)	22.2 (6.6)	16.5 (5.9)	15.4 (7.2)	17.4 (2.8)	2.20	0.698
Leptochloa panicoides	3.4 (1.7)	6.3 (5.6)	5.0 (2.2)	8.5 (6.4)	1.3 (0.9)	4.9 (1.8)	3.32	0.506
Rorippa islandica	2.5 (1.3)	1.6 (0.6)	1.8 (0.6)	3.1 (0.7)	1.7 (0.7)	2.1 (0.4)	3.40	0.494
Woody plants[d]	0.9 (0.5)	0.9 (0.5)	0.9 (0.5)	1.9 (0.7)	1.3 (0.7)	1.2 (0.2)	2.22	0.696
Lindernia dubia	2.8 (1.8)	2.2 (1.9)	1.6 (1.3)	1.9 (0.7)	2.1 (0.7)	2.1 (0.6)	4.69	0.320
Amaranthus rudis	5.3 (2.4)	1.6 (1.3)	0.9 (0.7)	1.9 (1.3)	0.0 (0.0)	2.1 (0.7)	7.89	0.096

Table 3. Continued.

	Elevation below full pool							
Taxa	5	20	35	50	75	Overall	*H*	*P*
Leersia oryzoides	1.6 (0.8)	1.6 (0.8)	0.9 (0.5)	0.8 (0.5)	0.8 (0.6)	1.2 (0.3)	0.92	0.922
Xanthium strumarium	1.9 (1.1)	1.6 (0.9)	0.6 (0.4)	0.0 (0.0)	0.0 (0.0)	0.9 (0.3)	5.17	0.271
Eragrostis hypnoides	0.0 (0.0)	0.0 (0.0)	1.9 (1.9)	0.4 (0.4)	0.4 (0.4)	0.5 (0.4)	2.47	0.651
Bidens spp.	0.3 (0.3)	0.3 (0.3)	0.0 (0.0)	0.0 (0.0)	0.8 (0.8)	0.3 (0.2)	2.16	0.707

[a]Includes *Polygonum lapathifolium* and *P. pensylvanicum*

[b]Includes *Echinochloa crusgalli* and *E. muricata*

[c]Includes *Cyperus esculentus* and *C. erythrorhizos*

[d]Includes *Populus* spp., *Acer* spp., and *Salix* spp.

Table 4. Estimated seed biomass ($\bar{x} \pm SE$) produced by moist-soil plant groups measured at Batchtown, Jim Crow, and both locations combined in Pool 25, Mississippi River, during summer 1999. Seed biomass estimates were calculated using regression equations[a] developed by Laubhan and Fredrickson (1992).

	Batchtown			Jim Crow			Sites Combined		
Taxa	*n*	kg/ha	SE	*n*	kg/ha	SE	*n*	kg/ha	SE
Echinochloa[b]	232	114.3	21.0	20	18.5	18.5	252	106.7	19.4
Leersia oryzoides[c]	232	12.1	4.8	20	0.0	0.0	252	11.1	4.4
Cyperus erythrorhizos[d]	232	1,263.8	133.0	20	746.6	420.9	252	1,222.7	127.0
Leptochloa panicoides[e]	232	3.6	2.6	20	820.2	224.0	252	71.4	23.2
Polygonum lapathifolium[f]	232	1,148.4	65.9	20	293.0	82.5	252	1,083.7	62.9
Total		2,542.2			1,878.3				2,495.6

[a] Variables in regression equations: HT = plant height (m); HEADS = number of seed heads in sample frame; HL = height of representative seed head (cm); HD = diameter of representative seed head (cm)

[b] (HT x 3.67855) + (0.000696 x ((HEADS) x (π(HD/2)²(HL))))

[c] (0.2814 x HEADS)

[d] (3.08247 x HEADS) + (2.38866 x HD) - (3.40976 x HL)

[e] (1.4132 x HT) + (0.00208 x ((HEADS) x (1.33π(HD/2)²/2)))

[f] (0.10673 x HEADS)

Table 5. Number of invertebrate taxa per trophic guild collected from nektonic and benthic samples at Jim Crow Island (JC) and Turner Island (TURN) during October 1998 and Jim Crow Island, Turner Island, Batchtown West (BTW), and Batchtown East (BTE) during October 1999 in Pool 25, Mississippi River. Nematoda, Ceratopogonidae, and Chironomidae are represented in both Predator and Collector guilds, however, they were counted only once for column total number of taxa collected.

	1998			1999				
	JC	TURN	Total	JC	TURN	BTW	BTE	Total
Guild								
Predator	24	23	30	9	9	13	12	19
Collector	6	5	6	3	3	3	3	3
Filterer	2	1	2	1	1	5	5	5
Scraper	4	3	4	2	1	1	3	3
Shredder	5	4	6	3	0	2	2	3
Parasite	0	0	0	0	1	0	0	1
Scavenger	5	5	6	4	4	3	3	6
Borer	1	1	1	1	1	0	1	1
Total	44	39	55	21	18	22	26	41

Table 6. Number of taxa per trophic guild, total number of taxa, Shannon diversity index (H'), and proportion of maximum diversity (J')[a] of invertebrates collected from nektonic and benthic samples, in vegetated (Veg) and devegetated plots (Deveg), at Jim Crow Island and Turner Island during October 1998 and Jim Crow Island, Turner Island, and 2 sites at Batchtown (BT West and BT East), Pool 25, Mississippi River, October 1999. During 1998, vegetation was present in devegetated plots, but were controlled for vegetation growth during 1999. Nematoda, Ceratopogonidae, and Chironomidae are represented in both Predator and Collector guilds, however, they are considered only once for total number of taxa collected.

	1998				1999							
	Jim Crow		Turner		Jim Crow		Turner		BT West		BT East	
	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg
Guild												
Predator	18	19	20	17	9	5	8	4	11	5	9	3
Collector	6	4	5	2	3	3	3	2	3	3	2	3
Filterer	2	1	1	1	1	0	0	1	3	2	2	4
Scraper	4	3	3	3	2	2	1	1	1	1	2	2
Shredder	3	4	3	3	2	1	0	0	2	0	2	0
Parasite	0	0	0	0	0	0	0	1	0	0	0	0
Scavenger	5	3	4	4	4	1	1	1	2	0	3	1
Borer	1	1	1	0	1	0	1	0	0	0	1	0

Table 6. Continued

	1998				1999							
	Jim Crow		Turner		Jim Crow		Turner		BT West		BT East	
	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg
No. Taxa												
Nektonic	35	31	34	27	20	10	16	8	18	6	20	11
Benthic	7	5	7	6	4	4	4	3	6	5	6	5
Total	35	31	34	27	19	10	16	8	18	9	19	11
H'	1.39	1.36	1.40	1.33	1.16	0.92	1.04	0.70	1.08	0.62	1.12	0.93
J' [a]	0.78	0.76	0.78	0.74	0.65	0.52	0.59	0.40	0.61	0.35	0.62	0.52

[a] $J' = H'/H'_{max}$, where H'_{max} (maximum diversity) = 1.78

Table 7. Mean density [individuals/m^2 (SE)] and Least Significant Difference multiple comparison grouping[a] of invertebrates collected from nektonic and benthic samples, in vegetated (Veg) and devegetated plots (Deveg), at Jim Crow Island and Turner Island during October 1998 and Jim Crow Island, Turner Island, and 2 sites at Batchtown (BT West and BT East), Pool 25, Mississippi River during October 1999.

		Jim Crow		Turner		BT West		BT East	
Year		Veg	Deveg[b]	Veg	Deveg	Veg	Deveg	Veg	Deveg
1998									
	Nektonic	14.9 (2.8)A	14.1 (2.0)A	6.2 (1.4)B	8.7 (2.0)B				
	Benthic	34.4 (9.5)B	21.3 (8.1)B	56.2 (6.6)A	100.9 (25.0)A				
1999									
	Nektonic	3.9 (0.6)A	17.0 (3.4)A	3.1 (0.4)AB	1.2 (0.3)B	2.3 (0.9)B	0.9 (0.5)B	0.7 (0.1)C	1.2 (0.3)B
	Benthic	9.6 (2.2)A	41.1 (10.1)A	18.8 (8.1)A	13.8 (2.5)AB	11.6 (2.9)A	21.4 (4.8)B	17.2 (4.6)A	10.6 (2.6)B

[a] Comparisons are between similar plot categories within a sample type, means with same letter are similar; P 0.05

[b] During 1998, vegetation was present in devegetated plots but vegetation growth was controlled during 1999

Table 8. Mean density (individuals/m^2 ± 1 SE) of select invertebrate taxa collected in nektonic samples in vegetated (Veg) and devegetated (Deveg) plots at sites located in Pool 25, Mississippi River during October 1998 and 1999. Standard Error is listed in parentheses below density. Significantly higher mean density (P < 0.05) than the comparison plot at the same site is noted in boldface type.

	1998				1999							
	Jim Crow		Turner		Jim Crow		Turner		BT West		BT East	
Taxon	Veg	Deveg[a]	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg
Oligochaeta	4.7 (2.2)	7.9 (1.5)	1.9 (1.8)	2.5 (2.4)	0.8 (0.2)	4.2 (0.9)	0.8 (0.2)	0.3 (0.1)	0.9 (0.5)	0.6 (0.3)	0.1 (0.1)*	0.6 (0.3)
Chironomidae	0.2 (0.1)*	0.1 (0.1)*	0.7 (0.3)	0.3 (0.1)	1.0 (0.2)	8.9 (1.6)	0.4 (0.2)	0.8 (0.3)	0.1 (0.1)*	0.2 (0.1)	0.1 (0.1)*	0.3 (0.1)*
Corixidae	0.7 (0.3)	1.5 (0.5)	1.9 (0.7)	1.0 (0.4)	0.5 (0.4)	3.4 (1.6)	1.3 (0.2)	0.2 (0.1)	0.1 (0.1)*	0.1 (0.1)*	0.3 (0.1)*	0.1 (0.1)*
Remaining Taxa	4.6 (1.4)	1.3 (0.2)	1.4 (0.3)	2.5 (0.7)	1.4 (0.5)	0.3 (0.1)	0.5 (0.1)	0.1* (0.1)*	1.4 (0.4)	0.1* (0.1)*	0.2 (0.1)	0.1 (0.1)*

* Denotes values < 0.01.

[a] Devegetated plots in 1998 had vegetation present but were controlled for vegetation growth in 1999.

Table 9. Density ($\bar{x}$ individuals/m^2 ± 1 SE) of select invertebrate taxa collected in benthic samples in vegetated (Veg) and devegetated (Deveg) plots at sites located in Pool 25, Mississippi River during October 1998 and 1999. Standard Error is listed in parentheses below density. Significantly higher mean density (P < 0.05) than the comparison plot at the same site is noted in boldface type.

	1998				1999							
	Jim Crow		Turner		Jim Crow		Turner		BT West		BT East	
Taxon	Veg	Deveg[a]	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg	Veg	Deveg
Oligochaeta	152.7 (45.6)	97.3 (41.6)	267.5 (37.8)	496.6 (129.5)	40.2 (8.5)	**192.3** **(50.4)**	88.2 (41.9)	56.6 (12.0)	55.4 (15.2)	96.1 (23.5)	69.6 (22.7)	19.8 (5.1)
Chironomidae	2.3 (1.5)	0.0 (0.0)	6.2 (3.8)	5.7 (2.2)	6.2 (2.9)	12.4 (3.3)	4.5 (2.9)	11.9 (2.9)	0.6 (0.6)	6.8 (2.8)	0.6 (0.6)	1.7 (0.8)
Physidae	15.3 (3.7)	8.5 (2.2)	8.5 (3.1)	6.2 (2.4)	1.1 (0.7)	4.0 (1.4)	0.6 (0.6)	1.7 (1.2)	0.6 (0.6)	0.6 (0.6)	11.3 (3.1)	13.6 (5.2)
Remaining Taxa	4.0 (2.2)	2.8 (1.2)	2.8 (1.2)	4.5 (1.8)	0.1* (0.1)*	0.6 (0.6)	0.1* (0.1)*	0.1* (0.1)*	2.3 (0.9)	3.6 (2.8)	5.6 (1.8)	18.7 (5.4)

* Denotes values < 0.01.

[a] Devegetated plots in 1998 had vegetation present but were controlled for vegetation growth in 1999

Table 10. Waterfowl-use days and their relative distribution (%) between vegetated and open water habitats for guilds of waterfowl (dabblers, divers, geese) surveyed weekly ($n = 6$) in the lower reach of Pool 25, Mississippi River, during late February through early April 1999 and 2000.

		Year	
Guild	Habitat	1999	2000
Dabbler	Vegetation	213,226 (98)	166,540 (99)
	Water	4,045 (2)	1,902 (1)
	Total	217,271	168,442
Diver	Vegetation	479 (5)	31 (1)
	Water	9,433 (95)	2,725 (99)
	Total	9,912	2,756
Geese	Vegetation	986 (79)	266 (69)
	Water	258 (21)	119 (31)
	Total	1,244	385
All Guilds	Vegetation	214,691 (94)	166,837 (97)
	Water	13,736 (6)	4,746 (3)
	Total	228,427	171,583

Table 11. Pre and post Environmental Pool Management annual spring waterfowl aerial survey data for Batchtown Pool and Turner Island collected by Illinois Natural History Survey

Year	EPM	MALL[a]	NOPI	AGWT	GADW	NSHO	LESC	CMER	DABBS[b]	DIVES[c]	TOTAL[d]
1992	pre	540	0	0	0	0	1,175	0	540	1,175	1,715
1993	pre	12,150	3,700	0	1,000	0	1,000	3,840	16,850	2,650	19,500
1994	pre	2,440	0	1,700	0	100	2,700	1,620	4,240	2,900	7,140
1995	post	13,470	0	0	0	100	0	1,300	13,670	0	13,670
1996	post	615	50	50	0	0	300	50	815	500	1,315
1997	post	970	50	70	300	75	550	500	1,465	820	2,285
1998	post	3,015	1,420	100	210	640	0	140	5,410	0	5,410
1999	post	20,910	25,400	200	0	255	300	0	47,265	300	47,565
2000	post	11,120	4,500	1,800	200	770	4,500	100	18,790	4,600	23,390

[a]Waterfowl species codes are: MALL = mallard, NOPI = northern pintail; AGWT = American green-winged teal; GADW = gadwall, NSHO = northern shoveler, LESC = lesser scaup; CMER = common merganser; DABBS = all dabbling duck species; DIVES = all diving duck species (not including mergansers); TOTAL = all waterfowl species.

[b]Includes data for some dabbling duck species not presented in this table.

[c]Includes data for some diving duck species not presented in this table.

[d]TOTAL = (DABBS + DIVES), therefore TOTAL includes data for some waterfowl species not presented in this table.

48

Table 12. Diurnal behavior [Mean % (SE)] and total hours observed of female and male American green-winged teal (AGWT), mallards (MALL), and northern pintails (NOPI) in moist-soil vegetated habitats in lower Pool 25, Mississippi River, during spring 1999 and spring 2000. Significantly higher proportion ($P < 0.05$) for between sex comparisons within species is noted in boldface type.

	AGWT		MALL		NOPI	
	f	m	f	m	f	m
Behavior						
Feed	**59 (7)**	37 (6)	27 (6)	33 (4)	52 (7)	40 (5)
Loaf	22 (7)	29 (6)	47 (6)	43 (4)	29 (6)	31 (4)
Comfort	5 (2)	10 (2)	8 (2)	9 (1)	5 (1)	11 (2)
Locomotion	11 (3)	**18 (2)**	14 (3)	11 (1)	9 (2)	13 (2)
Aggression	1* (1*)	2 (1*)	1* (1*)	1* (1*)	1* (1*)	1* (1*)
Courtship	1* (1*)	2 (1)	1 (1*)	1* (1*)	1 (1*)	2 (1*)
Hours Observed	11.5	16.7	18.4	36.8	12.8	24.4

* Denotes values <1.0.

Table 13. Estimated seed biomass (kg/ha) of selected moist-soil plants, metabolizable energy (ME kcal/g) of mallards and pintails (Hoffman and Bookhout 1985), total metabolizable energy (ToME kcal/ha) available to mallards and pintails, and calculated waterfowl-use days (WUD) produced via EPM in Pool 25, Mississippi River, during summer 1999.

Species	Seed biomass	ME	ToME[a]	WUD[b]
Polygonum lapathifolium	1,084			
Mallard[c]		1.08	1,170,720	4,037
Pintail[d]		1.25	1,355,000	5,576
Echinochloa[e]	107			
Mallard		2.86	306,020	1,055
Pintail		2.82	301,740	1,242
Leersia oryzoides	11			
Mallard		3.00	33,000	114
Pintail		2.82	31,020	128

[a] ToME = (Seed Biomass x ME)

[b] WUD = (ToME)/Daily energy expenditure (DEE) of waterfowl (Reineke et al 1989)

[c] DEE = 290 kcal/day (Prince 1979, Hoffman and Bookhout 1985)

[d] DEE = 243 kcal/day (Prince 1979, Hoffman and Bookhout 1985)

[e] Includes *Echinochloa crusgalli* and *E. muricata*

Figure 1. Map of lower Pool 25, Mississippi River. Study sites for invertebrate sampling were located at Jim Crow Island, Turner Island, and 2 sites (Batchtown West and Batchtown East) located within the Batchtown State Fish and Waterfowl Management Area.

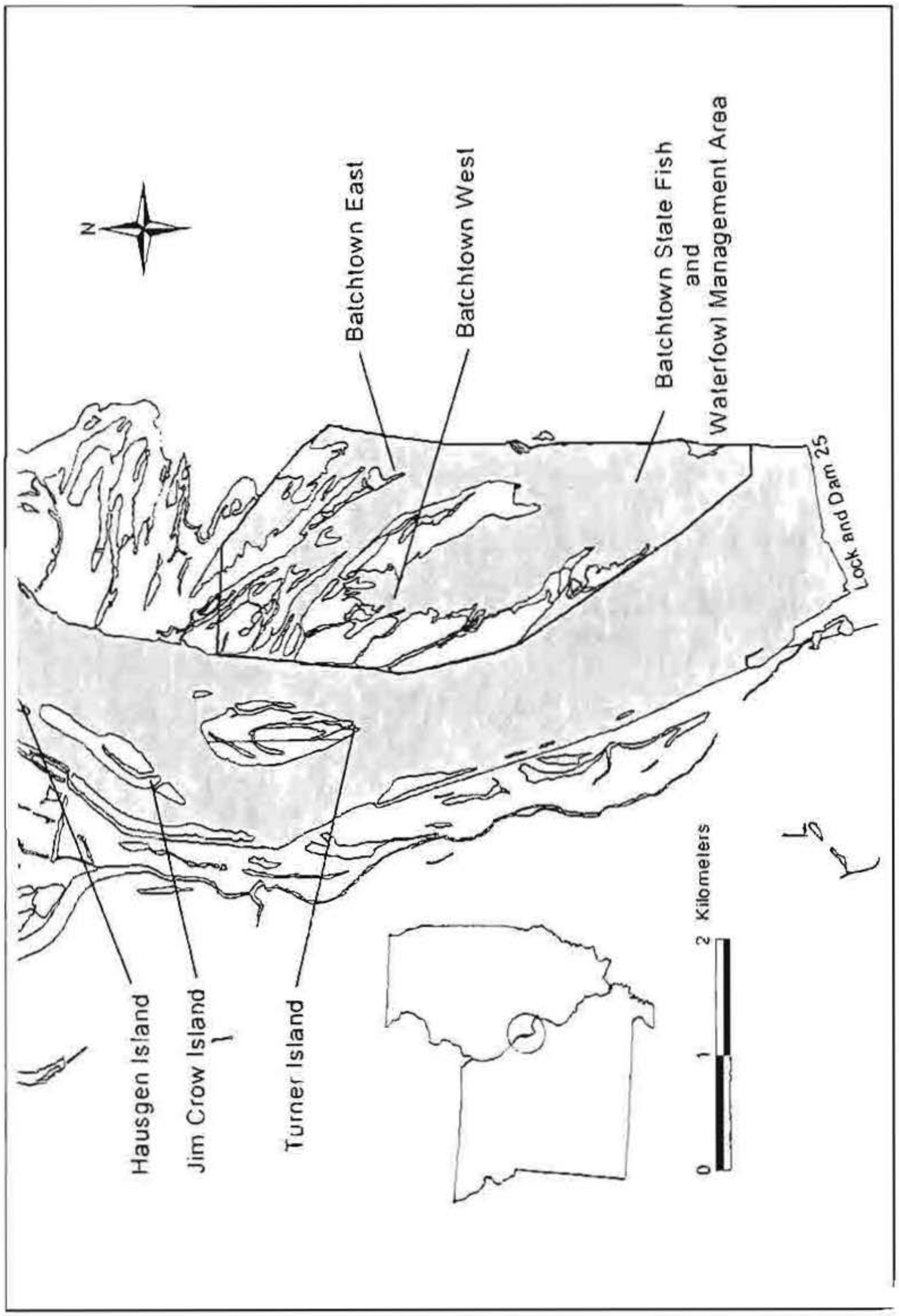

N
Batchtown East
Batchtown West
Batchtown State Fish
and
Waterfowl Management Area
Lock and Dam 25
Hausgen Island
Jim Crow Island
Turner Island
0
1
2 Kilometers

Figure 2. Water levels recorded at Lock and Dam 25 between 15 September - 15 October 1998.

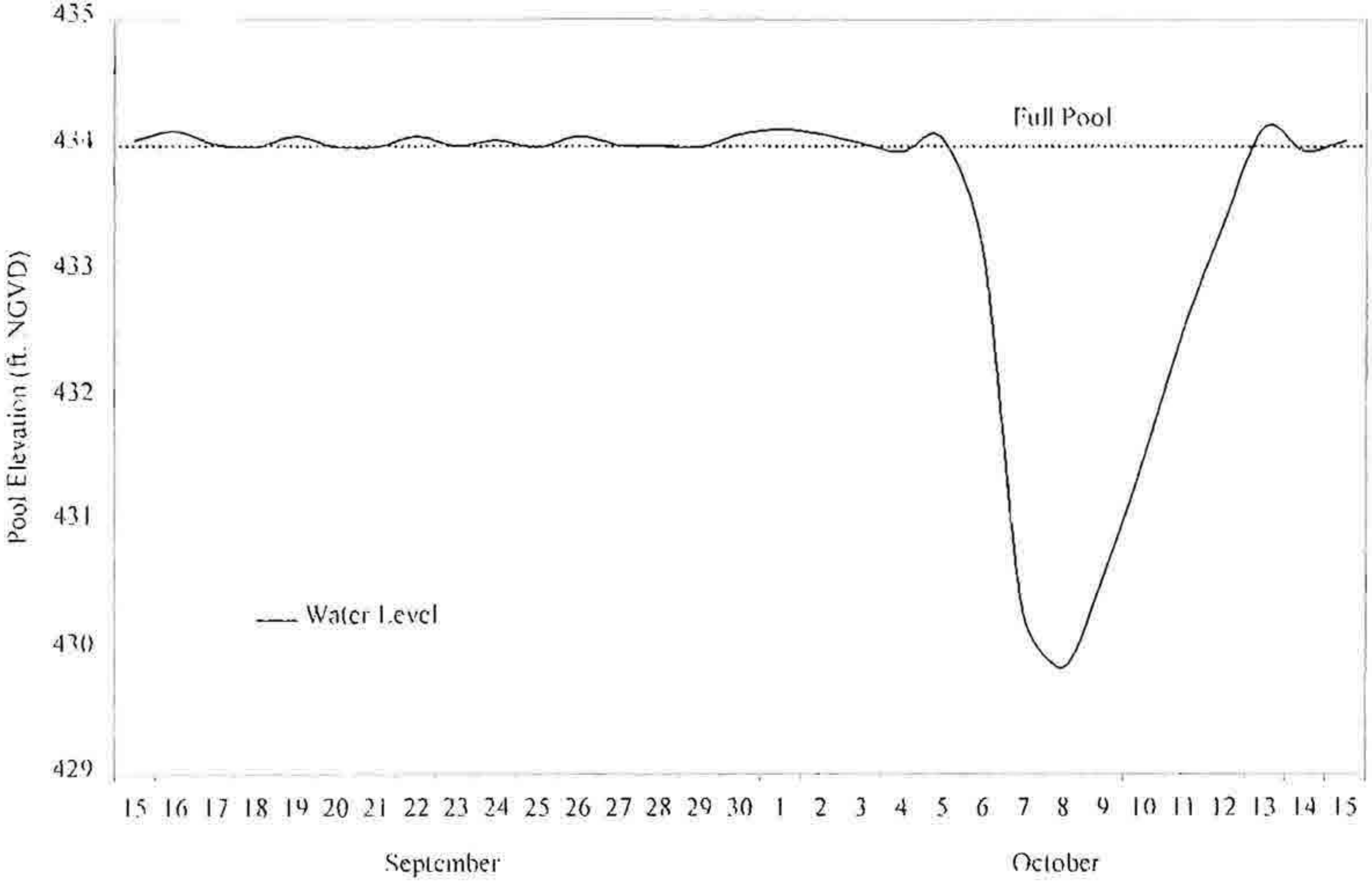
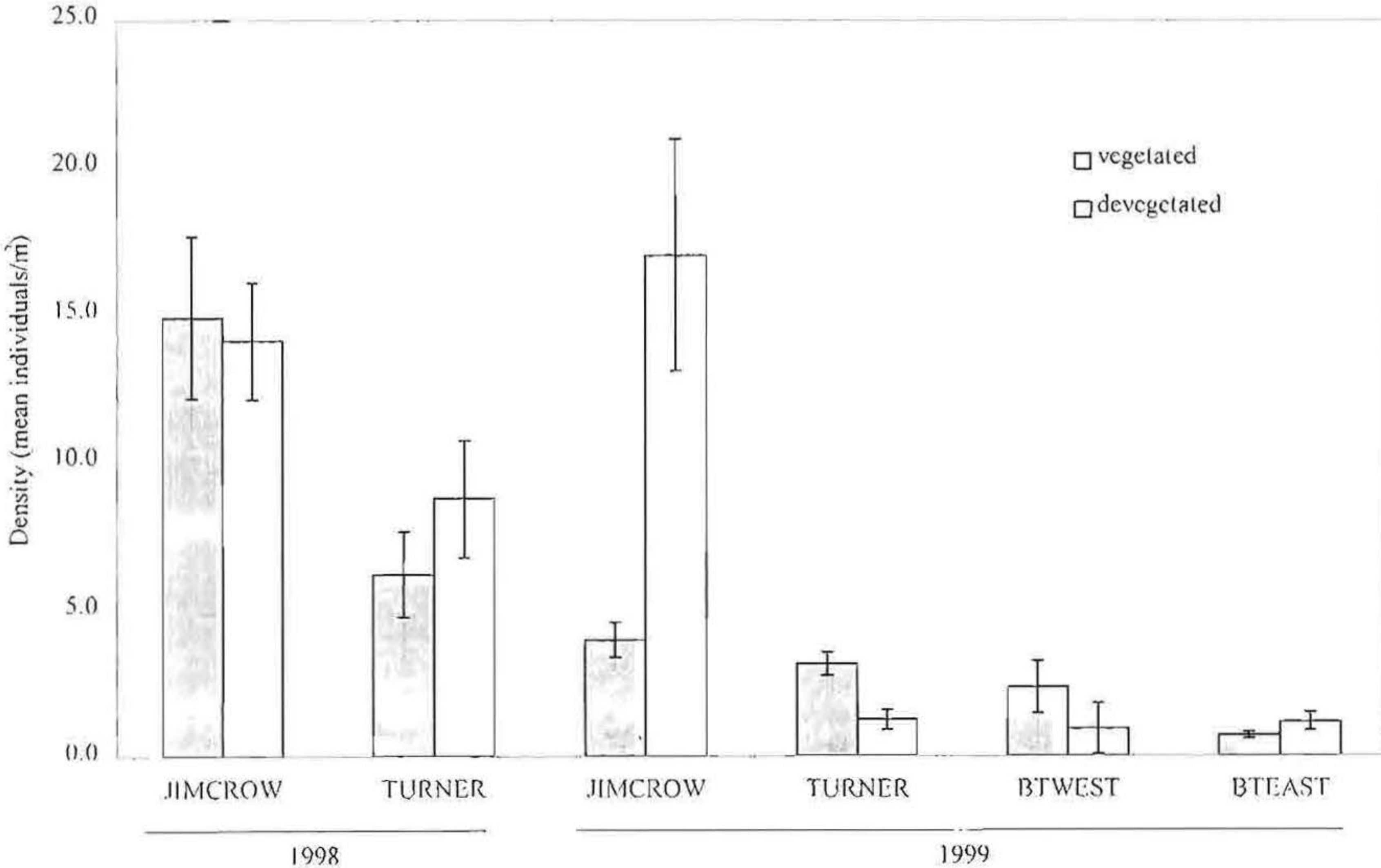

Pool Elevation (ft. NGVD)
435
434
433
432
431
430
429
Full Pool
Water Level
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
September
October

Figure 3. Invertebrate density ($\bar{x} \pm 1$ SE) in vegetated and devegetated plots from nektonic samples collected at Jim Crow and Turner during 1998 and Jim Crow, Turner, Batchtown West (BTWest), and Batchtown East (BTEast), during 1999. During 1998, vegetation was present in devegetated plots but vegetation growth was controlled during 1999.



25.0
20.0
15.0
10.0
5.0
0.0
Density (mean individuals/m)
vegetated
devegetated
JIMCROW
TURNER
JIMCROW
TURNER
BTWEST
BTEAST
1998
1999

53

Figure 4. Invertebrate density ($\bar{x}$ ± 1 SE) in vegetated and devegetated plots from benthic samples collected at Jim Crow and Turner during 1998 and Jim Crow, Turner, Batchtown West (BTWest), and Batchtown East (BTEast), during 1999. During 1998, vegetation was present in devegetated plots but vegetation growth was controlled during 1999.

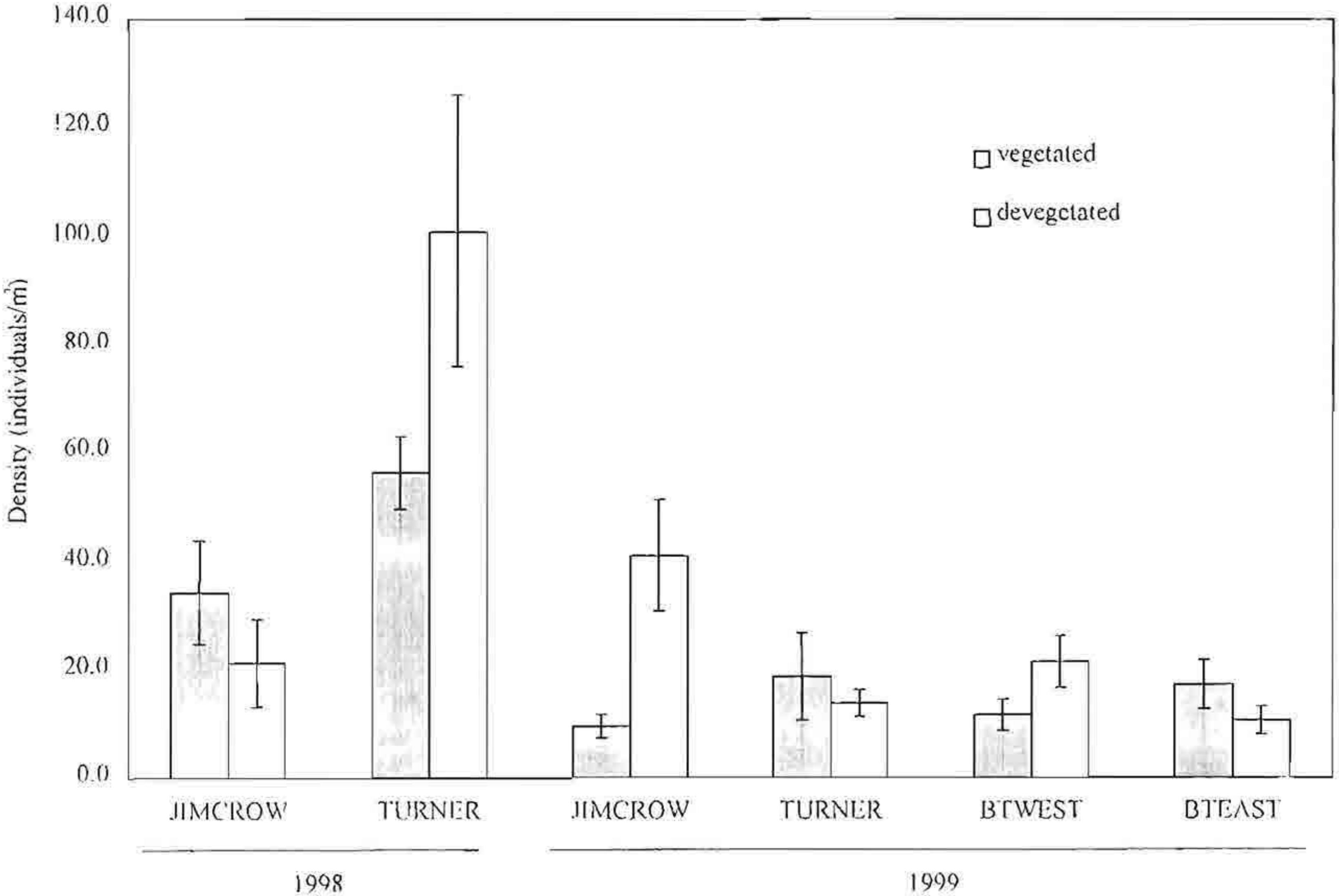

140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Density (individuals/m²)
vegetated
devegetated
JIMCROW
TURNER
JIMCROW
TURNER
BTWEST
BTEAST
1998
1999

Figure 5. Weekly number of ducks surveyed in lower Pool 25, Mississippi River between 27 February - 2 April 1999 and 25 February - 31 March 2000

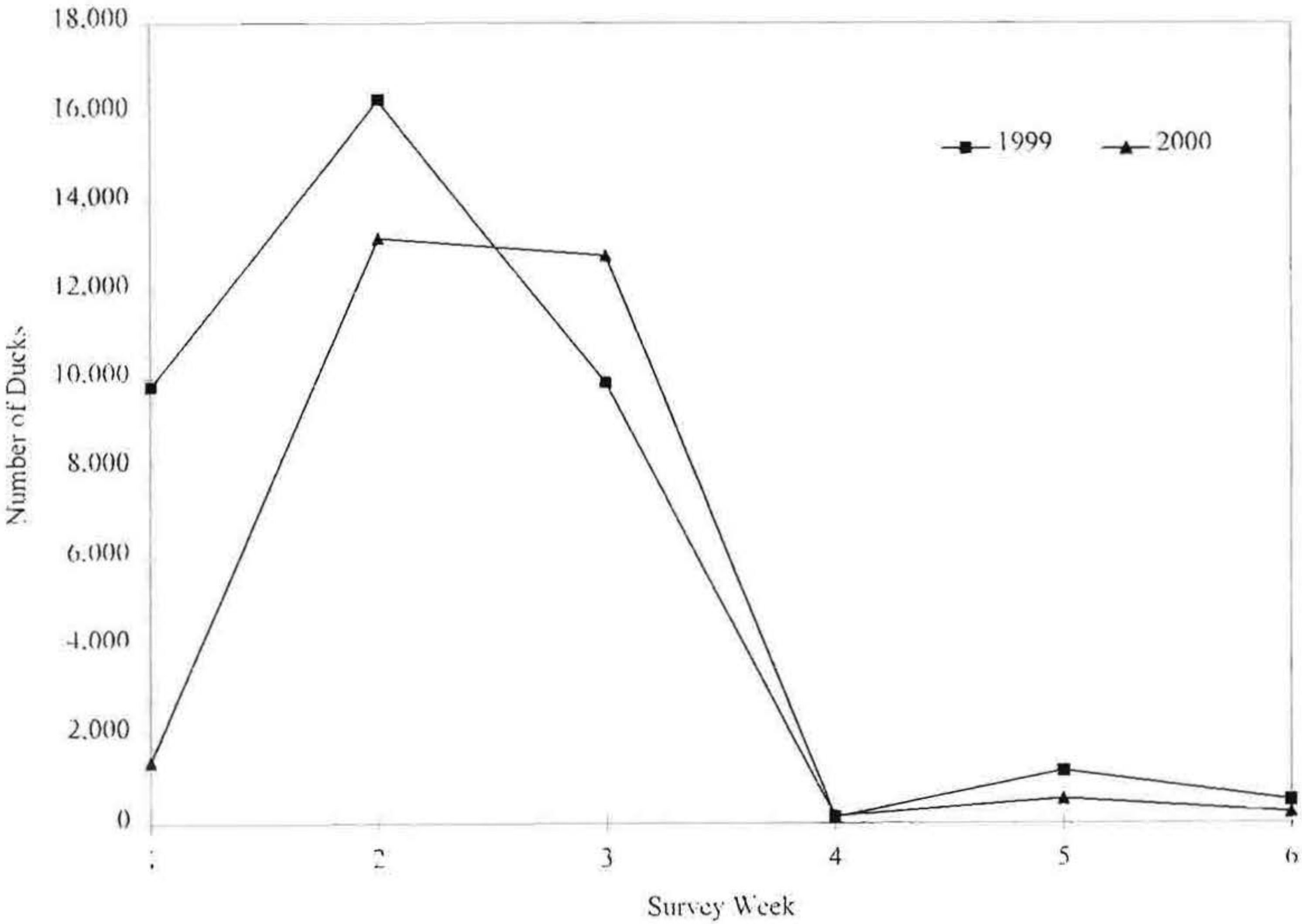

18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Number of Ducks
1999
2000
2
3
4
5
Survey Week

Figure 6. Weekly number of Canada geese surveyed in lower Pool 25, Mississippi River between 27 February - 2 April 1999 and 25 February - 31 March 2000.

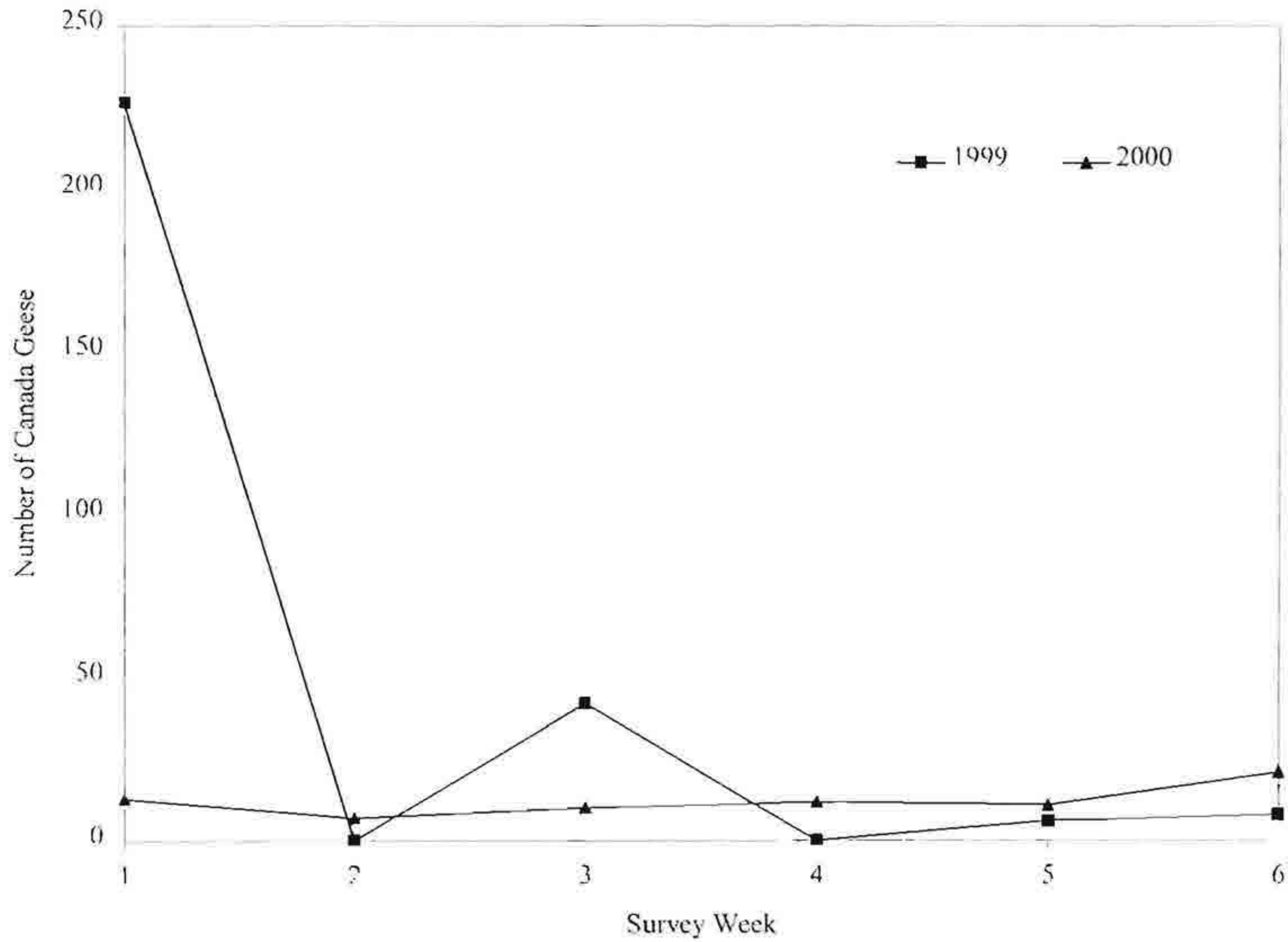

Number of Canada Geese
250
200
150
100
50
0
1
2
3
4
5
6
Survey Week
1999
2000

Figure 7. Diurnal time-activity budgets of spring migrating American green-winged teal (AGWT), mallards (MALL), and northern pintails (NOPI), using vegetated habitats in lower Pool 25, Mississippi River, late February - early April 1999 and 2000.

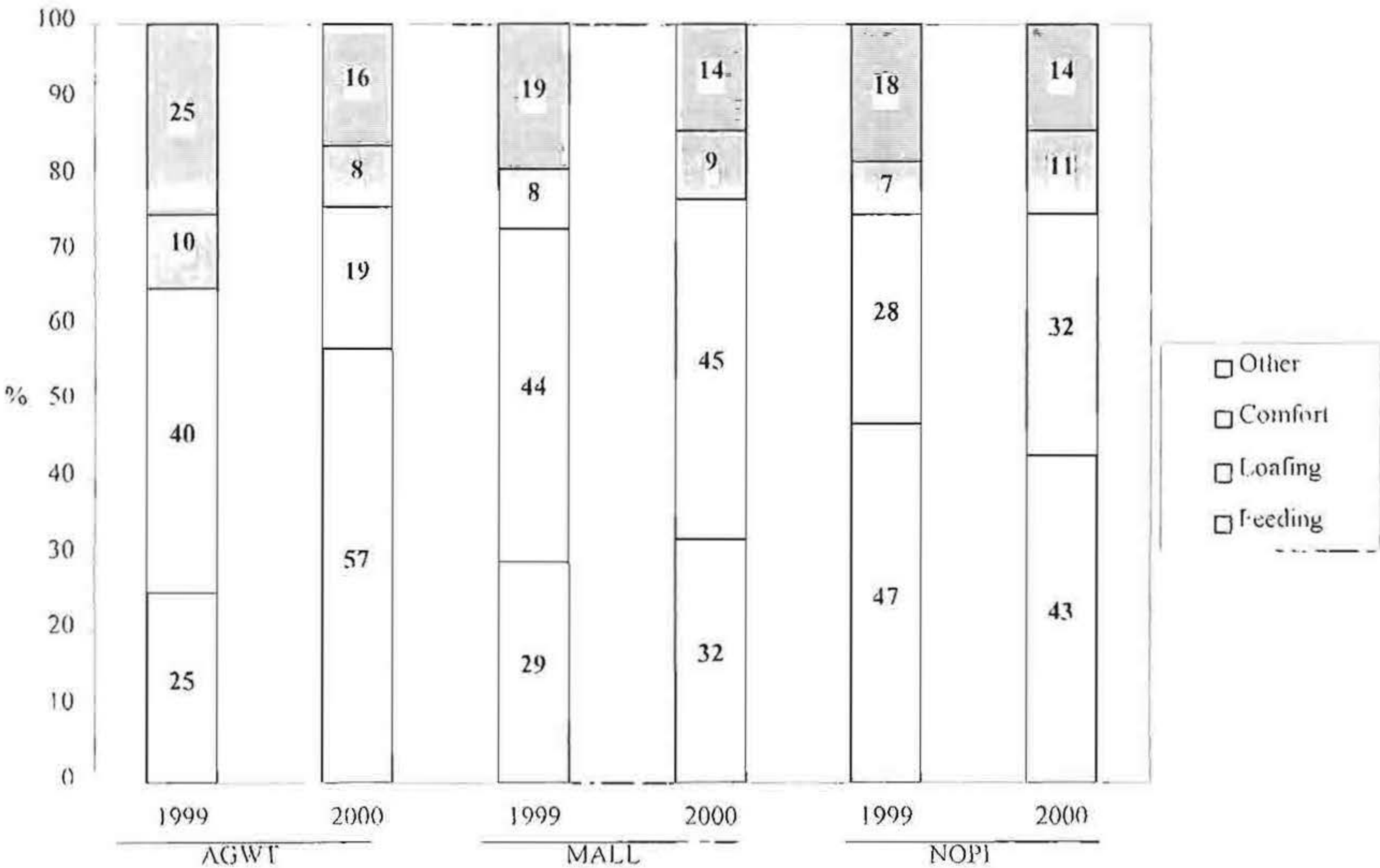

100
90
80
70
60
50
40
30
20
10
0
%
25
10
40
25
16
8
19
57
19
8
44
29
14
9
45
32
18
7
28
47
14
11
32
43
1999
2000
1999
2000
1999
2000
AGWT
MALL
NOPI
Other
Comfort
Loafing
Feeding

Figure 8. Daily water levels recorded at Lock and Dam 25, Mississippi River during (A) 1 May - 1 September 1995, (B) 1996, and (C) 1997.

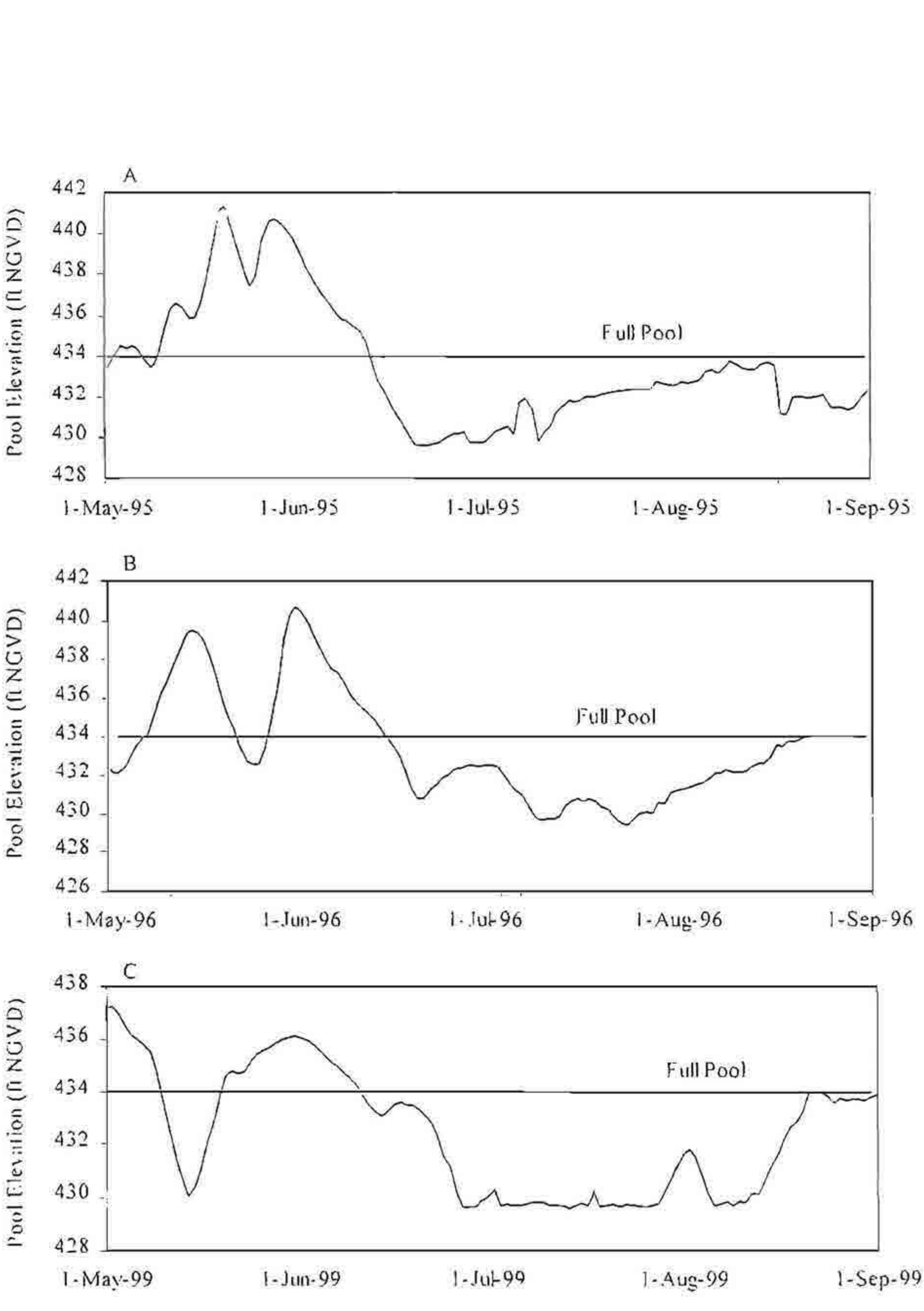
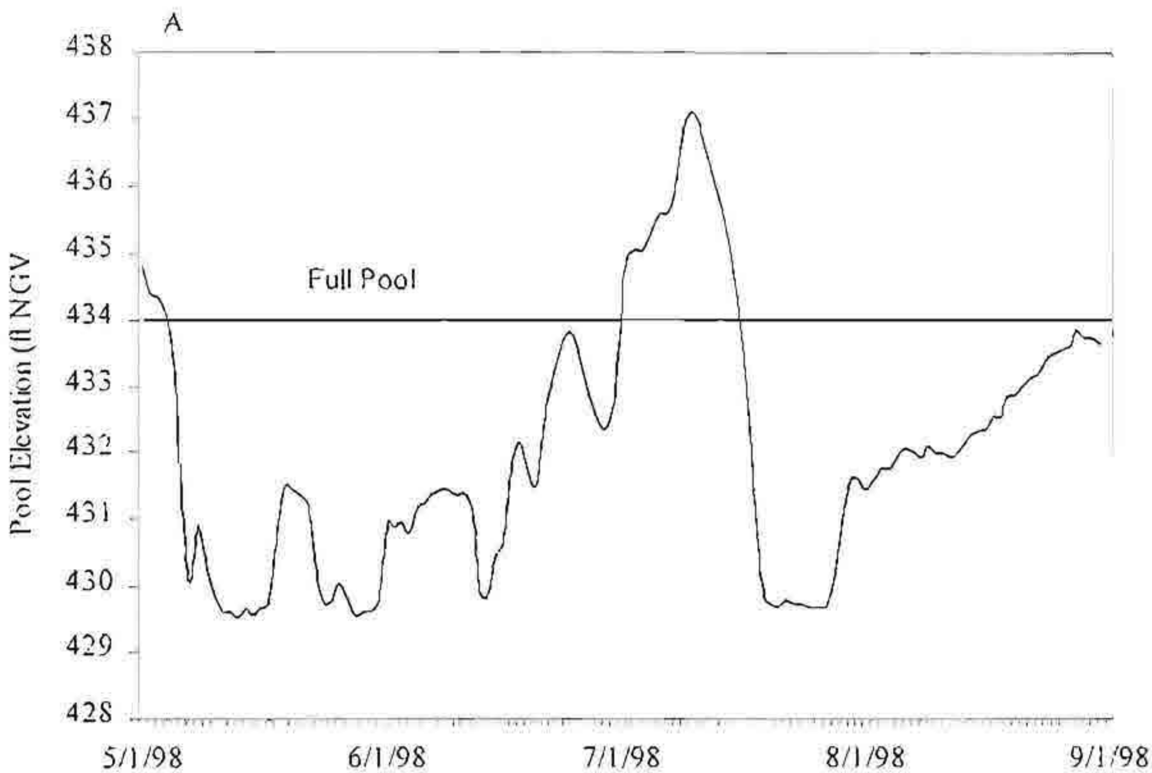
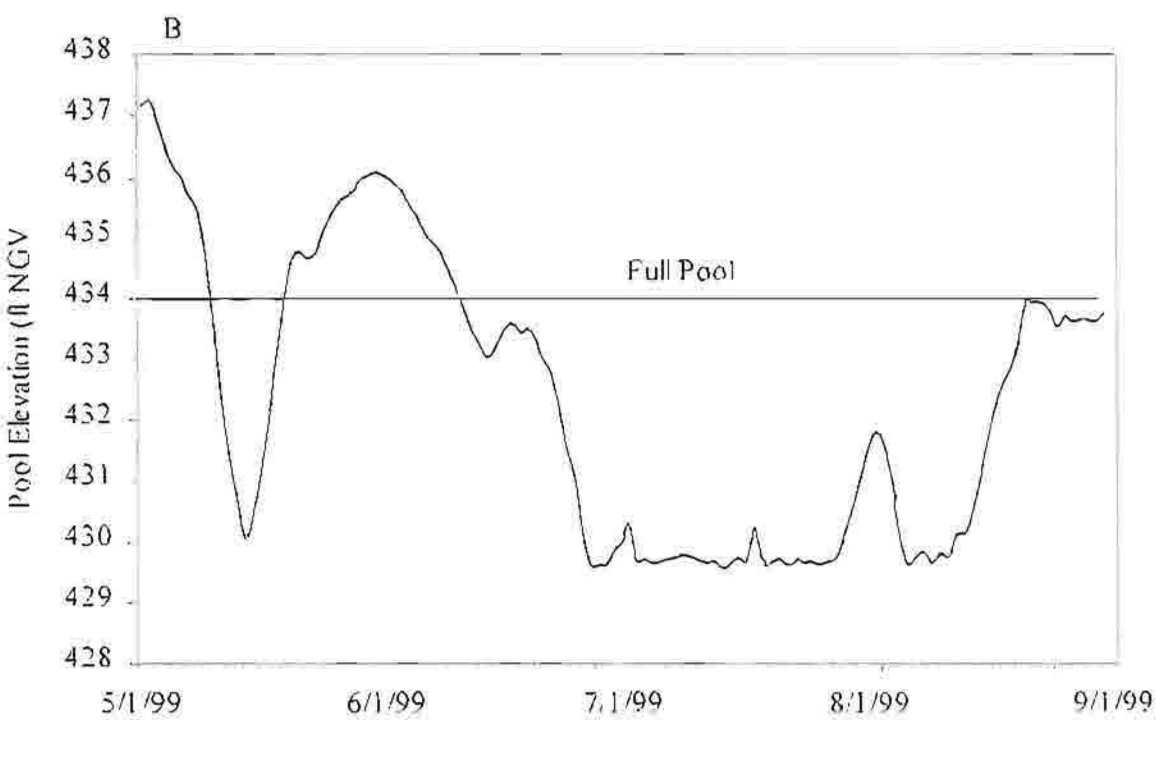

A
Pool Elevation (ft NGVD)
442
440
438
436
434
432
430
428
Full Pool
1-May-95
1-Jun-95
1-Jul-95
1-Aug-95
1-Sep-95
B
Pool Elevation (ft NGVD)
442
440
438
436
434
432
430
428
426
Full Pool
1-May-96
1-Jun-96
1-Jul-96
1-Aug-96
1-Sep-96
C
Pool Elevation (ft NGVD)
438
436
434
432
430
428
Full Pool
1-May-99
1-Jun-99
1-Jul-99
1-Aug-99
1-Sep-99

Figure 9. Daily water levels recorded at Lock and Dam 25, Mississippi River, during (A) 1 May - 1 September 1998 and (B) 1999.


A
438
437
436
435
434
433
432
431
430
429
428
Pool Elevation (ft NGV
Full Pool
5/1/98
6/1/98
7/1/98
8/1/98
9/1/98


B
438
437
436
435
434
433
432
431
430
429
428
Pool Elevation (ft NGV
Full Pool
5/1/99
6/1/99
7/1/99
8/1/99
9/1/99

Appendix A. Density of invertebrate taxa (x individuals/m²), number of macroinvertebrate taxa, Shannon index of diversity (H')ª, and proportion of maximum diversity (J')ᵇ of invertebrates collected in nektonic and benthic samples from vegetated (V) and devegetated (D) plots at Jim Crow Island, Turner Island, and Batchtown, Pool 25, Mississippi River during October 1998 and 1999. In 1998, devegetated plots had vegetation present, but were controlled for vegetation growth during 1999; no samples were collected at BT East and BT West during 1998. Trophic status of invertebrate taxa is represented in parentheses after taxon listing; Sc = scraper, Fi = filterer, Sh = shredder, Pr = predator, Co = collector, Sv = scavenger, Pa = parasite, Bo = borer.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Gastropoda																	
Lymnaeidae (Sc)	1998	0.2	0.2	0.0	1.3	0.1	0.2	0.6	0.0								
	1999	0.1*	0.1*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1*	0.1*	1.1	1.1
Physidae (Sc)	1998	4.7	3.4	15.3	8.5	0.4	2.6	8.5	6.2								
	1999	0.3	0.3	1.1	4.0	0.2	0.1*	0.6	1.7	0.0	0.0	0.6	0.6	0.1*	0.1	11.3	13.6
Planorbidae (Sc)	1998	0.2	0.2	0.6	0.0	0.1*	0.1*	0.0	0.0								
	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1*	4.5	17.0
Pelecypoda																	
Dreissenidae (Fi)	1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								
	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	5.1	0.0	0.1*	0.0	0.0

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Pelecypoda																	
Sphaeriidae (Fi)	1998	0.0	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.1*		
Unionidae (Fi)	1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								
	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Nematoda (Sh/Pr)	1998	0.1*	0.1*	0.0	0.6	0.0	0.1*	1.7	2.8								
	1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1*	0.0	1.1	0.0	0.1*	0.0	0.0	0.0
Annelida																	
Oligochaeta (Co)	1998	4.7	7.9	152.7	97.3	1.8	2.4	267.5	496.6								
	1999	0.8	4.2	40.1	192.3	0.7	0.3	88.2	56.6	0.9	0.6	55.4	96.1	0.1	0.6	69.6	19.8
Hirudinea (Sv)	1998	0.1*	0.1*			0.0	0.0										
	1999	0.1*	0.1*			0.0	0.0			0.1*	0.0			0.0	0.0		

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Crustacea																	
Cladocera (Fi)	1998	1.8	0.1*			0.3	1.1										
	1999	0.1*	0.0			0.0	0.1*			1.2	0.0			0.1	0.0		
Ostracoda (Sv)	1998	0.6	0.1	2.3	0.0	0.3	0.2	0.0	1.7								
	1999	0.1*	0.0	0.0	0.0	0.1	0.1*	0.0	0.0	0.1*	0.0	0.6	0.0	0.1*	0.0	0.0	0.0
Copepoda (Fi)	1998	0.1*	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.1*	0.1*			0.1*	0.1*		
Argulidae (Pa)	1998	0.0	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.1*			0.0	0.0			0.0	0.0		
Isopoda																	
Asellidae (Sv)	1998	0.0	0.0	1.1	0.0	0.1	0.1	0.6	0.0								
	1999	0.1*	0.1*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1*	0.0	0.0

Appendix A. Continued

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Amphipoda																	
Gammaridae (Sv)	1998	0.1*	0.0			0.1*	0.0										
	1999	0.0	0.0			0.1*	0.0			0.0	0.0			0.1*	0.0		
Talitridae (Sv)	1998	0.0	0.0			0.0	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Decapoda																	
Cambaridae (Sv)	1998	0.1*	0.1*			0.1*	0.1*										
	1999	0.1*	0.0			0.1*	0.0			0.1*	0.0			0.0	0.0		
Palaemonidae (Sv)	1998	0.0	0.0			0.0	0.0										
	1999	0.0	0.0			0.1*	0.0			0.0	0.0			0.0	0.0		

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Insecta																	
Ephemeroptera																	
Baetiscidae (Co)	1998	0.1*	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Odonata																	
Aeshnidae (Pr)	1998	0.1*	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Coenagrionidae (Pr)	1998	0.0	0.1			0.1*	0.2										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Cordulegastridae (Pr)	1998	0.0	0.0			0.0	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Gomphidae (Pr)	1998	0.0	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.1*	0.0			0.0	0.0		

Appendix A. Continued

Taxon	Year	Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
		V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Odonata																	
Lestidae (Pr)	1998	0.1*	0.1			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.1*	0.0			0.1*	0.0		
Libellulidae (Pr)	1998	0.1	0.1			0.0	0.0										
	1999	0.1*	0.1*			0.0	0.0			0.0	0.1*			0.1*	0.0		
Coleoptera																	
Dytiscidae (Pr)	1998	0.0	0.0			0.0	0.0										
	1999	0.1	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Gyrinidae (Pr)	1998	0.1*	0.0			0.1*	0.1*										
	1999	0.0	0.0			0.1*	0.0			0.0	0.0			0.0	0.0		
Haliplidae (Sh)	1998	0.0	0.1*			0.1*	0.0										
	1999	0.0	0.1*			0.0	0.0			0.0	0.0			0.1*	0.0		

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Coleoptera																	
Hydrophilidae (Pr)	1998	1.2	0.5	1.1	0.0	0.3	0.4	1.1	0.6								
	1999	1.1	0.3	1.1	0.0	0.3	0.1*	2.3	0.0	0.1*	0.0	0.0	0.0	0.1*	0.0	0.6	0.0
Noteridae (Pr)	1998	0.0	0.0			0.0	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Staphylinidae (Pr)	1998	0.0	0.0			0.1*	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Hemiptera																	
Belostomatidae (Pr)	1998	0.1*	0.1*			0.1*	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Corixidae (Pr)	1998	0.7	1.5			1.9	1.0										
	1999	0.5	3.4			1.3	0.2			0.1	0.1			0.3	0.1		

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Hemiptera																	
Gerridae (Pr)	1998	0.1*	0.1*			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Hydrometridae (Pr)	1998	0.0	0.1*			0.1*	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.1*	0.0		
Hydroptilidae (Sc)	1998	0.1*	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Hebridae (Pr)	1998	0.0	0.1*			0.1*	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.1*	0.0		
Macroveliidae (Pr)	1998	0.1*	0.1*			0.1	0.2										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Naucoridae (Pr)	1998	0.0	0.1*			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		

Appendix A. Continued

		Jim Crow				Turner				BF West				BF East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Hemiptera																	
Notonectidae (Pr)	1998	0.0	0.1*			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Saldidae (Pr)	1998	0.1*	0.1*			0.1*	0.1*										
	1999	0.1*	0.0			0.1*	0.0			0.1*	0.0			0.0	0.0		
Homoptera (Sh)	1998	0.1	0.1*			0.1*	0.1*										
	1999	0.1*	0.0			0.0	0.0			0.1*	0.0			0.0	0.0		
Lepidoptera																	
Arctiidae (Sh)	1998	0.1*	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Cossidae (Bo)	1998	0.1*	0.1*			0.1*	0.0										
	1999	0.1*	0.0			0.1*	0.0			0.0	0.0			0.1*	0.0		

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Lepidoptera																	
Noctuidae (Sh)	1998	0.0	0.0			0.0	0.0										
	1999	0.1*	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Neuroptera																	
Sisyridae (Pr)	1998	0.1*	0.0			0.1*	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Orthoptera																	
Gryllidae (Sh)	1998	0.0	0.1*			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Diptera																	
Ceratopogonidae (Pr/Co)	1998	0.1*	0.1*	0.0	1.1	0.1*	0.0	0.0	0.0								
	1999	0.1*	0.0	0.0	0.6	0.0	0.1*	0.0	0.0	0.1*	0.0	0.0	0.6	0.0	0.1*	0.0	0.0

Appendix A. Continued

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Diptera																	
Chironomidae (Co Pr)	1998	0.2	0.1	2.3	0.0	0.7	0.3	6.2	5.7								
	1999	1.0	8.9	6.7	12.4	0.4	0.8	4.5	11.9	0.1	0.2	0.6	6.8	0.1	0.3	0.6	1.7
Culicidae (Co)	1998	0.1*	0.0			0.1*	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Dolichopodidae (Pr)	1998	0.0	0.0			0.0	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Empididae (Pr)	1998	0.0	<0.01			0.1*	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Sciomyzidae (Pr)	1998	0.1*	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.1*	0.0			0.0	0.0		
Stratiomyidae (Co)	1998	0.1*	0.0			0.1*	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		

Appendix A. Continued.

Taxon	Year	Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
		V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Diptera																	
Tabanidae (Pr)	1998	0.0	0.0			0.1*	0.0										
	1999	0.0	0.0			0.1*	0.0			0.0	0.0			0.0	0.0		
Tipulidae (Sh)	1998	0.0	0.0			0.0	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Hymenoptera																	
Scelionidae (Pi)	1998	0.0	0.0			0.1*	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0		
Hydracarina (Pr)	1998	0.0	0.0			0.0	0.0										
	1999	0.0	0.0			0.0	0.0			0.0	0.1*			0.0	0.0		

Appendix A. Continued.

		Jim Crow				Turner				BT West				BT East			
		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic		Nektonic		Benthic	
Taxon	Year	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D
Arachnida																	
Araneidae (Pr)	1998	0.1*	0.1*			0.1*	0.1*										
	1999	0.1*	0.0			0.1*	0.0			0.1*	0.0			0.0	0.0		
Lycosidae (Pr)	1998	0.1*	0.1*			0.1	0.1										
	1999	0.1*	0.0			0.1*	0.0			0.1*	0.0			0.1*	0.0		
Pisauridae (Pr)	1998	0.1*	0.0			0.1*	0.1*										
	1999	0.0	0.0			0.0	0.0			0.0	0.0			0.1*	0.0		
Total Density	1998	14.9	14.1	175.3	108.6	6.2	8.7	286.2	513.5								
	1999	3.9	17.0	48.6	209.2	3.1	1.2	95.6	70.1	2.3	0.9	58.8	109.2	0.7	1.2	87.7	53.7
No. Taxa	1998	35	31	7	5	34	27	7	6								
	1999	20	10	4	4	16	8	4	3	18	6		6	5	20	11	6.5

* Denotes values < 0.01.

Appendix B Combined total of spring migrating waterfowl counted during six weekly waterfowl surveys of vegetated and open water habitats in lower Pool 25, Mississippi River during late Feb - early Apr 1999 and 2000.

	1999			2000		
Species	Vegetated	Open Water	Total	Vegetated	Open Water	Total
Branta canadensis	218	65	283	51	23	74
Anas platyrhynchos	18,378	434	18,812	13,058	111	13,169
Anas acuta	16,420	165	16,585	5,682	2	5,684
Anas americana	30	0	30	100	2	102
Anas strepera	65	40	105	1,220	14	1,234
Anas crecca	360	34	394	3,747	125	3,872
Anas clypeata	40	25	65	1,011	35	1,046
Anas discors	47	5	52	319	15	334
Anas rubripes	25	0	25	0	0	0
Aix sponsa	7	0	7	19	2	21
Mergus merganser	0	0	0	100	0	100
Lophodytes cucullatus	0	0	0	6	3	9
Aythya americana	20	65	85	0	200	200
Aythya collaris	15	390	405	0	1,429	1,429
Aythya valisineria	36	16	52	0	201	201
Aythya affinis	0	1,102	1,102	0	827	827
Bucephala albeola	0	0	0	0	11	11
Bucephala clangula	0	0	0	0	9	9
Oxyura jamaicensis	0	0	0	0	45	45
Total	35,661	2,341	38,002	25,238	3,054	28,292

Fish and Water Quality Responses to Vegetation Produced via Environmental Pool Management Pool 25, Mississippi River

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To:

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St. Louis District

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Introduction

Water levels in Pool 25, Mississippi River, are currently managed at a midpool control point located near Mosier Landing at river mile 260.3 by the U.S. Army Corps of Engineers (USACE), St. Louis District. To maintain a 2.7-m navigation channel, water levels are managed between 434 - 437 ft at Mosier Landing and from 429.7 - 434 ft at Lock and Dam 25 over a specific range of discharges. During a moderate flood pulse, the pool becomes "tilted" when gates are lifted to maintain water levels at the midpool control point: tilting can result in the dewatering of backwaters in lower reaches of pools (Sparks 1995). When discharge exceeds values manageable through operation of Lock and Dam 25 (often occurring during spring high water events) all gates at the dam are raised out of the water and the river is said to be at "open river." Spring flood waters may recede to an elevation of 429.7 at Lock and Dam 25. This elevation, also referred to as "maximum drawdown," is the maximum drop in water level that will still allow navigation in a 2.7-m channel (Wlosinski and Hill 1995). If the discharge continues to fall, the pool is regained based on discharge rates. Typically, the Corps starts to regain pool when the discharge causes the water level at Mosier Landing to fall below 437.0 feet. Herein, "drawdown" is synonymous with the maximum drawdown which generally follows spring floods.

Resource agencies recognize the need to work in conjunction with the USACE to improve hydrologic conditions for biota within the constraints of a multi-use system (Woltemade 1997). Given the real estate requirement that the St. Louis District operates under, the L&D has no control over the timing of the drawdown during open river conditions. However, there is some flexibility in how water levels are managed during the return of the river to the target pool elevation. Since 1994, the time period conducive to water-level management has ranged from approximately 38 to 57 days during the summer months.

The operational goal of Environmental Pool Management (EPM) is to maintain relatively low, stable water levels following drawdown in the spring in order to better simulate the natural hydrograph (Figure 1). When implementing EPM, water levels are held 0.5 to 2.0 feet below the target pool elevation at the lock and dam for at least 30 days (Atwood et al. 1996). Under some circumstances (e.g., high discharges), water levels may descend to elevations greater than 2.0 feet below the target pool elevation due to management of the pool with a midpool control point. Environmental Pool Management prolongs the dry phase during the growing season for nonpersistent wetland vegetation. The EPM-induced vegetation is primarily found in backwaters located in the lower reach of the pool. The St. Louis District implemented EPM in 1994 on Pools 24, 25, and 26. Investigations of mudflats exposed via EPM showed lush production of nonpersistent wetland vegetation consisting mainly of millet, chufa, and smartweeds (Atwood et al. 1996).

Many ecological benefits are expected from EPM. On a large scale, the management regime could provide system-wide benefits by consolidating substrates and re-establishing wetland biogeochemical processes. The Mississippi River is a major migratory route for waterfowl, and moist-soil plants provide food sources directly through seed and tuber production and indirectly by increasing invertebrate abundance (Fredrickson and Taylor 1982). Benefits to fish are expected, as at least 84 fish species in the Upper Mississippi River (UMR) reportedly utilize aquatic plants for reproduction, nursery habitat, cover, as feeding grounds, or some combination of these uses (Janecek 1988).

Very few studies have been conducted to evaluate the successes and/or shortcomings of EPM. The response of plants has received most of the attention from researchers (Atwood et al. 1996; J.H. Wlosinski, U.S. Geological Survey), but data also exist for fish. Wlosinski and Atwood (1999) analyzed seine data taken in multiple habitat types from 1986 to 1996 in Pools 24, 25, and Melvin Price Pool, and concluded that maintaining lower water levels during the summer did not negatively impact small, nearshore fishes. During fall 1997, fish were seined in vegetated and adjacent nonvegetated areas in Pools 24, 25, and 26 to examine fish use of EPM-induced vegetation; this study indicated the vegetation was providing habitat for small forage fish, particularly the emerald shiner, *Notropis atherinoides* (Heidinger et al. 1998).

In conjunction with the SIUC Cooperative Wildlife Research Laboratory, our main objective was to provide relevant data on ecosystem responses to EPM that could be used to evaluate the management plan and provide a basis for recommendations. The specific objectives were 1) to evaluate fish use of EPM-induced vegetation versus adjacent, non-vegetated areas of similar depth and velocity, 2) to monitor the effects of vegetation on water quality and zooplankton, and 3) to determine if residual vegetation could be providing fish habitat in spring.

Materials and Methods

Fish, Water Quality, and Zooplankton Response to Flooded Vegetation in Fall:

Study Sites - Reconnaissance indicated most, if not all. vegetation produced via EPM was located in the lower impounded reach; therefore. all sampling was conducted in the lower portion of Pool 25. In the fall of 1998, four study sites were chosen based on evidence (presence of emergent vegetation) the area was affected by EPM (Figure 2) (Table 1). Two sites (Batchtown West and Batchtown East) were sampled in the extensive, shallow backwater complex located in the Batchtown State Fish and Waterfowl Management Area, Calhoun County, Illinois. Historically, most of the EPM-induced vegetation in Pool 25 has been found in the Batchtown area. Batchtown West was located in the northern end of a shallow. expansive bay characterized by soft substrates, and was more vulnerable than the other sites to wind-induced wave action. Batchtown East was situated near the limestone bluffs of the Illinois river bank. In addition to Batchtown, relatively small acreages of vegetation were produced on islands near the main channel. Study sites were established on the downstream tip of Turner Island and within a semi-isolated slough on Jim Crow Island. Two 400 m^2 plots (one vegetated and one to be experimentally devegetated) were delineated at all four sites. The devegetated plot was intended to simulate conditions in shallow littoral habitats without the presence of vegetation and provided an area of similar depth and water velocity to the vegetated area from which samples could be taken.

Fish Sampling in Experimental Plots - Due to a delayed project start date and onset of the waterfowl hunting season, experimental devegetation was not possible in 1998. Fish samples, however, were taken within the established plots (plots that would be either vegetated or devegetated in the following year) and sites to evaluate the study design and determine if our collecting techniques were effective in the emergent vegetation. During October 3-4 and October 14, 1998, fish were sampled within the vegetation at each site with a 3.66-m seine having a mesh size of 6.4 mm. A total of 8-10 seine hauls were made in each plot (Table 2). We constructed twelve popnets (a modified design from Dewey et al. (1989)) having a 1-m^2 buoyant frame of polyvinyl chloride pipe (3.18 cm diameter), an open bottom anchored on two sides with steel conduit pipe, and a mesh size of 4.7 mm. Popnets were placed collapsed on the substrate for 3-4 hr and then remotely triggered to collect fish in a 1-m^2 column of water extending from the bottom to the water's surface. Three samples were collected in vegetated and "devegetated" plots at Jim Crow and Turner Island on 3-4 October 1998 (Table 2).

On 7 July 1999 all plots to be devegetated were cleared of woody debris and residual vegetation remaining from the previous year. One plot at each site was treated with Rodeo® herbicide on 13 July, 24 July, and 13 August 1999 with a backpack sprayer. Devegetated plots were completely devoid of vegetation prior to reflood. Our goal was to achieve devegetated plot sizes of 400 m^2, but we sprayed an additional 5 meters around the perimeter to minimize an edge bias during fall sampling. Plots at Turner Island, Batchtown East, and Batchtown West were devegetated out to the adjacent open water area so that water quality parameters (e.g., turbidity) would better reflect the absence of vegetation.

In Fall 1999, following reflood, fish were sampled at each site and plot on five sampling trips from 28 August to 14 October. Sampling was conducted at each site on multiple dates to minimize bias in captures due to time-of-day and chance events (e.g., a windy day) and to encompass variation in fish distribution and abundance that may occur over time in the fall. Fish were sampled with a 3.66-m seine and 1-m^2 popnets constructed with netting of a smaller mesh (1.6-mm) than used in the previous year. We used a smaller mesh size because very small fish present in the vegetated habitats in 1998 were observed to escape through the larger mesh. Two seine hauls, each 10 m long, were made in devegetated plots (total area sampled = 72.2 m^2), and five kicksets were made in vegetated plots (total area sampled = 72.2 m^2). The use of a series of stationary kicksets was the best method for sampling with a seine in the dense emergent vegetation. Kicksets were accomplished by holding the deployed seine stationary while one person "kicked" vigorously into the seine starting 4 m away.

Two seine hauls, each 10 m long, were also made at the natural deeper edge of the vegetation at Batchtown East and Batchtown West during five sampling trips. The seine was pulled parallel with the vegetated edge with one brail approximately one meter within the vegetation. Seine samples were taken in the deep portion of the devegetated plot on three sampling trips. These samples were kept separate from fish collected directly within the plots.

Specimens were fixed in 10% formalin in the field. They were identified in the laboratory and total length (TL) measured on at least 50 individuals of each species per sample. With the exception of the western mosquitofish, *Gambusia affinis*, individuals were classified as adults or young-of-the-year (YOY) based on total lengths reported in Becker (1983) and Pflieger (1997). Voucher specimens will be catalogued in the SIUC Fluid Vertebrate Collection.

Water Quality Sampling in Experimental Plots - Point-in-time measurements of major water quality variables (dissolved oxygen (DO), temperature, pH, conductivity, and turbidity) and water depth were made in each plot on each sampling trip in 1999 between 0830 and 1600 hr. Water quality, including depth, was measured at two stations to characterize the range of conditions in each plot. Dissolved oxygen level (accuracy = $\pm$ 0.2 mg/L) and temperature (accuracy = $\pm$ 0.2 ^{0}C) were measured with a Yellow Springs Instrument YSI Model 95 digital meter. Dissolved oxygen and temperature were measured at approximately 5 cm below the water's surface and 5 cm above the substrate if water depth exceeded 30 cm. A Hanna Instruments pHep®2 pocket-sized meter was used to measure pH ($\pm$ 0.1 pH). Dissolved ion concentration was measured with a YSI Model 33 conductivity meter. Conductivity and pH were measured at approximately 5 cm below the water's surface. A 10-ml water sample was taken in each plot, and turbidity determined in the laboratory with a Chemtrix Type-12 turbidimeter. A wooden meter stick was used to measure water depth.

Zooplankton Sampling in Experimental Plots - Vertically integrated zooplankton samples were taken in triplicate from each plot using a modified littoral sampling tube (Pennak 1962). Samples were filtered through a Wisconsin-style plankton net that had a collection bucket lined with 80 µm Nitex® mesh. Samples were rinsed in the field with 90% ethanol and preserved in 5% buffered formalin. Laboratory analysis of these samples has not been completed.

Boat Electrofishing in Lower Pool 25 - Boat Electrofishing (one pilot, one dip netter) was conducted in lower Pool 25 on 13-14 October 1998. Electrical Current was supplied by a 3-phase 5 KW generator producing 240 volts AC. Fish were netted with a dipnet having a mesh size of 6.4 mm. Due to lack of sufficient water depth, sampling was limited to deeper water located adjacent to the experimental plots at the four study sites. Electrofishing was conducted at an additional site within Batchtown and on the river and backwater side of a rock revetment located on the upstream end of Stag Island. Creation of the rock revetment was a result of the Stag Island Habitat Rehabilitation and Enhancement Project (1998). Electrofishing effort was 30 min for all sites except for Stag Island, where effort was 15 min each for the river and backwater side of the revetment. On 21 October, 1999, boat electrofishing, as previously described, was conducted for a total of 1 hr along the edge of the vegetation within the large bay in Batchtown near Batchtown West. Boat electrofishing was not possible directly within experimental plots because the water was too shallow.

Data Analysis - A randomized block experimental design was used to test the null hypotheses that mean total number of fish, number of species, Shannon diversity index, and water quality were equal among treatments (vegetated plot and devegetated plot). Treatments were interspersed at four sites ($N = 4$). Two-way analysis of variance (ANOVA) tests, with Plot as the treatment variable and Site as the block variable, were used to test the null hypotheses that total number of fish and water quality were equal between vegetated and devegetated plots. Data collected over multiple days were averaged prior to analysis. Values of total number of fish and water quality were $\log_{10}$ - transformed to satisfy assumptions of parametric tests. Mean number of species, Shannon diversity index (H′), and mean abundance of common species were compared between plots using the Mann-Whitney *U* - Test. Shannon diversity index was calculated using the following formula:

$$H' = -\Sigma p_i \ln p_i$$

where p_i is the proportional abundance of the *i*th species (n_i/N). The widely used Shannon diversity index is a richness dominated index moderately sensitive to sample size and usually falls between 1.5 and 3.5 (Magurran 1988). Fish community similarity was examined between sampling gears and experimental plots with Spearman's rank correlation coefficient (r_s) which uses relative abundance values to compare species ranks between two sets of samples. This correlation coefficient is highly sensitive to sample size (number of species) and may perform better in low-diversity communities (Krebs 1989). To avoid inflating the chance of finding a significant correlation due to a preponderance of rare species, species represented by < 10 individuals total were considered "rare" and excluded from most analyses. In all statistical tests, significance was indicated by an alpha < 0.05.

Fish Use of Residual Vegetation in Spring 1999

Researchers suspect that residual vegetation produced during the previous fall will benefit fish by providing spawning and nursery habitat (Atwood et al. 1996); however, no data exist to substantiate this claim. Residual vegetation was present in established plots at Batchtown East, Batchtown West, Turner, and Jim Crow in spring of 1999. Fish, zooplankton, and water quality samples were taken in the plots from 8 June to 20 June. Batchtown East and Batchtown West were each sampled on two trips, and Turner and Jim Crow were sampled on three occasions. Five seine hauls, were made in each plot with a 3.66-m seine (1.6 mm mesh) to collect YOY and littoral fish. Fish were fixed in 10% formalin and identified in the laboratory. Water quality and zooplankton samples were taken as previously described. Fish collections are also reported from three sites in lower Pool 25 that did not have residual vegetation present

Miscellaneous Fish Collections

Fish collections were made at various sites in lower Pool 25, including the slough on Jim Crow Island, in the summer of 1999. Fish were sampled with a 3.66-m seine having a mesh size of 1.66 mm. Fish were fixed in 10% formalin and identified in the laboratory. Collections will be catalogued in the SIUC Fluid Vertebrate Collection.

Results

Fish, Water Quality, and Zooplankton Responses to Flooded Vegetation in Fall 1999:

The summer hydrologic regime of 1999 exposed mudflats in lower Pool 25 for an extended period of time and was very successful in producing annual vegetation, particularly smartweed (*Polygonum pensylvanicum* and *P. lapathifolium*), flatsedge (*Cyperus*), and millet (*Echinochloa*) (Table 3). These nonpersistent plant species are typical of poorly drained, seasonally flooded basins (Eggers et al. 1997). The seeds are utilized by migrating waterfowl (Fredrickson and Taylor 1982) and song birds (Eggers et al. 1997), and reportedly provide late-season cover for fish and invertebrates (Janecek 1988). Following reflood, smartweed was the primary plant type persisting in the plots. Maximum drawdown was reached on approximately 29 June, and water levels generally remained below 430 ft until reflooding began 12 August (Figure 3).

Fish Sampling in Experimental Plots - Popnets and seining captured eighteen fish species encompassing seven families (Table 4). The family Cyprinidae (minnows) was represented by ten species, including two exotics, the common carp and grass carp. Collections were dominated numerically by the channel shiner, western mosquitofish, and spotfin shiner which collectively comprised 82% of all fish collected. The majority of species present in collections, with the exception of two species, were represented by young-of-the-year (YOY) (Table 4). A preponderance of individuals ≤ 1.5 cm TL indicated several species had spawned late in the year (late August - early October): channel shiner, spotfin shiner, river shiner, common carp, orangespotted sunfish, and western mosquitofish.

Seining generally captured more fish and more fish species in both vegetated and devegetated plots, and six species were captured only with the seine (Table 5). Overall (sites combined) relative abundance of the seven most common fish species in the vegetated plots was significantly correlated between seine and popnet samples (N = 7; Spearman's $r_s = 0.82$; $P = 0.023$). In devegetated plots, concordance of ranks was not found in the seven most abundant species (N = 7; Spearman's $r_s = 0.68$; $P = 0.094$), but a perfect correlation of ranks was found (Spearman's $r_s = 1.0$) when the emerald shiner (*Notropis atherinoides*) and orangespotted sunfish (*Lepomis humilis*) were left out of the analysis. Popnets were probably not as efficient at sampling the emerald shiner in devegetated plots because of a combination of their pelagic nature, schooling behavior, and larger size relative to other YOY cyprinids in the habitats. Popnets may have attracted YOY orangespotted sunfish by providing structure to a homogeneous habitat otherwise devoid of structure.

In general, both sampling gears provided a similar description of the fish communities in the experimental plots; therefore, data from seine and popnet samples were combined when comparing total number of fish, total number of species, and Shannon diversity index (H′) between vegetated and devegetated plots. Based on the collection of 11,061 fish, we did not detect differences in numbers of fish in vegetated and devegetated plots (two-way ANOVA; $F_{1,3} = 2.63$; $P = 0.203$) (Figure 4). Number of species and H′ were not significantly different between vegetated and devegetated plots (N = 4; Mann-Whitney U-Test: $P = 0.8852$ and $P = 0.665$, respectively) (Table 6).

Relative abundance of fish species was calculated from data combined across gears and sites in order to examine fish community structure between vegetated and devegetated plots. No significant correlation was found in the relative abundance of the eight most common fish species, which encompassed greater than 99% of fish captured, between vegetated and devegetated plots (N = 8; Spearman's $r_s = 0.50$; $P = 0.207$) (Figure 5). A major difference was the emerald shiner was the most abundant fish in devegetated plots, but it was the sixth most abundant fish in vegetated plots. Concordance of ranks between treatment plots was also evaluated at each individual site. At Batchtown West, Batchtown East, and Turner Island, relative abundance of species was not correlated between vegetated and devegetated plots; however, concordance of ranks between plots was found at Jim Crow when all species captured were considered (Table 7).

Based on apparent differences in fish community structure between treatment plots at three of the sites, abundances for the eight most common species were examined separately for differences between vegetated and devegetated plots without including collections from Jim Crow. Mean abundance of mosquitofish, common carp, and spotfin shiner was significantly higher in vegetated plots, and mean abundance of emerald shiner and orangespotted sunfish was significantly higher in devegetated plots (Table 8).

Water Quality in Experimental Plots - The most distinct trends in water quality were evident in temperature and dissolved oxygen (DO), with temperature decreasing and DO increasing over time (Figures 6 and 7). Mean depth, temperature, DO, pH, conductivity, and turbidity were not significantly different in vegetated and devegetated plots during the Fall 1999 sampling period (Table 9).

It is of biological importance that DO values less than or equal to 3.0 mg/L were recorded in vegetated plots at Batchtown East, Batchtown West, and Turner Island, but DO was never limiting in any devegetated plots or at Jim Crow (Table 10, Figure 9). At Turner Island and Batchtown West, DO in the vegetated plot was hospitable by 10 and 25 September, respectively; DO remained very low in the vegetated plot at Batchtown East throughout the sampling period (Figure 9). Time-of-day probably introduced some variation into DO measurements, but most measurements were made between the hours of 1100 and 1600. The lowest DO recorded at Batchtown East and Batchtown West was on a sunny day at 1145 and 1600 hr., respectively.

Edge Habitat at Batchtown East and Batchtown West - The edge habitat sampled at Batchtown East and Batchtown West was approximately 20-30 cm deeper than the respective experimental plot. Of the major water quality parameters measured, only DO in the vegetated plot and vegetated edge were different. Unlike the respective vegetated plots, DO was never limiting at the vegetated edge at Batchtown East (mean = 6.56 mg/L ; range = 4.68 - 7.88 mg/L) or Batchtown West (mean = 8.83 mg/L; range = 7.08 - 11.44 mg/L). Number of fish species and H′ tended to be higher at the vegetated edge compared with the respective vegetated and devegetated plot at Batchtown East and Batchtown West (Table 11). Relative abundance of species captured in the vegetated edge was not significantly correlated with that of the vegetated plot at Batchtown East (N = 10; Spearman's $r_s = 0.01$; $P = 0.984$) or Batchtown West (N = 10; Spearman's $r_s = 0.41$; $P = 0.277$).

Boat Electrofishing - In both 1998 and 1999, gizzard shad and omnivorous. benthic feeding fishes (common carp and suckers) were well represented in samples taken within the Batchtown State Wildlife Management Area (Table 12). Our boat electrofishing data are qualitative since only one sample is taken at a site within a given year. However, a higher number of species was collected in Batchtown in 1998 than in 1999, and sunfish catch-per-unit-effort was higher in 1998 (0.1 fish /min) than in 1999 (0.02 fish/min). The highest number of species (4) and catch-per-unit effort of sunfishes (1.73 fish/min) was recorded during 1998 in the backwater created by the Stag Island Habitat Rehabilitation and Enhancement Project, Pool 25, Mississippi River (Table 13).

Fish Use of Residual Vegetation in Spring 1999

Twenty-eight fish taxa from 10 families were collected at four sites in the residual vegetation. comprised exclusively of smartweed stalks (Table 14). The family Cyprinidae was well represented with 17 species collected, two of which were exotic species (common carp and bighead carp). The majority of taxa collected in the residual vegetation (23) was represented by late larvae and/or early juveniles (YOY) (Table 14). The number of taxa is a conservative estimate since carpsuckers, buffalofishes, and redhorses could not be identified beyond the genus level with any certainty. Young of the mooneye, silver chub, emerald shiner, and slenderhead darter are not typically associated with vegetation in backwaters, but these fish were relatively abundant in our samples of the residual vegetation (Table 14). Ten taxa were collected only at sites containing residual vegetation, but strong relationships cannot be determined because sites differed in factors other than presence of vegetation. Three of the YOY species collected in the vegetation are considered "rare and uncommon" by the state of Missouri as of 1999: the mooneye, silver chub, and blue sucker. Water quality data during collections are summarized in Table 15.

Miscellaneous Fish Collections in Summer 1999

A series of collections made in the slough on Jim Crow Island, following drawdown in 1999, documented changes in the fish community prior to reflood in August (Figure 10). After drawdown in late June, the slough was isolated from the river for approximately 35 days; during this time period, water surface area and maximum depth (<0.5 m) decreased, and water temperatures as high as 40 ^{0}C were recorded. On 13 July 1999, 17 days after isolation, we documented the stranding of 10 fish species (Table 16) and observed dead and dying fish. A rise in water level on day 35 (July 31) reconnected the slough for approximately 5 days (Figure 10). By 13 August, the slough was once again very shallow and only 5 fish species were collected, 3 of which were recently spawned Asian carps that were not present in the previous sample (Table 16). The overall trend at Jim Crow was a decline in species richness following isolation from the river.

Fish collections from three additional sites in lower Pool 25 are reported in Table 17. Of significance was the capture of 3 adult western sand darters (*Ammocrypta clara*) on 7 July 1999 within the side channel. directly east of the experimental plots on Turner Island (River Mile 244.4: SIUC 35591). The western sand darter is on the Watch List in Missouri and Endangered in Illinois. The fish were located just downstream of exposed sand near the confluence of the side channel with the main channel; depth ranged from 10 to 36 cm. temperature was 29 ^{0}C, substrate was sand overlain with a thin layer of silt. and surface water velocity was 5-10 cm/s.

Discussion

Due to elevated discharges upstream throughout the summer months in 1999, water levels in lower Pool 25 remained 3-4 ft below the target pool elevation of 434 ft (rather than the 0.5 to 2.0 ft below 434 ft prescribed under EPM) for a substantial time period (Figure 3). The elevated discharges resulted in tilting of the pool as mandated by the operating plan for Lock and Dam 25. The increased duration and extent of exposure of mudflats produced a strong response by emergent vegetation; however, water quality conditions in backwaters of lower Pool 25 deteriorated during the summer due to isolation from the main channel. When Environmental Pool Management is implemented, water levels are held between 0.5 and 2 ft below the target pool elevation (Atwood et al. 1996) and water levels are raised gradually at the end of the drawdown, back to a target pool elevation of 434 ft. The discharge regime in the summer of 1999 did not allow the flexibility to fully implement Environmental Pool Management (water levels were below the 2 ft target). Only the gradual water rise back to an elevation of 434 was implemented in 1999. However, valuable information, having implications for EPM. was gained by studying the fish and water quality responses to vegetation produced in 1999.

Based primarily on one year of data, fish generally appeared to benefit from the production of emergent vegetation. The fish response cannot be generalized adequately by one single community metric (e.g., an increase or decrease in total abundance, diversity, etc.). but requires consideration of the individual species comprising the community and their respective biologies and tolerances. Two abiotic characteristics of EPM exist that will primarily influence the overall fish response: vegetation production and the hydrology associated with vegetation production. Our results thus far will be discussed within the context of these two attributes.

Vegetation Production

Variability in fish response among sites - We sampled the fish community in devegetated plots and adjacent vegetated plots at four sites to quantify the effects of the vegetation with a field-based, manipulative experiment. Based on knowledge of how fish interact with plants (Janecek 1988; Dibble et al. 1996) and previous research in UMR Pools 24, 25, and 26 (Heidinger et al. 1998), we predicted that overall fish abundance and diversity would be higher in the vegetated plots. Although the relative abundances for common fish species in vegetated plots (rank order abundance of species) was not significantly correlated with species ranks in devegetated plots, no significant difference in total fish abundance and diversity was found between the experimental plots. (Figure 4). A possible explanation for the lack of statistically significant findings in this respect was the relatively small number of replicates (4) combined with variability in the fish responses between replicates (sites). Some of the variability in fish responses among sites can be attributed to differences in site location and dissolved oxygen concentration.

The largest difference in response by fish to vegetated and devegetated plots was observed at Turner Island (Table 6). Turner Island had a relatively small patch of vegetation that was accessible to fishes of flowing water habitats. The vegetation provided nursery habitat for the recently spawned young of the channel shiner, spotfin shiner, and river shiner which are associated with currents as adults and known to spawn late in the season (Trautman 1981; Becker 1983); these minnows are probably utilized as forage by predatory fishes. Also, the availability of small fish as forage items in fall and winter may help facilitate the overwinter survival of a wider size range of piscivorous fishes. The vegetation community at Turner Island was not dominated by smartweed (Table 3), and was relatively vulnerable to wave action that "opened" the vegetation; therefore, DO was not an issue at the Turner Island site after the initial sampling date (Figure 9).

Vegetated plots at Batchtown East and Batchtown West were located in a shallow backwater macrohabitat. Smartweed was abundant and persistent throughout the plots at both sites. Dissolved oxygen less than 3 mgO_2/L was found at both sites and were in the "biotic crisis" range described by Bain (1999). The low DO was most probably due to decomposition of emergent vegetation. The dense vegetation also probably prevented wave action and subsequent atmospheric mixing, and it may have inhibited photosynthesis by phytoplankton since DO was limiting during the middle of the day. Vegetated plots in Batchtown were inhabited primarily by western mosquitofish and common carp (Table 6), which are known to be relatively tolerant of low DO (Becker 1983). Low DO was a chronic problem at Batchtown East throughout the sampling period, but became adequate for fish (> 5.0 mgO_2/L) over time at Batchtown West (Bain 1999) (Figure 9). This improvement in DO, however, was not followed by a noticeable change in the fish community, suggesting additional factors were influencing fish use of the vegetation (e.g., vegetation composition or density). Stem density of smartweed was higher at Batchtown East and additional plant types (not as resistant to inundation) were a significant component of the plant community at Batchtown West (Table 3): open spaces created by the decomposition of plants less tolerant of inundation may explain why DO improved over time at Batchtown West.

Experimental plots at Jim Crow Island were different from all other sites in that they were located within a small backwater slough near the main channel. During fall sampling, connection to the channel was maintained by a narrow beaver run. The shoreline gradient was steeper than other sites which resulted in a narrow band of vegetation around the perimeter. The fish community was well represented by species typical of both backwaters (e.g., western mosquitofish) and flowing water habitats (e.g., channel shiner). Additional testament to the uniqueness of Jim Crow is that three fish species were found only at that particular site, including the grass carp, which was relatively abundant (Table 6). Dissolved oxygen was never found to be limiting in vegetated or devegetated plots. The large-scale influence of the presence of vegetation in Jim Crow slough probably inhibited our ability to detect differences between plots.

The data indicate effects of emergent vegetation will vary with location (macrohabitat) and patch size (vegetated area). The importance of relatively small acreages of vegetation present on islands near the main channel cannot be overlooked, as they provided nursery habitat for fish spawning late in the season. Also, the vegetation at Turner and Jim Crow islands was utilized by (and therefore benefited) more small, littoral fish species than Batchtown (Table 6). Results from the two Batchtown sites indicate that many fish may be excluded from using the internal portions of large expanses of dense emergent vegetation in backwaters because of low DO. Low DO may be more of an issue in dense stands of smartweed because it is relatively tolerant of inundation (unless completely overtopped) and tends to inhibit DO replenishment from wave action.

Edge habitat - In comparison to the vegetated plots at Batchtown East and Batchtown West, which were located totally within the vegetation, more fish species utilized the deeper edge of the vegetation. In fact, the highest diversity of fish at any site sampled was recorded at the edge of the vegetation at Batchtown West (Table 11). An additional four species were collected by boat electrofishing around the edge of the vegetation in Batchtown in 1999 that were not collected by seining (Table 12). Fish have also been observed to congregate at edges of submergent vegetation, particularly piscivorous fish, which use the edge as an ambush point (Killgore et al. 1989; Dibble et al. 1996). Piscivorous fish were absent from our collections, but minnow species and orangespotted sunfish tended to be more abundant at the vegetated edge compared to within the vegetation (Table 11).

Seining technique was different within the vegetation (kicksets) compared to the edge (hauls) and it can be reasoned that more fish are captured by actively pulling the seine versus with kicksets. Perhaps abundance of pelagic species within the vegetated plots was underestimated because of avoidance, accounting for the difference with samples taken from the edge. We do not believe this to be the case, however, because popnet captures within the vegetated plot corroborated seine samples. Additionally, the water was relatively clear within the vegetation, and fish (namely emerald shiners) were not observed avoiding kicksets.

Animals in general are naturally attracted to edges (habitat transitions) because of the increase in heterogeneity due to the availability of multiple habitat types in close proximity; this phenomena is termed the "edge-effect" (Leopold 1933; Yahner 1988). The vegetated edge in Batchtown represented a habitat separating two relatively homogeneous environments: the open water and dense stands of smartweed. Unlike within the vegetation, the edge offered cover and food without the problems of low DO and, potentially, too much structural complexity. Our devegetated plots created additional edge and probably attracted edge-dwelling species. Evidence of this can be seen with the emerald shiner which was the most abundant fish at both the vegetated edge and within the devegetated plot in Batchtown (Table 11). The emerald shiner was very abundant in the vegetation in an earlier study (Heidinger et al. 1998), comprising 88% of fish captured; sampling in that study included the vegetation edge habitat.

Increasing edge to benefit wildlife has been used by resource managers for the management of terrestrial game species (Leopold 1933). Investigators caution against the creation of too much edge because it could become a population sink, particularly for interior specialists (Yahner 1988). Increasing edge habitat in dense, homogeneous stands of emergent vegetation, such as existed in Batchtown in 1999, would probably benefit most fish. Not only would edge habitat be created, but this could also alleviate low DO conditions within the vegetation, potentially a very substantial benefit. We increased edge through formation of our devegetated plots and created conditions that attracted some fish species that were otherwise not found at the same depth within the vegetation (e.g., orangespotted sunfish, emerald shiners, and brook silversides). This management practice is already employed in most years by duck hunters in the Batchtown area who create open areas around duck blinds and cut boat lanes through the vegetation. The potential benefits to fish of edge created by duck hunters should be investigated.

Residual vegetation - Many studies have demonstrated the benefits of living vegetation as habitat for fish (Janecek 1988), but the benefits and use of residual, annual vegetation in the UMR is not well documented. Dead stalks of smartweed still attached to the substrate remained through the winter and were utilized by fish, particularly YOY (Table 14). The stalks, which at some sites formed a dense underwater network, could have provided direct spawning substrate for fish with adhesive eggs (e.g., *Lepisosteus* and *Ictiobus*). Although all the leaves were gone, the remaining stalks offered shallow-water structure at water depths that otherwise would have contained no cover. This was particularly true at the Batchtown sites where no other form of mid-water cover was available. Also, the benefit of residual vegetation as littoral zone cover probably increases when water levels drop, no longer inundating terrestrial vegetation. Residual vegetation could increase invertebrate abundance, and therefore food for fish, by providing cover, a direct food source, or by releasing nutrients once decomposition resumes.

The spring 1999 collections were significant in that they documented fish use of the residual vegetation, but they also contain information on YOY habitat use of poorly known UMR fishes. On 9 June, two YOY blue suckers (2.3 and 2.1 cm TL) were collected at Batchtown East, and one specimen (3.8 cm TL) was captured at Turner. Early YOY blue suckers are rare in collections, but, interestingly, 7 larvae in a Missouri River backwater were also associated with smartweed (Fisher and Willis 2000). The 135 silver chub and 42 slenderhead darter specimens may be the largest collections in the UMR of this relatively unknown life stage. In addition to rare and uncommon fishes, habitat use information was obtained for YOY bighead carp whose numbers are increasing in the Mississippi River and elsewhere.

From a management standpoint, it is important to understand the factors related to if and how much residual vegetation remains following ice-out. Certainly the amount and composition of vegetation present going into the winter will be a factor. Smartweeds appear to be more tolerant of inundation than the other vegetation types and are more likely to be present following ice-out. The temperature regime is also probably important. For example, decomposition rate will be higher during a mild winter combined with fast rising spring temperatures. The majority of residual vegetation is likely lost to water level fluctuations during ice cover; stems attached to ice will be ripped from the bottom during a rise in water level. Location is a factor since scouring due to thawing ice and open river conditions will impact some sites more than others. Continued data collection will enable us to better understand the factors most important in determining the presence of residual vegetation in spring.

Hydrology

Hydrology is one of the most important factors structuring fish communities in lotic systems (Horwitz 1978; Poff and Allan 1995). By influencing reproduction and recruitment processes, water level manipulations (via midpool control point management and EPM) can affect the fish community composition of UMR pools, since fish species may respond differently to a particular hydrologic regime. The timing, rate, and duration of the late spring/early summer maximum drawdown (a result of midpool control point management) can have significant impacts on fish. Spring spawning species, already facing restricted access to quality floodplain habitat (Sheehan and Konikoff 1998), may suffer from a shortened spawning season if maximum drawdown is too early in the year. Year-class strength may also be affected if the drawdown strands (isolates) or forces newly hatched young from backwater nursery areas before they are fully prepared for life in river channel habitats.

In the summer of 1999, we documented the isolation of fish in Jim Crow slough. Fish species richness in Jim Crow slough declined from 23 species prior to drawdown to 5 species 49 days post isolation. Some of this decline was probably due to fish escaping the slough as water levels receded. Nonetheless, we did document that harsh conditions existed, fish were isolated, and mortality was observed first hand. Other backwaters in lower Pool 25 were probably impacted in a manner similar to Jim Crow in 1999 following drawdown. On 13 July, many recently opened mussel shells (*Amblema*, *Quadrula*, and *Megalonaias*) were found scattered in one of the side channels traversing Batchtown. The exposed mussels appeared to have been easy prey for raccoons. Directly adjacent to the experimental plots at Batchtown West, we observed thousands of dead fish on 24 July, encompassing at least 11 species, mostly YOY channel catfish and river carpsucker. The fish were in and around a shallow pool and probably died from the combined effects of extremely high midday temperatures and low DO.

The summer hydrologic regime of 1999 was perhaps extreme compared to other years. Because of the combination of midpool control point management and elevated discharges upstream, Pool 25 was on tilt for most of the summer, resulting in extremely low water levels in the lower pool. Following maximum drawdown, water levels remained 2 ft below full pool (434 ft) for 54 days and 4 ft below full pool for 30-35 days. We observed that at elevations below approximately 431 ft, many backwaters in lower Pool 25 become isolated or completely dry. The fact that mussel beds containing relatively large, old individuals were exposed in Batchtown suggests the combined magnitude and duration of the low water period that occurred in 1999 does not happen frequently.

Evidenced by observations in Jim Crow and Batchtown, the 30-35 days below an elevation of 431 ft was harsh on the aquatic biota in backwaters, but probably increased vegetation production. The vegetation response in 1999 may have been higher than in other years because vegetation at lower elevations probably was able to grow tall enough to withstand reflooding in August; this is supported by our qualitative observation of more vegetation present in 1999 than in 1998. The low DO found in the vegetation in 1999 may not be indicative of DO in the vegetation in most years under EPM. Data need to be collected in additional years to better evaluate the fish response to vegetation produced in 1999.

Although hydrological conditions in 1999 were driven mainly by midpool control point management of Pool 25, the biotic response observed in 1999 has implications for future management strategies of EPM. Within a given year, EPM can be practiced in such a way that it minimizes or negates many of the negative impacts of maximum drawdown on backwater inhabitants but still produces ample vegetation. For example, in situations where river discharge allows some control over water levels, EPM can be employed such that backwaters are reconnected to the river, but mudflats are still exposed for a sufficient amount of time to allow vegetation to grow. In general, we have observed that backwaters in lower Pool 25 become disconnected from the main channel at an elevation between 432 and 431 ft. Also, an "irrigation event" (sensu Dugger and Feddersen 2000), where water levels are allowed to inundate backwaters for a short time period, may be employed following a significant dry period that induced vegetative growth. However, it is unclear whether such an event would rescue fish isolated in backwater ponds or if it would strand additional fish. A mid summer rise or irrigation event did occur during 1998. Sunfish abundance in fall, namely bluegill and orangespotted sunfish, can be used as an indicator of backwater quality since they will be sensitive to water level fluctuations and the absence of nursery habitat (Kohler et al. 1993; Raibley et al. 1997). Sunfish abundance at Jim Crow was 98% higher in 1998 (44 fish) than in 1999 (1 fish), even though sampling effort was much greater in 1999. Qualitative electrofishing samples from Batchtown in 1998 also yielded higher numbers of sunfish. These data indicate the summer hydrologic regime of 1998 was more amenable to backwater fish than in 1999. Environmental Pool Management can also be used to compensate for the negative impacts of drawdown in subsequent years. Following the extreme drawdown in 1999, water levels were kept near full pool throughout the summer in 2000, and preliminary indications are that sunfish abundance was much higher in fall 2000.

Conclusions

Despite the issue of low DO associated with the dense vegetation produced in 1999, fish generally benefited from the presence of late season cover. The vegetation provided nursery habitat for late spawning forage fishes (e.g., channel shiner, spotfin shiner, and river shiner) whose abundances were particularly high at Turner Island. The vegetated edge provided a habitat type for fish that would not have existed without EPM. Residual vegetation was used as nursery habitat by at least twenty-three YOY fish species in late winter and spring. In years when the hydrological regime is not as extreme as in 1999, benefits of EPM to fish may be more pronounced. Our observation of fish stranding and backwater isolation in the summer of 1999 at water elevations near 431 ft supports a maximum drawdown target of 2 ft as outlined by Atwood et al. (1996) for EPM in Pool 25.

Sampling in subsequent years will allow us to evaluate EPM under varying scenarios of vegetation production and hydrological conditions upon which management recommendations can be based. Data collected in 1999 suggest low DO may exclude fish species from using the vegetation at some sites, and fish species richness is generally higher at the vegetated edge. Future studies should further evaluate the relative importance of DO and edge habitat in influencing fish responses to EPM-induced vegetation. We plan to explore management options that would alleviate low DO in the vegetation, increase vegetated edge habitat, and produce ample amounts of vegetation.

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Table 1.

Location of experimental plots at four sites in lower Pool 25. Mississippi River.

Site	Locality
Batchtown East	Pool 25, Mississippi River; approx. 0.5 mi North of boat ramp in Cockrell Hollow; Calhoun Co. Illinois; T12S. R2W, Sec 6; N39°02.361 W90°40.669; River Mile 244
Batchtown West	Pool 25, Mississippi River; in northend of large bay: Calhoun Co. Illinois; T12S, R2W, Sec 6; N39°02.362 W90°41.456; River Mile 244
Jim Crow	Pool 25, Mississippi River; slough on Jim Crow Island; Lincoln Co. Missouri; T50N, R3E, Sec 25; N39°03.792 W90°42.685; River Mile 246
Turner	Pool 25, Mississippi River; southern tip of Turner Island: Calhoun Co. Illinois; T12S, R2W, Sec 1; N39°02.720 W90°42.347; River Mile 244.

Table 2.

Fish collected by seining and popnets combined in October 1998 in Pool 25, Mississippi River. Numbers represent data combined from vegetated and devegetated plots at each study site: Batchtown West (BW), Batchtown East (BE), Jim Crow Island (JC), and Turner Island (Turner).

Common Name	Scientific Name	BW	BE	JC	Turner
Gizzard Shad	*Dorosoma cepedianum*	2	0	8	3
Grass Carp	*Ctenopharyngodon idella*	0	0	1	0
Spotfin Shiner	*Cyprinella spiloptera*	2	0	5	12
Common Carp	*Cyprinus carpio*	0	0	0	0
Emerald Shiner	*Notropis atherinoides*	9	10	65	54
Sand Shiner	*Notropis ludibundus*	2	0	0	0
Channel Shiner	*Notropis wickliffi*	3	1	17	5
Bullhead Minnow	*Pimephales vigilax*	2	1	0	4
Western Mosquitofish	*Gambusia affinis*	16	0	11	1
Brook Silverside	*Labidesthes sicculus*	0	0	3	0
Orangespotted Sunfish	*Lepomis humilis*	0	2	40	1
Bluegill Sunfish	*Lepomis macrochirus*	0	0	4	0
Totals					
	Number of Species:	7	4	9	7
	Fish Abundance:	36	14	154	80

Table 3.

Major emergent plant types present in experimental plots at Batchtown West (BWest), Batchtown East (BEast), Jim Crow, and Turner Island in summer 1999 in Pool 25, Mississippi River. Values represent mean number of stems per m^2 determined from 3 stations at each site (4 stations were present at Turner). Percent occurrence in the stations is also stated. Data were collected prior to reflood and are from Dugger and Feddersen (personal communication).

Plant Genera	BWest	BEast	Jim Crow	Turner
Polygonum	14.67 (100%)	41.33 (100%)	16.0 (66.7%)	11.0 (100%)
Cyperus	104.0 (100%)	25.33 (66.7%)	36.0 (100%)	104.0 (100%)
Echinochloa	9.33 (100%)	34.67 (66.7%)	104.0 (66.7%)	0.0 (0.0%)
Lindernia	45.33 (100%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
Leptochloa	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	229.0 (75%)
Amaranthus	1.33 (33.3%)	2.67 (33.3%)	6.67 (33.3%)	5.0 (50.0%)

Table 4.

Fish species collected with popnets and by seining in vegetated and devegetated plots at four sites in lower Pool 25, Mississippi River, during Fall 1999. An "X" denotes presence in samples as adults and/or young-of-the-year (YOY). Fish were classified as adults or YOY based on total lengths reported in Becker (1983) and Pflieger (1997).

Common Name	Scientific Name	Adult	YOY
Gizzard Shad	*Dorosoma cepedianum*		X
Grass Carp	*Ctenopharyngodon idella*		X
Common Carp	*Cyprinus carpio*		X
Spotfin Shiner	*Cyprinella spiloptera*	X	X*
Emerald Shiner	*Notropis atherinoides*	X	X*
River Shiner	*Notropis blennius*	X	X*
Sand Shiner	*Notropis ludibundus*	X	
Silverband Shiner	*Notropis shumardi*		X
Channel Shiner	*Notropis wickliffi*	X	X*
Bluntnose Minnow	*Pimephales notatus*		X
Bullhead Minnow	*Pimephales vigilax*		X
River Carpsucker	*Carpiodes carpio*		X
Channel Catfish	*Ictalurus punctatus*		X
Western Mosquitofish	*Gambusia affinis*	X	X
Brook Silverside	*Labidesthes sicculus*		X
Orangespotted Sunfish	*Lepomis humilis*		X
Bluegill	*Lepomis macrochirus*	X	
Green Sunfish	*Lepomis cyanellus*		X

* Indicates the majority of specimens were YOY.

Table 5.

Fish abundance and species richness in vegetated and devegetated plots based on collections using two sampling gears. Numbers are pooled from four sites in lower Pool 25, Mississippi River, and totaled over five sampling trips during fall 1999.

Species	Vegetated Plot		Devegetated Plot	
	Seine	Popnet	Seine	Popnet
Dorosoma cepedianum	2	1	2	0
Ctenopharyngodon idella	196	15	24	3
Cyprinus carpio	370	145	127	26
Cyprinella spiloptera	1121	459	125	18
Notropis atherinoides	84	26	700	109
Notropis blennius	52	33	3	0
Notropis ludibundus	0	0	1	0
Notropis shumardi	0	0	1	0
Notropis wickliffi	2234	1027	423	120
Pimephales notatus	1	0	0	0
Pimephales vigilax	2	0	3	3
Carpiodes carpio	0	0	3	0
Ictalurus punctatus	0	2	0	1
Gambusia affinis	2242	543	452	268
Labidesthes sicculus	0	0	6	2
Lepomis humilis	3	4	13	64
Lepomis macrochirus	1	0	0	0
Lepomis cyanellus	2	0	0	0
Totals:				
Number of Species	13	10	14	10
Fish Abundance	6310	2255	1883	614

Table 6.

Species abundance and richness in vegetated (Veg) and devegetated (DeVeg) plots at four sites in Pool 25 of the Mississippi River. Numbers represent pooled seine and popnet samples based on five sampling trips during fall 1999.

Species	Batchtown West		Batchtown East		Jim Crow Island		Turner Island	
	Veg	DeVeg	Veg	DeVeg	Veg	DeVeg	Veg	DeVeg
Dorosoma cepedianum	1	0	0	0	0	0	2	2
Ctenopharyngodon idella	0	0	0	0	211	27	0	0
Cyprinus carpio	285	3	87	0	84	149	59	1
Cyprinella spiloptera	75	5	57	26	61	88	1387	24
Notropis atherinoides	30	78	0	400	5	56	75	275
Notropis blennius	1	0	0	0	1	3	83	0
Notropis ludibundus	0	0	0	0	0	1	0	0
Notropis shumardi	0	0	0	1	0	0	0	0
Notropis wickliffi	1	18	0	22	102	414	3158	89
Pimephales notatus	0	0	0	0	1	0	0	0
Pimephales vigilax	0	0	0	2	0	1	2	3
Carpiodes carpio	0	1	0	1	0	1	0	0
Ictalurus punctatus	0	0	0	0	0	0	2	1
Gambusia affinis	230	1	201	1	2262	718	92	0
Labidesthes sicculus	0	0	0	8	0	0	0	0
Lepomis humilis	2	61	2	5	0	1	3	9
Lepomis macrochirus	0	0	0	0	0	0	1	0
Lepomis cyanellus	2	0	0	0	0	0	0	0
Totals:								
Number of Species	9	7	4	9	8	11	11	8
Fish Abundance	627	167	347	466	2727	1459	4864	404
Shannon Index (H')	0.52	0.52	0.43	0.27	0.30	0.58	0.40	0.41

Table 7.

Correlation analyses comparing the rank-order abundances of species collected in vegetated and devegetated plots at each site (sampling gears combined) in Fall 1999 in Pool 25, Mississippi River. Correlations were calculated using all species present and including only common species. An asterisk denotes a significant correlation in fish community structure between vegetated and devegetated plots.

Site	N	Spearman r_s	*P* - value
Batchtown West	10	0.35	0.326
	6	-0.71	0.111
Batchtown East	10	-0.32	0.359
	5	-0.72	0.172
Jim Crow Island	12	0.83	0.001*
	6	0.43	0.396
Turner Island	11	0.32	0.331
	7	0.16	0.728

Table 8.

Mean (± 1SE) abundance for common species collected in vegetated (Veg.) and devegetated (DeVeg.) plots at Batchtown West, Batchtown East, and Turner Island in Fall 1999, Pool 25, Mississippi River. The null hypothesis that no difference in species abundance existed between vegetated and devegetated plots was tested with a Mann-Whitney *U*- test. An asterisk (*) denotes a significant difference.

Species	Veg. Plot	DeVeg. Plot	*P* - value
Cyprinus carpio	128.75 (52.46)	38.25 (36.92)	0,049*
Cyprinella spiloptera	395.0 (330.69)	35.75 (18.05)	0.049*
Notropis atherinoides	27.5 (17.14)	202.25 (82.27)	0.049*
Notropis blennius	28.0 (27.50)	0	0.121
Notropis wickliffi	1053 (1052.5)	43.0 (23.03	0.513
Gambusia affinis	696.25 (522.76)	180.0 (179.33)	0.049*
Lepomis humilis	1.75 (0.63)	19.0 (14.09)	0.046*

Table 9.

Results of two-way ANOVA tests examining the effect of Plot (vegetated or devegetated) and Site on habitat parameters at four sites in lower Pool 25, Mississippi River in Fall 1999. An asterisk denotes significant ($P < 0.05$) differences.

Independent Variable	Effect	F - value	P - value
Depth	Plot	$F_{1,3} = 0.081$	0.432
	Site	$F_{3,3} = 123.016$	0.001*
Temperature	Plot	$F_{1,3} = 0.12$	0.751
	Site	$F_{3,3} = 15.37$	0.025*
Dissolved Oxygen	Plot	$F_{1,3} = 8.025$	0.066
	Site	$F_{3,3} = 8.051$	0.06
pH	Plot	$F_{1,3} = 1.918$	0.26
	Site	$F_{3,3} = 3.841$	0.149
Conductivity	Plot	$F_{1,3} = 0.479$	0.538
	Site	$F_{3,3} = 1.277$	0.423
Turbidity	Plot	$F_{1,3} = 4.764$	0.117
	Site	$F_{3,3} = 3.43$	0.169

Table 10.

Habitat measurements in vegetated (Veg) and devegetated (DeVeg) plots at four sites in Pool 25 of the Mississippi River. Means (ranges) are based on five sampling trips during fall 1999. Only ranges are provided for pH and conductivity.

	Batchtown West		Batchtown East		Jim Crow Island		Turner Island	
	Veg	DeVeg	Veg	DeVeg	Veg	DeVeg	Veg	DeVeg
Water Depth (cm)	44.4 (38.0-47.0)	42.0 (34.0-46.0)	53.5 (49.0-57.0)	55.2 (53.8-58.0)	27.3 (25.0-29.0)	28.5 (25.0-31.5)	24.8 (20.5-27.0)	27.4 (20.0-32.0)
Temperature (^{0}C)	22.0 (18.6-27.9)	22.2 (17.1-29.5)	20.6 (16.3-25.6)	21.2 (17.2-25.6)	23.1 (17.4-31.0)	23.2 (16.7-32.1)	21.9 (17.3-28.1)	21.4 (16.7-27.2)
Dissolved Oxygen (mg/L)	5.9 (2.23-10.4)	8.1 (6.1-9.8)	2.5 (1.4-3.5)	5.6 (4.4-7.9)	8.7 (6.2-11.4)	10.2 (5.9-12.4)	6.7 (3.0-12.8)	9.0 (6.3-11.4)
pH	7.9-8.7	8.1-8.7	7.4-8.0	7.8-8.4	8.2-9.0	8.0-8.7	7.8-8.8	8.3-8.8
Conductivity (µmhos/cm)	400-450	400-460	300-447	300-441	350-468	400-476	350-450	300-410
Turbidity (NTU)	61.6 (15.5-100)	64.6 (46-100)	17.5 (5-43.5)	48.9 (23-67)	26.7 (4-47.5)	56.9 (8-100)	67.4 (40.5-100)	81.6 (31-100)

Table 11.

Comparison of fish collected by seining in the vegetated plot (VegPlot) and devegetated plot (ØPlot) to collections at the deeper edge of the vegetated plot (VegEdge) and devegetated plot (ØEdge) at Batchtown East and Batchtown West, Pool 25, Mississippi River. Data are summarized from five sampling trips in Fall 1999, except for ØEdge, which are based on three sampling trips.

	Batchtown East				Batchtown West			
Species	VegPlot	VegEdge	ØPlot	ØEdge	VegPlot	VegEdge	ØPlot	ØEdge
Dorosoma cepedianum	0	0	0	0	0	1	0	0
Cyprinus carpio	79	0	0	0	177	2	0	0
Cyprinella spiloptera	3	353	26	0	33	47	2	0
Notemigonus crysoleucas	0	0	0	0	0	1	0	0
Notropis atherinoides	0	400	349	3	16	95	37	19
Notropis blennius	0	3	0	0	0	0	0	0
Notropis ludibundus	0	1	0	0	0	0	0	0
Notropis shumardi	0	0	1	0	0	0	0	0
Notropis wickliffi	0	5	3	2	0	10	4	0
Pimephales notatus	0	1	0	0	0	0	0	0
Carpiodes carpio	0	1	1	0	0	0	1	0
Gambusia affinis	131	4	1	0	188	12	1	0
Labidesthes sicculus	0	0	6	0	0	0	0	0
Lepomis cyanellus	0	0	0	0	2	0	0	0
Lepomis humilis	0	2	0	1	1	21	3	0
Totals:								
Number of Species	3	9	7	3	6	8	6	1
Fish Abundance	213	770	387	6	417	189	48	19
Shannon Index (H')	0.32	0.36	0.18		0.47	0.60	0.38	

Table 12.

Fish collected by boat electrofishing from the Batchtown State Wildlife Management Area 1998-1999. Pool 25, Mississippi River. Numbers are based on 1-1.5 hrs of electrofishing in 1999 and 1998, respectively.

Common Name	Scientific Name	October 1998	October 1999
Gizzard Shad	*Dorosoma cepedianum*	144	141
Common Carp	*Cyprinus carpio*	17	7
Emerald Shiner	*Notropis atherinoides*	5	0
River Carpsucker	*Carpiodes carpio*	12	14
Smallmouth Buffalo	*Ictiobus bubalus*	20	13
Bigmouth Buffalo	*Ictiobus cyprinellus*	1	1
Black Buffalo	*Ictiobus niger*	4	6
Redhorse	*Moxostoma sp.*	2	0
Channel Catfish	*Ictalurus punctatus*	2	1
White Bass	*Morone chrysops*	1	0
Bluegill	*Lepomis macrochirus*	4	0
Orangespotted Sunfish	*Lepomis humilis*	4	1
Warmouth	*Lepomis gulosus*	1	0
Freshwater Drum	*Aplodinotus grunniens*	2	0
Number of Species		14	8

Table 13.

Fish collected by boat electrofishing adjacent to the vegetation on Jim Crow Island (JC) and Turner Island (TR) and on the riverside (SR) and backwater side (SB) of the rock revetment on Stag Island in October 1998, Pool 25, Mississippi River. Effort ranged from 30 - 15 min.

Common Name	Scientific Name	JC	TR	SR	SB
Shortnose Gar	*Lepisosteus platostomus*	0	0	0	1
Skipjack Herring	*Alosa chrysochloris*	0	2	1	0
Gizzard Shad	*Dorosoma cepedianum*	14	88	6	25
Common Carp	*Cyprinus carpio*	6	10	2	1
Grass Carp	*Ctenopharyngodon idella*	0	2	0	0
Emerald Shiner	*Notropis atherinoides*	3	4	0	2
River Carpsucker	*Carpiodes carpio*	1	0	0	1
Smallmouth Buffalo	*Ictiobus bubalus*	1	0	1	2
Channel Catfish	*Ictalurus punctatus*	2	3	0	0
Brook Silverside	*Labidesthes sicculus*	0	0	0	2
White Bass	*Morone chrysops*	0	4	0	0
White Crappie	*Pomoxis annularis*	0	0	0	2
Warmouth	*Lepomis gulosus*	0	0	0	2
Bluegill	*Lepomis macrochirus*	1	4	4	14
Orangespotted Sunfish	*Lepomis humilis*	0	2	0	8
Freshwater Drum	*Aplodinotus grunniens*	2	4	2	6
Number of species		8	10	6	12

Table 14. Spring 1999 fish collections from 7 sites located in lower Pool 25, Mississippi River. Sites were sampled from 8-20 June, 1999. Numbers represent YOY fish unless separated by a colon (YOY:Adult). Residual vegetation was present at Batchtown West (BWest), Batchtown East (BEast), Jim Crow (JC), and Turner. Additional collections are summarized from the Batchtown Boat Ramp (Bramp), Stag Island Slough (Stag), and Stag Island Border (Border).

Species	BWest	BEast	JC	Turner	BRamp	Stag	Border
*Lepisosteus osseus**	-	-	27	6	3	3	1
Hiodon alosoides	-	-	-	5	-	-	-
H. tergisus	8	2	13	9	-	-	16
*Dorosoma cepedianum**	1:1	15	745	10	47	210	2
Campostoma anomalum	-	-	-	-	12	-	-
Cyprinella spiloptera	0:5	0:25	0:11	0:34	0:15	-	-
*Cyprinus carpio**	-	-	14	-	18	-	-
*Hybognathus nuchalis**	1	-	-	-	134	-	3
Hypophthalmichthys nobilis	-	-	12	-	-	-	-
Macrhybopsis hyostoma	-	-	-	-	-	-	0:2
M. storeriana	-	-	70	65	-	-	0:1
Notropis atherinoides	0:9	4:21	25:6	47:31	-	1	0:4
*N. blennius**	-	-	1	-	-	-	2:4
N. dorsalis	-	-	-	1	-	-	-
N. hudsonius	-	-	1	3	7	-	-
N. ludibundus	-	-	-	-	5	-	-
N. wickliffi	0:11	0:12	0:17	0:40	0:12	0:1	0:52
Phenacobius mirabilis	-	1	-	1	-	-	-
Pimephales notatus	-	-	-	-	0:1	-	-
P. vigilax	0:1	0:3	-	0:1	1:24	-	-
*Semotilus atromaculatus**	-	1	-	-	1	-	-
Carpiodes sp.*	-	-	4	1	52	-	1
Cycleptus elongatus	-	2	-	1	-	-	-
Ictiobus sp.*	-	1	28:1	4	64	1	-
Moxostoma sp.*	-	-	1	7	-	-	-
Ictalurus punctatus	-	-	0:1	-	-	-	5
*Gambusia affinis**	1	-	107	3	116	75	-
*Labidesthes sicculus**	-	-	-	-	2	-	-
*Morone chrysops**	-	-	20	13	7	23	5:1
*Lepomis humilis**	-	4	0:3	0:1	15:5	20:1	-
*L. macrochirus**	-	-	0:3	-	-	0:3	-
*Micropterus salmoides**	-	-	-	-	2	-	-
*Pomoxis annularis**	-	-	-	-	2	-	-
*P. nigromaculatus**	-	-	-	-	7	4	-
Etheostoma nigrum	1	-	1	-	-	-	-
Percina phoxocephala	-	-	12	29	-	-	1
P. shumardi	1	-	-	-	-	-	-
Stizostedion canadense	-	-	1	1	-	-	0:1
*Aplodinotus grunniens**	-	2	3:1	163	-	-	-
Number of Taxa:	10	13	23	22	21	10	14

* Denotes species reported to utilize vegetation for spawning and/or nursery habitat. Determinations are from Becker (1983), Holland and Huston (1985), Janecek (1988), and Etnier and Starnes (1993).

Table 15.

Water quality data corresponding with fish collections at 7 sites in lower Pool 25, Mississippi River. from 8-26 June, 1999.

Site	Temp. (°C)	DO (mgO_2/L)	pH	Cond. (µmhos/cm)	Turb. (NTU)
Batchtown West	25.7-26.2	6.2-5.8	7.8-8.3	420-440	69
Batchtown East	24.2-25.8	6.2-5.5	7.4-8.0	400-410	87
Jim Crow	24.7-27.9	4.8-9.2	7.5-7.9	430-440	42-54
Turner	25.3-27.3	5.8-6.5	7.6-8.3	425-450	49-71
Batchtown Boat Ramp	26.5-31.3	8.9-12.0			
Stag Island Slough	25.8	7.9	6.8	430	28
Stag Island Border	23.4	6.2			

Table 16.

Late spring/summer 1999 fish collections from the slough on Jim Crow Island prior to (Pre-Drawdown) and following (Post-Drawdown) maximum drawdown in lower Pool 25, Mississippi River. Pre-Drawdown data are combined from three sampling trips (8,15,20 June 1999). Numbers represent Age-0 fish unless separated by a colon (Age-0:Adult). No designation was attempted for western mosquitofish.

Species	Pre-Drawdown	Post-Drawdown	
		13 July	13 August
Lepisosteus osseus	27	2	0
Hiodon tergisus	13	0	0
Dorosoma cepedianum	745	7	0
Ctenopharyngodon idella	0	0	505
Cyprinella spiloptera	:11	0	0
Cyprinus carpio	14	0	1050
Hypophthalmichthys nobilis	12	0	40
Macrhybopsis storeriana	70	0	0
Notropis atherinoides	25:6	15	0
N. blennius	1	0	0
N. hudsonius	1	0	0
N. wickliffi	:17	0	0
Pimephales notatus	0	3	0
Carpiodes sp.	4	4	1
Ictiobus sp.	28:1	33	0
Moxostoma sp.	1	0	0
Ictalurus punctatus	:1	0	0
Gambusia affinis	107	182	53
Morone chrysops	20	0	0
Lepomis humilis	:3	18:4	0
L. macrochirus	:3	0	0
Pomoxis annularis	0	2	0
Percina phoxocephala	11	0	0
P. shumardi	2	0	0
Stizostedion canadense	1	0	0
Aplodinotus grunniens	211	1	0
Number of Taxa:	23	10	5

Table 17.

Fish collected by miscellaneous seining in lower Pool 25, Mississippi River. The riverside sandbar on Jim Crow Island (Jim Crow Sandbar) was sampled on 13 July 1999. The side channel east of Turner Island (Turner Side Channel) and channel traversing Batchtown (Batchtown Side Channel) were sampled on 7 July 1999. Numbers represent Age-0 fish unless separated by a colon (Age-0:Adult). No designation of age was attempted for western mosquitofish.

Species	Jim Crow Sandbar	Turner Side Channel	Batchtown Side Channel
Hiodon tergisus	0	1	0
Dorosoma cepedianum	2	0	5
Campostoma anomalum	0	0	1
Cyprinella spiloptera	:4	:25	:81
Notropis atherinoides	33:3	147:5	260:1
N. blennius	1:2	0	0
N. dorsalis	3	2	1
N. hudsonius	3	0	0
N. ludibundus	0	0	1
N. wickliffi	:29	:1	17
Pimephales notatus	0	0	2
P. vigilax	:2	0	4
Gambusia affinis	11	2	15
Labidesthes sicculus	3	0	7
Morone chrysops	0	0	2
Lepomis humilis	0	0	2
Pomoxis annularis	0	0	1
Ammocrypta clara	0	:3	0
Stizostedion canadense	0	0	1
Aplodinotus grunniens	1	0	0
Number of Species:	11	7	15

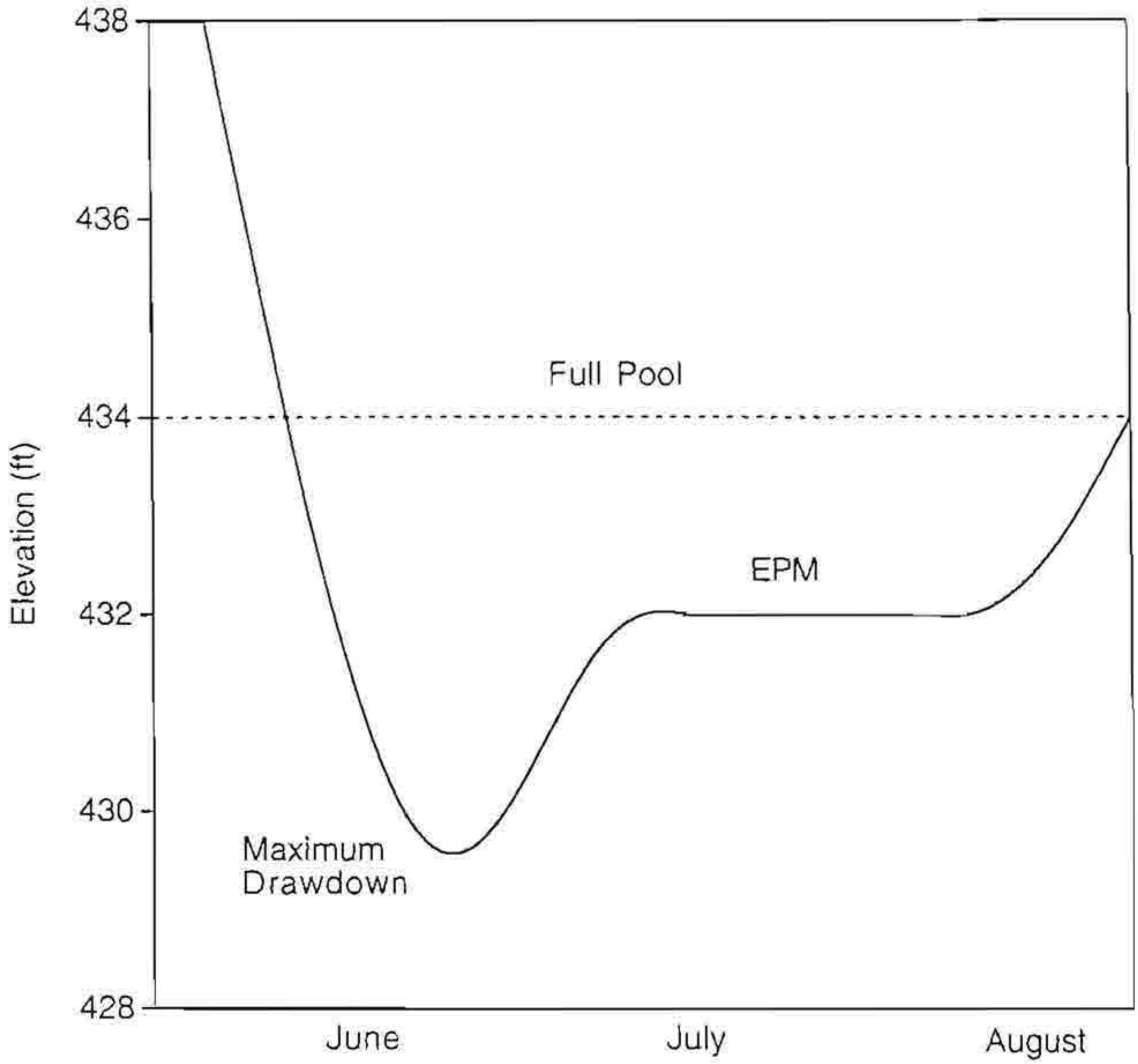
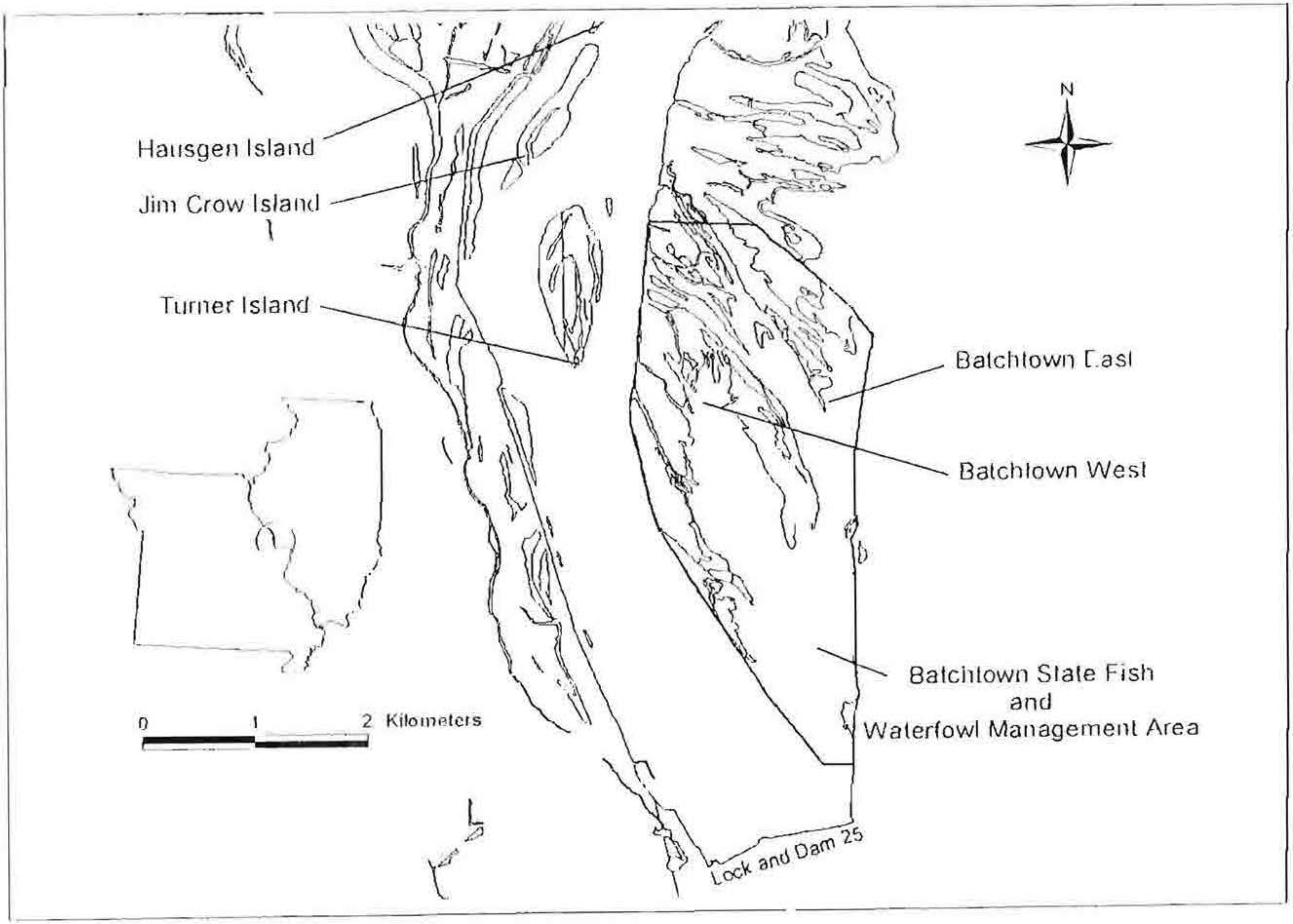


Figure 1. A theoretical depiction of Environmental Pool Management (EPM) in Pool 25, Mississippi River.

Figure 2.

Four study sites located in lower Pool 25, Mississippi River.



N
Hausgen Island
Jim Crow Island
Turner Island
Batchtown East
Batchtown West
Batchtown State Fish and Waterfowl Management Area
0 1 2 Kilometers
Lock and Dam 25

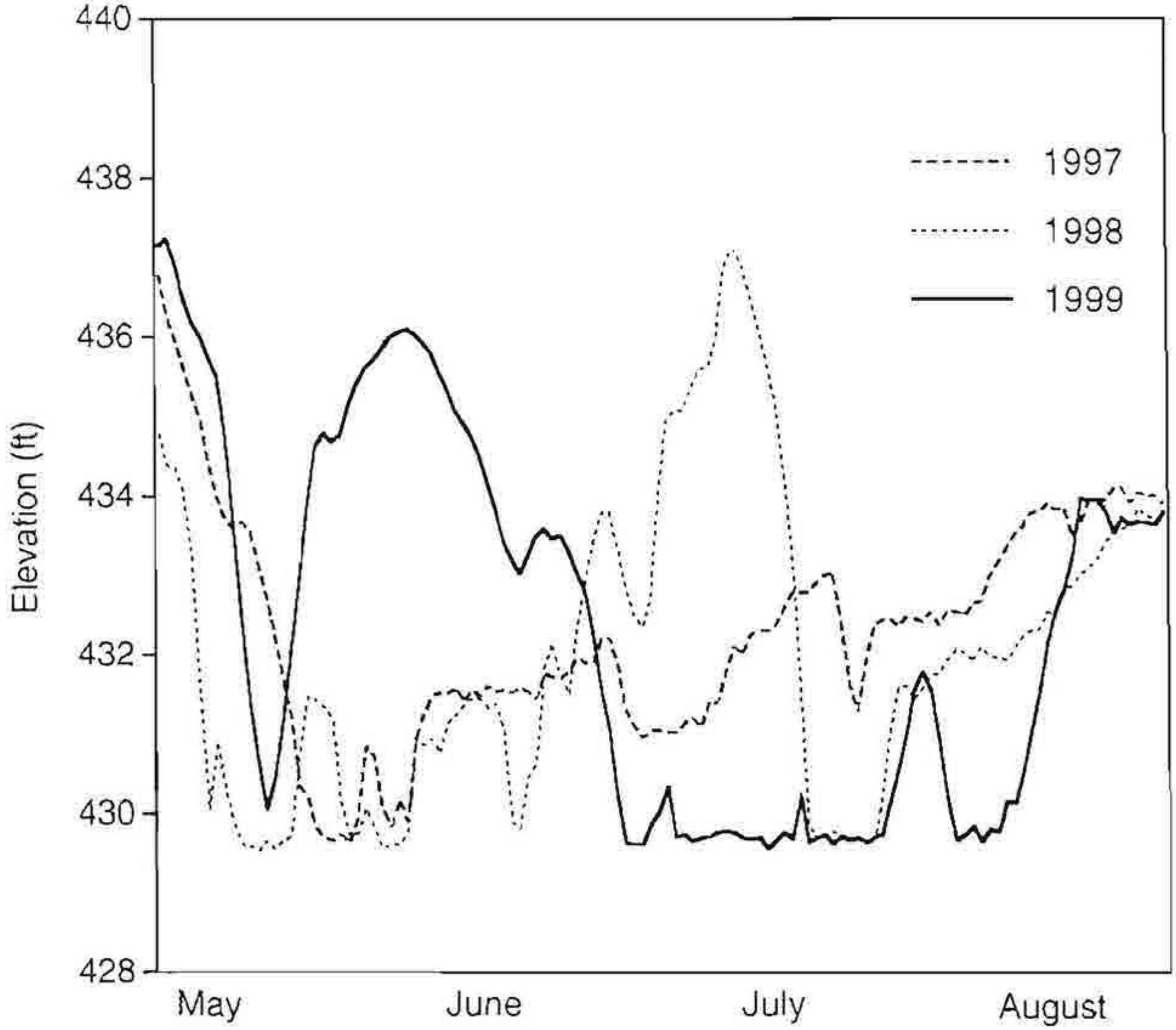


Figure 3. Summer hydrographs for lower Pool 25, Mississippi River in 1997, 1998, and 1999. Daily stages were obtained from Lock and Dam 25 (Upper) Winfield, MO.

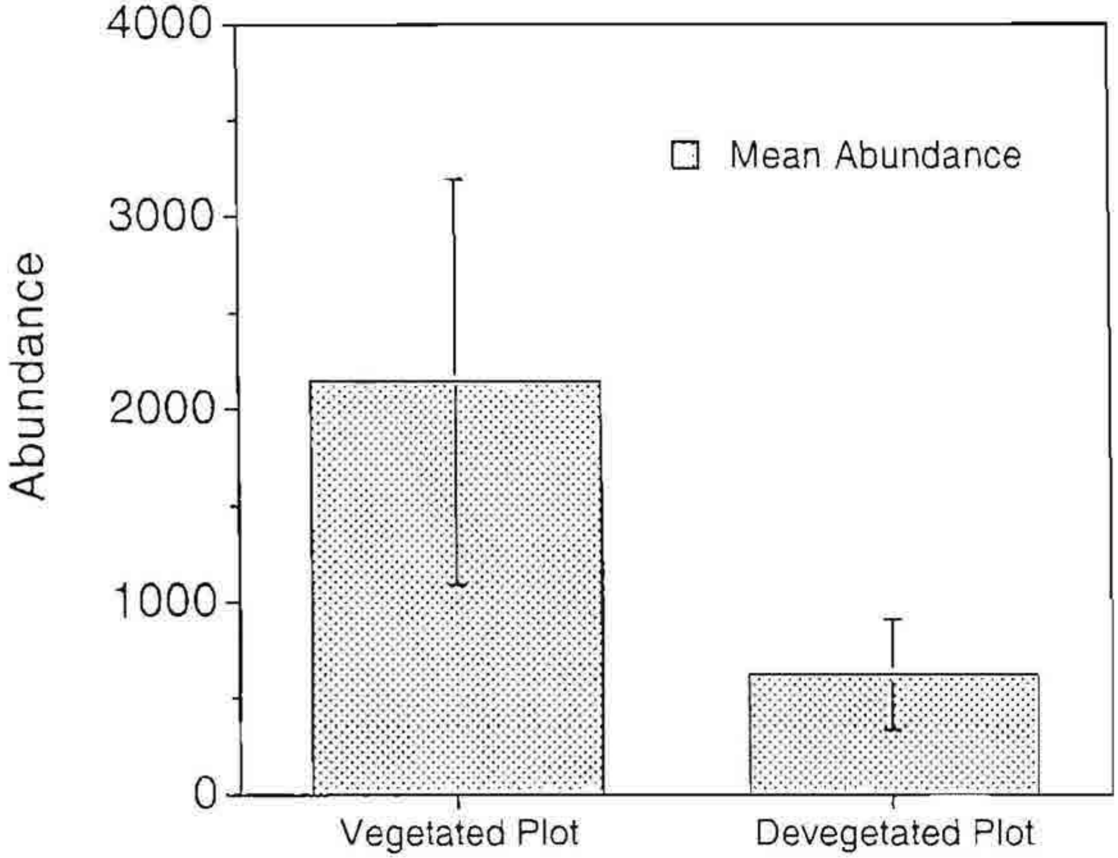


Figure 4. Mean abundance (N = 4) of fish collected using two capture methods from four sites in lower Pool 25, Mississippi River. Error bars represent ± 1 SE. No significant difference was detected between means (two-way ANOVA, $P = 0.203$).

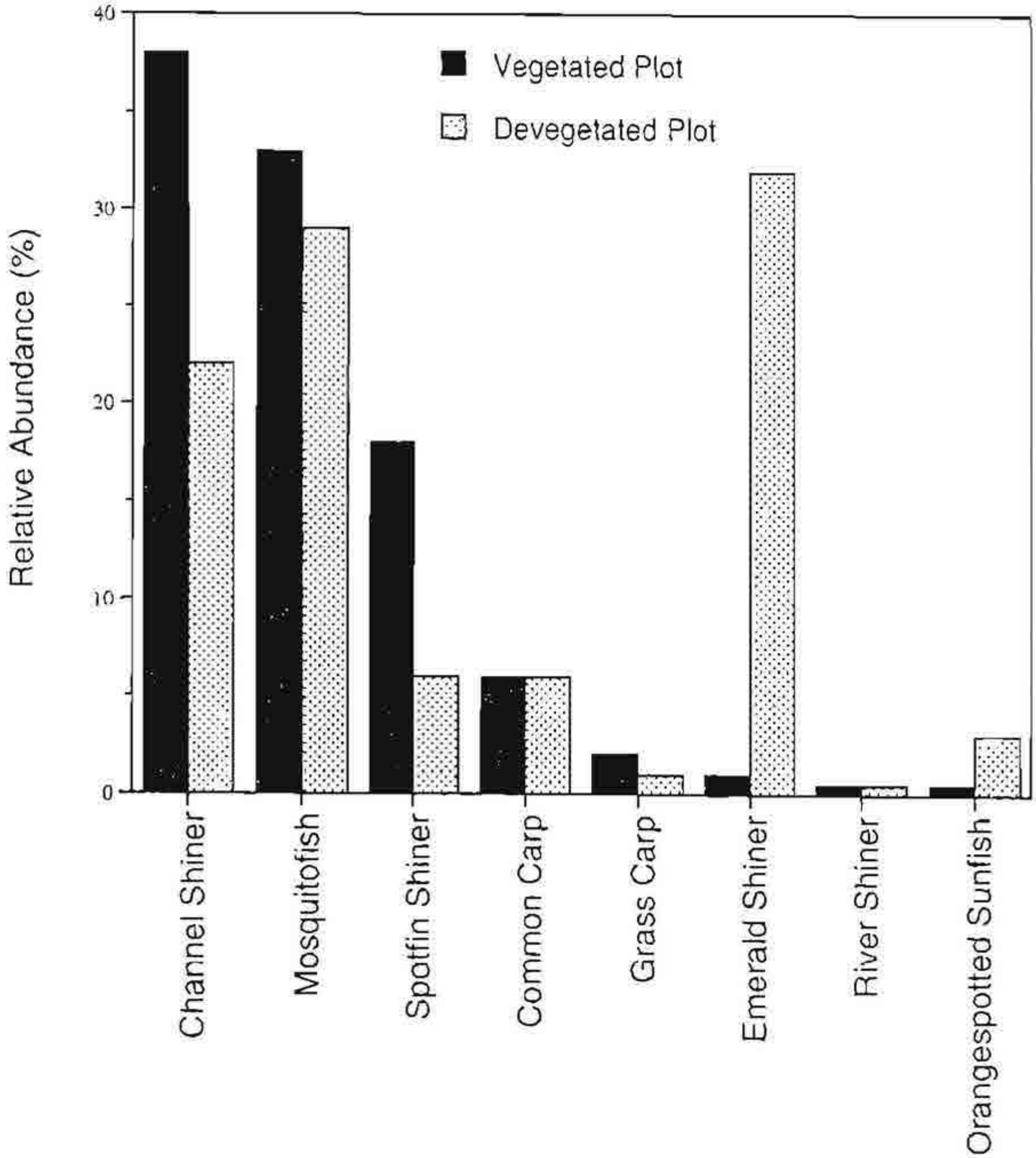


Figure 5. Relative abundance of the eight most abundant fish species in vegetated and devegetated plots in Fall 1999. Data are based on combined samples collected with two gear types and at four sites in lower Pool 25, Mississippi River.

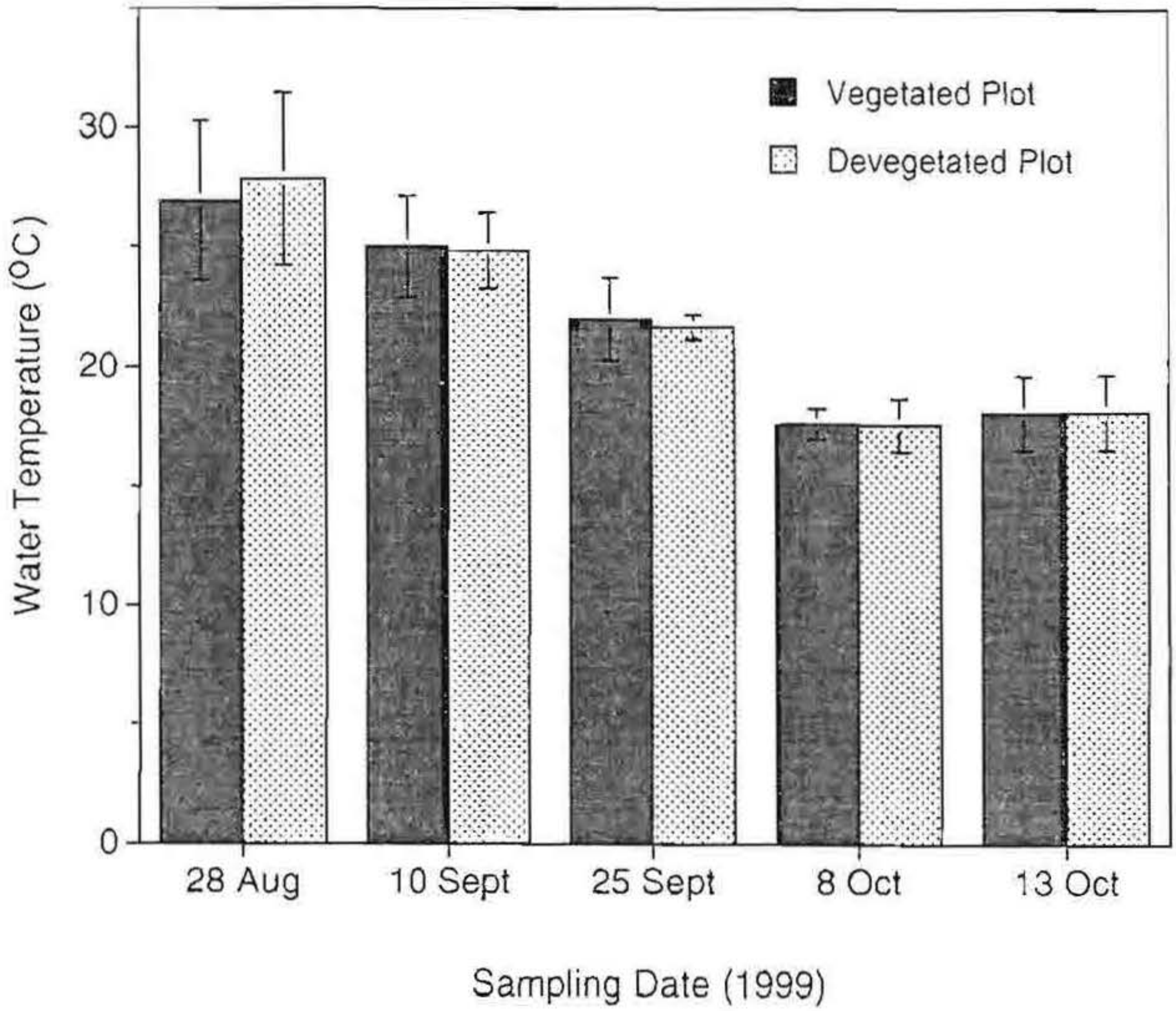


Figure 6. Mean water temperature on five sampling dates in treatment plots at four sites in lower Pool 25, Mississippi River. All N = 4 and error bars represent ± 2 SE.

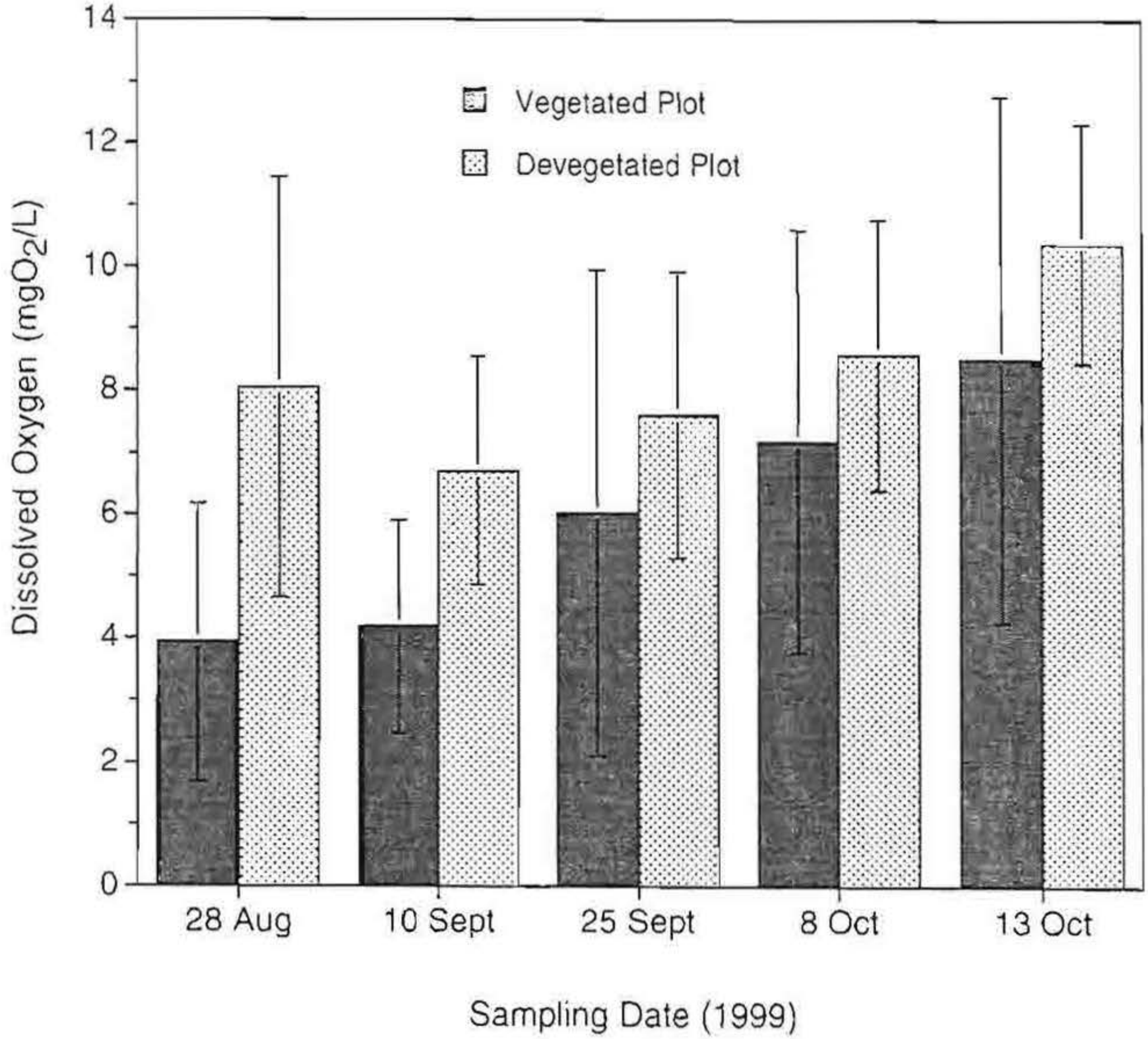


Figure 7. Mean dissolved oxygen concentration on five sampling dates in treatment plots at four sites in lower Pool 25, Mississippi River. All N = 4 and error bars represent $\pm$ 2 SE.

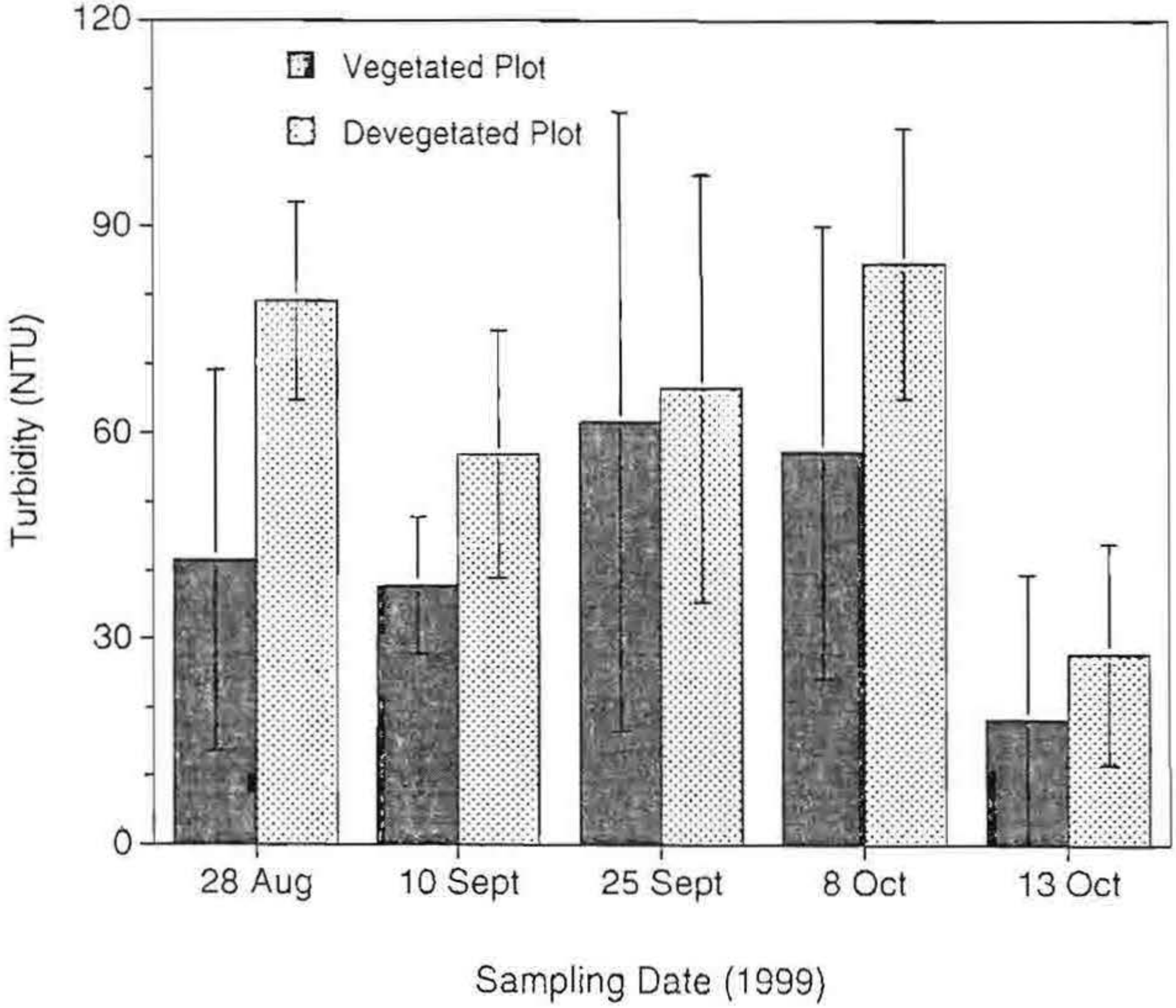


Figure 8. Mean turbidity on five sampling dates in treatment plots at four sites in lower Pool 25, Mississippi River. All N = 4 and error bars represent ± 2 SE.

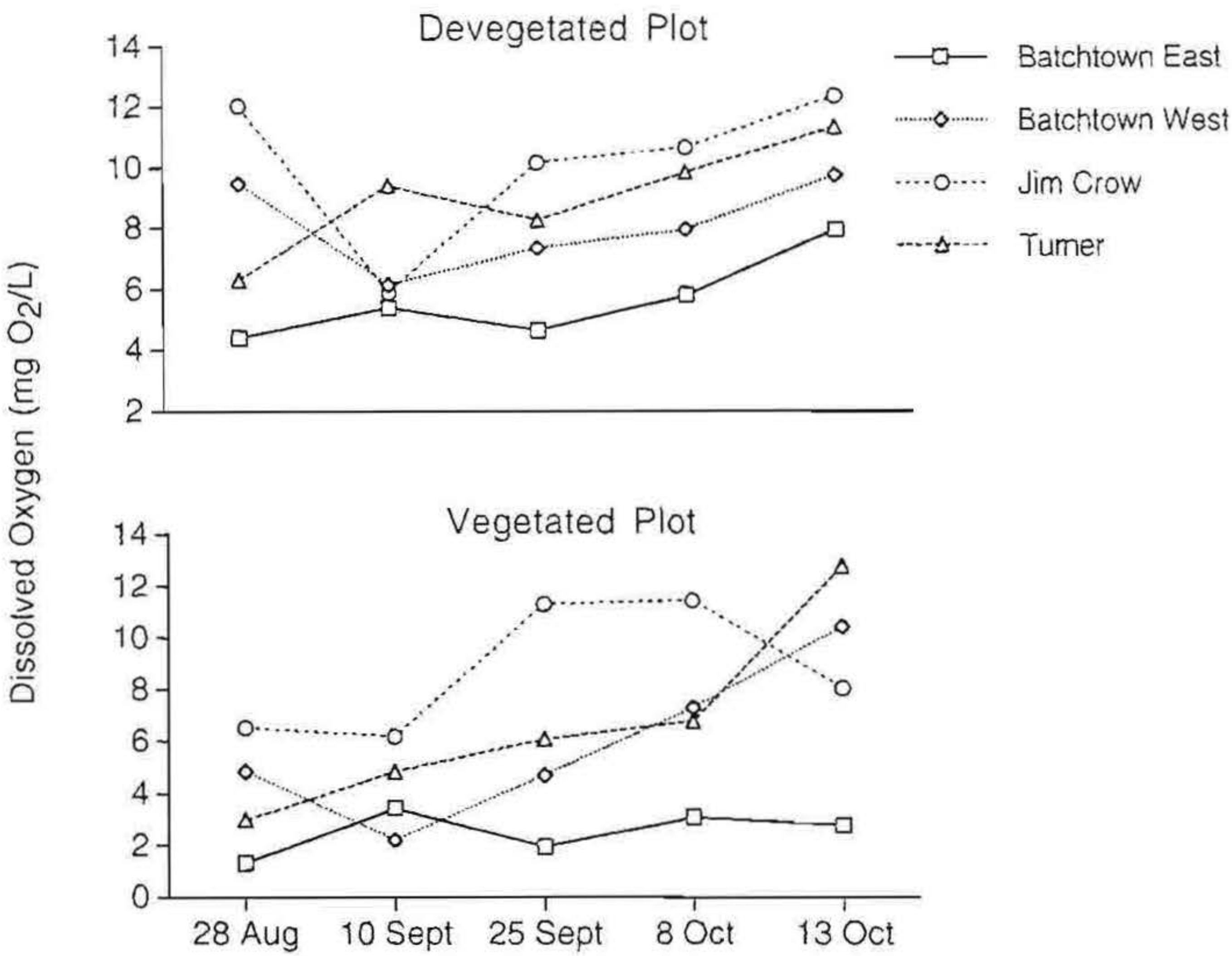


Figure 9. Dissolved oxygen values on five sampling dates in 1999 from treatment plots at four sites in lower Pool 25, Mississippi River.

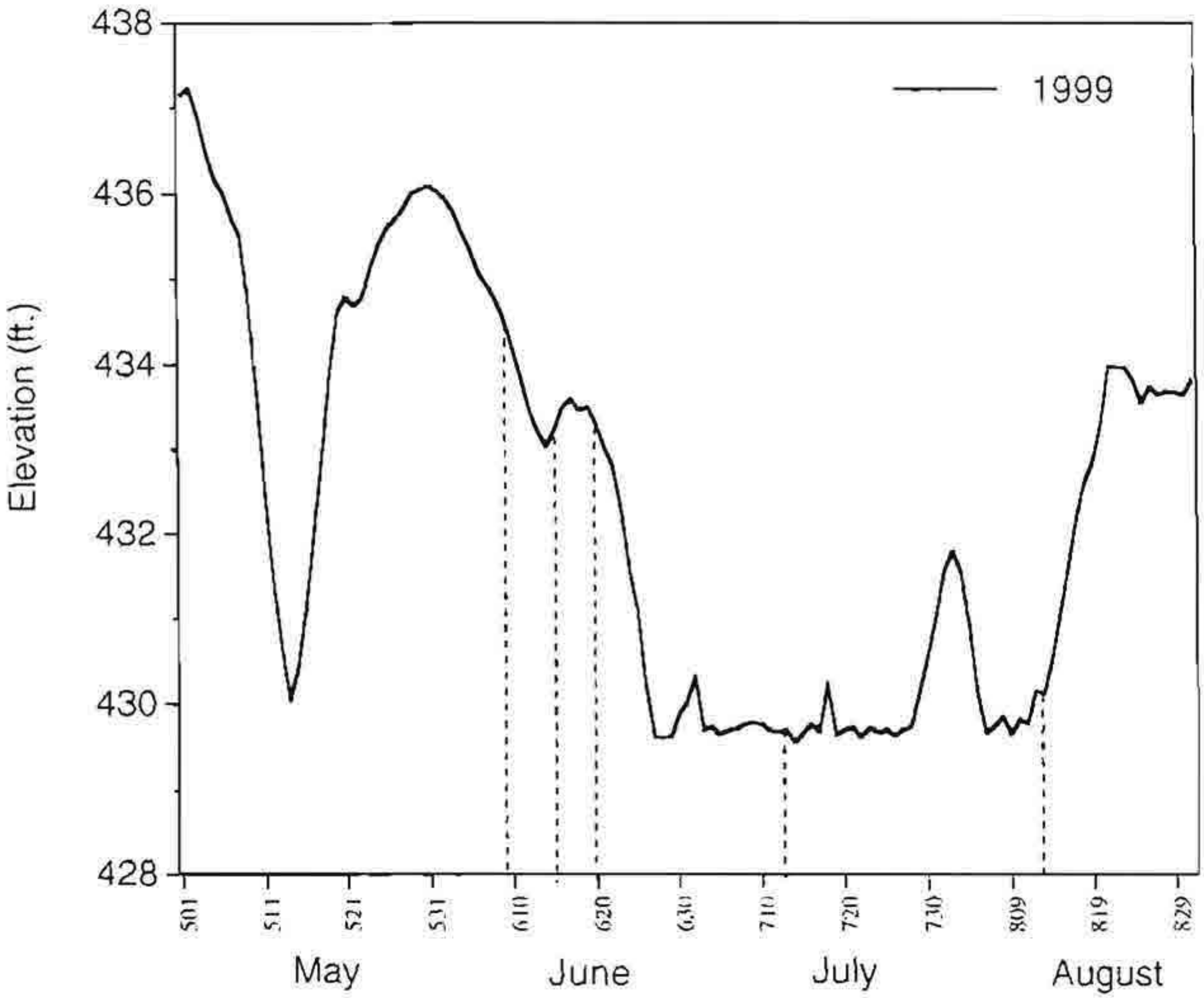


Figure 10. Summer hydrograph for lower Pool 25, Mississippi River in 1999. Daily Stages were obtained from Lock and Dam 25 (Upper) Winfield, MO. Vertical dotted lines indicate dates (month/day) the slough on Jim Crow Island was sampled.

Appendix E.

2000 Progress Report – Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University – Carbondale, Fisheries Research Laboratory and Department of Zoology.

Middle Mississippi River Pallid Sturgeon Habitat Use Project: Supplemental Report on Bendway-Weir Field Use by Pallid Sturgeon. Southern Illinois University – Carbondale, Fisheries Research Laboratory and Department of Zoology.

Middle Mississippi River Pallid Sturgeon Habitat Use Project

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Southern Illinois University

Carbondale, IL 62901-6511

Year 5

Annual Progress Report

January 2001

INTRODUCTION

Overview

The pallid sturgeon *Scaphirhynchus albus* was listed by the U.S. Fish and Wildlife Service as endangered in 1990. The biology of this species is poorly understood, as is the case for many species existing in low numbers. Consequently, the Pallid Sturgeon Recovery Plan (Dryer and Sandvol 1993) identified the need to gain better understanding of the basic biological characteristics of the species.

The present study, funded by the U.S. Fish and Wildlife Service (USFWS) and U.S. Army Corps of Engineers (USACE) and recommended with high priority by the Central States Pallid Sturgeon Work Group, was principally designed to address the Recovery Plan's Primary Task 3.2.1, Conduct field investigations to describe the micro- and macro-habitat components of spawning, feeding, staging, and rearing areas. Because of its approach, the study also addresses several Recovery Plan Secondary Tasks: 1) 1.1, Reduce or eliminate potential and documented threats from past, present and proposed developments initially within recovery priority areas; 2) 3.1, Obtain information on life history of the pallid sturgeon; 3) 3.3, Obtain information on genetic makeup of hatchery-reared and wild *Scaphirhynchus* stocks;

and 4) 3.4, Obtain information on population status and trends. Sonic telemetry techniques were used to determine the movements, locations, and habitat use of pallid sturgeon in the middle Mississippi River (MMR); i.e., the River between the mouths of the Missouri and Ohio Rivers.

This report describes our activities during the fifth year of the study (January 1,2000 through December 31,2000). Goal 1 during year 5 was to continue studying habitat use and movements of wild pallid sturgeon in the Middle Mississippi River. Specific objectives for Goal 1 were as follows. Objective A was the identification and quantification of macrohabitats that pallid sturgeon are associated with on an overall and a seasonal basis in the MMR. Objective B was the determination of whether or not pallid sturgeon select macrohabitat types out of proportion to their availability in the MMR. Objective C was to examine the effects of temperature and discharge on habitat selection by pallid sturgeon in the Mississippi River. Objective D was to quantify home ranges and movement patterns exhibited by pallid sturgeon in the MMR.

Goal 2 during year 4 was to make additional observations of habitat at a site in the MMR near Chester, Illinois, considered to be a putative sturgeon-spawning site by local fishers. Objective A was to attempt to collect sturgeon eggs at this site during the reported spawning season using a benthic dredge specifically designed for this purpose. Objective B was to characterize the community of larger river fishes occupying the area around the spawning site.

Large River Habitats and Their Utilization by the Pallid Sturgeon

The bottom-dwelling pallid sturgeon prefers large, swift, free-flowing mainstem rivers with high turbidity, such as the Missouri and Mississippi (Kallemyn 1983). To date there have been few investigations into habitat use and movements of pallid sturgeon. Clancey (1990) tracked the movements of six pallid sturgeon in the Missouri River near Fort Peck and down stream of the Yellowstone River using a combination of radio and sonic telemetry. Two fish caught by SCUBA, tagged with combination radio/sonic tags, and released in the tailwaters of the Fort Peck Dam remained there for an unspecified period during which they appeared to prefer the deeper (>15 ft) areas of the tailrace. Of the four fish caught below the confluence of the Yellowstone River only two were relocated, both "within a mile or so of their original capture site." Watson and Stewart (1991) described the capture site of a single pallid sturgeon from the Yellowstone River as being on the upstream side of a gravel bar ("gravel and rock with some large rocks in deeper water") on a bend with depths down to ten feet on the outside edge.

A study by Bramblett (1996) concerning movement and habitat use contributed a great deal to our knowledge of the biology of the pallid sturgeon in the northwestern portion of its geographical range. He found they favored habitats with a diversity of depths, current velocities, and substrates. His results showed that pallid sturgeon used areas with depths ranging from 0.6 m to 14.5 m with a mean of 3.30 m, and bottom current velocities ranging between 0 to 1.37 m/s with a mean 0.65 m/s. They appeared to use sand and avoided gravel-cobble substrates. They ranged as far as 331.2 km and moved up to 21.4 km/d. Bramblett (1996) characterized the macrohabitat of pallid sturgeon as "sinuous channels with islands or alluvial bars present." During spring and early summer of both 1993 and 1994 he documented aggregations of pallid sturgeon, which included a female known to be gravid when tagged, in the lower 12 km of the Yellowstone River. He surmised that these aggregations were related to spawning.

Bramblett (1996) focused on pallid sturgeon found in the Missouri River and its tributaries. It is not known whether pallid sturgeon in other portions of their geographic range behave similarly.

Both the Mississippi and Missouri Rivers have been greatly modified by man, but the characteristics of the two differ substantially. The Missouri River is impounded at its confluence with the Mississippi River by the Chain-of-Rocks low-head dam and in its upper reaches by a series of flood-control reservoirs. The lower reach of the Missouri River is channelized and stabilized. The MMR and lower Mississippi River are free flowing, but both have been channelized, leveed, and contain many navigation-aid structures (e.g., wing dams and closing dams)(Sheehan and Rasmunssen 1993).

Habitats available to fish have become reduced in diversity and abundance due to influence of modifications man has made on the MMR. Under natural conditions, fluvial processes both create and destroy aquatic habitats. Today, the MMR is mostly fixed in its bed by bank stabilization and levees, eliminating erosional processes which create and restructure riverine habitats. Depositional processes continue, causing off-channel habitats to become eliminated or aggraded (Sheehan and Rasmunssen 1993). These changes may have affected pallid sturgeon spawning habitat, perhaps forcing them into spawning areas of the closely related shovelnose sturgeon *S. platorynchus* (Carlson and Pflieger 1981).

Perhaps the most severe anthropogenic impact upon the ecology of the MMR results from the extensive drainage and leveeing of floodplain wetlands (Sheehan and Konikoff, 1998). Isolation of the River from its historical floodplain reduces river/floodplain interactions during periods of high water. Many researchers believe the so-called flood pulse is crucial to the trophic dynamics and fishes of large floodplain rivers (see reviews in *Bioscience* Volume 45, 1995). It is not known to what extent MMR pallid sturgeon population size and growth is affected by this reduction in floodplain inundation.

Identification of Pallid Sturgeon

No single morphological characteristic distinguishes pallid from shovelnose sturgeon, due to overlapping character values. Hybrids show characteristics intermediate to parental species, further complicating identification problems. Consequently, biologists have used sets of characteristics to identify *Scaphirhynchus* specimens.

Carlson and Pflieger (1981) concluded that 4,036 of the 4,062 sturgeon they examined were shovelnose, and hybrid sturgeon (15) were about equal in number to pallid sturgeon (11). They devised a mathematical "Character Index," a composite of 13 characteristics, to identify the two species and the presumptive hybrids. There were 10 shovelnose, 12 hybrids, and 8 pallid sturgeon in the Carlson and Pflieger (1981) data set. A similar technique for distinguishing pallid sturgeon broodfish from shovelnose and hybrids uses standardized characteristics based on the minima and maxima which have been reported for those characteristics (Krentz and Dryer 1996). The latter index was developed using characteristics of sturgeon collected in the northern reaches of the Missouri River. We applied the Krentz and Dryer (1996) index to data (reported in Carlson and Pflieger 1981) for *Scaphirhynchus* specimens from the Middle and Lower Missouri River and the Mississippi River, and it failed to distinguish between pallid, shovelnose, and the presumed hybrids. There are at least three possible explanations for the lack of success with the Krentz and Dryer index when applied to the Carlson and Pflieger (1981) data. First, morphological characteristics for pallid and shovelnose sturgeon populations appear to vary across geographical populations (Clancey 1990; Dryer and Sandvol 1993). Clancey (1990) noted that the values for OB/IB (the ratio the length of the outer barbels (OB) to the inner barbels (IB)) from five pallid sturgeon collected near the Fort Peck Dam were far greater than the range for this character reported by Bailey and Cross (1954). This was not the case for values for this character calculated from data reported by Carlson and Pflieger (1981).

A second possible explanation for our failure to successfully apply the Krentz and Dryer index to the data from Carlson and Pflieger (1981) is the possibility that all indices which have been developed to date have used data sets in which some specimens have been misidentified. It is not possible at this time to say with certainty whether specimens identified as species are not in actuality genetically introgressed. Misidentification would cause more overlap in character values for the two species.

A third possible reason for the poor fit of the Carlson and Pflieger (1981) data to the Krentz and Dryer index is that pallid sturgeon in the MMR are genetically introgressed. The degree of overlap in morphological characteristics and the failure of protein electrophoresis to distinguish between pallid sturgeon and shovelnose sturgeon (Phelps and Allendorf 1983) have led some to question if pallid and shovelnose sturgeon should be recognized as distinct species (Campton et al. 1995). Using DNA sequencing of the mitochondrial DNA (mtDNA) control region Campton et al. (1995) were unable to distinguish between the pallid and shovelnose sturgeons, but they claimed to be able to distinguish them from the Alabama sturgeon *S. suttkusi*. The degree of difference in mtDNA haplotypes which they did document supports the contention of Phelps and Allendorf (1983) that evolutionarily the pallid and shovelnose sturgeon are only recently diverged; about 33,000 years ago.

May *et al.* (1997) used microsatellite primers developed for *Acipenser* sturgeon to identify 6 homologous, polymorphic microsatellites (both tri- and tetranucleotide) loci in both *Scaphirhynchus* species. Although they did not focus on the *Scaphirhynchus* species, their work demonstrated the feasibility of amplifying homologous microsatellites in these species. In addition, they illustrated the ability of the technique to reveal polymorphic variation in *Scaphirhynchus* spp. where other techniques have failed. Further, May and colleagues (Bernie May, Director, Genomic Diversity Laboratory, University of California-Davis analyzed tissue samples from sturgeon collected in the lower Mississippi River and found that specimens which were thought to be hybrid sturgeon showed microsatellite allelic frequencies that were intermediate to pallid and shovelnose sturgeon. This is consistent with the observations of Carlson and Pflieger (1981) and others regarding the relatively high incidence of hybridization between pallid and shovelnose sturgeon. However, hybridization is a controversial issue; Mayden and Kuhajda (1997) contend that there is no empirical evidence indicating that hybridization between the two species is common. Only the development of a genetic technique which definitively discriminates between pallid and shovelnose sturgeon will resolve this controversy with any certainty.

Given conflicting information in the literature regarding pallid and shovelnose sturgeon characteristics, the overlap in characters, the incidence of hybrids in field collections, and the apparently recent divergence between the two species, we believed that identification of pallid sturgeon in the field would not be an easy task. Therefore, during Year 1 of the study a character index was developed to aid in the efficiency and accuracy of identification of pallid sturgeon in the field as well as to help distinguish possible pallid X shovelnose sturgeon hybrids (Sheehan et al. 1997a). This index has been used in subsequent to Year 2 to differentiate pallid sturgeon, shovelnose sturgeon, and hybrid sturgeon caught by commercial fishers.

Methods

Goal 1 - Habitat Utilization and Movements of Adult Pallid Sturgeon In the Middle Mississippi River

Pallid sturgeon used to study habitat use and movements(Goal 1) were obtained from commercial fishers, the Missouri Department of Conservation, and sampling conducted by Southern Illinois University at Carbondale (SIUC).

A procedure was developed for taking meristic counts and morphometric measurements while simultaneously surgically implanting sonic transmitters while the study specimens were anesthetized. Total length, standard length, fork length, and weight were taken prior to surgery. Morphometric measurements taken included outer barbel length (OB), inner barbel length (IB), mouth to inner barbel distance (MIB), interrostrum length (IL), and head length (HL). Meristic counts including anal and dorsal fin ray counts (AFC and DFC respectively) were taken upon placement into the recovery tank. Surgery techniques took approximately 10 minutes from removal from anesthesia to placement into the recovery tank.

Sonic transmitters were surgically implanted using the following procedures. The fish were placed in a 114-L ice chest one-half full of fresh river water oxygenated to supersaturation. Carbon dioxide gas was bubbled into the water at a rate of 3.0 cfm until the fish were anesthetized to the surgical plane (loss of equilibrium and diminished struggling when captured by hand). Oxygenation was continued throughout anesthetization. The average time of carbon dioxide exposure was 4.5 min (maximum was 5.8 min; minimum was 3.5 min). The anesthetized fish were removed from the ice chest, and examined to make a qualitative decision regarding whether or not the specimen was a pallid sturgeon. Once it was determined that the specimen fit pallid sturgeon characteristics another biologist initiated the transmitter surgical implantation procedure by placing the specimen on an adjustable "V-shaped" plexiglass surgery table designed to hold the fish with its ventral surface upright. Water was flushed over the gills and skin periodically to prevent drying. The transmitter and all surgical equipment were soaked in 70% ethanol prior to surgery, and the surgical site swabbed with Betadine disinfectant. A 50-mm anterior-posterior incision was made approximately 30-mm anterior to the pelvic fins, one-eighth of body diameter lateral to the midline.

The transmitter was then inserted pushing toward the anterior using a slight rolling motion with the fingers and following the ventral portion of the lateral body wall. The inserted transmitter was moved posterior until its posterior end was approximately 20-mm past the posterior end of the incision. This technique was used to decrease chances of transmitter expulsion and to relieve any pressure on organs that might have occurred during insertion. The incision was closed with simple interrupted sutures using Ethilon® 3/0 monofilament nylon suture attached to a FS-1 curved cutting needle. The incision and sutures were then sealed with cyanoacrylate resin to prevent contamination of the incision and to prevent suture knot failure. Following surgery fish were placed in oxygenated river water to recover for approximately 30 min. Wild fish used for goal 1 were released as close to their capture site as possible.

Transmitters used for the study were 18 mm in diameter and 90 mm in length, 12 g, transmitted at 40 khz, and were uniquely pulse-coded. Estimated life of the transmitters was 13 months. Fish locations were taken with a Sonotronics USR-91 receiver with a dual hydrophone array. Fish were located by tracking downstream at boat velocities of 11 to 13 km/h. After initial contact was made, a series of additional passes were made to triangulate and fix the location of the fish. Location coordinates were then taken using a differential global positioning system, and the position was recorded on U.S. Corp of Engineer Navigation Charts. Depth was taken by sonar and surface temperature was measured at each location a fish was found. Macrohabitat type was determined from a list of habitat classifications (Table 1, Figure 1). These habitat classifications included: main channel (MCL), main channel border (association with an shoreline lacking current-obstructing features)(MCB), immediately upstream of a wing dam (WDU), immediately downstream of a wing dam (WDD), the wing dam tip (WDT), between two consecutive wing dams (WDB), and the downstream side of an island tip (ITD). Beginning in the summer of 1997, substrate samples were taken at points of relocation using a sampler constructed from a length of 16.1-cm diameter steel pipe.

Habitat availability data were gathered using U.S. Army Corp of Engineer Navigation Charts. Twenty, one-river-mile stretches were randomly chosen from the river stretch occupied by the study fish. The navigation charts of these 20 stretches were ground-truthed to ensure up-to-date accuracy. Ground-truthing involved physical examination of each 1-mi stretch to determine if habitats shown on the charts had been modified, added, or removed. Changes typically included the addition or removal of wingdams and the disappearance of small islands, presumably due to erosional processes. These changes were transferred to the navigation charts. The charts were then enlarged to a scale of 3.5 in = 3000 ft.

The occurrence of each macrohabitat type in each one-mile stretch was outlined according to the parameters in Table 1. These parameters were derived from the average of measurements taken in the field using a prismatic rangefinder. Three different examples of each habitat were arbitrarily selected. At three arbitrary locations in each of these areas two measurements were taken from the edge of that particular habitat.

The delineated areas on the charts were then measured using a planimeter. Each habitat was measured three times and the measurements averaged. The results were summed by macrohabitat type and the percentage of all available habitat was calculated for each macrohabitat.

Analysis

The objectives of goal 1 were to identify macrohabitats used by pallid sturgeon in the MMR, to determine if MMR pallid sturgeon were using any given macrohabitat out-of-proportion to its availability in the MMR, to examine the effects of temperature and discharge on habitat selection by pallid sturgeon in the MMR, and to quantify the observed home ranges and movement patterns of the pallid sturgeon in the MMR.

Habitat Associations

Macrohabitat associations were expressed as a proportion of relocations within each habitat type. Additionally, habitat associations were characterized according to surface water temperatures at point of relocation. Macrohabitat associations were separated into groups with surface water temperatures at point of contact below 4° C, between 4° and 10° C, between 10° and 20° C (during both spring and fall months), and above 20° C. Increased mortality and decreased swimming ability have been shown in some fishes at temperatures below 4 °C (Sheehan et.

al. 1994, Sheehan et. al. 1990). The other temperature ranges were chosen to represent the remainder of the winter season, spring and fall, and summer, respectively.

Habitat Selection

Strauss's linear selectivity index (L_i) was chosen to examine habitat selection by pallid sturgeon in the Middle Mississippi River. Strauss's index was more desirable than other popular selectivity indices, such as Ivlev's electivity index, because it is not as susceptible to sampling bias when the habitat type represents a small or minute proportion of all available habitats (Lechowicz 1982). L_i values (Strauss 1979) were calculated for each macrohabitat type using the formula:

$$L_i = r_i - p_i$$

where L_i = linear index value, r_i = proportion of ith habitat in all relocations, and p_i = proportion of ith habitat in the environment. These calculations resulted in an L_i value for each habitat ranging from -1 to 1 with 0 representing random use of a macrohabitat type and no selection occurring. Positive numbers represented positive selection, or selection for, the given habitat while negative numbers represented negative selection, or selection against, the given habitat. To determine direction of selection for each habitat, L_i values were graphed with their 95% confidence intervals. A t-test was used to determine whether L_i values were significantly different from zero (i.e., whether significant positive or negative selection was occurring). A chi-square test was performed to determine whether the distribution of habitat use by the study fish was significantly different from the distribution of habitat available in the stretch of MMR studied.

Effects of Temperature and Discharge

To examine the effects of temperature, L_i values were calculated for each habitat for four temperature ranges (0-4, 4-10, 10-20, and above 20° C). A chi-square goodness-of-fit test was used to determine if significant selection occurred within each temperature range. To examine changes in selection for individual habitats due to temperature, L_i values were grouped by temperature and habitat and graphed with their 95% confidence intervals. A t-test was used to determine whether L_i values were significantly different from zero.

To examine the effects of discharge, L_i index values were calculated for each habitat for three daily mean discharge ranges (Low, Medium, and High). The low, medium, and high discharge ranges were 0 - 165,000, 165,001 - 270,000, and above 270,000 cubic feet per second, respectively. These breakpoints corresponded to the 33.3% and 66.6% daily mean discharge for all days during the sampling period. All discharge data were obtained from the Chester, Illinois, U.S. Geological Survey gauging station. A chi-square goodness-of-fit test was used to determine if significant selection occurred within each discharge range. To examine the changes in selection for individual habitats due to discharge, L_i values were grouped by discharge group and habitat and graphed with their 95% confidence intervals. A t-test was used to determine whether L_i values were significantly different from zero.

Observed Home Ranges and Movements

Observed home ranges for individual study fish were calculated by subtracting the river mile at the lower-most relocation from the river mile at the upper-most relocation. The location of release sites were included in home range calculations. Observed home ranges were reported for each study fish in addition to the calculation of a grand mean observed home range. Movement patterns were visualized by plotting the river mile at each relocation against date for each fish.

Goal 2 - Observations on habitat of sturgeon spawning site near Chester, Illinois

The objectives of Goal 2 were to continue observations of the habitat of a purported sturgeon spawning site near Chester, Illinois to determine substrate type, attempt to collect sturgeon eggs during the spawning season using a benthic egg dredge specifically designed for this purpose, and characterize the fish community at the site.

The site is located on the western shore (Missouri Shore) of the Mississippi River directly below the automobile bridge at Chester, Illinois. During year four of this study substrate was sampled on two separate days once in spring (22 April 1999) and once in early fall (27 October 1999). The fall substrate sample was taken due to concern, expressed by the Long Term Resource Monitoring Program (LTRMP) staff at Cape Girardeau, Missouri, that the site might be overburdened by sand at low river stages (5.7 Ft NGVD on 27 October 1999 at Chester, Illinois). The substrate was sampled using the gear described above. On both occasions three drags of approximately 50 m were made within the purported site and the substrate characterized visually.

An attempt was made to collect a sample of eggs on three occasions during the spring of 2000 on 27 April 2000, 3 May 2000, and 10 May 2000 from the alleged spawning site using a benthic egg dredge (Table 2). Water temperature during this sampling period was between 17° C and 20° C. The benthic egg dredge consisted of a heavy metal sled onto which was attached a 250 µm nylon mesh bag, a brush, and a spray nozzle. During operation a water pump in the boat pumped water down to the dredge through the spray nozzle. The action of the brush in concert with the water spray washes the substrate allowing eggs, if present, and other light debris to collect within the mesh bag. The debris collected in the bag was examined upon retrieval of the apparatus to determine whether eggs were present. Each day of dredge sampling covered a total of at least 300 linear meters of river bed.

In addition samples of fish present over the putative spawning site were collected on the same days using a trammel net. At least three successful drifts were made with the trammel net. Each drift covered approximately 100 meters. The trammel net was 50 meters long with a 38 mm bar mesh multifilament inner panel and a 254 mm bar mesh multifilament outer panel. We had scheduled to have the U.S. Army Corps of Engineers collect bathymetric data at the same time as these samples were collected, however, the water depths at the site were to shallow to allow their boat access.

Results

Goal 1 - Habitat Utilization and Movements of Adult Pallid Sturgeon In the Middle Mississippi River

No additional pallid sturgeon were obtained from commercial fishers and implanted with sonic transmitters during Year 5. Bounties will be raised for year 6 to stimulate the commercial fishers to collect more sturgeon.

Two other pallid sturgeon were examined but not implanted with sonic transmitters due to their small size (Table 3). One of these fish had a scar at the base of the left pectoral fin, but none carried a Missouri Department of Conservation (MDOC) floy tag. The scarred fish was presumably from the group stocked by the MDOC. The MDOC floy tagged each of the pallid sturgeon stocked. The scars on their pectoral fins were probably caused by a floy tag, yet since no tag was observed, we could not confirm that these were MDOC's stocked sturgeon.

Contacts from five pallid sturgeon were added to the study data during Year 5, including four contacts with a fish (transmitter number 3334) identified as a female with eggs at the time of capture. The following analysis is a synopsis of all relocation data gathered throughout the five years of this project.

Habitat Associations

A total of 195 relocations of the study fish were made from November 13, 1995 to December 31, 2000. These 195 contacts were all made during daylight hours. Approximately 3910 miles of tracking effort were exerted during the five years of this study to accumulate these relocations. Most tracking effort was expended between river miles 81 and 151 (Figure 2). This was the portion of the study area that was occupied by the sturgeon for the majority of the study and effort was focused in this stretch in order to maintain contact with the study fish and maximize relocations.

During each year, tracking was typically not possible for a short time during the late winter and early spring due to unsafe ice cover on the river or decreased transmitter range during high water periods in the spring. At river stages above 7.6 m at the Chester, Illinois, U.S. Geological Survey gauge the detection range of the transmitters diminished to less than 3 meters making it impractical to track the study fish.

The study sturgeon were located in the MCL 38% of all relocations. The MCB and WDB habitats were used during 27% and 14% of all contacts, respectively. All other habitats comprised between 1% and 9% of all relocations (Figure 3).

Sheehan et al. (1994, 1990) found that swimming ability decreased and mortality increased for some river species below 4 °C. For this reason, habitat associations for the winter season were broken down into two different temperature regimes: below 4 °C and above 4 °C yet below 10 °C. Below 4 °C, the study sturgeon were found in association with current-disrupting habitat features such as the ITD and WDD more frequently than during the study as a whole (12% and 9%, respectively). However, the MCL (48%) was still used most often (Figure 4). The MCB (14%) was used less frequently than at other temperature regimes. Habitat associations below 4°C were as or more diverse than any other season with 6 of the 7 habitats being used.

Once winter temperatures rose above 4 °C, study sturgeon were found in association with the MCL, MCB, WDB, WDD, and ITD habitats. However, the MCL (52%) and the MCB (30%) together comprised 82% of all relocations (Figure 5).

Habitat associations at temperatures above 10 °C but below 20 °C during the spring months deviated from those during the rest of the year. The MCL habitat, which was used heavily during the rest of the year, comprised only 25% of the relocations during the spring (Figure 6). Use of the MCB (21%) habitat remained similar to most other seasons. Use of the WDB habitats increased greatly during the spring at 33% of the contacts. The ITD (13%) and WDD (8%) habitats were also used (Figure 6). It is notable, however, that the number of contacts during this period was low (n = 24) due to tracking difficulties during spring flooding.

During the fall months at temperatures at or above 10°C but below 20°C, habitat associations were similar to those during the rest of the year. Similar to the winter 4°C to 10°C period, MCL associations comprised 56% of the contacts and MCB comprised 28% totaling 84% of contacts (Figure 7). The ITD, WDT, and WDB habitats were also used at 3%, 10%, and 3%, respectively.

During the summer (surface water temperatures over 21 °C), habitat associations were diverse and resembled the overall habitat associations. The WDT macrohabitat saw its heaviest use during the summer months at 14%. The major habitats of use during the summer were the MCL (26%), MCB (34%), ITD (9%), and the WDB areas (15%) (Figure 8).

Maximum water depths at the point of relocations could be important as pallid sturgeon are generally considered to be a benthic species. The study sturgeon were found in locations with water depths ranging from 1.82 to 19.17 m. They were found most often (88.8% of all relocations; n=157) in water with maximum depths from 3 to 12 m (Table 4). Sturgeon were most commonly found (37.4% of relocations) at depths ranging between 6 and 9 meter (table 4). The study sturgeon were primarily found in the MCL and MCB habitats, where depths in these ranges are common.

Fifty-five substrate samples were taken at points where pallid sturgeon were relocated. Study fish were found over sand substrates 81.8% of the time (n = 45) (Table 5). Sturgeon were found over sand/gravel substrates 9.1% of the time (n=5). Fish were located over mud/silt substrates 5.5% of the time (n = 3). The mean surface velocity measurement taken at points where pallid sturgeon were relocated was 0.55 m/s (SD=0.27; n=28).

Habitat Selection

Habitat availability analysis indicates that the study area was approximately 64.85% MCL and 11.05% MCB. The ITD habitat comprises the smallest amount of the study area at 0.67%. The other macrohabitat types, WDD, WDB, WDU and WDD, comprise 8.73%, 7.82%, 3.71%, 3.04% and 8.73% respectively (Figure 9).

Strauss's selectivity index values (L_i) ranged from -0.2536 to 0.1562 (Figure 10). All L_i values were significantly different from zero (t-test; alpha=0.05). A Chi-square goodness-of-fit test indicated that the distribution of habitat use was significantly different from the habitat availability (χ^2 = 144.70, critical value with 6 df = 12.59). The study sturgeon showed positive selection for, in rank order: MCB, ITD, WDB, and WDT habitats. The study fish exhibited negative selection for, in rank order: MCL, WDD, WDU (Figure 10).

Effects of Temperature and Discharge

A Chi-square goodness-of-fit test indicated that the distribution of habitat use was significantly different from the habitat availability at each temperature regime (Table

6). However, only three habitats showed a change in selection. WDT habitats were positively selected for during each temperature regime except at 4-10° C. Selection of WDD habitat was not significantly different from zero during the 0-4° C temperature range(t-test; alpha=0.05), and L_i for the WDB was not significantly different from zero at the 4-10° C temperature range (t-test; alpha=0.05)(Figure 11).

A Chi-square goodness-of-fit test indicated that the distribution of habitat use was significantly different from the habitat availability at the low, medium, and high discharge regimes (Table 7). Selection direction did not change for any habitat during the three discharge regimes (Figure 12). L_i values for each habitat type at all three discharge regimes were significantly different from zero (t-test; alpha=0.05).

Observed Home Ranges and Movements

Observed home ranges for the study sturgeon varied greatly. Pallid sturgeon 7-8 and 2273 (with 1 post-release contact each) were each located along a 0.1-mi stretch of river. In contrast, pallid sturgeon 384 was located along a 72.2-mi stretch of river in 6 contacts (Table 8). The mean observed home range was 18.0 mi (SD=18.4). These observed home ranges represent the minimum range occupied by the study fish since they may have moved in and out of the observed range between consecutive tracking trips. In addition, six study fish were never relocated and seven other study fish were relocated fewer than two times. These fish may have died, moved outside the study area, or remained in inaccessible areas and should be considered with care when examining the observed home range data.

Twenty-one of the 27 fish implanted with a transmitter were relocated at least one time during the five years of this study. The longest period of contact on a fish to date was fish 2237 at approximately 19 months (Figure 13). The observed movements of each of these fish are depicted in Figures 14-34. Figure 35 provides daily discharges from 1 January 1996 through 31 December 2000 of the study period.

Goal 2 - Observations on habitat of sturgeon spawning site near Chester, Illinois

The substrate samples taken below the automobile bridge at Chester, Illinois during year 4 on 22 April 1999 consisted of very course sand, gravel, and pebbles. On 27 October 1999 the samples consisted of some sand, very course sand, gravel, and pebbles. Sampling with the benthic egg dredge produced no fish eggs, sturgeon or otherwise, from this site during Spring 2000. The two most abundant species captured in association with the site were shovelnose sturgeon and river carp sucker. No pallid sturgeon were captured (Table 9).

Discussion

Goal 1 - Habitat Utilization and Movements of Adult Pallid Sturgeon In the Middle Mississippi River

Habitat Associations

Overall, study fish were contacted most often in the MCL. The study sturgeon were also often found in association with the MCB and the WDB macrohabitats. The only temperature regime (i.e., season) that this trend did not hold was during the spring months when surface water temperatures were at or above 10°C but below 20°C. During these periods, the WDB habitat was used most frequently. This was the only obvious seasonal difference in the habitat associations.

There are several possible explanations for the decreased use of MCL areas and higher use of WDB areas during the spring. During the high water periods in the spring, telemetry efficiency may have been higher in the WDB areas than in the other habitats, resulting in a sampling bias. While no evidence exists to support or disprove such a bias, it is doubtful that such a bias would favor the WDB areas rather than habitats such as the MCB. Therefore, the increased use of WDB habitats and reduction in the use of MCL habitats during the spring months is likely an accurate depiction.

Pallid sturgeon are generally thought to be late spring spawners, although in all practicality nothing is known about their reproductive behavior. If the pallid sturgeon spawning period does occur during spring water temperatures between 10°C and 20°C, then the shift to using WDB habitats over MCL and MCB habitats may represent areas used for spawning or staging by pallid sturgeon. While no information is known about pallid sturgeon reproductive biology (Dryer and Sandvol 1993), data suggests that pallid sturgeon are hybridizing with shovelnose sturgeon (Carlson et al. 1985, Sheehan et al. 1997a, Sheehan et al. 1997b). This hybridization points to the fact that similar areas are probably being used by both species for spawning. Examination of shovelnose sturgeon reproductive biology shows that shovelnose sturgeon typically spawn over rock, rubble, and gravel in the main channel or on rip-rap wing dams (Moos 1978, Helms 1974). Shovelnose spawning habitat, therefore, seems to be distinctly different than that in the WDB areas that are mainly sand. Furthermore, pallid sturgeon produce adhesive eggs, i.e., an eggs type that fishes typically release over a flat firm substrate such as rock or gravel. WDB habitats, by contrast, typically have sandy unstable substrates. The increased use of WDB habitats during the spring does not appear to be consistent with inferred spawning migrations.

Another possible explanation is that pallid sturgeon may use the WDB habitats as feeding stations during the high spring flows. Most of the sandbar depositions in the WDB areas are underwater at high river stages and the water current cuts away at the sand substratum. This may help in exposing benthic invertebrates common in the pallid sturgeon diet (Carlson et al. 1985), creating favorable feeding areas in the WDB habitats.

The most likely explanation, however, may be that pallid sturgeon were using the WDB habitats during high spring flows as velocity refugia. The WDB areas may provide lower velocities than the MCL and MCB areas that were more commonly used than the WDB habitat during the other seasons. It should be noted, however, that if this is the case, study fish were apparently not seeking zero-current habitats such as the WDD areas. Rather, they were seeking areas with reduced currents. Since other reduced current habitats, such as the ITD, were also being used to a greater extent during the spring, this explanation seems the most plausible.

Habitat associations during the winter (water temperature less than 4°C) did not differ from those found during the rest of the year. Habitat associations were also as diverse as those during any other season with the study fish being found in 6 different habitats. It appears that winter temperatures did not have a substantial effect on habitat use by the study fish as they continued to be found in association with the high-current MCL and MCB habitats.

Habitat Selection

A distinction needs to be made between habitat use and habitat selection. Habitat use, in the context of this study, refers to the areas where study sturgeon were located. Areas of high use are important simply for the fact that pallid sturgeon were commonly found in these areas. These are habitat types where water use changes or habitat modifications need to be carefully examined for their effects on pallid sturgeon because of the high probability of their presence.

Habitat selection takes into account the availability of the habitat and compares that availability to the amount of use each habitat receives. Habitats that are negatively selected may represent areas either undesired or simply not used by pallid sturgeon. Habitats that are positively selected represent areas that may be preferred by pallid sturgeon and may be important their survival. Habitats that were positively selected may represent the types of habitat that should be created for the benefit of pallid sturgeon.

MCB, ITD, BWD, and WDT areas are important areas of habitat selection since they are all positively selected for. These areas would seem to be preferred by MMR pallid sturgeon and may represent important pallid sturgeon habitat.

The ITD represents 1% of the habitat available in the MMR. While this is not a common habitat, pallid sturgeon seemed to prefer this habitat. This could be due to its characteristics providing a prime feeding area, much as the MCB may be during high river flows. River flows cut away at embankments of side channels, potentially exposing benthic macroinvertabrates. The ITD habitats could function much as do feeding focal points of trout (Hunter 1991) with the sturgeon using these habitats as breakwater structures with lower velocities while feeding on invertebrates and small fish being swept out of the side channel.

While the study sturgeon were found most often in the MCL, the study fish exhibited selection against the MCL more than any other habitat. This is not surprising considering the MCL comprised 64.85% of the available habitat (Figure 9). The MCL habitat would seem to be an area where pallid sturgeon are commonly found, yet it may not be a preferred macrohabitat for pallid sturgeon.

Effects of Temperature and Discharge

For the most part habitat selection did not change with changes in temperature regimes. Combined with the fact that habitat use at even extreme winter temperatures (0-4 °F) did not deviate from the norm, temperature did not appear to have a substantial effect on either habitat use or habitat selection by MMR pallid sturgeon. In addition, there were no shifts between habitat selection and avoidance at the three different discharge regimes.

Temperature and water velocity are two environmental factors that greatly affect behavior and habitat use of many riverine fishes. Temperature can severely affect swimming ability and mortality of riverine fishes at winter temperatures less than 4 °C (Sheehan et al. 1994, Sheehan et al. 1990). Habitat use and selection by pallid sturgeon, however, appeared to be minimally affected by temperature and discharge in the MMR. The only temperature or discharge regime where habitat use differed from the norm was during spring months with water temperatures between 4 and 10° C.

Observed Home Ranges and Movements

Study sturgeon showed a large individual propensity for movement. However, observed home ranges for the study sturgeon were lower than what has been previously reported for the species. Bramblett (1996) reported that pallid sturgeon studied in the Upper Missouri and Lower Yellowstone Rivers had an average home range of 48.8 mi. Study fish in the MMR had an average home range of only 18.0 mi, less than half of the average observed by Bramblett (1996). The study sturgeon that were not relocated might have had substantially-larger home ranges as they my have moved beyond the study area. However, these fish would have had to have observed home ranges of almost 200 miles in order for the average MMR pallid sturgeon home range to be near that found by Bramblett (1996). Movements of this magnitude have yet to be reported for the species in the literature.

Bramblett (1996) described a variety of habitat and riverine conditions in his study area ranging from near-pristine stretches of the Yellowstone to more lentic stretches of the Missouri that have been impacted by Fort Peck Dam. With different habitats available, larger movements and home ranges may be beneficial for sturgeon as they could efficiently search for preferred areas. Habitat in the MMR is extremely uniform as the river has been highly channelized and has relatively few islands, sidechannels, and backwaters (Dryer and Sandvol 1993). Large movements and home ranges may not be as beneficial to fish in the MMR as in Bramblett's area as it is unlikely that study fish may happen across new habitats.

Some seasonal trends were observed in the movements of the study fish. Study fish appeared to slowly move downstream during the winter months (December through March). Movements of study fish during the spring and summer months (March through July) were variable, with a few large movements observed in both the downstream and upstream direction. During the late summer and fall months (July through October), the study fish generally moved upstream.

These seasonal periods coincide with different discharge regimes as well. During the winter months of December to March the study sturgeon made slow downstream movements. Daily mean discharge during these months was generally the lowest during the year (Figure 36). Logically, these periods also had the lowest temperatures of the study period. Bramblett (1996) found that pallid sturgeon had significantly smaller home ranges during the winter months than during the rest of the year. Erickson (1992) found that pallid sturgeon movements in Lake Sharpe were positively correlated with temperature, and pallid sturgeon moved the least during November through April. Erickson's study was conducted in a mostly lentic environment. MMR pallid sturgeon live in a lotic environment. If pallid sturgeon exhibit decreased movements at colder temperatures then it is logical that not only will sturgeon move less during the winter months, but in a riverine setting would move or be moved in a downstream direction.

MMR pallid sturgeon movements during the spring and summer months of March through July were variable. These were periods of high daily mean discharge in the MMR (Figure

35). Pallid sturgeon movement rates in Lake Sharpe, SD were highest during the months of June through August (Erickson 1992).

Upstream movements were noticed in MMR pallid sturgeon during the months of August through October. These were months of mid-level discharge values. In addition, daily mean discharge values generally decreased throughout this period.

As previously discussed, temperature and daily mean discharge levels did not seem to affect habitat selection in MMR pallid sturgeon. However, seasonal movement patterns observed in MMR pallid sturgeon appear to be affected by daily mean discharge, temperature, or both. During periods of low discharge and low temperatures, i.e., in winter, study fish appeared to move downstream. During periods of high discharge, i.e., in spring and summer, study sturgeon movements were highly variable with large movements taking place. Finally, during periods of mid-level, decreasing discharges, i.e., in late summer and fall, MMR pallid sturgeon tended to move upstream.

Goal 2 - Observations on habitat of sturgeon spawning site near Chester, Illinois

It is difficult to say whether the putative spawning site at Chester Illinois is or could be used for spawning by pallid sturgeon, or even shovelnose sturgeon, based on our observations. The site does seem to be being used by sturgeon however. This line of investigation, however, may be important in locating sites and identifying habitat characteristics needed for spawning.

Management Implications

Habitat loss and alteration is believed to be the primary cause of the decline of the pallid sturgeon. Both the Missouri and Mississippi River have been highly altered by the placement of hydrological and navigation dams as well as having been highly channelized (Dryer and Sandvol 1993). With very little natural, pristine habitat still available it is difficult to determine critical habitat needs for pallid sturgeon.

Habitat use and habitat selection are both important pieces of information. Low habitat use does not mean such habitat is not of importance to pallid sturgeon while areas of positive habitat selection may also be areas of high habitat use. Areas of high use should therefore be viewed as areas to be protected for the benefit of pallid sturgeon commonly located there while areas of positive habitat selection should be the type of areas considered for habitat creation projects.

In the MMR river, pallid sturgeon are often found in the MCL and MCB habitats. The high use of these areas make any changes to these habitats potentially harmful to pallid sturgeon. Any changes in use of these habitats or alterations to them should be examined before future projects are undertaken. Likewise, the three wingdam habitats represent the low-use habitats examined in this study. Any alterations or changes to these habitats would have a reduced chance of harming pallid sturgeon populations due to their infrequent use of these areas.

While the MCL is the area of highest use by MMR pallid sturgeon, the habitat selectivity analysis presented here indicates that the ITD, MCB, and WDB areas may actually represent preferred habitats. These habitats should be given consideration for any future projects aimed at creating pallid sturgeon habitat as they may be of critical importance for the rejuvenation of this species. Restoration of these habitats would represent an increase in habitat diversity that could benefit many species in addition to the endangered pallid sturgeon. Identification and characterization of spawning habitats should remain a focus since little is known about them.

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Table 1. Distances used in delineating borders between different macrohabitats for habitat availability analysis. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip.

Habitat	Standards For Delineation
WDU	246 ft upstream and inside of tip of wingdam
WDD	561 ft downstream and inside of tip of wingdam
WDT	144 ft radius around tip of wingdam
WDB	all area between and inside tips of consecutive wingdams not otherwise delineated
ITD	393 ft radius around downstream tip of islands
MCB	294 ft from shore lacking wingdams
MCL	all area not otherwise delineated

Table 1. River temperature, river stage, and amount of effort by gear type used to sample the putative pallid sturgeon spawning site at Chester, Illinois, during Spring of 2000.

Date	Temp (C)	River Stage[a]	Egg Dredge Pulls (n)	Total Distance Dredged (m)	Trammel Net Sets (n)
4/18	17	4.6	-	-	4
4/27	17	11.1	4	497	3
5/3	17.5	9.9	2	472	3
5/10	20	12	1	304	3

[a] Stage in feet above datum NGVD at Chester, Illinois, USGS gauging station number 07020500

Table 3. Meristic and Morphometric measurements, and Character index (CI) values for pallid sturgeon and putative hybrids captured in the Middle Mississippi River during Year 5 and not implanted with a sonic transmitter. All measurements are in millimeters and grams. OB = outer barbel mean length, IB = inner barbel mean length, HL = head length, MIB = mouth to inner barbel distance, and IL = interrostrum length.

Standard Length (mm)	Weight (g)	CI	OB/IB	HL/IB	HL/MIB	IL/IB	IL/MIB	Fin Ray Counts Anal	Fin Ray Counts Dorsal	Ventral Scutes
559	725.7	-1.58	2.04	7.35	6.00	2.98	2.43	39	27	None
552	635	0.06	1.40	5.16	5.16	2.13	2.13	36	23	Few
618	952.5	-1.46	1.70	6.59	5.39	3.07	2.52	37	29	Few
669	997.9	-0.51	1.73	2.55	2.68	2.28	2.39	37	24	Few
691		-0.35	1.79	5.11	5.11	2.05	2.05	35	24	Many
633	1224.7	-0.39	1.77	4.56	5.00	1.85	2.03	37	25	Many
699		-0.55	1.58	4.89	5.94	2.07	2.51	36	26	Many

Table 4. Maximum water depths at locations where pallid sturgeon were found.

Depth (m)	Contacts	Percent
<3	9	4.8
3 - 6	42	22.5
6 - 9	70	37.4
9 - 12	54	28.9
12 - 15	9	4.8
15 - 18	1	0.5
>18	2	1.1

Table 5. Substrate type at locations where pallid sturgeon were found in the Middle Mississippi River.

Substrate Type	Observations	Percentage
Mud/Silt	3	5.5
Sand	45	81.8
Course Sand	1	1.8
Sand/Gravel	5	9.1
Gravel	1	1.8

Table 6. Chi-square goodness-of-fit results comparing distribution of habitat use to distribution of habitat available by temperature regime. χ^2 > critical value indicates significant selection occurred.

Temperature Regime (°C)	χ^2	df	Critical Value
0-4	190.4	6	12.59
4-10	90.3	6	12.59
10-20	114.9	6	12.59
20-	134.5	6	12.59

Table 7. Chi-square goodness-of-fit results comparing distribution of habitat use to distribution of habitat available by discharge regime. Low, medium, and high discharge regimes were 0-165,000; 165,001-270,000; and 270,000+, respectively. χ^2 > critical value indicates significant selection occurred.

Discharge Regime	χ^2	df	Critical Value
Low	87.4	6	12.59
Medium	124.3	6	12.59
High	399.1	6	12.59

Table 8. Range of river miles over which individual pallid sturgeon were contacted.

Transmitter Number	River Mile[1] Upstream	River Mile[1] Downstream	Number of Observations[2]	Miles
7--8[3]	118	118	1	0.1
2273	106	106	1	0.1
5--10[3]	103	104	2	0.7
338	131	132	1	1.4
239	118	120	1	2
456	104	106	2	2.2
267	114	118	15	4.3
366	108	117	19	9.7
2363	126	136	3	9.9
2237	115	126	9	11.4
249	109	121	21	11.9
276	130	142	1	11.9
294	124	143	18	18.7
2264	98.4	120	6	21.5
357	95.5	118	23	22.9
3334	80.2	110	7	30.1
2388	109	142	17	32.6
465	107	142	11	35.2
339	106	142	5	35.4
375	98.2	142	12	44.1
384	32.3	105	6	72.2

[1] Includes river mile of release site.
[2] Observations subsequent to release only.
[3] Dash indicates a two second pause in pulse cycle as part of the transmitter code.

Table 9. Species composition (n) of fishes captured in trammel net drifts of the putative pallid sturgeon spawning site at Chester, Illinois, during Spring of 2000.

	Date				
Species	4/18	4/27	5/3	5/10	Total
Bighead Carp	0	3	1	0	4
Black Buffalo	0	0	1	2	3
Blue Sucker	0	0	4	0	4
Common Carp	1	0	1	5	7
Gizzard Shad	0	0	0	1	1
Quillback Sucker	0	7	1	0	8
River Carpsucker	0	6	7	0	13
Shovelnose Sturgeon	26	2	25	8	61
Smallmouth Buffalo	0	0	1	1	2
White Bass	0	0	1	0	1

Figure 1. Macrohabitat classifications used when describing the location of pallid sturgeon. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WIB = between wing dams, ITD = downstream island tip.

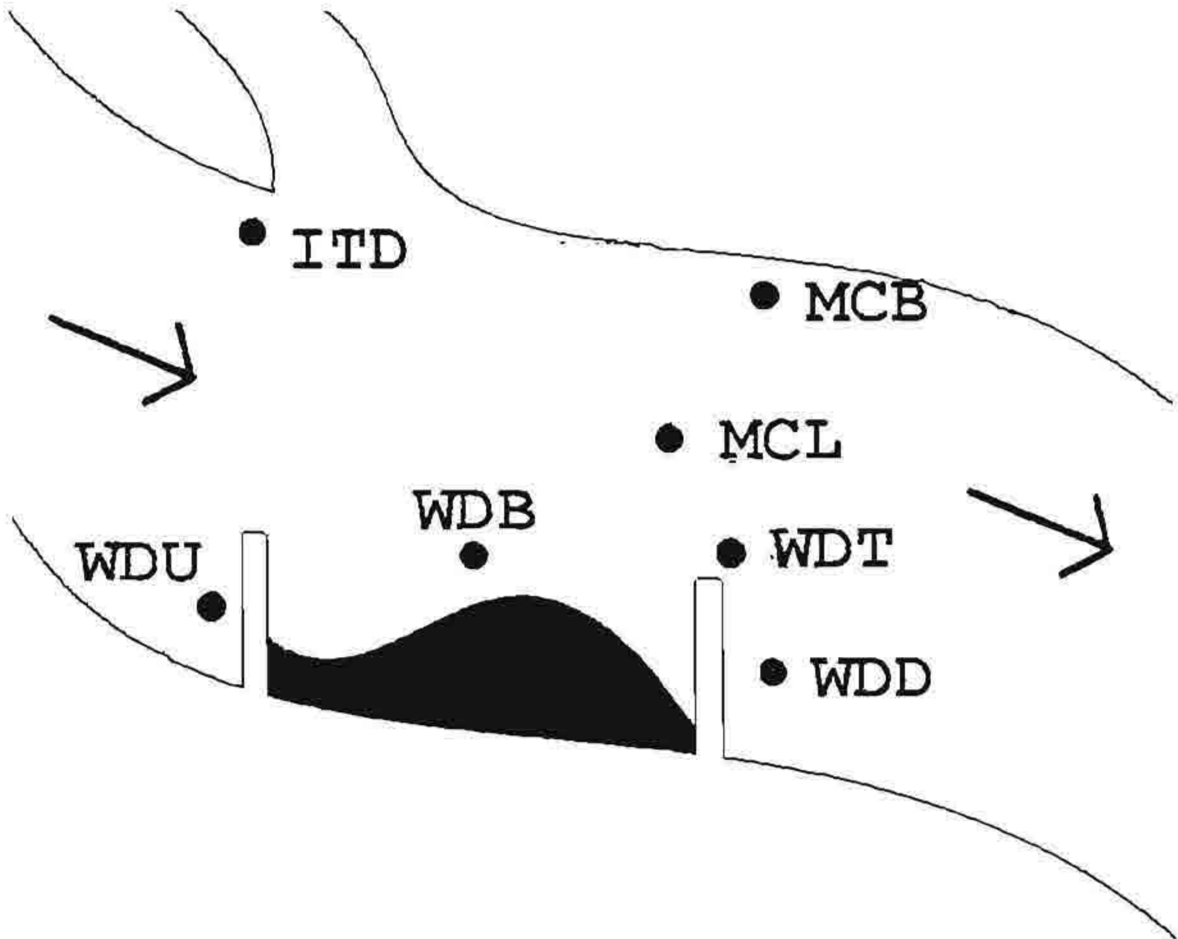


Figure 2. Tracking effort expressed as the frequency that each river mile in the study area was tracked from November 1995 through December 2000.

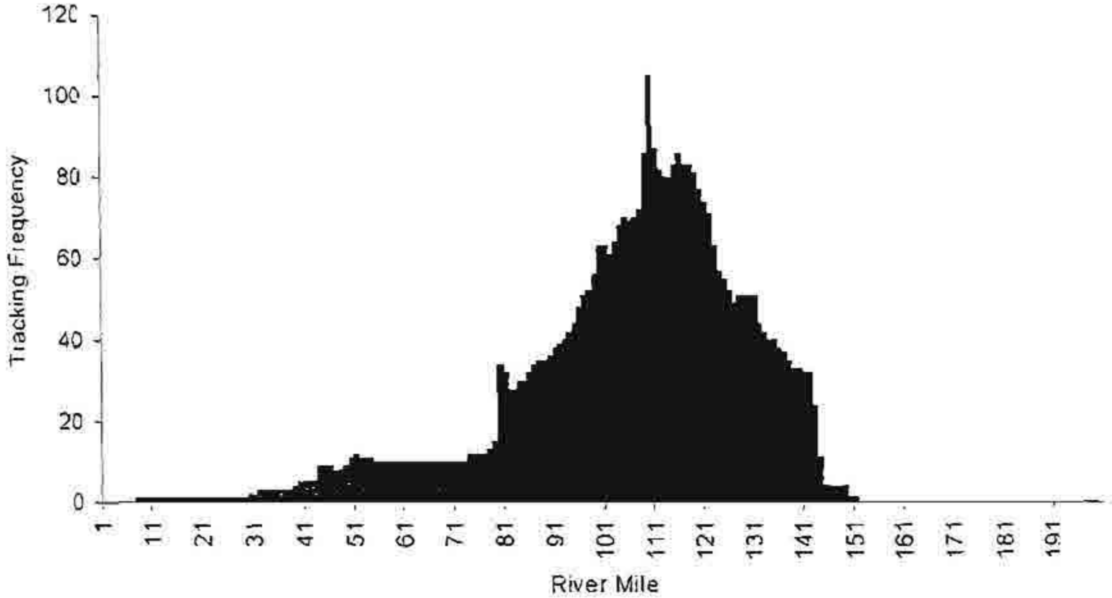


Figure 3. Pallid sturgeon habitat associations in the middle Mississippi River from November 1995 through December [illegible]. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 195.

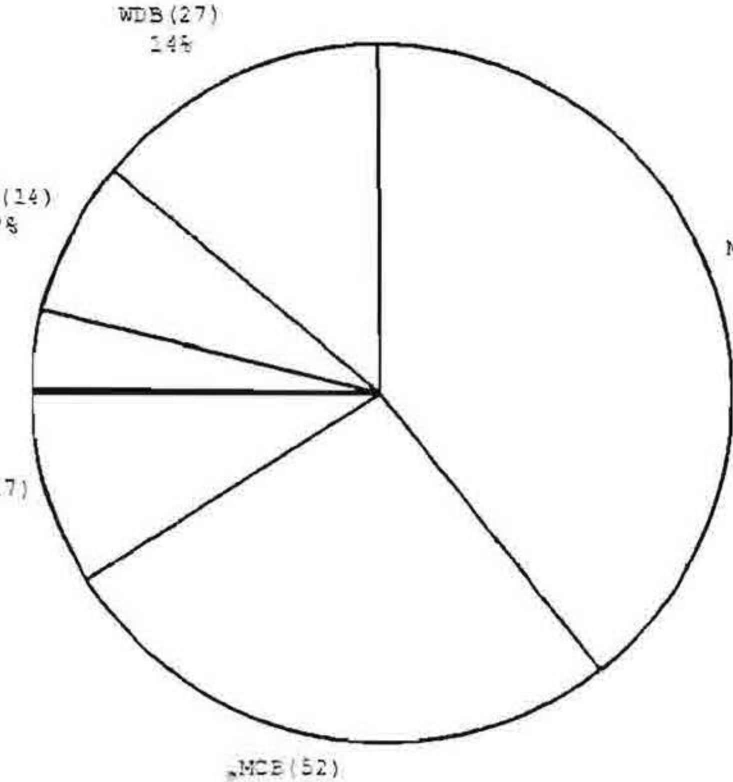


Figure 4. Pallid sturgeon habitat associations at surface water temperatures at or below 4° C in the middle Mississippi River from November 1995 through December 2000. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N =43.

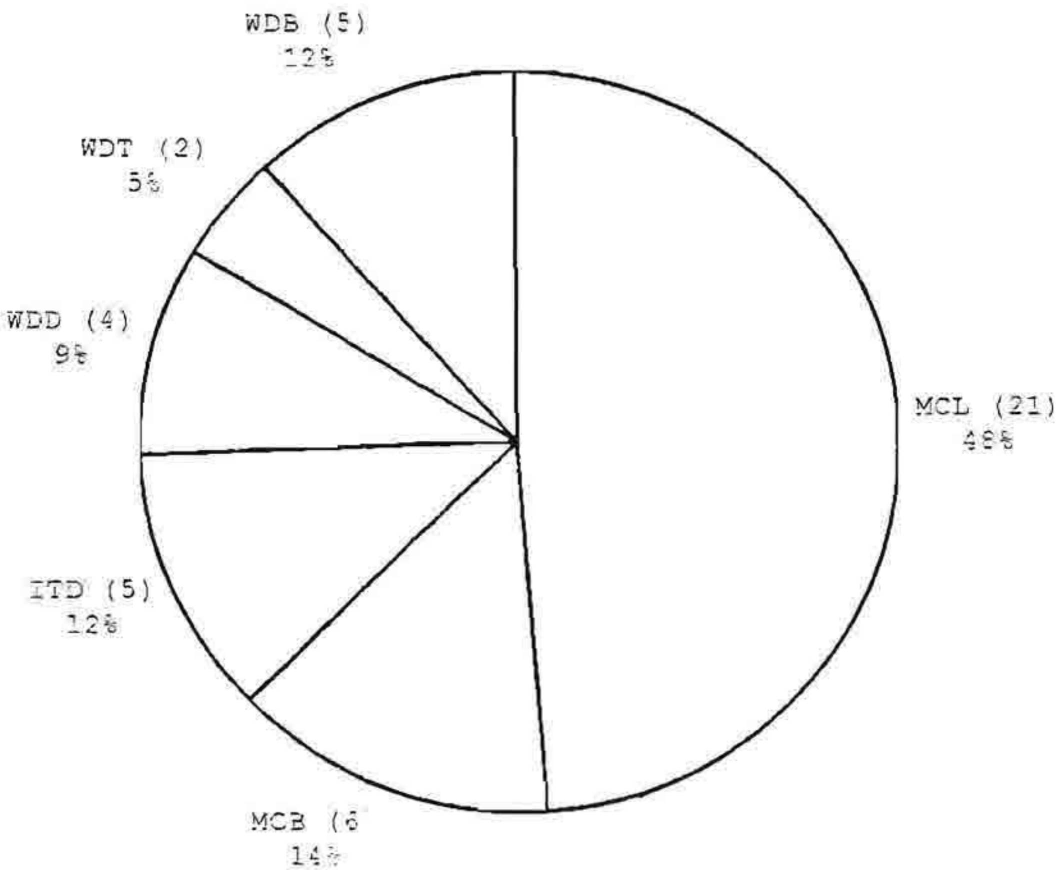


Figure [illegible]. Pallid sturgeon habitat associations at surface water temperatures at or above 4° C and below 10° C in the middle Mississippi River from November 1995 through December 2000. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 33.

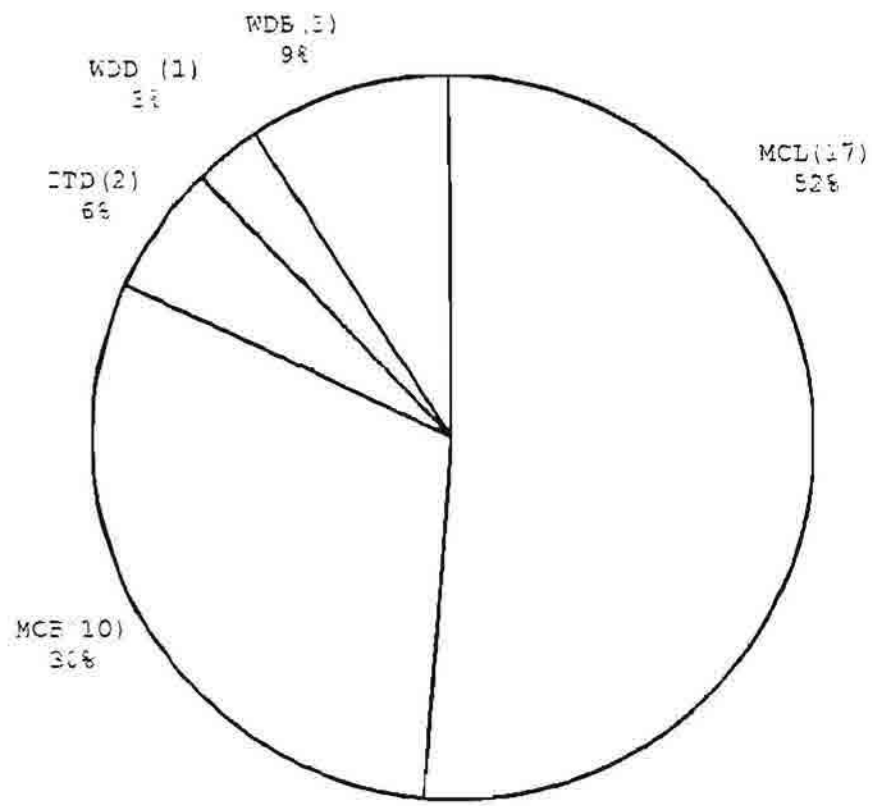


Figure 6. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River during spring months during 1996-2000. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 24.

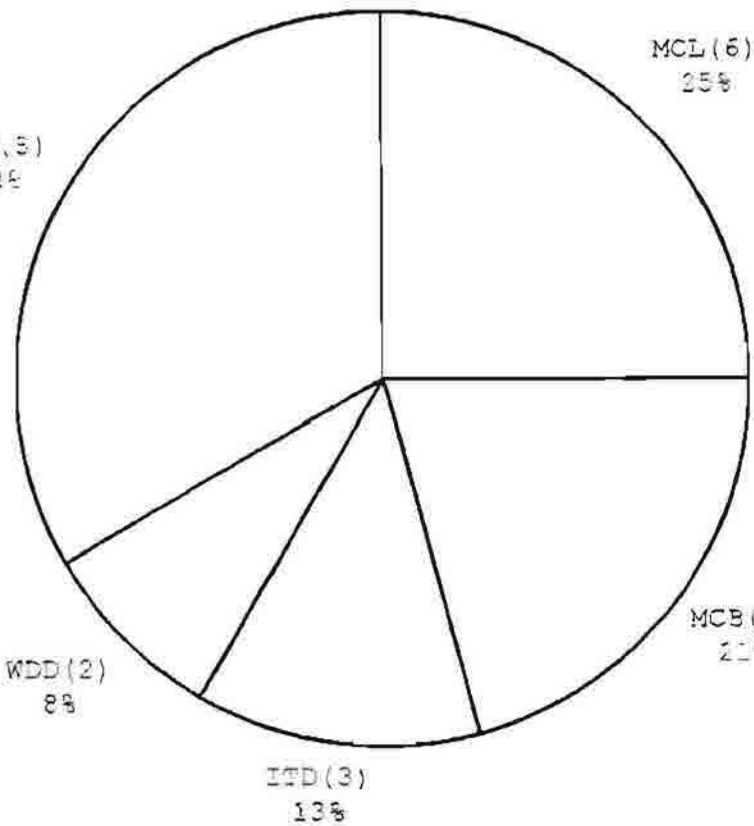


Figure 7. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River during fall months of 1996-2000. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 29.

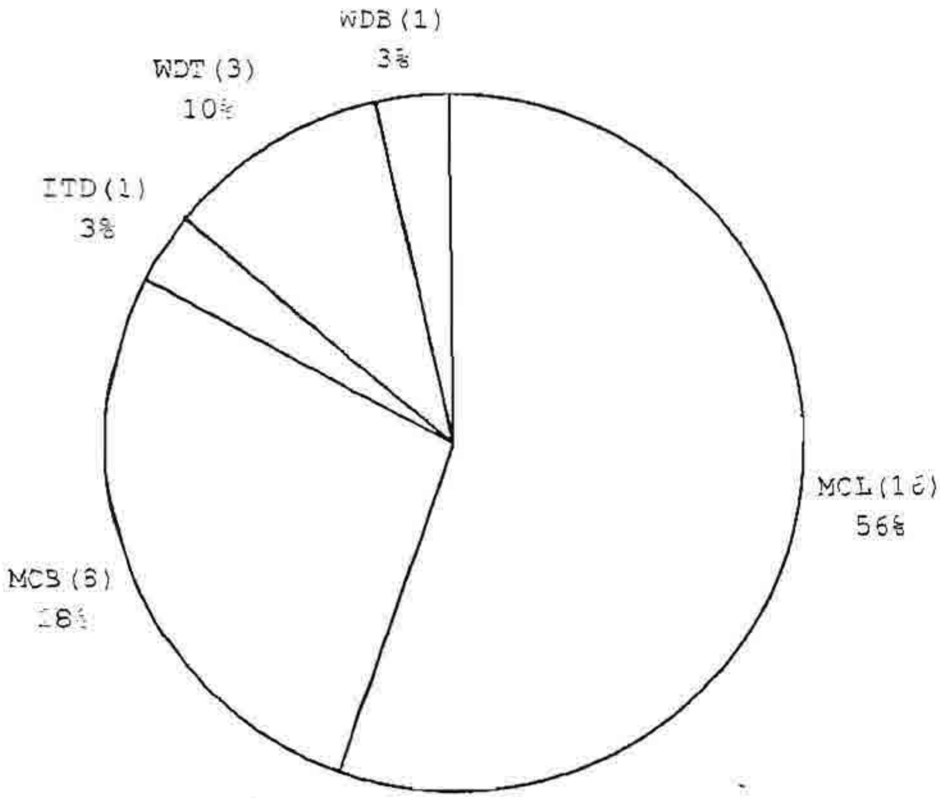


Figure 8. Pallid sturgeon habitat associations at surface water temperatures at or above 20° C in the middle Mississippi River from November 1995 through December 2000. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 66.

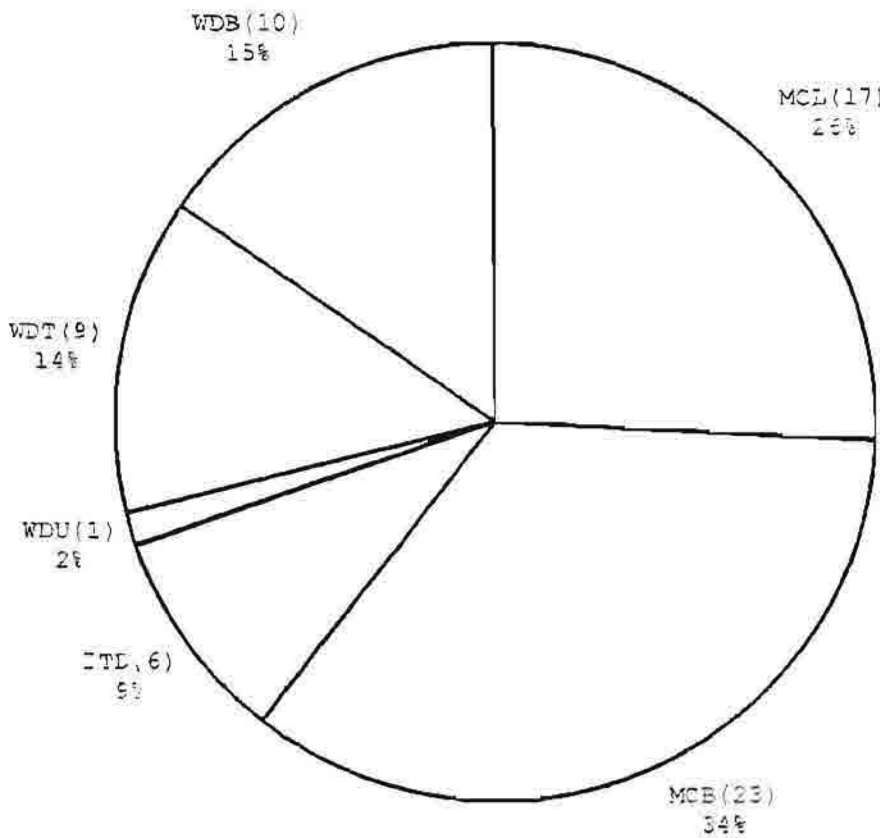


Figure 9. Habitat availability in the Middle Mississippi River expressed as a percentage. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip.

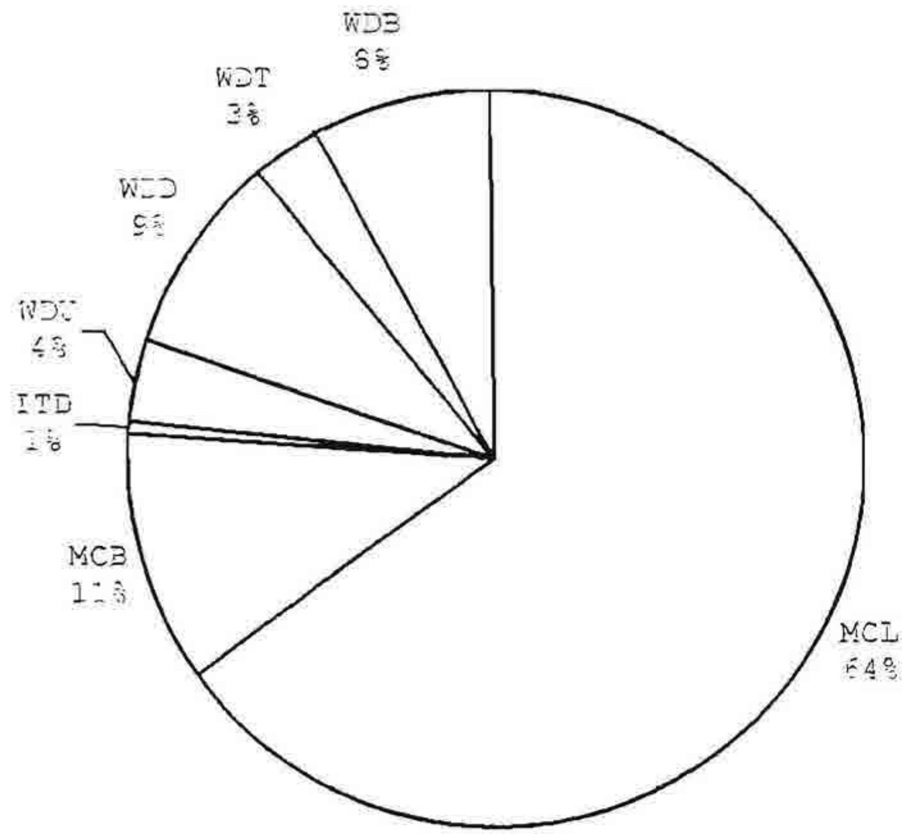


Figure 10. Strauss's linear selectivity index (L_i) values for each macrohabitat in the middle Mississippi River from November 1995 through December 2000. Positive values represent selection for a habitat while negative values represent selection against a habitat. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. Values indicated by an "*" are not significantly different from zero (t-test; alpha=0.05).

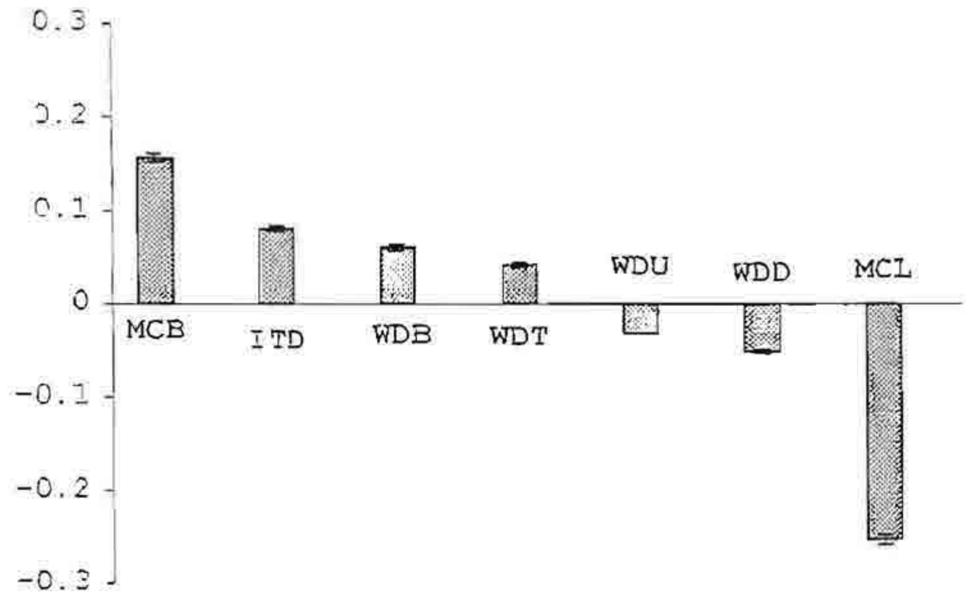


Figure 11. Strauss's linear selectivity index (L_i) values for each macrohabitat by temperature regimes (°C) in the middle Mississippi River from November 1995 through December 2000. Positive values represent selection for a habitat while negative values represent selection against a habitat. Error bars represent 95% confidence interval. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. Values indicated by an "*" are not significantly different from zero (t-test; alpha=0.05).

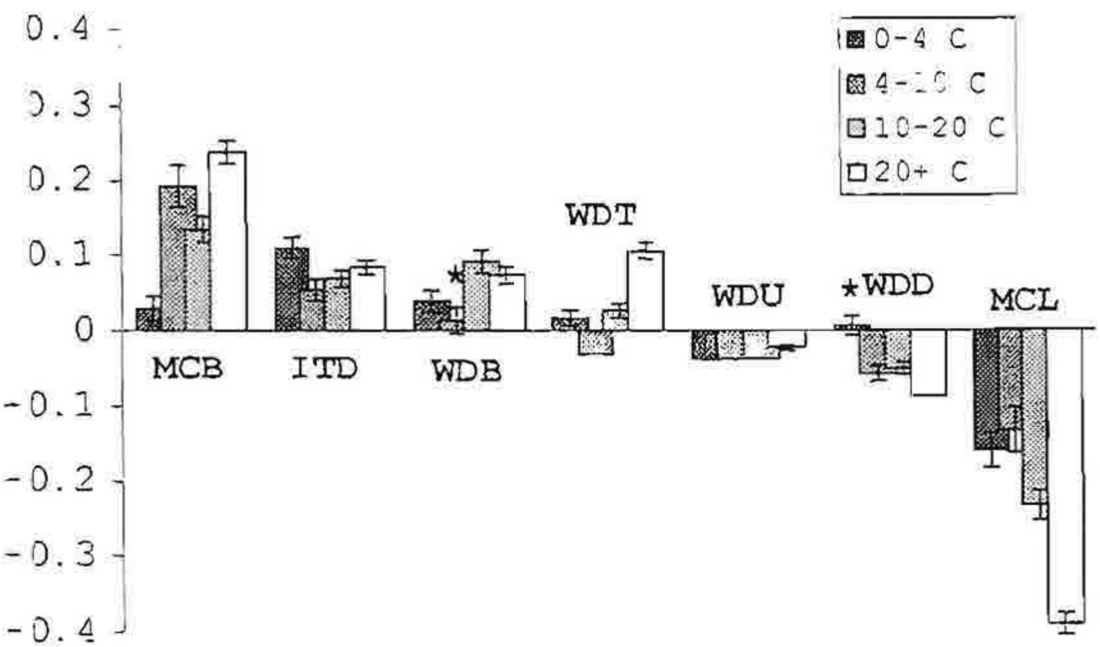


Figure 11. Strauss's linear selectivity index (L_i) values for each macrohabitat by discharge regimes. Positive values represent selection for a habitat while negative values represent selection against a habitat. Error bars represent 95% confidence interval. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. Values indicated by an "*" are not significantly different from zero (t-test; alpha=0.05).

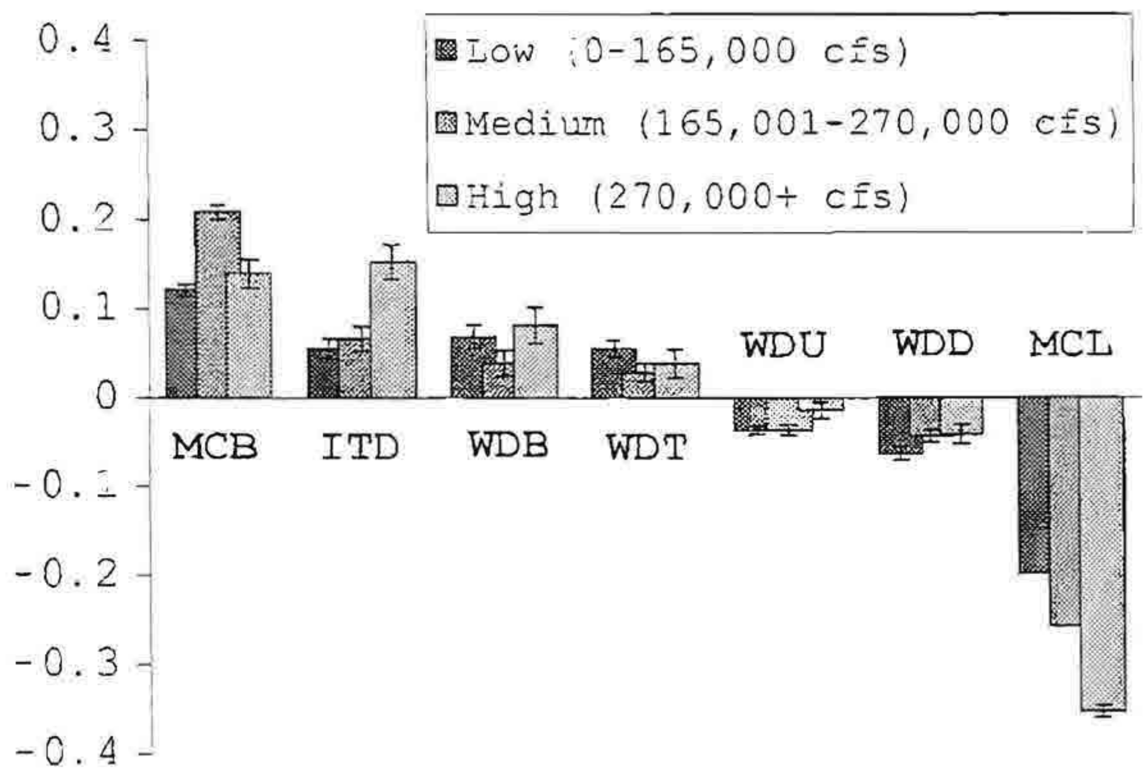


Figure 13. Contact period (date of release to last contact date) for each fish with at least one post-release contact from October 1995 through December 2000.

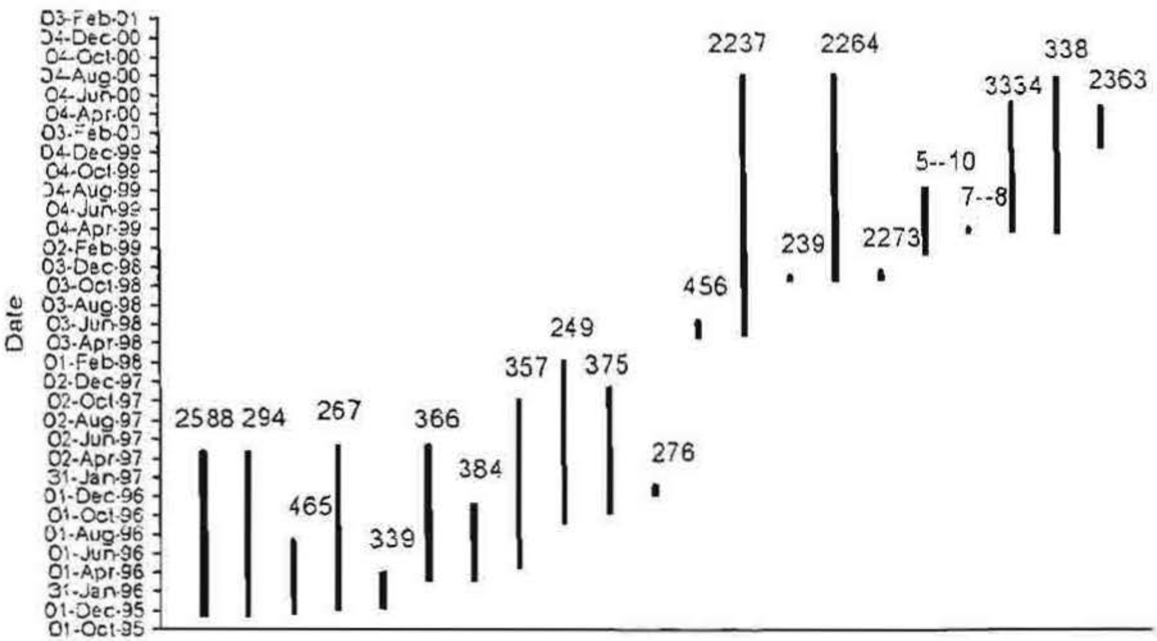


Figure 14. Observed movements of pallid sturgeon 2588 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

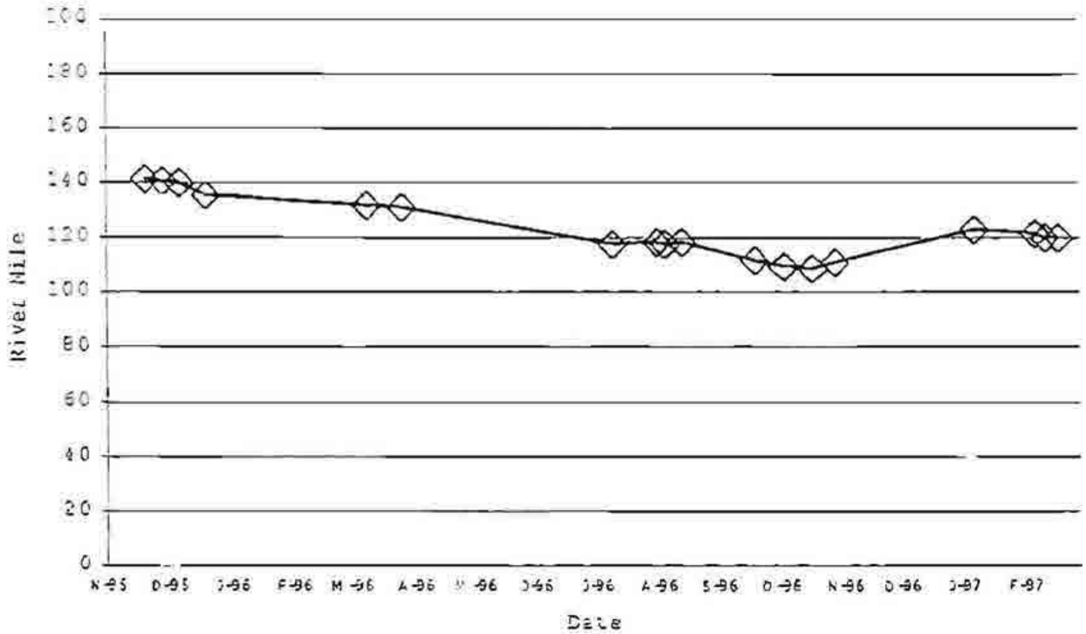


Figure 15. Observed movements of pallid sturgeon 294 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

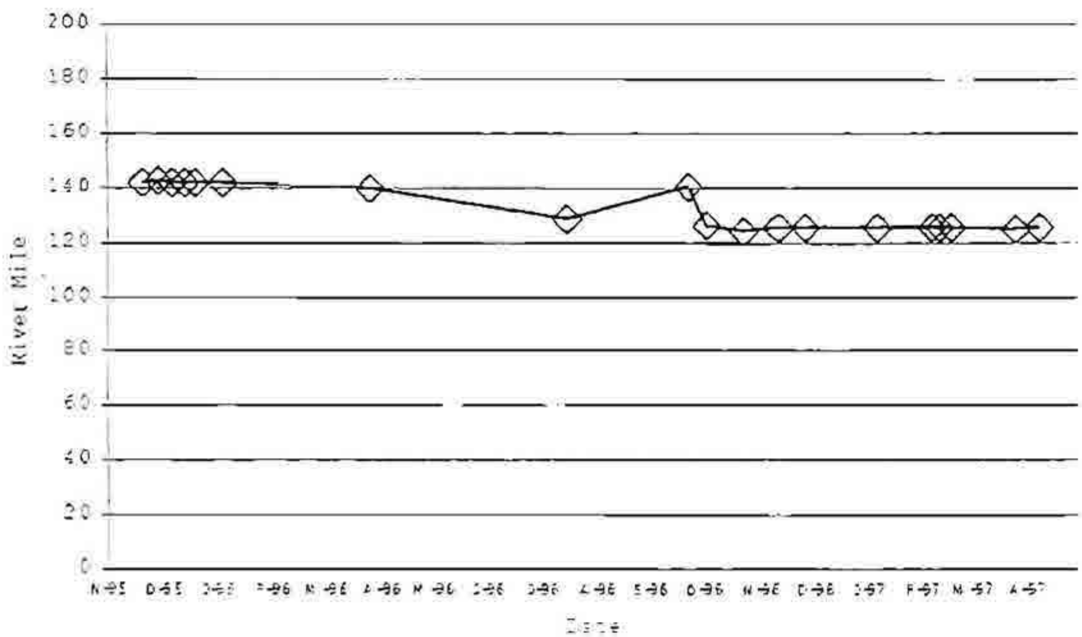


Figure 16. Observed movements of pallid sturgeon 465 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

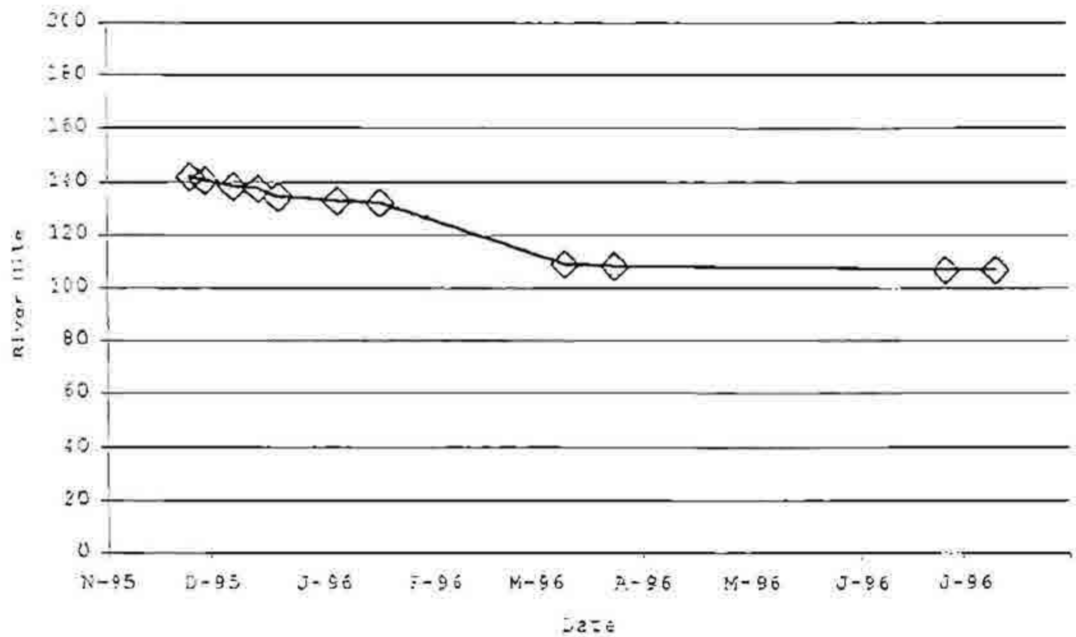


Figure 17. Observed movements of pallid sturgeon 267 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

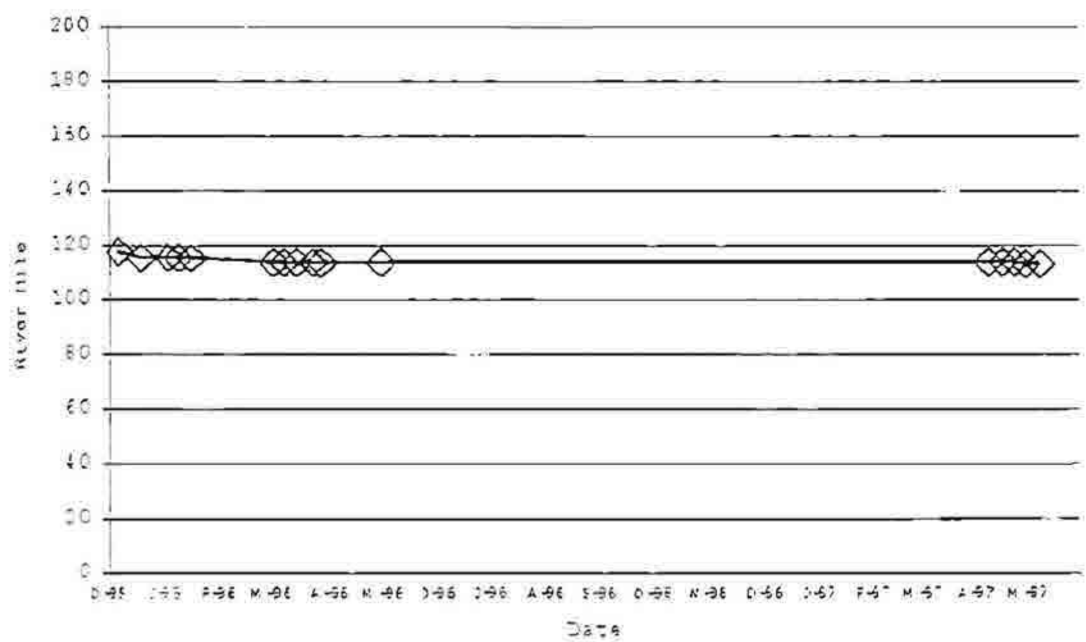


Figure 18. Observed movements of pallid sturgeon 339 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

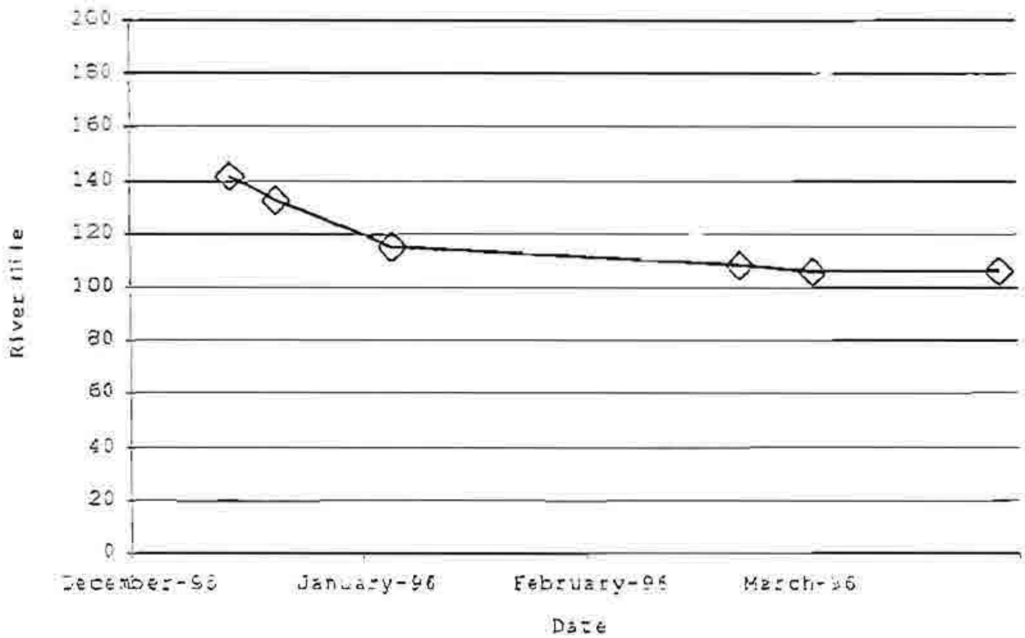


Figure 19. Observed movements of pallid sturgeon 366 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

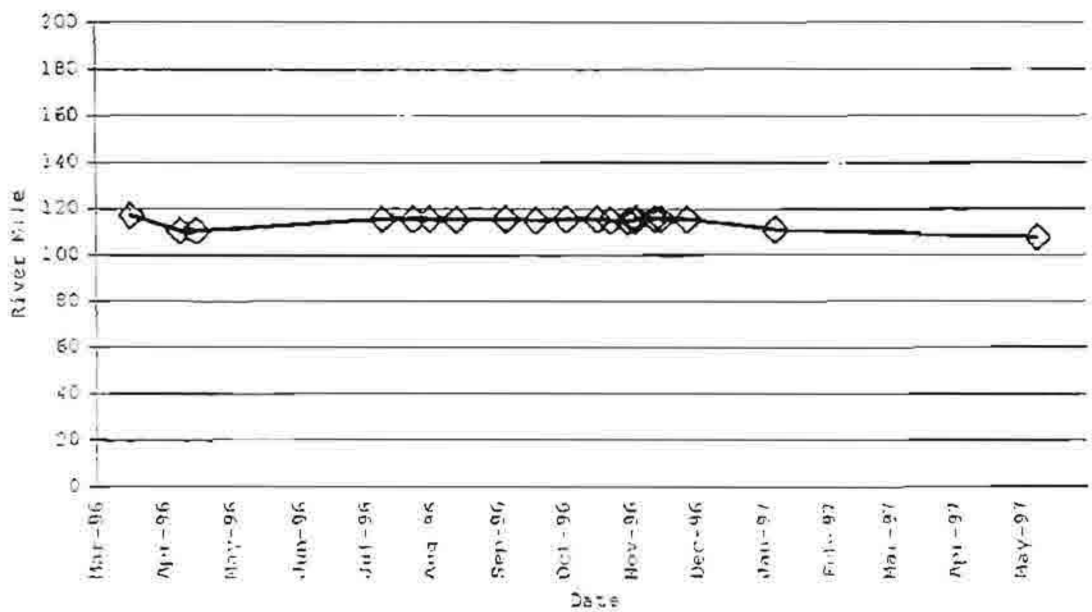


Figure 20. Observed movements of pallid sturgeon 384 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

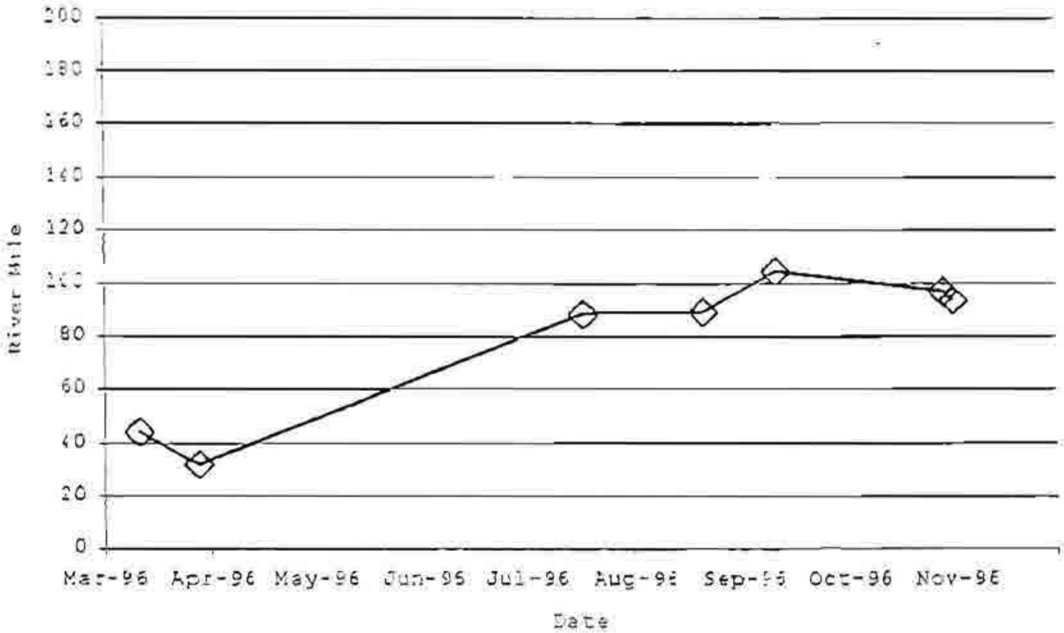


Figure 21. Observed movements of pallid sturgeon 357 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

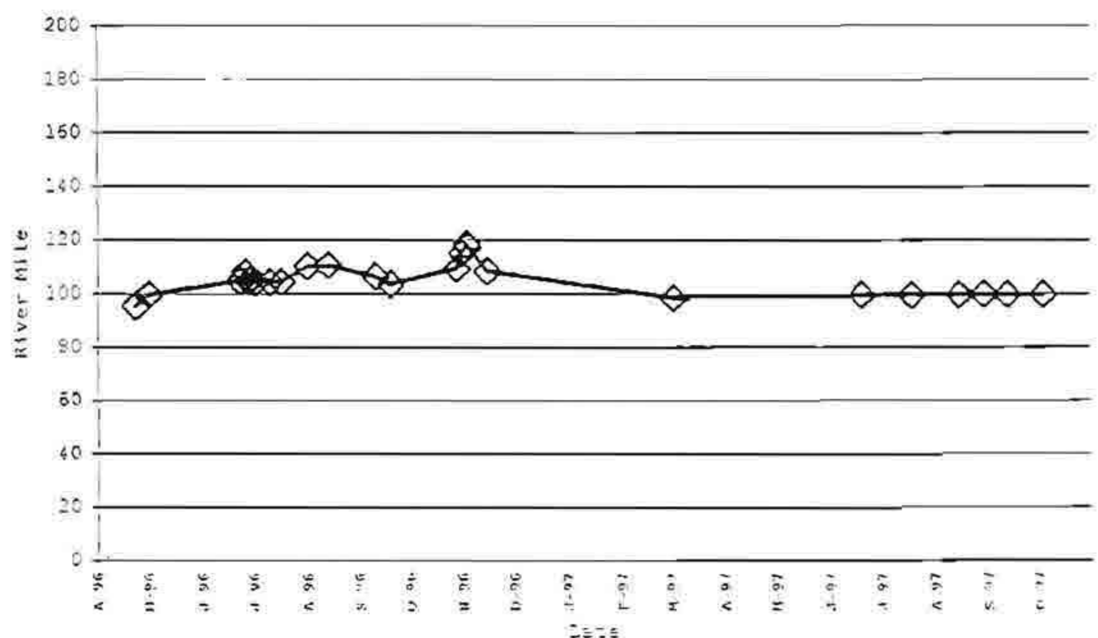


Figure 22. Observed movements of pallid sturgeon 249 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

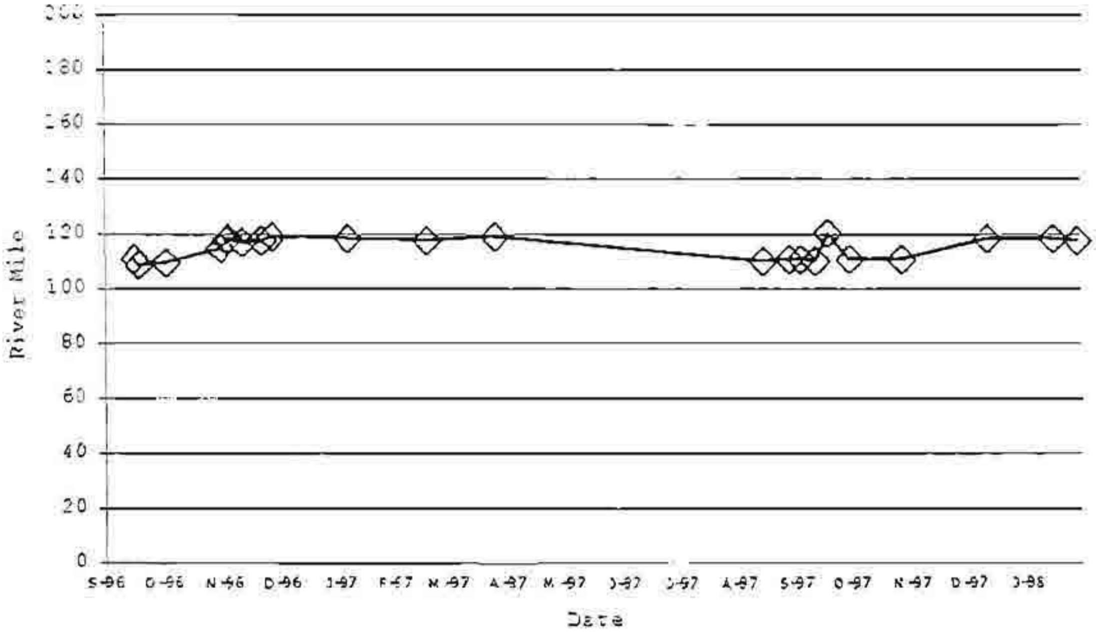


Figure 23. Observed movements of pallid sturgeon 375 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

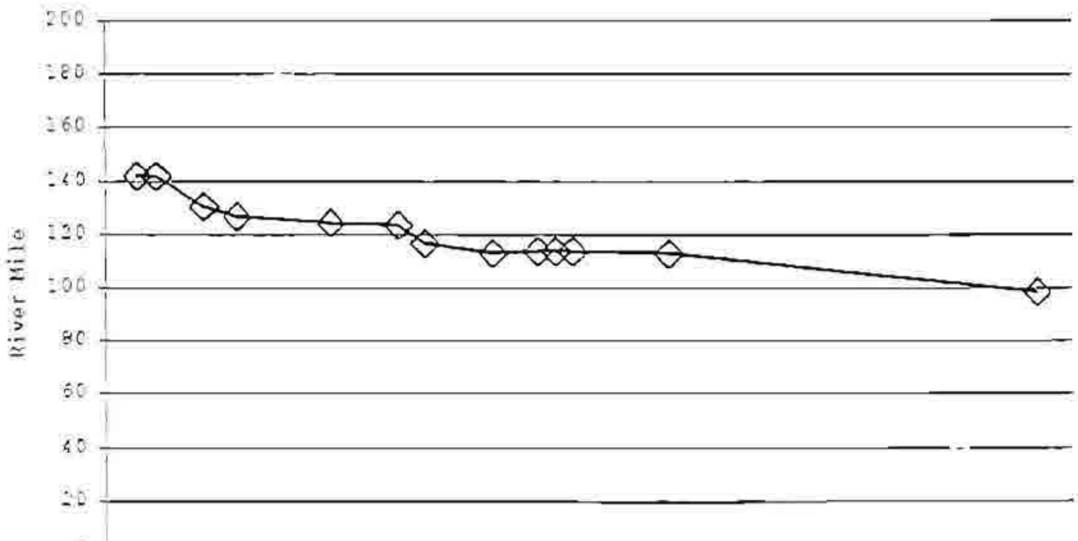


Figure 24. Observed movements of pallid sturgeon 276 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

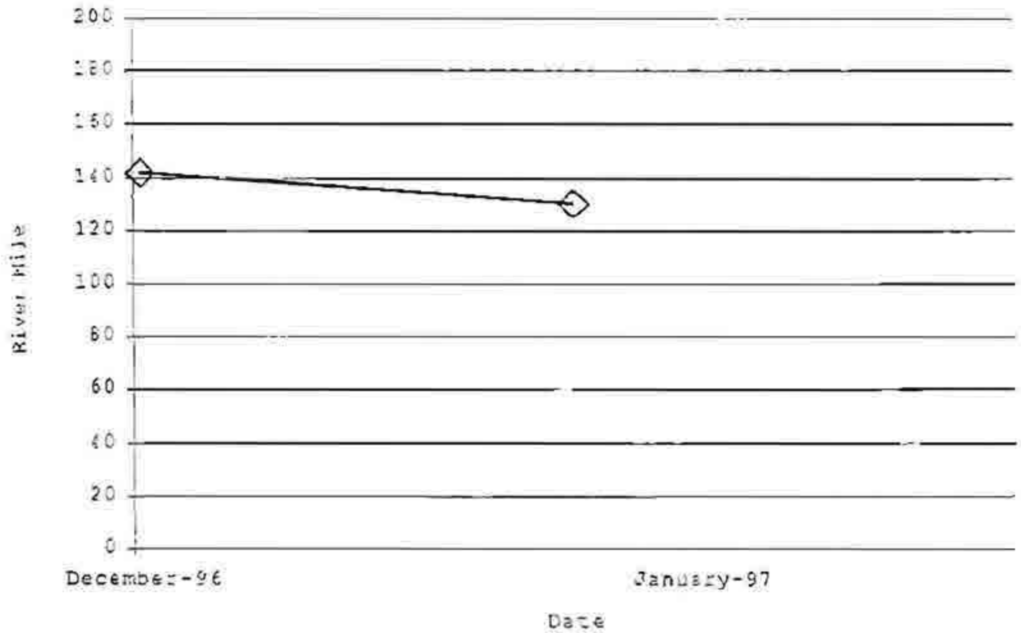


Figure 25. Observed movements of pallid sturgeon 456 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

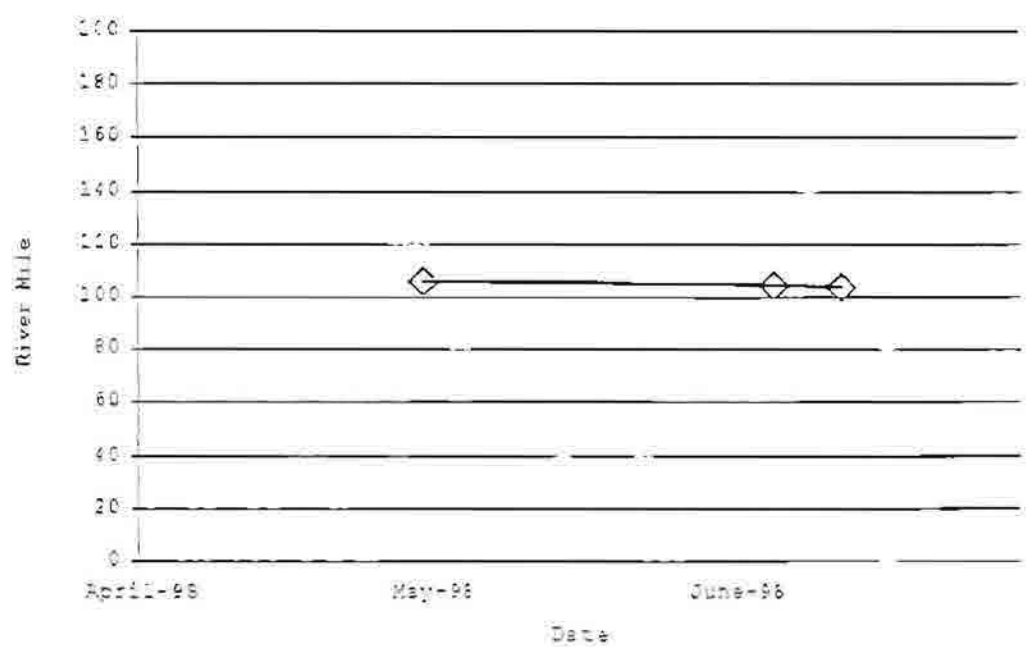


Figure 26. Observed movements of pallid sturgeon 2237 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

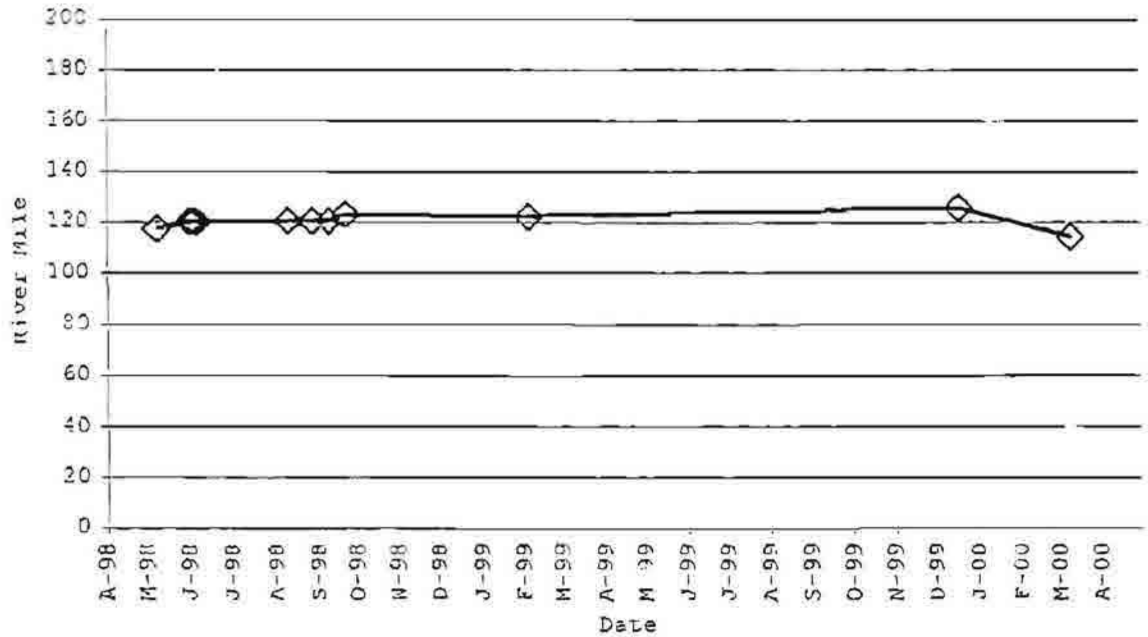


Figure 27. Observed movements of pallid sturgeon 239 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

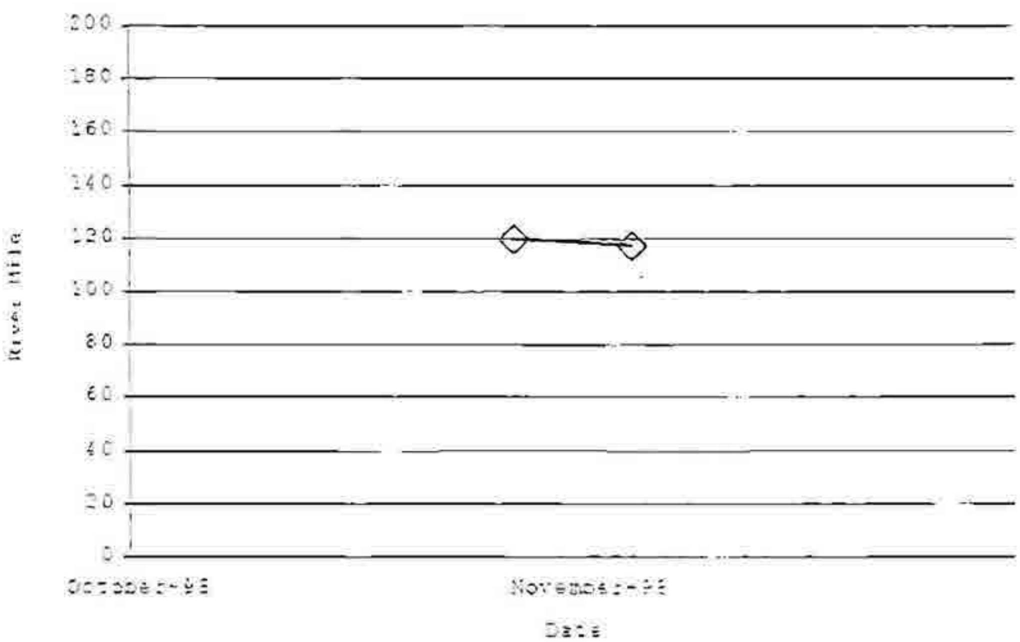


Figure 28. Observed movements of pallid sturgeon 2264 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

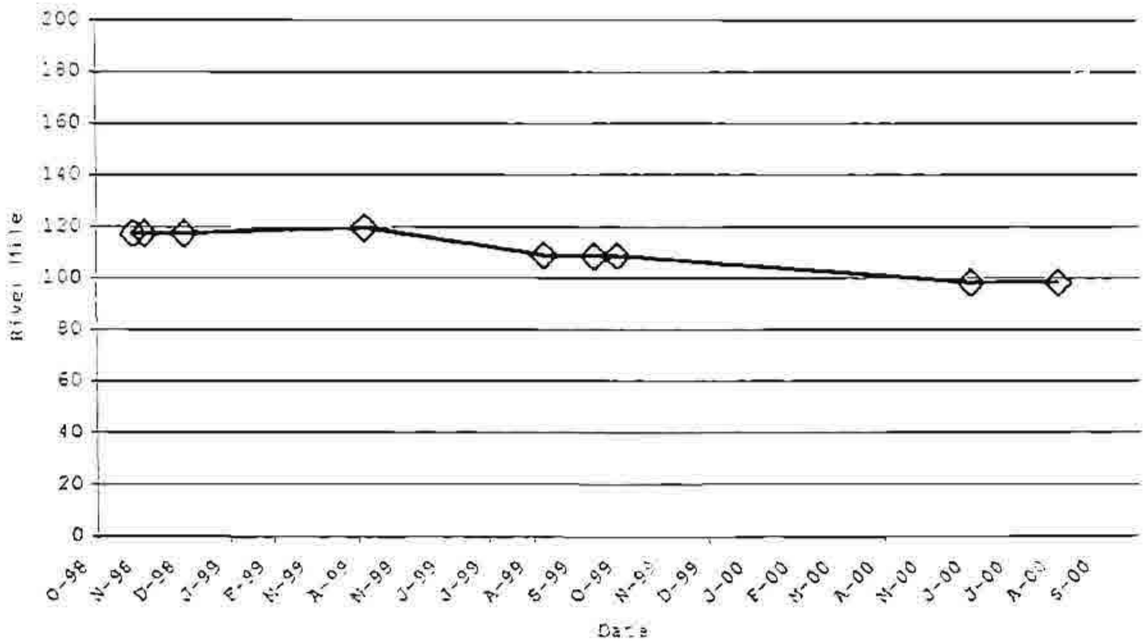


Figure 29. Observed movements of pallid sturgeon 2273 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

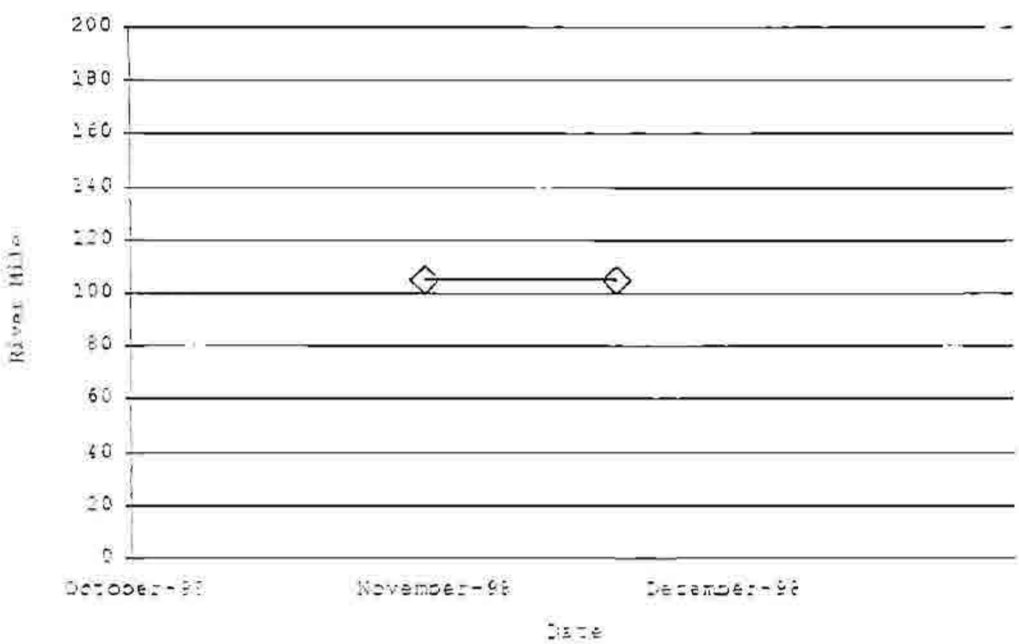


Figure 30. Observed movements of pallid sturgeon 5--10 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

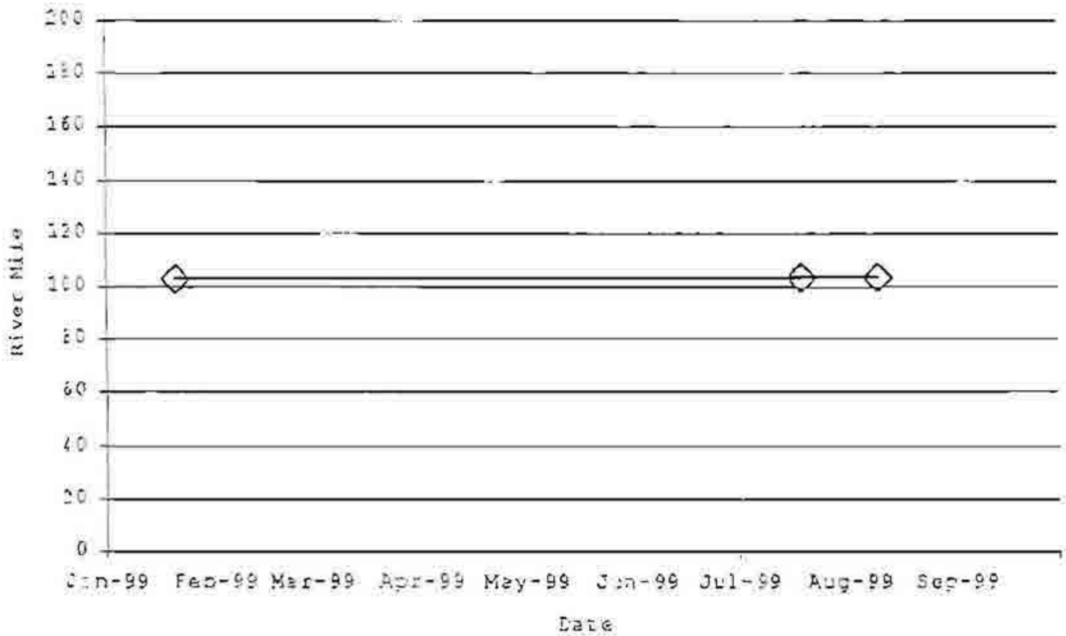


Figure 31. Observed movements of pallid sturgeon 7--8 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

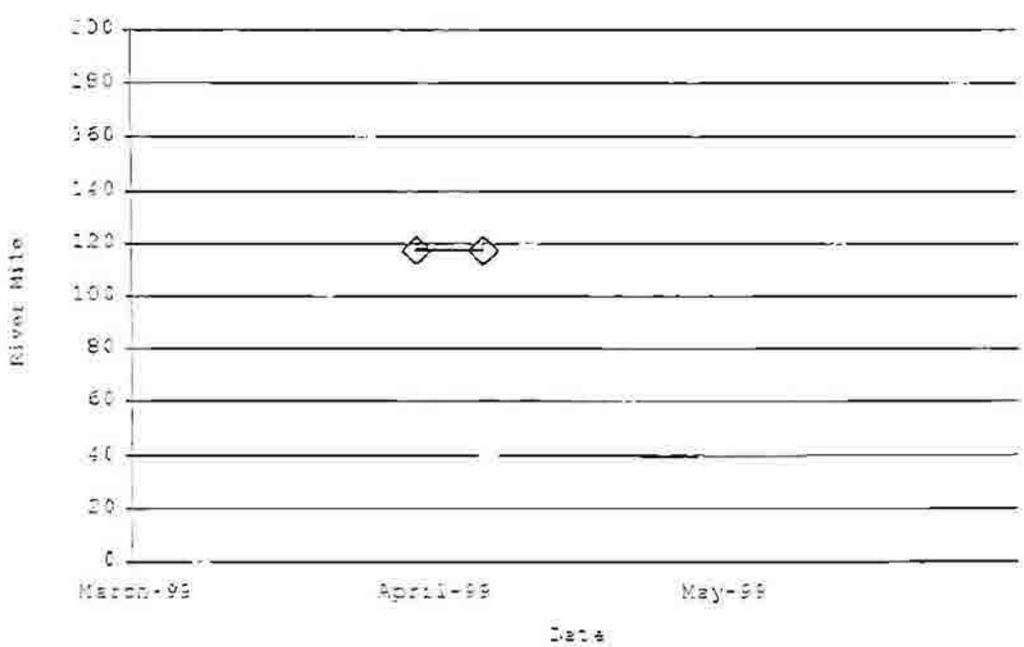


Figure 32. Observed movements of pallid sturgeon 3334 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

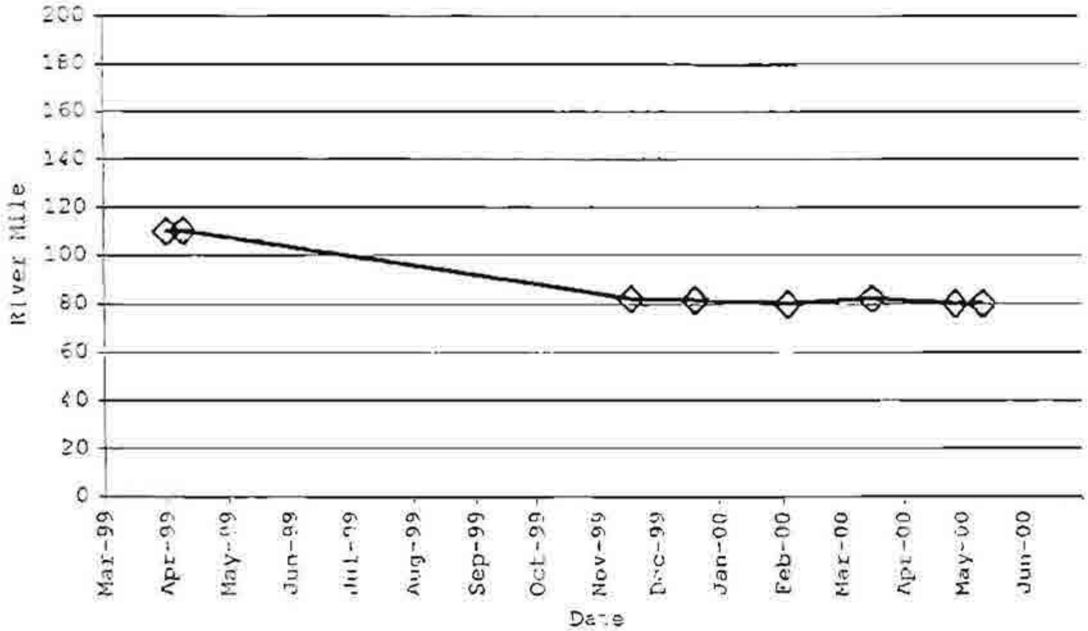


Figure 33. Observed movements of pallid sturgeon 338 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

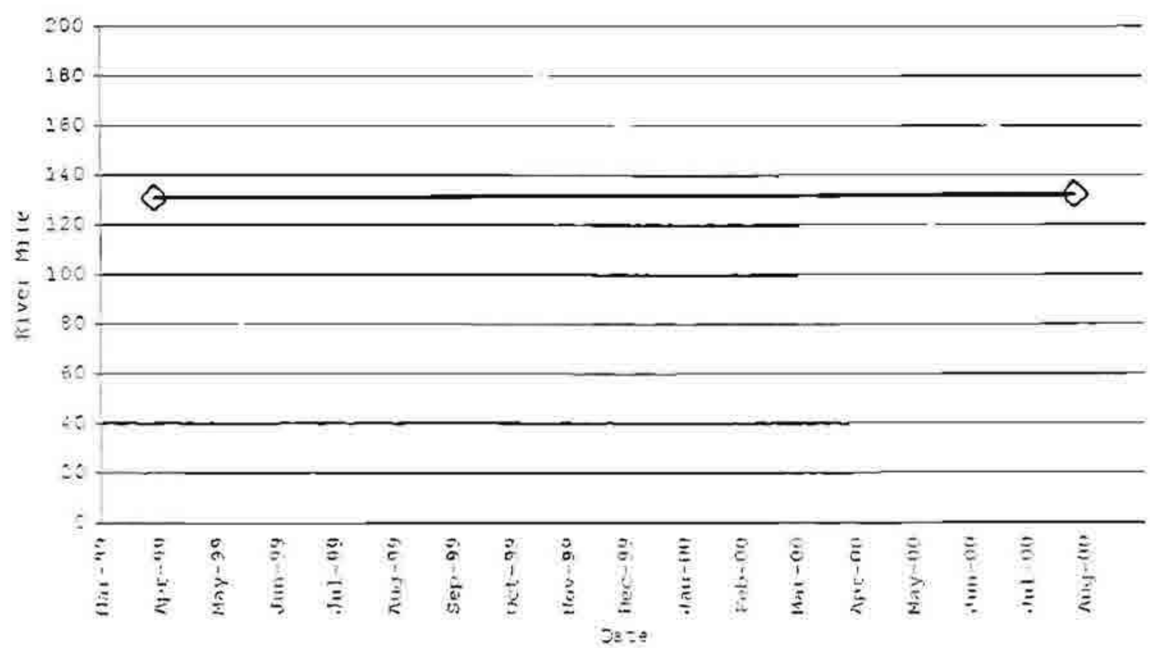


Figure 34. Observed movements of pallid sturgeon 2363 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

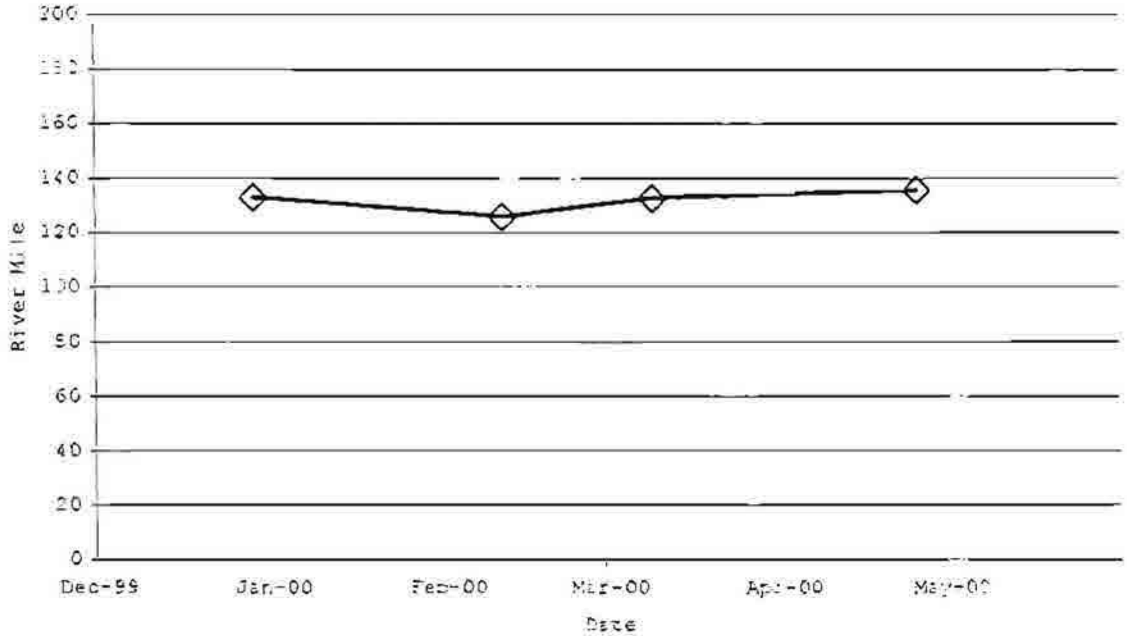
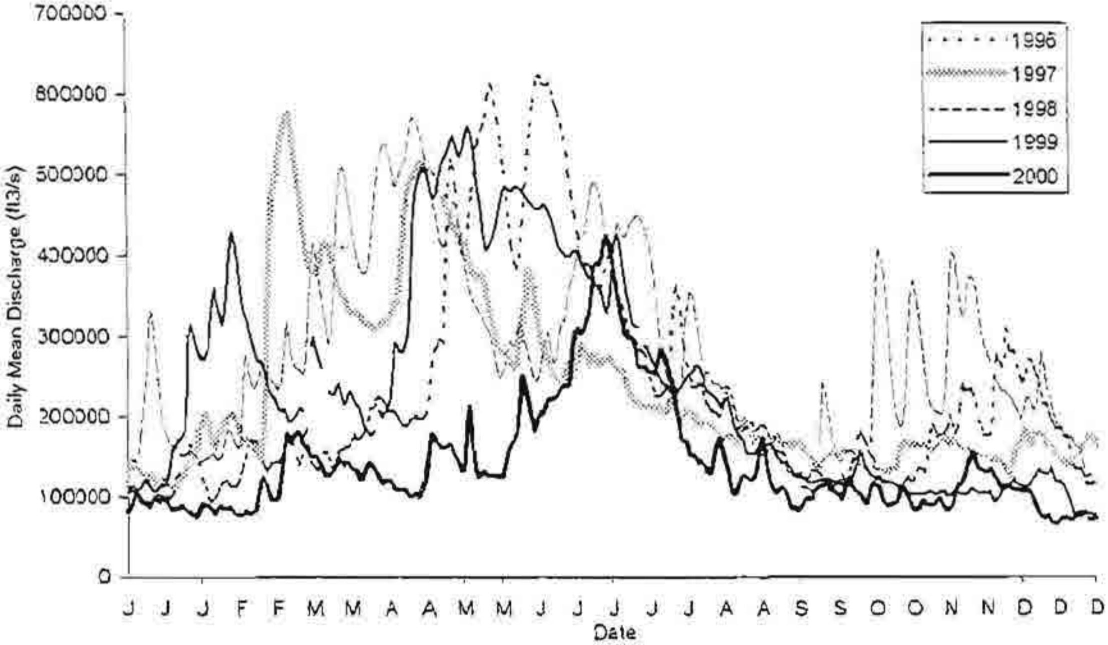


Figure 35. Daily mean discharge values from January 1, 1996 through September 30, 1998. Discharge values were obtained from the U.S. Geological Survey and taken at the Chester, IL gauging station on the Mississippi River.



Middle Mississippi River Pallid Sturgeon Habitat Use Project: Supplemental Report on Bendway-Weir Field Use by Pallid Sturgeon

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Year 5

Supplemental Report

May 2001

Introduction

This report supplements the findings reported for Goal 1, Objective B in the Middle Mississippi River (MMR) Pallid Sturgeon Habitat Use Project year five annual performance report (Sheehan et al. 2001). Specifically, this supplement reports our findings in regard to pallid sturgeon use of river reaches with bendway weirs in them.

Methods

Goal 1 - Habitat Utilization and Movements of Adult Pallid Sturgeon In the Middle Mississippi River

Data describing locations where we found pallid sturgeon in our habitat use study (Sheehan et al. 2001) were re-analyzed to calculate a Strauss's linear selectivity index (L_i)(Strauss 1979) value for use of bendway-weir river reaches located in the study area. The formula used for L_i was:

$$L_i = r_i - p_i$$

where L_i = linear index value, r_i = proportion of pallid sturgeon located within river reaches with bendway-weir fields, and p_i = proportion of river miles occupied by bendway-weir fields in the sample area (see below for delineation of the sample area). L_i values can range from

-1 to 1 with 0 indicating no selection for a particular habitat. A positive L_i indicates selection for a given habitat, whereas a negative L_i represents negative selection, or selection against, a given habitat. A chi-square test was performed to determine whether the proportion of use of river reaches with bendway-weir fields by pallid sturgeon was significantly different from the proportion of bendway-weir field river reaches available in the stretch of MMR studied.

Bendway-weir location and construction dates were obtained from the St. Louis District U.S. Army Corp of Engineers office (Brian L. Johnston, MVS), so that bendway-weir fields could be delineated in space and time. For the purpose of this analysis, the pallid sturgeon locations data set was restricted to the portion of the river that received the most tracking effort, River Miles 94 to 123 (Figure 1). In other river reaches where bendway weirs are found, we do not believe we had sufficient sampling (i.e., tracking) effort over all times of the year to examine this question.

Contacts were counted as being in a bendway-weir field only after the date that a weir field was constructed. There are two bendway-weir fields within this stretch of river, St. Genevieve (constructed during September 1997) and Kaskaskia (constructed during January and February 1993). These fields total 3.1 miles of the 30 river miles analyzed. Pallid sturgeon found anywhere within that 3.1 miles were considered to be using bendway-weirs river reaches, since these structures affect the entire cross-section of the river channel.

The linear selectivity index (L_i) value for bendway-weir field river reaches was compared graphically with L_i values reported for other habitat types identified within the MMR (see Sheehan et al. 2001). The habitat types were BWW = bendway-weir fields, MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip (Figure 2).

Results

Goal 1 - Habitat Utilization and Movements of Adult Pallid Sturgeon In the Middle Mississippi River (addenda)

We located study fish 140 times during 13 November 1995 to 1 May 2001 within the 30 river miles examined to determine bendway weir use. Eleven (11) of those contacts were within the river reaches occupied by the two bendway-weir fields. In essence, bendway-weir reaches comprised 10% of the habitat, and pallid sturgeon used that habitat 8% of the time.

Strauss's selectivity index value (L_i) for the bendway-weir river reaches was -0.025 (Figure 2). A chi-square goodness-of-fit test indicated that the use of bendway-weir field river reaches by pallid sturgeon was not significantly different from bendway-weir field river reach availability within the analyzed stretch of the MMR (χ^2 = 0.23, critical value with 1 df = 3.814; alpha = 0.05).

Habitat types used by pallid sturgeon within these reaches of river included MCL, MCB, ITD, and BWD. The study sturgeon showed positive selection for, in rank order: MCB, ITD, WDB, and WDT habitats. The study fish exhibited negative selection for, in rank order: MCL, WDD, WDU, BWW (Figure 3).

Discussion

Goal 1 - Habitat Utilization and Movements of Adult Pallid Sturgeon In the Middle Mississippi River

Study pallid sturgeon were located approximately 8% of the time within the river reaches occupied by bendway-weir fields. Several of the habitat types within these reaches were used, including the MCL habitat. We have consistently found in our habitat use study that pallid sturgeon show strong avoidance of the MCL habitat, although they are often found in the MCL. This apparent contradiction is because the MCL habitat is the predominant (64%) habitat in river reaches in our study; MCB is a distant second in abundance (11%).

Bendway weirs are positioned in the river in what we define as MCL habitat.

In conclusion, we were unable to demonstrate that pallid sturgeon showed either selection for or against river reaches with bendway-weir fields. Bendway weirs do not appear to affect habitat use in pallid sturgeon.

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Figure 1. Tracking effort expressed as the frequency that each river mile in the study area was tracked from November 1995 through December 2000.

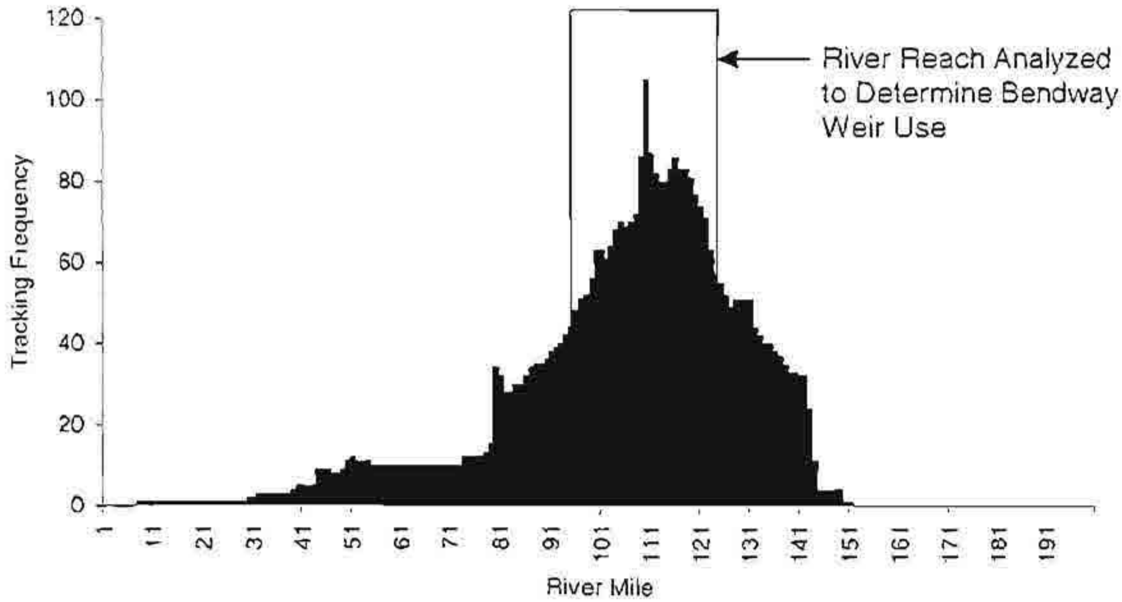


Figure 2. Habitat classification scheme used to describe the locations of pallid sturgeon. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip.

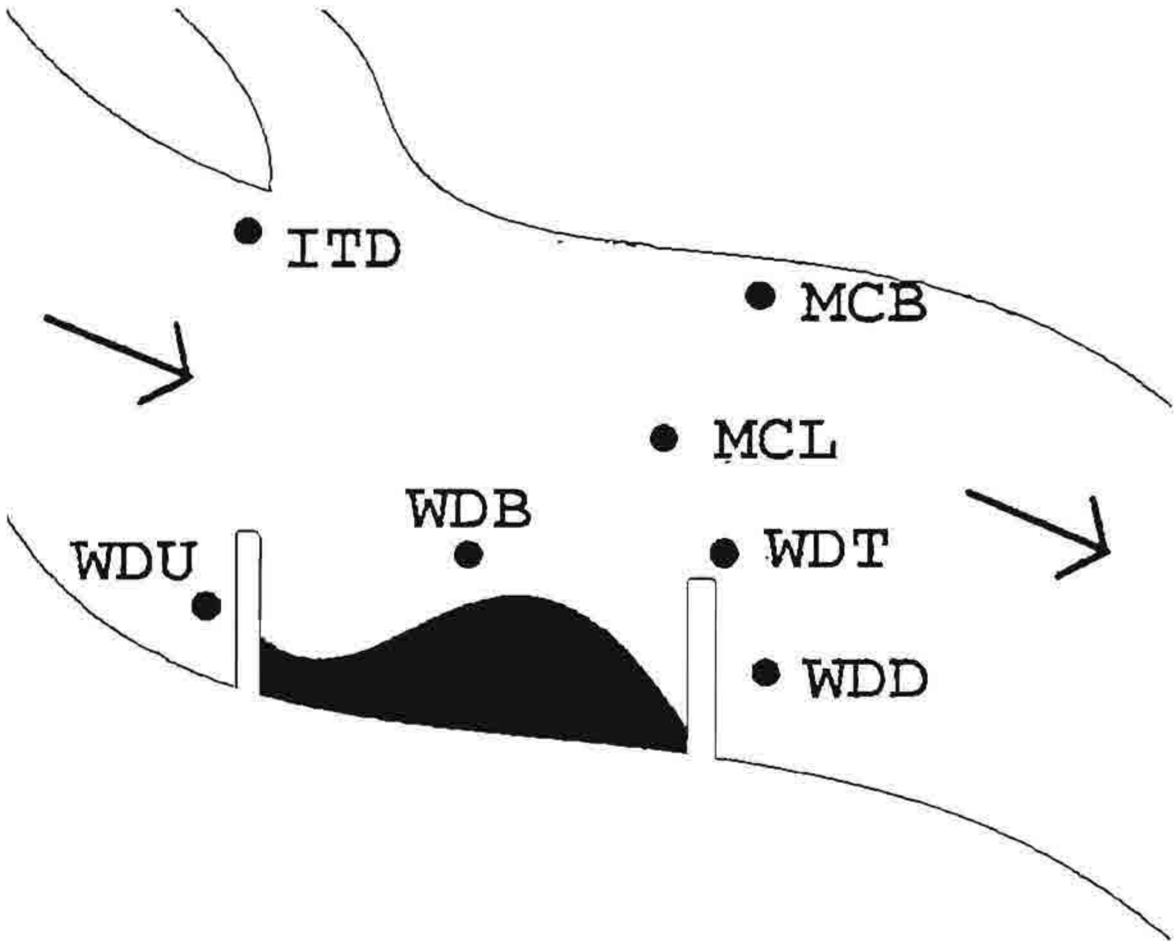
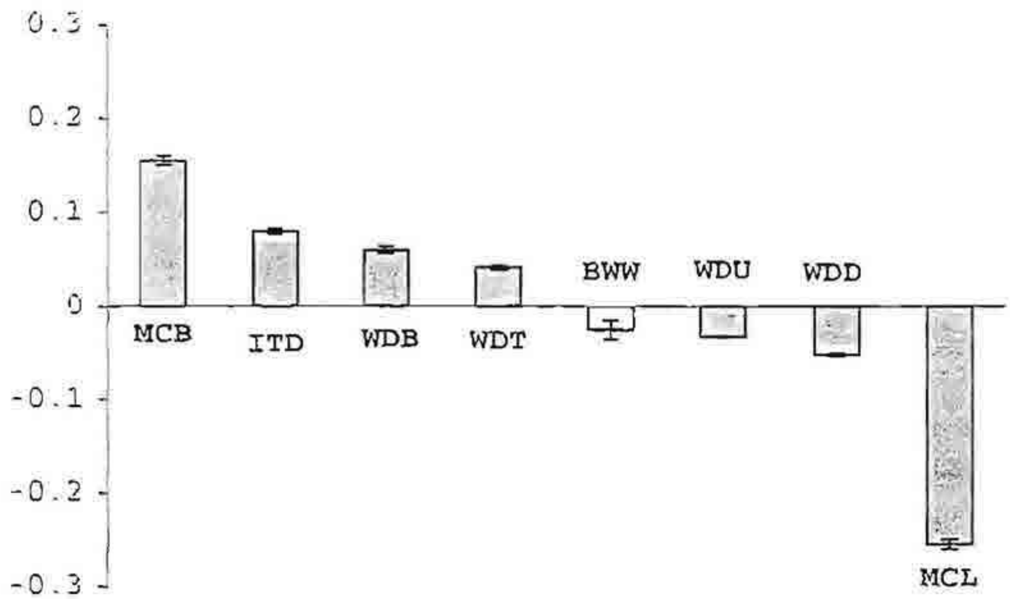


Figure 3. Strauss's linear selectivity index (L_i) values for each habitat type in the middle Mississippi River from November 1995 through April 2001. Positive values represent selection for a habitat while negative values represent selection against a habitat. BWW = Bendway-Weir fields, MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip.



Appendix F.

Draft Report: The Use of High Explosives to Conduct a Fisheries Study at a Bendway Weir Field on the Mississippi River - U.S. Army Corps of Engineers, St. Louis District and Missouri Department of Conservation

THE USE OF HIGH EXPLOSIVES TO CONDUCT A FISHERIES SURVEY AT A BENDWAY WEIR FIELD ON THE MIDDLE MISSISSIPPI RIVER

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Abstract

Fish sampling in a deep-water, high velocity, environment is extremely difficult. Conventional techniques such as electro-fishing and netting have been limited to depths generally less than 7 meters and velocities below 1 meter per second.

The goal of our study was to sample a bendway weir field on the Mississippi River to assess the effects of the weir field on the fishery. In a bendway weir field, depths can exceed 20 meters, and velocities can exceed 3 meters per second, making conventional sampling techniques inefficient.

A 152-meter section over a bendway weir field was blasted using a series of 3.4 kg charges of T-100 binary explosive. Preparation for the blast (placing charges and catch nets), took approximately 6 hours. A total of 217 fish was captured, representing 12 different species. Freshwater drum (*Aplodinotus grunniens*) dominated the catch comprising 35.5% of the total catch, followed by gizzard shad (*Dorosoma cepedianum*) (27.2%), and blue catfish (*Ictalurus furcatus*) (16.6%).

Introduction

Bendway weirs (Figure 1) are low-level rock structures designed to create a variety of improvements to the navaigation channel in the bendways (curved reaches) of large river systems. They consist of a series of submerged rock dikes (> 3m below the low water reference plane) constructed around the outer edge of a river bend. Each dikes is angled 30° upstream of perpendicular to divert flow, in progression, toward the inner bank.

The structures are designed to redistribute flow and sediment within the bends to reduce or eliminate dredging requirements in river bends by controlling point bar development (Davinroy 1990). The redistribution of flow produces safer navigation conditions and has significantly reduced the number of accidents in each bend (Davinroy et al. 1998). The channel bottom affected by the dikes has increased structure and hydraulic variation, both positive changes with respect to aquatic habitat diversity in the river bends. A major challenge that faced fishery biologists was developing a methodology to sample fish populations within the dynamic and turbulent bendways. In a bendway weir field, depths can exceed 20 meters, and velocities can exceed 3 meters per second, making conventional fish sampling techniques inefficient. Fish sampling in such deep-water, high velocity, environments is extremely difficult. Conventional techniques such as electrofishing and netting have been limited to depths generally less than 7 meters and velocities below 1 meter per second.

A deep-water sampling group was formed, made up of various interagency members, including the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, the Missouri Department of Conservation, the Illinois Department of Natural Resources, and the University of Southern Illinois Department of Fisheries. The team, comprised of engineers and fisheries biologists, developed a deep water sampling strategy that included a combination of hydroacoustic surveys and blast fishing (Davinroy et al. 1998).

The use of explosives to collect fish is not considered a "standard" fish sampling technique in the United States (Nielsen and Johnson 1983). However, explosives have been successfully used to conduct fishery surveys in a number of different aquatic habitat types (Table 1) and have been found effective in large river systems where sampling is difficult using conventional techniques (Forbes and Richardson 1913; Averett and Stubbs 1962; Hesse et al. 1979; Rasmussen et al. 1985).

The goal of our study was to sample a single weir at Price Towhead weir field, a bendway weir field on the Middle Mississippi River, to determine the species composition at the bendway weir using both hydroacoustics and blast fishing. The hydroacoustic survey was conducted to provide quantitative information on fish numbers, location, and size; however, hydroacoustics does not provide information on the species being observed. The blast survey was conducted to identify the fish species present at the bendway weir, thus complimenting the hydroacoustic survey.

Materials and Methods

On 20 September 1995, a 152-meter section over a bendway weir (Mississippi River Mile 30.0) at Price Towhead weir field was surveyed with explosives to document fish use.

Explosive. IBLAST (Coastline Environmental Services Ltd 1986), a fish mortality model, was used to determine the explosive charge size required to kill fish within 30 meters of the blast. The calculated charge weight was then increased by 1/3 to ensure mortality. Fish sampling blasts utilized 3.4 kg charges of T-.00 Two Component (green stick) explosive and initiated by two Atlas #8 instantaneous electric blasting caps. Slurry Explosive Corporation's T-100 Two component is a water-resistant, Class A, high explosive with a 1.6 relative bulk strength equivalency to ammonium nitrate and fuel oil (ANFO). It has a detonation velocity of 14 meters/second and a density of 1.22 g/cm3 (Slurry Explosive Corporation 1991).

A 12.5 mm steel cable was attached to a 680 kg anchor and a buoy on the other end of the cable to keep the line taut. Five sticks of T-100 were attached to the cable 1.2 m above the anchor. Two blasting caps were attached to each explosive charge. A kill area of 30.5 by 91.5 m was divided into five cells of 30.5 (upstream-downstream) by 18.3 meter cross current. An anchor/charge system was placed at the center of each cell. Thus, five 3.4 kg charges were set in place on 18.3 m centers along the center of 30.5 m upstream-downstream areas (15.2 m downstream of the weir toe) using a crane operated from a work barge.

Fish Recovery. Six chase boats and sixty-eight catch nets were used to capture fish. Each chase boat had a minimum crew of three, a boat operator and two dip netters. The catch nets each had a 1.2 m diameter opening and either 4.7 mm or 18.8 mm inch mesh. The catch nets had a bridle with a swivel clip to keep the net from fouling in the current. Catch nets were fastened to a 12.5 mm steel cable was attached to a 680 kg anchor and a buoy on the other end of the cable to keep the line taut. Catch nets were at 3, 9, and 15 meters above the anchor.

Conventional Fishery Survey Methods. On September 26, 1995 trotlines, gillnets, and hoop nets were deployed at Price Towhead bendway weir field for approximately 24 hours. Two 91.5 m trotlines, each with 50-hooks bated with cut shad were set parallel to the shoreline at River Mile (R.M.) 29.8 and R. M. 29.6. Two 45.7 m gillnets were set. The first was set below the weir, parallel to the shoreline at R.M. 30.1 and the second was set at R.M. 29.8, parallel and downstream of the weir. Three hoop net sets, each with 4 hoop nets, were set at R. M. 30.5,5. 30.5 and 30.3, parallel to and downstream of the weir. Each hoop net had a 1.2 m diameter mouth, two had 37.5 mm mesh and two had 18.8 mm mesh.

Results

A total of 217 fish was captured using blast fishing, representing 12 different species (Table 2). Freshwater drum (*Aplodinotus grunniens*) dominated the catch, comprising 35.5% of the total catch, followed by gizzard shad (*Dorosoma cepedianum*) (27.2%), and blue catfish (*Ictalurus furcatus*) (16.6%). Mid-water catch nets and surface collections produced similar total numbers of fish collected. Ninety-nine specimens of ten species were collected in catch nets and 118 specimens of eight species were dip netted from the surface ("floaters"). Species composition differed by capture method (Table 2, Figure 2). Four species, shovelnose sturgeon (*Scaphirhynchus platorynchus*), skipjack herring (*Alosa chrysochloris*), stonecat (*Noturus flavus*) and freckled madtom (*Noturus nocturnus*), were collected only in the mid-water catch nets. Two species, carp (*Cyprinus* *carpio*) and smallmouth buffalo (*Ictiobus babalus*), were collected only in the surface collections. The mid-water catch nets were more effective than surface collecting in sampling gizzard shad (58 vs. 1 specimen) and blue catfish (24 vs. 12 specimens), while surface collecting was more effective in collecting freshwater drum (75 vs. 2 specimens).

The total length of all fish captured also varied by capture method. Ninety-two percent of the fish collected (floaters) from the surface by chase boats were greater than 200 mm total length, while 100% of fish collected in catch nets were less than 200 mm total length.

Two freckled madtoms and two stonecats were captured in the mid-water catch nets. Both of these species occupy the interstitial areas of the rocky habitat along the river. Apparently, these two species were dislodged from the rocks by the blast.

Conventional fish collection techniques (e.g., trotlines, gill nets, and hoop nets) captured eleven fish specimens representing 7 different species (Table 3). One blue catfish was caught on the two troutlines. Four specimens of four species (1 gizzard shad, 1 carp, 1 paddlefish, 1 sturgeon) were caught in gill nets. Three species (3 flathead catfish, 2 blue catfish and 1 channel catfish) were captured in hoop nets.

Discussion

Hyrodaccustic studies (Kasual and Baker 1996) have indicated that bendway weirs can increase the local abundance of fish in affected areas of the river channel by approximately two-fold. Kasul and Baker (1996) conducted a pre-blast hydroacoustic survey of the of the test weir in the Price Towhead weir field. They detected 58 fish in the area surrounding the weir and estimated the density of fish surrounding this weir at 2,003/ha, approximately twice the mean density of fish obtained from the entire weir field (984/ha). Fish were found throughout the water column from near surface to near bottom. More fish were detected along the channel-ward half of the weir than along the shore-ward half. Inspection of echo detections also suggested that in 6 of 8 passes over the weir, fish were more often found immediately downstream of the weir than immediately upstream of it.

Fish detected in the pre-blast hydroacoustic survey (Kasual and Baker 1996) varied in size from approximately 3 to 96 cm. Eight echoes of fish that were approximately 50 cm or larger were all found on the downstream side or downstream base of the weir. Blast fishing produced four species: blue catfish, channel catfish, drum and buffalo that exceed 50 cm total length.

Comparisons of fish densities (number of fish per ha) between the hydroacoustic survey and the blast survey are impossible. Fish mortality is species specific (Ogawa et al. 1978; Teleki and Chamberlain 1978; Goertner et al. 1994), size specific (Yelverton et al. 1975), and undoubtedly depth specific. Because each of these factors can affect fish mortality, the kill radius for the test blast was not precisely known making it impossible to calculate fish density at the weir. If 100% fish mortality occurs within a measured area (i.e., a small pond, lake, or netted off area in a larger lake, stream, or canal), then calculating fish density would have been possible. However, the use of nets to completely enclose a measured area at the test weir was impossible because of the water depth and high velocities.

Published, incidental observations indicate that the number of dead fish floating on the surface immediately after an explosion does not represent the total number of fish killed (Brown and Smith 1972; Coker and Hollis 1950; Gitschlag 1997; Ferguson 1962; Fitch and Young 1948; Indrambarya 1949; Kearns and Boyd 1965; Knight 1907). The proportion of "floaters" to the actual number of fish killed is species specific, but has never been documented. In this study, species composition differed dramatically with respect to the location of fish capture. Four species were collected only in the mid-water nets while two species were collected only in the surface collections. The mid-water nets were more effective in sampling gizzard shad and blue catfish, while surface collecting was more effective in collecting freshwater drum. These results indicate that researchers have to sample the surface (floaters), water column, and in slack water, the stream or lake bottom to obtain a total picture of species composition and density.

Conventional fish collection techniques (e.g., trotlines, gill nets, and hoop nets) were ineffective capture methods in the bendway weir field when compared with the blast fishing. Eleven fish specimens were collected using conventional collection methods compared with 217 by blast fishing. There were only two species (blue catfish, 3 specimens and flathead catfish, 3 specimens) with more than one specimen collected. The larger number of fish collected using blast fishing produced a better size distribution of specimens to compare with the hydroacoustic survey data. Only 7 species were collected using conventional techniques compared with 12 species taken by explosives. One new species, the paddlefish (*Polyodon spathula*) was added to the species list by the conventional sampling. The most numerically abundant species taken by explosives (freshwater drum, 35.5%) was not taken by conventional sampling techniques. The gill net set parallel to the revetted shoreline became twisted in the high water currents and no fish were collected in this net.

The shots did not fire flawlessly. Only the two shots nearest the shoreline (charges 1 and 2) fired. An open circuit in down line 3 isolated charges 4 and 5, which in turn lead to a 10-minute firing delay for shooting charges 4 and 5. Charge number 3 was fired approximately 3 hours later. The down line to charge 3 was severed after the circuit was checked, when wiring the circuits together. The cut in the down line was likely due to: abrasion by the skiff against the buoy; water-borne debris snagging the line, or, most probably, the continued twisting of the buoy in the swift current pulling on the down line. Explosive engineering also proved difficult in the deep water with the fast currents.

In August of 1994, an attempt was made to sample the same bendway weir field using explosives. Capture boats and a 45.7 m long experimental gillnet were deployed to capture fish. The net was deployed downstream of the blast. After the blast the net was gone. The ropes attaching the net to the anchor buoys had snapped in the high currents.

The 1.2 m mouth opening catch nets used during 1995 sampled only a small fraction of the water column below the bendway weir. Deployment of large gill nets would have sampled a much larger portion of the water column than possible with the catch nets. It may be possible to design gillnets to withstand the high currents and increase catch efficiency. Because of the high current, small mesh sizes may be impractical. Although more fish may be captured, they may be larger specimens. Another potential sampling method would be to drift experimental gill nets between two boats that are moving downstream slower than the currents. Should additional bendway weir blast sampling be conducted, it is recommended that the drift net capture method be tested and nets should be specially designed to withstand the high water velocities, thus increasing catch.

The results of this study indicate that blast sampling provided an effective technique to sample the bendway weir field when combined with the hydroacoustic survey. Blast sampling provided species composition data and the hydroacoustic survey provided fish location, density, and size data. Fish species composition and density data would have been impossible to obtain using conventional fishery techniques.

Acknowledgements

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Table 2: Fish species collected using catch nets (mid-water collection) and chase boats (surface collection) during blast sampling of the Price Towhead bendway weir.

Species	Catch Nets (Mid-Water Collection)	Chase Boats (Surface Collection)	Total
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	1	0	1
Gizzard shad (*Dorosoma cepedianum*)	58	1	59
Skipjack herring (*Alosa chrysochloris*)	2	0	2
Carp (*Cyprinus carpio*)	0	11	11
Smallmouth buffalo (*Ictiobus bubalus*)	0	6	6
Stonecat (*Noturus flavus*)	2	0	2
Freckled madtom (*Noturus nocturnus*)	2	0	2
Flathead catfish (*Pylodictis olivaris*)	4	9	13
Channel catfish (*Ictalurus punctatus*)	3	2	5
Blue catfish (*Ictalurus furcatus*)	24	12	36
Goldeye (*Hiodon alosoides*)	1	2	3
Freshwater drum *Aplodinotus grunniens*)	2	75	77
Total	99	118	217

Table 1: Published studies of fishery surveys employing explosives as a sampling method.

Habitat Sampled	State	Explosive Type	Authors
Large Rivers			
Upper Illinois River	Illinois	dynamite	Forbes & Richardson 1913
Clark Fork River	Montana	dynamite	Averett & Stubbs 1962
Hiwassee & Ocoee Rivers	Tennessee	dynamite	Stubbs 1964
Blackwater River	Florida	detonating cord	Bass & Hitt 1977
Niobrara-Missouri River	Nebraska	detonating cord	Hessee et al. 1979
Upper Mississippi River	Iowa/Illinois	detonating cord	Rasmussen et al. 1985
Small Streams			
Salmon streams		detonating cord	Platts 1974
Stillwater Creek	Oklahoma	detonating cord	Layher and Maughan 1984
Canals			
Canal systems	Florida	detonating cord	Metzger and Shafland 1986
Impoundments			
	Florida	detonating cord	Metzger and Shafland 1987
	Illinois	detonating cord	Bayley & Austin 1988

Table 3. Fish species collecting using conventional (trotlines, gill nets hoop nets) during sampling of the Price Towhead bendway weir.

Species	Number	Total Length (cm)
Trotlines		
Blue catfish (*Ictalurus furcatus*)	1	19.0
Gill Nets		
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	1	79.2
Paddlefish (*Polyodon spahtula*)	1	23.3
Gizzard shad (*Dorosoma cepedianum*)	1	19.0
Carp (*Cyprinus carpio*)	1	19.0
Hoop Nets		
Flathead catfish (*Pylodictis olivaris*)	3	range 24.2-40.8
Channel catfish (*Ictalurus punctatus*)	1	68.8
Blue catfish (*Ictalurus furcatus*)	1	38.1, 44.0

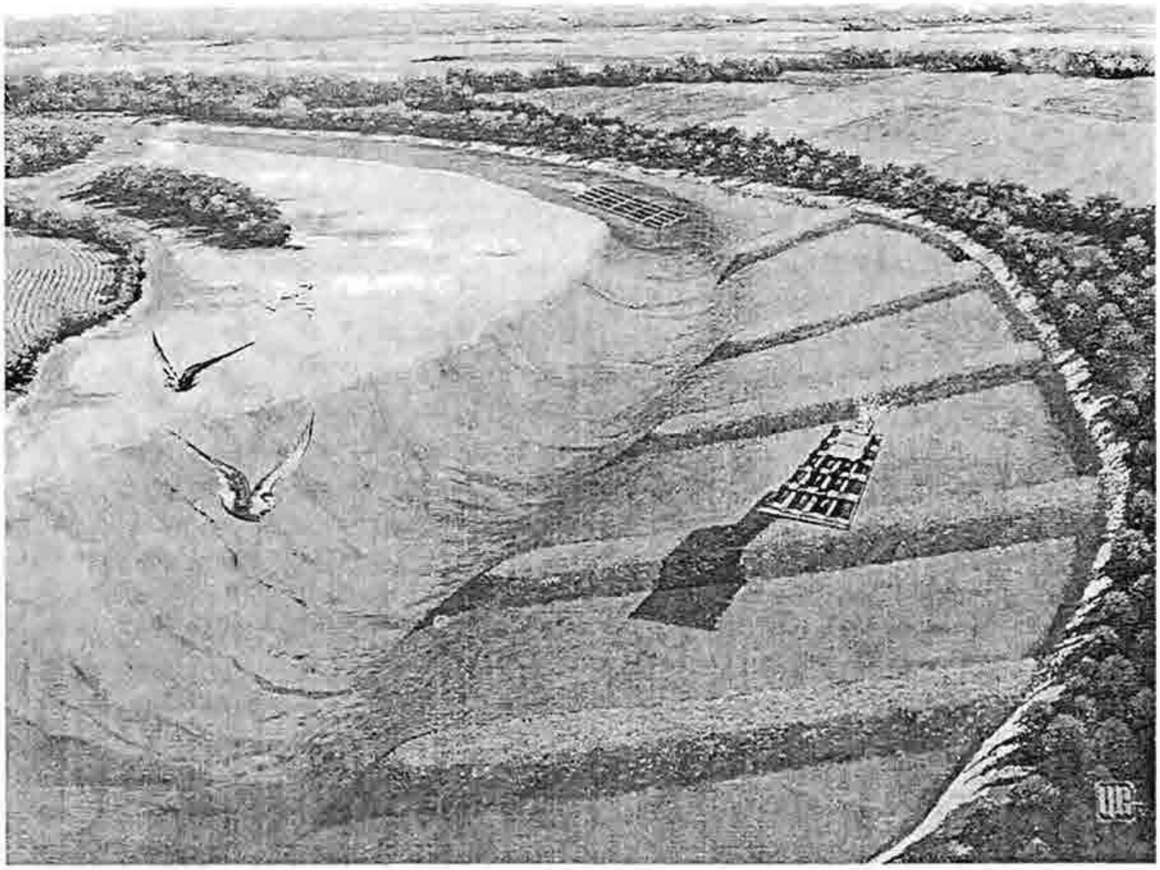


Figure 1. Illustration of a towboat passing over a bendway weir field.

Appendix G.

Wood Structure Meeting Summary, November 2000 - U.S. Army Corps of Engineers, St. Louis District.

Results of the St. Louis District Corps woody structure meeting 11/30/00

The Corps of Engineers, St. Louis District held a meeting on 11/30/00 to discuss the placement of woody structure into the Mississippi River. Present were the Corps, IDNR, and the USFWS. MDC was invited, but unable to attend.

Background information

Our partner agencies have asked the St. Louis Corps to examine ways to incorporate woody structure into our Mississippi River operation and maintenance program. Following that request, the St. Louis District has explored options to both obtain and utilize woody structure in our programs.

The Westvaco Corporation has offered the St. Louis District wood from its cull pile. The cull pile contains trees that were rejected by the lumber mill because of the presence of metal. The cull pile contains large, skinned (no branches) trees of varying sizes. The pile is located at the Westvaco plant in Wyckliffe, KY, about a mile off of the Mississippi River, and just below the confluence with the Ohio River. Westvaco has loading facilities on the river.

Westvaco cull pile

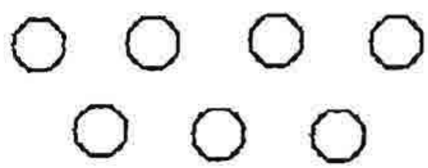
The St. Louis District intends to have culled logs loaded onto a flat barge at the Westvaco facility and transported the District Service Base prior to use. This activity is expected to take place in place in early 2001.

Meeting results

At the woody structure meeting, it was decided to begin placement of wood structure as soon as possible to determine what methods will work, or not work, for placing wood in the river. We have initially decided to build two types of structures, a modified pile dike and bundled log structures. A lot of what these structures will look like will depend on what is possible once the work crew is mobilized and out on the river. Work is expected to commence soon after the logs arrive from Westvaco, likely in January or February 2001. This work will be conducted under our Avoid and Minimize program.

Modified pile dikes

The modified pile dike will hopefully look something like the following:



In this configuration logs, or a group of logs, are driven in a pattern that allows them to collect debris while still functioning a dike. These structures are planned for two sites.

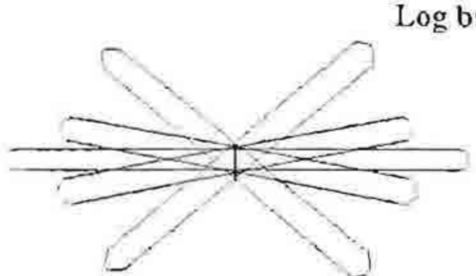
The first work site will be in the dike field between dikes 164.9 and 165.1. This site will service as the testing site to see what is possible when driving logs (Can we drive these logs? If so, what size of logs can we drive? How close together can we drive them? How far down can we drive them? etc.,).

Once it has been established what is "doable", we intend move downstream and place an unrooted dike at about 163.8R near the head of the sandbar. This site was chosen by the group because we felt that placement here would collect debris and also push flow around the backside of the sandbar, helping to isolate the sandbar from the bank.

Log bundles

The District will also be constructing individual log bundle structures and placing them in the river. These log bundles will be constructed on-site by cinching together a number of logs. Once cinched, these logs are expected to splay out, creating a structure similar to a logjam. These bundles will be held in place with the same anchors rocks used to hold channel buoys in place.

Log bundle structure



Log bundles will be placed at two sites, behind the L-dike at rm. 165.65R and in the back end of a scour hole below dike 157.3L. It is expected that a series of bundles will be placed together at each site to form a log jam structure. These two sites were selected because one represents a shallow placement and the other a deep placement of the structures.

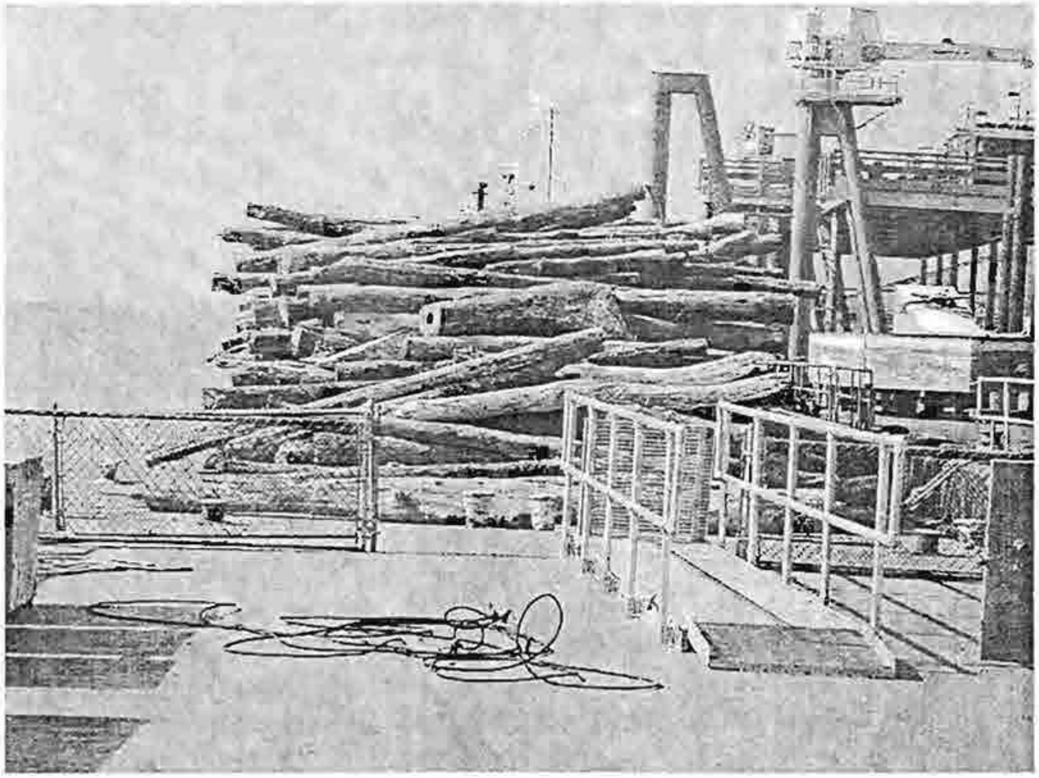
Monitoring

Pre- and post-construction surveys will be done at all sites. This work will include depth, velocity, and hydroacoustic fisheries measurements. Pre-construction surveys will be conducted in January. Post construction biological monitoring work will also be conducted to assess the impact of the structures. The structures will also be assessed as to how well they function as river training devices.

Future correspondence

The St. Louis District will inform our partner agencies in advance of survey work and the actual placement of the structures. We have encouraged our partners to participate in the monitoring effort and to be present during the placement of the structures. As this work is new to all of us, having our partners on site to provide input on the placement of these structures is important. The Corps point of contact for this work will be Brian Johnson. Brian can be reached at 314-331-8146.

12/5/00
Brian Johnson



Wood to be used for the woody structure project, loaded on the District barge.

Note the large cavities in some of the logs.

Appendix H.

Dike 53 Physical and Biological Monitoring Trip Report - U.S. Army Corps of Engineers, St. Louis District.

A&M Trip Report
Dike 53 monitoring

Sample Date: 18-20 January 2000

Purpose: Conduct pre-modification monitoring of an existing dike (RM 53.0L). This work is being completed under Avoid and Minimize measure A-16, dike configuration studies. Post-construction monitoring of the dike is also planned to determine the effects of the modification

Participants: Sampling was conducted on the M.V. Boyer and in cooperation with the Missouri Department of Conservation LTRMP station in Cape Girardeau, MO. Present from the Corps were Brian Johnson, John Naeger, Joe Burnett, and Eric Laux. Present from the Missouri Department of Conservation was Mike Peterson, Dave Herzog, and Dave Ostendorf.

Summary: On 18, 19, and 20 January 2000 we collected multi-beam bathymetry, velocity, and hydroacoustic fisheries data at an existing dike located at RM 53.0L. As constructed, the dike extends 600 ft. into the river and has an elevation of +15 ft. LWRP (310.48). The dike, which extends into the navigation channel and is considered a navigation hazard, is scheduled for modification during the spring of 2000. Several modification alternatives have been discussed, including removing the last 300 ft. of the dike, lowering the entire dike down to –12 ft. (creating a weir), or lowering the last 300 ft. of the dike to –12 ft. while leaving the rest of the dike intact. Rock removed from the dike will be placed on the bank above and below the structure.

To collect hydroacoustic and velocity data, forty-seven transects were run crosscurrent over the area, each approximately 30 ft apart. Velocity and hydroacoustic data were collected at the same time. Hydroacoustic data were collected using a split beam 208 kHz transducer, with a lower threshold of -70.0 dB, a pulse width of 0.2 ms, and at a rate of 7 pings per second. Differential Global Positioning System (DGPS) coordinate readings and depth readings were taken continually along each transect. Boat speeds were between 2.5-3 knots. The water temperature was 39°F. Sampling conditions were excellent. Transects were numbered from downstream to upstream. Data sheets (6) were completed on-site. Hydroacoustic and velocity data were collected on 19 January 2000. Multi-beam bathymetry was collected 18 January 2000. A bathymetry map of the site is attached.

Results of the bathymetric survey show the presence of two holes below the dike. One hole extends behind and riverward of the tip of the dike. The second hole, which appears to have been created by the plunging action of water overtopping the dike, is located outward from the toe of the dike. The hydroacoustic and velocity results have not been analyzed yet, but field observations showed a large number of fish using the entire area behind the dike, with the majority of the fish using the inside hole. Velocities in this area appear to be between 0-2 ft per second. A copy of the hydroacoustic output from transect 22, through the two holes, and a copy of the hydroacoustic output sampling downstream through the inner hole is attached.

On 19 January 2000 the Missouri Department of Conservation set four experimental gill nets (mesh openings ranged from 1-5 inches) below the dike. Each 300-ft. net was set on the bottom.

Coverage was likely limited to the bottom six feet on the water column. These nets were retrieved on 20 January 2000. Two nets were set in the inner hole, perpendicular to the bank, one net was set perpendicular to the dike on the ridge between the two holes, and one net was set perpendicular to the tip of the dike. Ninety-one fish were collected in the inside hole. The collection included 81 shovelnose sturgeon, 3 paddlefish, 3 blue catfish, 3 sauger, and 1 goldeye. Twenty-five fish were collected on the ridge between the two holes. All 25 were sturgeon. One appeared to be a shovelnose sturgeon/pallid sturgeon cross. Ten fish were collected in the net set off the dike tip. This area likely had flows higher than either of the other net set locations. The 10 fish included 4 paddlefish, 4 blue catfish, and 2 shovelnose sturgeon. Lengths were collected on all fish. Results are attached.

The fisheries data for this project are being analyzed by Aquacoustics, Inc. Detailed bathymetric and velocity maps will be created by ED-S. This information is being compiled and will be presented in a more complete report upon receipt.

Submitted 26 January, 2000

BRIAN JOHNSON
Fishery Biologist
Planning, Programs, and Project
Management Division
Environmental and Economics Branch
Environmental Section

Dike 53 Sampling 1/20/00

Water temperature: 2.5 C

Date: 1/20/00

NET 1
experimental gill net 300 ft
depth 10.5 m
location: in the inner hole

number	species	fork length (mm)	panel mesh (in)
1	SHOVELNOSE STURGEON	558	1.5
2	SHOVELNOSE STURGEON	606	|
3	SHOVELNOSE STURGEON	675	|
4	SHOVELNOSE STURGEON	518	|
5	SHOVELNOSE STURGEON	572	|
6	SHOVELNOSE STURGEON	469	|
7	SHOVELNOSE STURGEON	630	|
8	SHOVELNOSE STURGEON	618	|
9	SHOVELNOSE STURGEON	470	|
10	SHOVELNOSE STURGEON	468	|
11	SHOVELNOSE STURGEON	750	|
12	SHOVELNOSE STURGEON	490	|
13	SHOVELNOSE STURGEON	456	|
14	SHOVELNOSE STURGEON	470	|
15	SHOVELNOSE STURGEON	523	|
16	SHOVELNOSE STURGEON	418	|
17	SHOVELNOSE STURGEON	600	|
18	SHOVELNOSE STURGEON	558	|
19	SHOVELNOSE STURGEON	513	|
20	SHOVELNOSE STURGEON	440	|
21	SHOVELNOSE STURGEON	680	7.5
22	SHOVELNOSE STURGEON	673	|
23	SHOVELNOSE STURGEON	674	|
24	SHOVELNOSE STURGEON	628	|
25	SHOVELNOSE STURGEON	670	|
26	SHOVELNOSE STURGEON	620	|
27	SHOVELNOSE STURGEON	530	|
28	SHOVELNOSE STURGEON	662	|
29	SHOVELNOSE STURGEON	644	|
30	SHOVELNOSE STURGEON	618	|
31	SHOVELNOSE STURGEON	692	|
32	SHOVELNOSE STURGEON	517	|
33	SHOVELNOSE STURGEON	720	|
34	SHOVELNOSE STURGEON	658	|
35	SHOVELNOSE STURGEON	650	|
36	SHOVELNOSE STURGEON	612	|
37	SHOVELNOSE STURGEON	575	|
38	SHOVELNOSE STURGEON	690	|
39	SHOVELNOSE STURGEON	603	|
40	SHOVELNOSE STURGEON	678	|
41	SHOVELNOSE STURGEON	664	|
42	SHOVELNOSE STURGEON	655	|
43	SHOVELNOSE STURGEON	513	|
44	SHOVELNOSE STURGEON	590	|
45	SHOVELNOSE STURGEON	618	|
46	SHOVELNOSE STURGEON	679	|
47	SHOVELNOSE STURGEON	618	|
48	SHOVELNOSE STURGEON	530	|
49	SHOVELNOSE STURGEON	421	|
50	SHOVELNOSE STURGEON	558	|
51	SHOVELNOSE STURGEON	690	7.5
52	SHOVELNOSE STURGEON	652	|
53	SHOVELNOSE STURGEON	625	|
54	SHOVELNOSE STURGEON	664	|
55	SHOVELNOSE STURGEON	658	|

NET 2 (attached to end of net 1)
experimental gill net 300 ft
depth 10.5 m
location: in the inner hole

number	species	fork length (mm)	panel mesh (in)
1	SHOVELNOSE STURGEON	638	3.5
2	PADDLEFISH	670	|
3	BLUE CATFISH	626	|
4	PADDLEFISH	628	|
5	PADDLEFISH	865	2.5
6	SHOVELNOSE STURGEON	608	|
7	SHOVELNOSE STURGEON	690	|
8	SHOVELNOSE STURGEON	617	|
9	SHOVELNOSE STURGEON	590	|
10	SHOVELNOSE STURGEON	638	|
11	SHOVELNOSE STURGEON	646	|
12	SHOVELNOSE STURGEON	640	|
13	SHOVELNOSE STURGEON	468	|
14	SHOVELNOSE STURGEON	632	|
15	SHOVELNOSE STURGEON	640	|
16	SHOVELNOSE STURGEON	701	|
17	SHOVELNOSE STURGEON	632	|
18	SHOVELNOSE STURGEON	668	|
19	SHOVELNOSE STURGEON	630	|
20	SHOVELNOSE STURGEON	650	|
21	SHOVELNOSE STURGEON	618	|
22	SHOVELNOSE STURGEON	631	|
23	SAUGER	368	1.5
24	SAUGER	370	|
25	SHOVELNOSE STURGEON	508	|
26	SHOVELNOSE STURGEON	602	|
27	SHOVELNOSE STURGEON	495	|
28	SHOVELNOSE STURGEON	486	|
29	SHOVELNOSE STURGEON	450	|
30	BLUE CATFISH	302	|
31	SHOVELNOSE STURGEON	578	|
32	SAUGER	293	|
33	SHOVELNOSE STURGEON	465	|
34	SHOVELNOSE STURGEON	630	|
35	BLUE CATFISH	280	|
36	GOLDEYE	192	|

NET 3
experimental gill net 300 ft
depth 11 m
location: along the ridge between the holes

number	species	fork length (mm)	panel mesh (in)
		NO FISH	5
		NO FISH	4
		NO FISH	3
1	SHOVELNOSE STURGEON	609	2
2	SHOVELNOSE STURGEON	602	|
3	SHOVELNOSE STURGEON	646	|
4	SHOVELNOSE STURGEON	647	|
5	SHOVELNOSE STURGEON	593	|
6	SHOVELNOSE STURGEON	662	|
7	SHOVELNOSE STURGEON	762	|
8	SHOVELNOSE STURGEON	509	|
9	SHOVELNOSE STURGEON	670	|
10	SHOVELNOSE STURGEON	552	|
11	SHOVELNOSE STURGEON	596	|
12	SHOVELNOSE STURGEON	650	|
13	SHOVELNOSE STURGEON	580	|
14	SHOVELNOSE STURGEON	570	|
15	SHOVELNOSE STURGEON	568	|
16	SHOVELNOSE STURGEON	628	|
17	SHOVELNOSE STURGEON	576	|
18	SHOVELNOSE STURGEON	602	|
19	SHOVELNOSE STURGEON	563	|
20	SHOVELNOSE STURGEON	618	|
21	SHOVELNOSE STURGEON	573	|
22	SHOVELNOSE STURGEON	552	|
23	HYBRID	718	|
24	SHOVELNOSE STURGEON	560	|
25	SHOVELNOSE STURGEON	550	|

NET 4
experimental gill net 300 ft
depth 13.5 m
location: of the end of the dike tip

number	species	fork length (mm)	panel mesh (in)
1	PADDLEFISH	828	5
2	PADDLEFISH	640	|
		NO FISH	4
3	PADDLEFISH	872	3
4	BLUE CATFISH	630	|
5	BLUE CATFISH	582	|
6	BLUE CATFISH	436	2
7	PADDLEFISH	680	|
8	SHOVELNOSE STURGEON	546	|
9	SHOVELNOSE STURGEON	578	|
10	BLUE CATFISH	489	|

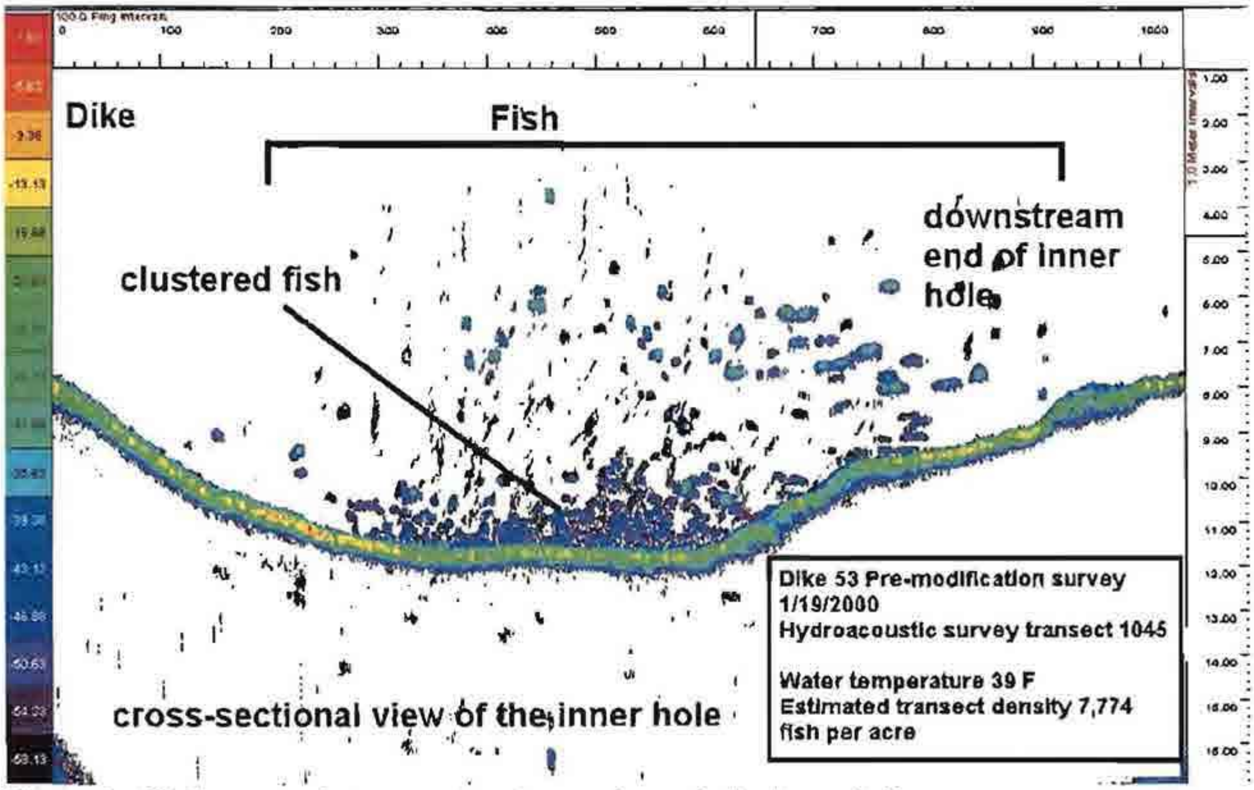


Figure 1. Hydroacoustic transect upstream through the inner hole.

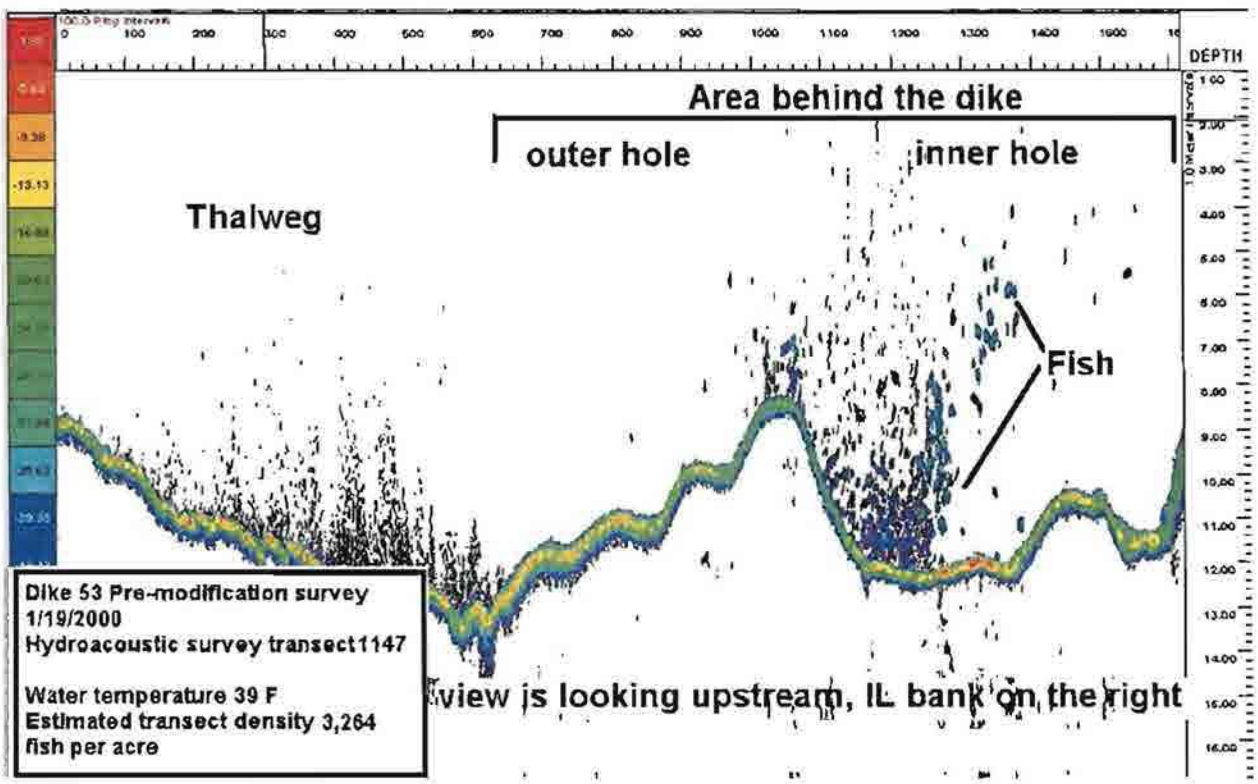


Figure 2. Hydroacoustic transect 1147 at dike 53 illustrating fish location. Transect location is shown in red on the map.

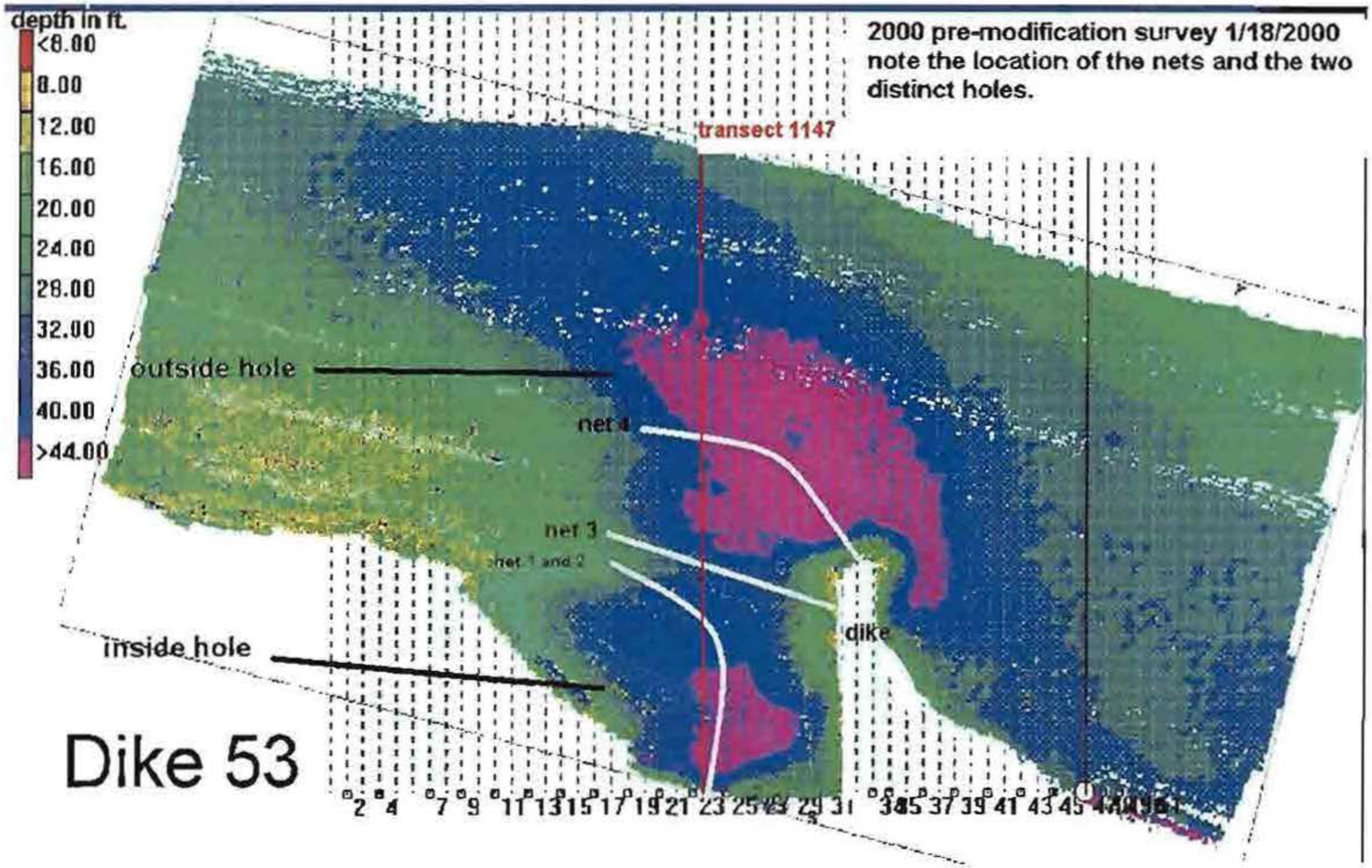


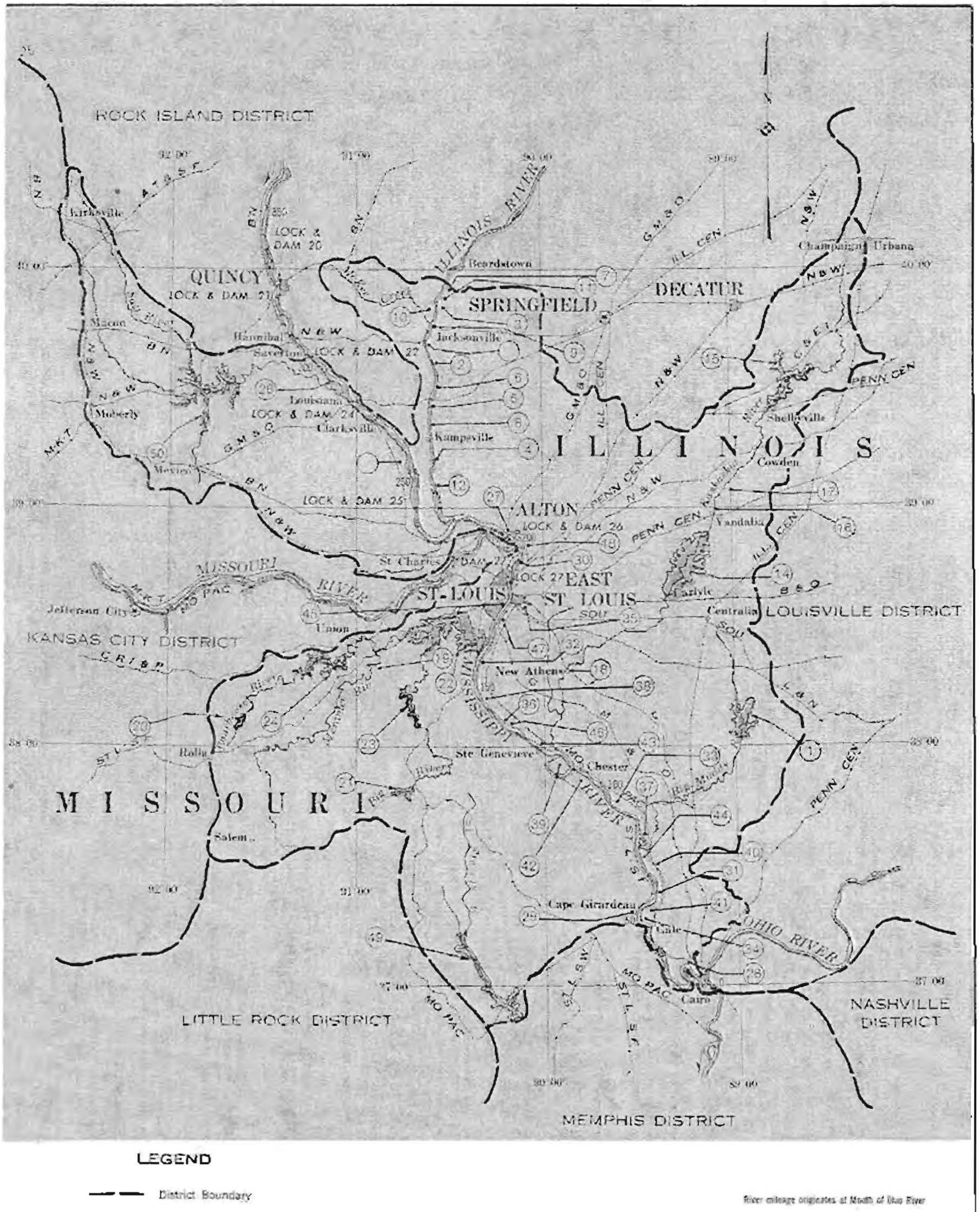
Figure 3. Bathymetry map of Dike 53. Transect 1147 (illustrated above) is shown in red.

Appendix I.

Middle Mississippi River Side Channel Vision - U.S. Army Corps of Engineers, St. Louis District.

MIDDLE MISSISSIPPI RIVER SIDE CHANNELS

A HABITAT REHABILITATION AND CONSERVATION VISION



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MIDDLE MISSISSIPPI RIVER
SIDE CHANNEL REHABILITATION AND CONSERVATION VISION

A. <u>INTRODUCTION</u>:

The Middle Mississippi River, for the purpose of this document extends from the tailwater of Melvin Price Locks and Dam down to the confluence of the Ohio River. The correct description of the Middle Mississippi River is that it extends from the mouth of the Missouri River to the mouth of the Ohio River. However, since we have elected to look at the area directly above the mouth of the Missouri, to include the Maple Island side channel, we have modified the historic definition to include this area.

A.1 **BACKGROUND**:

Side channels are a critical biological component of the Mississippi River. Most side channels within the MMR lack bathymetric diversity and tend to be somewhat homogenous, containing relatively few scour holes and flat, high elevation channel inverts. There is a critical need to rehabilitate and conserve these critical aquatic habitats. The purpose of this plan is to address the environmental health of the side channels of the Middle Mississippi River and to assure the continued accrual of benefits they provide to the system.

This plan outlines, in concept, actions that may be required at each side channel. Not all side channels require a large investment of resources, some require only monitoring at this time. Others, however, require substantial investment of resources to restore their health and proper functioning within the MMR system. Engineers within the Corps have an excellent knowledge base of the hydraulic processes in place and the engineering expertise and tools necessary to modify most of these processes. The Missouri Department of Conservation, the Illinois Department of Natural Resources, the Fish and Wildlife Service and Corps biologists have the expertise necessary to describe the desired conditions in the individual side channels and to verify conditions prior to and immediately following rehabilitation actions.

Individual side channels may be enhanced through land acquisition for reforestation, to reestablish the natural ridge and swale bottomland topography, to reconnect a portion of the floodplain to the river, to regain cut bank habitat, to provide public access, recreation and educational purposes. Some of the prescriptions within this plan call for reforestation and reestablishment of the ridge and swale system. In most cases, the adjacent land is not currently in public ownership. In some of these areas it will make management sense for an agency to acquire these lands through existing authorities. In other areas, it may make sense for other non-government organizations, concerned citizens or private industry to acquire these lands and, where possible, achieve the enhancement benefits through voluntary cooperative agreements. Still other areas may see this enhancement opportunity put on hold due to management concerns. unwilling sellers, and so forth. Where land acquisition may be involved to complete the overall prescription, the planning team will discuss the individual area and proceed as the situation warrants.

This is truly a cooperative effort. No one agency can accomplish everything that is prescribed for the side channels. By appropriately combining the authorities and resources of the Corps of Engineers, Illinois Department of Natural Resources, Missouri Department of Conservation, and other interested Federal and State agencies, the basic plan can be accomplished.

This plan is envisioned as an ongoing effort, subject to review and revision as necessary. At a minimum, this review and revision process will occur annually. Environmental concerns exist over the entire MMR. In addition to side channels, the main channel, main channel border, sand/gravel bar, riparian corridor, and other habitats along with system wide problems such as erosion, sedimentation, development, forest fragmentation and water quality must be programmatically addressed. To that end, we support and will participate in the development of a comprehensive plan to address the MMR in a systems wide approach. The side channel plan will be incorporated into the comprehensive plan and will cease to exist as a separate entity at the time the comprehensive plan is approved.

A.2 **COOPERATION**:

Since the mid 1960's the Corps of Engineers has been working with the Illinois Department of Natural Resources, the Missouri Department of Conservation, and the Fish and Wildlife Service on management of the Mississippi River within the St. Louis District. Our early efforts were concentrated on regulatory works and dredging activities. These early efforts were not always pleasant and success, by anyone's' standard, was tenuous at best.

The more time we spent together, the more we made an effort to teach ourselves a common language. Engineers, Biologists, and Foresters do not always use the same vocabulary and we recognized that some of our frustration was coming from communication problems. We also took the time to share and learn what each of our agencies missions were and what is required to continue to meet these missions. We shared our visions of the future for the Mississippi River and began to discuss actions that would help us achieve some of our common goals. The advent of the Avoid and Minimize program (A&M) and the Environmental Management Program (EMP) helped to focus our efforts. Not only do we continue to discuss beneficial actions, we are now able to physically put some plans in place and monitor for results.

As we began to discuss results and continued to look for opportunities to rehabilitate habitat, we gradually began to look at the river as a system rather than a collection of isolated reaches. This is particularly true of the Middle Mississippi River (MMR) where we do not have the constraints of navigation pools to interfere with our vision. The more we began to look at the MMR, the more it became apparent that the most critical part of the overall habitat that needed attention was the side channels. Instead of dealing with each side channel as a separate entity in the traditional manner, we decided to take a systems approach. In furtherance of this idea, we have developed an overall action plan that addresses individual side channels in the context of addressing this habitat type over the entire MMR system.

B. AUTHORITIES:

This is a large project. It is unlikely that all features within a side channel will be built using just one authority or the authorities of a single agency. It is also probable that not every action will be completed within a side channel prior to moving on to other side channels. In essence, the requirements for any given side channel may be accomplished using different authorities for each feature and may be staged over a number of years. Therefore, this project should be considered a process rather than the result of one contract and one authority.

B.1 CORPS OF ENGINEERS:

The Corps of Engineers is responsible for developing, operating and maintaining the Nine-Foot Navigation Channel. The Corps has the responsibility to accomplish this mission in an environmentally sound manner. The following documents and laws are the most germane to the management of the Middle Mississippi River. A complete list of authorities can be found in the Rivers Project Master Plan.

Regulating Works Project, Mississippi River, Between the Ohio and Missouri Rivers.
    Rivers and Harbor Acts of 21 January 1927.
    Rivers and Harbors Commission Document No. 9, 69th Congress, Second Session 3 July 1930.
    Rivers and Harbors Commission Document 12, 70th Congress, First Session.
Vegetative Management for Corps Projects
    Forest Conservation Act (PL 86-717)
Cost Sharing for Enhancement of Fish and Wildlife (Sec. 1135)
    Water Resources Development Act of 1974 (PL 93-251)
Non-Game Fish and Wildlife Management
    Fish and Wildlife Conservation Act of 1980 (PL 96-336)
Establishment of the Environmental Management Program (UMRS Management Act)
    Water Resources Development Act of 1986 (PL 99-662)
Restoration of Environmental Quality, Ecosystem Restoration, Beneficial Use of Dredge Material, and Cost Sharing for Environmental Projects (amends Sec. 103 of WRDA 86)
    Water Resources Development Act of 1996
Reauthorization of EMP and Establishment of the Missouri and Middle Mississippi Rivers Enhancement Project.
    Water Resources Development Act of 1999 (PL 106-53)
Other Authorities as they become available.

The different program authorities that are authorized in the above listing, include:

1. Maintenance Dredging Program
2. Channel Improvement Program
3. Channel Maintenance Dike and Revetment Program
4. Avoid and Minimize Program (DM 24)
5. Upper Mississippi River Environmental Management Plan - Habitat Rehabilitation Project, reauthorized in Section 509 of WRDA99 (cost share may or may not be required)
6. Missouri and Middle Mississippi Rivers Enhancement Project, authorized in Section 514 WRDA99 (cost share may be required)
7. Continuing Authorities Programs (historically cost share required)
   a. Section 206 – Aquatic Systems Restoration
   b. Section 207 -- Beneficial Uses of Dredged Materials
   c. Section 1135 – Project Modification for Improvement of Environment
   d. Section 204 – Restoration of Environmental Quality

These authorities are detailed in the Rivers Project Master Plan.

B.2 ILLINOIS DEPARMENT OF NATURAL RESOURCES:

The Department of Natural Resources Act (Act 801), section 801/25 effective 1 July 1995, transferred all the powers of the Department of Conservation to the Department of Natural Resources. For fish and game conservation, IL DNR is empowered to "take all measures necessary for the conservation, preservation, distribution, introduction, propagation, and restoration of fish, mussels, frogs, turtles, game, wild animals, wild fowls and birds." Specific authorities which may apply to cooperative projects with other states or with federal agencies on the Middle Mississippi include:

Transfer or acquisition of realty Act 805. Civil Administrative Code of Illinois
Contract with local governments to construct boat ramps Act 805.
Expend monies from the Park and Conservation Fund for conservation Act 805.
Enter into agreements with federal agencies to effect cooperative undertakings in conservation of wildlife Act 805.
Cooperate with other departments and agencies in conducting surveys, experiments, or work of joint interest or benefit Act 5. Fish and Aquatic Life Code

B.3 MISSOURI DEPARMENT OF CONSERVATION:

The Missouri Department of Conservation (MDC) has authority given in the State of Missouri Constitution to manage the State's forest, fisheries, and wildlife resources to preserve and enhance these resources for existing and future generations of Missouri citizens. The following authorities may apply in future cooperative projects between the Missouri Department of Conservation and the St. Louis District:

Serve as non-federal cost-share sponsor on Section 1135, 206, and Environmental Management Program (EMP) habitat enhancement projects. Water Resources Development Act of 1986 (PL-99-662).

Provide environmental comment on Corps Regulating Works Projects Fish and Wildlife Coordination Act.

Enact collaborative research with St. Louis District on middle Mississippi River species of concern. MOU between MDC and USGS to establish and operate an open river field station.

Authority to acquire and manage public lands for forestry, fisheries and wildlife enhancement. Missouri State Constitution.

Provide financial assistance to river front communities to construct river access ramps. MDC's Communities Assistance Program

C. PROJECT DESCRIPTION:

C.1.1 GENERAL:

The following opportunities have been identified for rehabilitating or creating fish and wildlife habitat along the Middle Mississippi River from Lock and Dam 26 to the mouth of the Ohio River at Cairo, Illinois:

1. Rehabilitate and or creating side channels at sites where levees exist. Individual projects will be selected on a case-by-case basis by the partner agencies participating in the Middle Mississippi River Side Channel Rehabilitation and Conservation Project.

2 Where the opportunity exists establish annual flow connectivity between the river and its floodplain. This component of the MMR side channel project may be achieved by identifying and securing flood easements or fee title to sites compatible with this project objective.

3. Increase wetland diversity along the MMR. To accomplish this it will be necessary to establish hydraulic connection between the river's main channel and selected semi-permanent wetlands while leaving other semi-permanent wetlands unconnected to dry annually (e.g., especially in the vicinity of known heron rookeries).

4. Seek opportunities to restore and create a portion the hard mast component of the bottomland hardwood forest through the use of innovative silvacultural practices, such as constructing dredge spoil ridges to improve tree root aeration, establishing grass cover for weed control (e.g., plant redtop), and planting containerized trees.

5. Determine feasibility of creating an island/side-channel complex within river mile 80 to 100. Similarly consider other open river areas for island/side-channel creation.

6. Identify chronic dredging areas that may provide the potential for sandbar or sand island creation. Assist in increasing the St. Louis District's capabilities, through

acquisition of new equipment and improved material handling and placement, to create artificial habitats through the use of dredge material.

7. Identify and concentrate habitat enhancement efforts on side-channels with the greatest need for habitat improvement(s), while relegating others to a lower priority. Be prepared to accomplish lower priority work prior to higher priority if it should become expedient to work on a particular side-channel first.

8. Provide off channel/wintering habitat for fish and other aquatic organisms at regular intervals within the MMR. Adequate habitat should be, at a minimum, nine feet deep.

9. Identify side-channels where woody structure is needed. Following site identification, develop and implement a plan incorporating a variety of designs such as trees, piles, combination of piles close to shore and rock on ends, etc., to install woody structure within open river side-channels.

10. In order to reduce or avoid industries' effects on off-channel areas it is important to establish communications between industry and state and federal agencies charged with environmental management along the Middle Mississippi River. This is especially true as it relates to the St. Louis Harbor and other areas of industrial development. An example of a successful initiative on the navigation pools involving river navigation and resource biologists is the "Biologist-on-Board Program".

11. Establish and expand riparian corridors along open river off-channel areas. To pursue this it will be necessary to identify lands adjacent to off-channel areas that are enrolled in the NRCS Wetlands Reserve Program, in public ownership (FWS, FS, COE and States), or controlled by not-for-profit groups such as American Land Conservancy or Trust for Public Lands.

12. In order to conserve, rehabilitate and or create habitat necessary to sustain life requirements of Federal and State listed threatened or endangered species along the open river it will be necessary to identify spawning, nursery, nesting, foraging and roosting areas for species such as the Bald Eagle, Mississippi Kite, pallid sturgeon, interior least tern, etc.

C.1.2 GOALS AND OBJECTIVES

The following is a list of the preliminary goals and objectives of this effort. This list may be modified or amended as this effort proceeds.

1. Provide over wintering habitat every 5-7 miles in the MMR

2. Provide off channel habitat every 5-7 miles in the MMR (may or may not coincide with point 1 above).

3. Increase the amount of riparian corridor and adjacent flood plain covered under the plan by approximately 200,000 ac. This increase would come from conservation easements, cooperative management agreements with state agencies, counties, municipalities, non-government agencies, industry and private landowners, as well as purchase of fee title by the states of Illinois and Missouri and the Fish and Wildlife Service from willing sellers. Restore a portion of the forested riverine habitat and provide limited flood plain connectivity on these lands.

4. Maintain connectivity and small craft access to the side channel areas.

5. Provide public access to river resources every 10 miles on average. The Corps, the Fish and Wildlife Service, states of Illinois and Missouri, counties, municipalities, various associations, private corporations, and non-government agencies would supply these accesses.

C.2 PHYSICAL AND BIOLOGICAL REQUIREMENT:

These are the preliminary considerations used for framing the MMR Side Channel Rehabilitation Project. As the project continues, these points may be modified, expanded or contracted as the situation warrants. In support of the Navigation Study Upper Mississippi River Environmental Management Program, information developed under this enhancement project will be supplied to the Habitat Needs Assessment and the O&M Biological Assessment Tier I teams as appropriate.

Each side channel of the open river is unique possessing different physical and biological characteristics requiring different management actions to conserve, rehabilitate, or enhance its habitat quality. The following is a partial listing of physical and or biological requirements necessary to sustain, enhance or create side channel habitat, and a sampling of tools/actions that may be used to address these requirements. This list is not intended to show every requirement or tool/action that may be used. It is important to note that several of these items may be necessary to address an individual side channel or area of the open river.

Need/Requirement	Tools/Actions
Flow Sinuosity	Use of hard points, short dikes, wooden pile dikes, rootless dikes, etc.
Depth Diversity	Notch dikes, stepped dikes, round points, dredging, etc.
Connectivity-Side Channels	Notch closure structures, experiment with different designs of closure structures, dredge in lower 1/3, etc.
Connectivity-Wetlands	Reopen ridge and swale system, remove sediment deposits at ditch/tributary opening, etc.

Woody Structure	Use pile dikes, cut trees and cable down, wooden cribbing weighted with stone, build hybrid dikes with trees and limbs intermixed with stone, etc.
Hard Mast Restoration	Use dredge spoil to build ridges and plant trees, open existing forest cover to release advanced regeneration, etc.
Interior Sedimentation Reduction	Work with NRCS and adjacent landowners to reduce erosion, leave sediment plugs in at drainage ditches and feeder creeks, reopen ridge and swale system in interior wetlands to act as sediment trap, etc.
Side Channel/Island Creation	Innovative experimental dike design and modification, strategically place dredge spoil in a dike field, build chevron dikes and use for dredge material placement, etc.
Cut bank	Identify areas in public ownership where cut bank habitat can be developed. Use hard points, short dikes, wooden pile dikes, etc to direct flow toward unprotected banks to encourage erosion and development of cut bank/deep hole habitat.

C.3 PHYSICAL AND BIOLOGICAL MONITORING

The physical and biological monitoring is based on the existing protocol established by the USGS Open River monitoring team. This protocol will be modified as necessary and as more experience is gained. The following is a quick look at the existing protocol.

Monitoring/sampling to begin one year before construction and end one year after Construction.

Pre and post construction bathymetric surveys and substrate evaluation (technology on MVS Boyer is adequate).

Sample the fisheries community once per season using multiple gear arrays.

During fisheries sample, collect water quality data (dissolved oxygen, water Temperature, conductivity, turbidity, and velocity from surface and bottom).

Limnological monitoring/sampling on same level of resolution as fisheries community sampling. Establish upper, middle and lower monitoring stations in deep water locations. The following will be collected, dissolved oxygen, water temperature, pH, and conductivity. In addition, chlorophyll-a will be taken at each station from the surface. At a minimum, these profile data will be taken seasonally.

Monitoring of invertebrates will not be included at this time. The importance of invertebrates is recognized, however, at this time we do not understand the ecological/biological relationships between invertebrate fauna and the environment of the Mississippi River. As this knowledge is gained, we will include monitoring as appropriate.

C.4 INITIAL RANKINGS:

After initial reconnaissance and evaluation, the existing major side channels are grouped by priority: High, Medium, Low, Further Investigation, and Monitor. These rankings may change based on the workings of a dynamic river system.

HIGH PRIORITY (needs attention now and good value for effort):

1. Salt Lake Chute (RM 139.5 – 136.0 L)
2. Fort Chartres Chute (RM 134.3 – 132.2 L)
3. Establishment Chute (132.5 – 130.0 R)
4. Jones Chute (RM 98.3 – 94.9 R)
5. Crawford Chute (73.9 – 71.5 L)
6. Buffalo Island Chute (26.3 – 24.5 R)
7. Area between RM 98.2 and 73.8 (no side channels, islands, or off channel habitats).
8. Marquette Chute -plans and specs ready, awaiting construction (RM 51.0 – 47.0 L)
9. Schenimann Chute – plans and specs ready, awaiting construction (RM 62.5 – 57.0 R)

MEDIUM PRIORITY (existing conditions not critical good value for effort):

1. Maple Island (RM 198.5 - 200.8 R)
2. Mosenthein/Gabaret/Chouteau side channel (RM 185.1 – 189.0 L)
3. Atwood Chute (RM 161.5 – 160.8 L)
4. Calico Island Chute (RM 148.2 – 147.1 L)
5. Osborne Chute (RM 146.3 – 144.1 L)
6. Picayune Chute (RM 60.8 – 54.7 L)
7. Liberty Chute (RM 103.0 – 100.0 L)

LOW PRIORITY (area in relatively good shape little or no action required):

1. Moro Chute (RM 122.6 – 120.0 L)
2. Beaver Island/Horse Island and adjacent channels (RM 117.9 R)

FURTHER INVESTIGATION (observe different water conditions, ownership, etc):

1. Arsenal/Cahokia Chute (RM 176 L)
2. Beard/Carroll. J B Chute (RM 167.7 – 166.5 L)
3. Crain's Chute (RM 105.2 – 104.4 R)
4. Billings/Powers Island (RM 31.2 – 35.6 R)
5. Thompson Chute (RM 15.7 R)
6. Sister Chute (RM 14.4 – 11.9 R)
7. Boston Bar Chute (RM 10.2 – 7.6 L)

8. Angelo Chute (RM 5.2 – 1.3 L)
9. Vancil Towhead (RM 69.0 - 67.4 L)
10. Brown's Bar (RM 24.5 – 21.8 L)
11. Duck Island Chute (RM 195.2-193.9R)

MONITOR (initial work completed need to confirm reaction of side channel):

1. Cottonwood Side Channel (RM 79.0 - 77.5 R)
2. Santa Fe Chute (RM 40.4 – 35.0 L)
3. Bumgard Chute/Island (RM 31.0 – 29.0 L)

D. SIDE CHANNEL DISCUSSIONS:

The descriptions below state the existing condition of the side channel and the proposed actions required for rehabilitation. The prescriptions will be confirmed and modified as necessary through the use of hydraulic micro model analysis, pre project monitoring and other appropriate management and design tools.

These prescriptions are rooted in the principles of adaptive management. The goal is not only to learn how to most effectively obtain desirable results in the MMR side channels, but also to develop understanding and techniques that can be exported to other portions of the Mississippi River as well as to other large river systems, such as the Missouri River. Monitoring the side channel will begin prior to implementation of the prescription. Monitoring will continue during and following major actions to assure positive results. During this process it may be necessary to modify or alter the prescription, based on analysis of the monitoring data, to achieve the desired results. As experience is gained, we will be able to target our monitoring efforts, modifying the scope to assure that the proper information required to assess the success of the action is gathered and analyzed. Monitoring is also a valuable tool to assist in the evaluation of different configurations of structures, determining which configuration(s) is the most efficient, and what actions yield the largest immediate benefit, which is critical when the prescription is staged over a period of time. In like manner, we should begin to rely less on modeling and more on accumulated knowledge and analysis based on real world on the ground experience. Monitoring and modeling will never disappear, but rather these efforts should evolve and become efficient complementary management tools able to be directed at a site-specific problem or take on a system wide problem with equal aplomb.

The side channels are listed in order from upstream to down stream.

D.1 MAPLE ISLAND CHUTE RM 200.7-198.0R

This chute is 150-900 feet wide, with an average width of approximately 325 feet. A secondary channel is located immediately upstream of the chute (90 ft average width), a second secondary channel (75 ft average width) is located with the chute. There is a public boat launch ramp at the upper end of the project area. Bathymetry is not available.

A deeply notched off bank-line stone revetment is located at the upper end of the main side channel. Three stone filled dikes (Dike Nos. 198.7 R, 198.2 R and 197.7 R) are located at the downstream end of the chute. There are approximately 650 acres of unleveed floodplain habitat (mostly forested) located within and adjacent to the project area (RM 200.5 -198).

Rehabilitation of the side channel may be accomplished by placement of hard points (wood, rock, or both) to diversify the existing channel within the chute. The addition of woody structure and selective dredging to remove large sand deposits will also be beneficial. Dredge material could be placed at the downstream end of the island to increase sandbar habitat. Secondary channels, as well as wetland areas on the interior of Maple Island should be addressed to provide additional off channel habitats. The advisability of modification of existing stone structures will be closely examined with micro model analysis.

D.2 **DUCK ISLAND CHUTE RM 195.2-193.9R**

Duck Island Chute is part of the recent MDOC Columbia Bottoms acquisition. Management of this chute is an integral part of the entire Columbia Bottoms area. Detailed study and planning for this chute will be accomplished as part of the planning effort for the entire area.

Initial efforts at this chute concentrate on stabilization. A portion of the island bank will be protected with riprap. Hand hard point structures, one above the riprap area and one below, will be placed in the chute. This will keep the chute from expanding during the study and plan formulation period.

D.3 **MOSENTHEIN CHUTE RM 189-185.0L**

This side channel (divided flow) is 1700-3000 feet wide, with an average width of approximately 2175 feet. Bathymetry indicates the average bottom elevation of the chute is approximately +18 feet LWRP, ranging from about -10 to +34 feet LWRP. Moderately good depth diversity exists within the side channel. Substrate is predominately sand. A stone filled dike with spur (Dike No. 189.3 L) is located at the upstream end of the chute, Dike No. 188.6 L extends northward off the upstream tip of the island and there are six stone filled dikes at the upper end of the chute along the left bank. Within and adjacent to the project area, there are approximately 2400 acres of floodplain habitat, half of which is forested, that is unprotected by federal levees. Trees along approximately 5000 feet of the left bank of the chute have been removed for agricultural production.

Rehabilitation of the side channel may be accomplished by reducing the amount of bedload entering the chute and increasing the amount of flow within the chute. Selective placement of hard points (wood, rock, or both) at 'high energy' areas to create scour holes and to enhance existing channels within the chute will increase depth diversity. Additional woody structure and selective dredging within the chute to remove large sand deposits will be beneficial. Material resulting from side channel dredging could be used to extend sidebar habitat at downstream end of the island. Enhancement measures include reforestation of denuded areas along the bank-line with at least a 100 ft wide buffer strip. A portion of the material resulting from side channel dredging could be used to create ridges for hardwood planting. Allow natural hydraulic processes to act, wherever possible, to create swales.

D.4 ARSENAL ISLAND/CAHOKIA CHUTE RM 176.0-173.0L

The Arsenal Island/Cahokia Chute complex occurs between RM 176.0 and 173.0 left descending bank. The area carries flow and is accessible by boat at only the highest river stages and is adjacent to a chronic channel dredging area. Dredge spoil has been placed on the riverside of the island (at or near the main channel border) several times in the recent past. Cahokia chute is extremely shallow and narrow, barely allowing out flow from Cahokia Creek (Harding Ditch), which enters the chute near the mid-point. The complex and adjacent areas become one large sandbar as river stages decrease.

This chute/island complex occurs in a stretch of river that has little to offer in the way of habitat diversity, either aquatic or terrestrial. Tow traffic is common next to this complex and the area is included in the river stretch known as St. Louis Harbor that is currently included in a Corps feasibility study.

Rehabilitation efforts will reflect and take advantage of the recommendations from the St. Louis Harbor study and the East St. Louis Interior Flood Control Project (affects Harding Ditch and watershed). Re-creation of Arsenal Island, as an island with the lower end of the chute as the outlet to the river for Harding Ditch is desirable. A series of notched dikes will aid in the establishment of the chute/island complex. Dredging is a complementary tool that may be used to create an outlet for Cahokia Creek.

D.5 CARROLL ISLAND -JEFFERSON BARRACKS CHUTE RM 168.8-166.5L

Carroll Island Chute, RM 168.8-167.6L, is 20-75 meters wide, available bathymetry indicates bottom elevations in lower one quarter of the chute range from approximately +11 to +16 feet LWRP. Bathymetric data have not been collected in the upstream three quarters of the chute, however aerial photos taken at +3.0 feet St. Louis gage (approximately +3.4 feet LWRP) show a series of 3 isolated pools in the upstream two thirds of this chute, indicating lower bottom elevations do exist. A recent field inspection of the site (+1.7 St. Louis Gage) revealed a series of three large logjams across the chute, each extending bank to bank. Water was present only in the upstream-most pool, just below the bridge. It is unclear if the logjams are associated with the pools. The substrate is predominately mud and sand. The bottom is relatively flat and featureless.

Rehabilitation will be difficult because the chute is located on the inside of a bend way, and is, therefore, in a depositional area. Over time a large amount of sediment has accumulated within the chute, and there may be little hydraulic energy available to reshape the channel. Rehabilitation of this side channel will require flow for a greater percentage of time than is currently available. Greater flow may be accomplished by a combination of dredging, logjam removal (or modification) and construction of a flow enhancing, bed load deflecting structure at the upstream mouth of the chute.

Jefferson Barracks Chute, RM 167.6-166.5, is 75-115 meters wide, bathymetry indicates bottom elevations range from -4 to +12 feet LWRP, averaging approximately +4.5 feet LWRP. The chute is slightly deeper below the mouth of Palmer Creek (RM 167.2). Substrate is mostly sand. Sand waves are present, indicating high-energy conditions may be available to reshape part of this chute during some flow conditions.

Rehabilitation of the side channel can be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) at 'high energy' areas to create scour holes will increase depth diversity. This will also increase habitat diversity. Additional woody structure and selective dredging in the lower half of the chute will also be beneficial.

Approximately 1000 acres of levee free floodplain habitat, about half of which is forested, is located within and adjacent to this side channel complex (RM 169.0-166.0). If these lands were in the public trust, they could be utilized to re-create ridge-swale topography. Material resulting from side channel dredging could be used to create ridges for hardwood planting. Allow natural hydraulic processes act, wherever possible, to create swales.

It is important to note that there is a need for off-channel habitat in this area. The nearest off-channel habitat upstream is at RM 185, while the nearest downstream off-channel habitat is at 161.5.

D.6 <u>ATWOOD CHUTE RM 161.7-160.8L</u>

Atwood Chute is located between RM 161.7 and 160.8, left descending bank. The chute is immediately across the Mississippi and slightly upstream of the mouth of the Meramec River. There is a wing dike just above the opening of the side channel, a dike that crosses the side channel just above the mid-point and a dike across the lower end. There is good depth at the lower end as a result of the plunge pool from the lower dike. The side channel shallows above the lower dike to about 0 LWRP indicating the aquatic habitat would be present at most river stages. The channel deepens toward the upper end in a hole that is about -20 LWRP. The side channel abruptly shallows immediately above the hole to 14 feet St. Louis gage, causing the upper end of the channel to close and prevent flow below moderate river stages. Potamology Section indicated on a recent river reconnaissance trip that the channel contains "good energy" and could be reconfigured using the natural forces of the river and strategically placed regulating structures. Connectivity with the river below the lower plunge pool appears to be poor indicating that it is unlikely that the deep holes in this side channel are available for over wintering fish. The side channel is in an area where dredging has been necessary in the past and spoil has been placed along the riverside of the island.

This side channel is located within a stretch of river where off-channel habitat for fish is extremely sparse. Improve connectivity at the lower end to the main channel at moderate to low river stages by dredging. There may be an opportunity to manage this island and side channel as part of a complex that includes the mouth of the Meramec and Chesley Island on the Missouri side of the river.

D.7 **CALICO ISLAND CHUTE RM 148.2-147.2**

This side channel is 125-250 feet wide, with an average width of approximately 200 feet. Bathymetry indicates the average bottom elevation of the chute is approximately +9 feet LWRP, ranging from about -3 to +21 feet LWRP. Good depth diversity exists within the side channel. Substrate is mostly sand. Recent field inspection revealed that a good amount of woody structure was present within the chute. Wooden pile dikes are located at the upstream and downstream ends of the chute. Approximately 750 acres of floodplain habitat, one third forested, is located within and adjacent to the project area (RM 149 -147). Trees along approximately 1200 feet on the left bank of the chute have been removed for agricultural production.

Conservation and minor rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) at 'high energy' areas to create scour holes will increase depth diversity. Selective dredging within the chute to remove large sand deposits will also be beneficial. Material resulting from dredging operations could be used to extend sandbar habitat at the downstream end of the island for improved fisheries habitat. The existing wooden pile dikes in the chute will be retained. Enhancement measures would include the reforestation of the denuded bank-line with at least a 100 ft wide buffer strip. A portion of the material resulting from side channel dredging could be used to create ridges for hardwood planting. Allow natural hydraulic processes to act, wherever possible, to create swales.

D.8 **OSBORNE CHUTE RM 146.3-144.1**

This side channel is 425-800 feet wide, with an average width of approximately 550 feet. Bathymetry indicates the average bottom elevation of the chute is approximately +6 feet LWRP, ranging from about -32 to +20 feet LWRP. Moderately good depth diversity exists within the side channel, but much of bottom is relatively featureless. Substrate is mostly sand and mud; little woody structure is present within the chute. There are closing structures at the upstream and downstream ends of the chute, and there are two wooden pile dikes and a stone closure dike located within the chute. Deep scour holes (>30 ft deep) have been created below the internal rock closure.

Approximately 950 acres of floodplain habitat, most of which is forested, is located within and adjacent to the project area (RM 147 -144).

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Encouraging the development of a sinusoidal flow pattern in the chute through the use of alternating hard points stone or wood or both) will increase depth diversity. Selective dredging to remove large sand deposits, especially at upper and lower ends of the chute will also be beneficial. Pile dikes in the chute will be retained. Material resulting from side channel dredging could be used to extend sandbar habitat at downstream end of island. Allow natural hydraulic processes act, wherever possible, to create swales. Secondary channels immediately upstream of the chute may be enhanced to provide additional off channel areas and/or high quality wetlands.

D.9 SALT LAKE CHUTE RM 139.5-136.0

This side channel is 350 to 1000 feet wide, with an average width of approximately 650 feet. Bathymetry indicates the average bottom elevation of the chute is approximately +12 feet LWRP, ranging from about -35 to +24 feet LWRP. Fair to poor depth diversity exists within the side channel; most of bottom is relatively featureless. Substrate is mostly sand and mud; little woody structure is present within the chute. There are closing structures at the upstream and downstream ends of the chute, and there are two wooden pile dikes and three stone closure dikes located within the chute. A deep scour hole (>30 ft deep LWRP) has been created below one of the internal rock closure structure (Dike No. 138.1 L). Approximately 2500 acres of floodplain habitat, most of which is forested, is located within and adjacent to the project area (RM 142 -136). Maeystown Creek enters the chute at its upper end (RM 139.5) through Beagle Island side channel. Old Maeystown creek also enters the chute between Dike Nos. 138.1 and 137.0. The bottom of this section of the chute is considerably higher in elevation than in the remainder of the chute. Treatment of the Maeystown Creek watershed to reduce the amount of sediment entering the chute may be an important tool for enhancement of this chute.

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Encouraging the development of an asymmetric sinusoidal flow pattern in the chute through the use of alternating hard points (stone or wood or both), or by modifying existing rock closing structures will increase depth diversity within the chute. Selective dredging to remove large sand deposits will be beneficial. Pile dikes in the chute will be retained. Material resulting from side channel dredging could be used to extend sandbar habitat at downstream end of island. Allow natural hydraulic processes act, where possible, to create swales. The secondary channels immediately upstream of the chute could be enhanced to provide additional off channel areas and/or high quality wetlands.

D.10 **FORT CHARTRES ISLAND AND CHUTE RM 134.4 - 132.2L**

Fort Chartres Island and side channel are located between RM 134.4 and 132.2 left descending bank. The side channel is relatively shallow with a few deep holes. Much of the channel would be dry at a LWRP reading of +10. There are two holes, both associated with rock dikes, one has depth equivalent to 0 LWRP, while the other has depth to about -10. The area is unique because of public ownership (Illinois Historic Preservation Agency owns approximately half of the island and side channel). A single private individual owns the balance. Much of the private portion of the island is farmed, while the remainder is bottomland forest, mostly soft maple and cottonwood.

The island/side channel complex is the subject of a micro model study by the District River Engineering Laboratory to determine the location and type of structural measures or dredging that might be helpful in an aquatic habitat improvement project. Dredging will be required to obtain a reconnection of the side channel to the main channel during moderate to low river stages. The side channel is being modeled in conjunction with Salt Lake Towhead another side channel just upstream. These two side channels along with Establishment Island/Side Channel just downstream of Fort Chartres and Kidd Lake Marsh, Maeystown Creek and Fults Creek, which are all inside the levee, may offer the opportunity for management of this reach of river and associated habitat as a complex. Recommendations for improvements will be made following the completion of the micro model study.

D.11 **ESTABLISHMENT CHUTE RM 132.5-130.0R**

This side channel is 150-700 feet wide, with an average width of approximately 320 feet. Bathymetry indicates the average bottom elevation of the chute is approximately +4 feet LWRP, ranging from about -35 to +20 feet LWRP. Fair to good depth diversity exists within the side channel. Substrate is predominately mud and sand, little woody structure is present within the chute. There is a rock closing structure at the upstream end of the chute and there are three wooden pile dikes and three stone closure dikes located within the chute. A pair of deep scour holes (>30 ft deep LWRP) have been created below the upstream rock closure and one of the internal rock closure structures (Dike No. 131.0 R). Approximately 1500 acres of non-leveed floodplain habitat, most of which is forested, is located within and adjacent to the project area (RM 134 -129).

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at 'high energy' areas to create scour holes will increase depth diversity. Selective dredging within the chute to remove large sediment deposits will be beneficial. Pile dikes in the chute will be retained and where possible improved. Material resulting from side channel dredging could be used to extend sandbar habitat at downstream end of island. Enhancement of the side channel may include reforestation of the riparian corridor. A portion of the material resulting from the side channel dredging could be used to create ridges for tree planting. Allow natural hydraulic processes act, where possible, to create swales. A secondary channel adjacent to the chute may be enhanced to provide additional off channel areas and/or high quality wetlands.

D.12 **MORO CHUTE AND ISLAND RM 122.5 - 120.0L**

Moro Chute and island are located on the inside of St. Genevieve Bend between RM 122.5 and 120.0. The upper end of the chute has two connections with the river. The largest is relatively shallow, about + 10 LWRP, while the smaller is much deeper, about -5 LWRP. The connection of the smaller chute is somewhat unique and the reason this chute retains flow at most river stages. The connection is immediately below a wing dike that has created a deep channel behind (plunge pool) that coincides with the opening of the chute. The chute is narrow and reconnects with the main part of the side channel at a confluence with the larger upriver connection and a deep hole that has formed as a result of high flows through the larger channel at high river stages. The deep hole is approximately -20 LWRP and contains a large amount of woody structure. The larger channel connection has a mixture of sand, gravel and cobble substrate and is especially diverse near the confluence with the smaller upriver connection. Below the deep hole the channel shallows to about -5 LWRP, until near the downstream end where there is a closing structure followed by a wing dike, before reconnection of the side channel with the river. The island is bottomland forest, mostly soft maple and cottonwood.

The habitat at Moro Chute is in relatively good shape. Minor rehabilitation measures that would improve the accessibility to the aquatic environment include a notch in the lower closing structure to improve fish access and a notch in the wing dike below, coupled with dredging to deepen the connection with the main channel at all but the lowest river stages. This appears to be an important over wintering area for fish that will be investigated further.

D.13 **BEAVER/HORSE ISLANDS AND ADJACENT CHANNELS RM 117.9R**

The width of this chute ranges from about 50-225 feet, with an average width of approximately 225 feet. A secondary channel is located immediately upstream of the chute (90 ft average width), a second secondary channel (75 ft average width) is located with the chute. Bathymetric data is not yet available. A secondary channel or a series of wetlands (depending on water level) extending up to RM 119.2 enters the chute near its upper end. There are two other secondary channels (about 200 ft wide) along the riverside of Beaver Island. Approximately 2000 acres of unprotected floodplain habitat, mostly agricultural land, is located within and adjacent to this side channel complex (RM 119.0-115.0).

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. The existing channels lack diversity and measures to increase depth diversity would be beneficial to aquatic resources. Additional woody structure and selective dredging within the chute to remove some sand deposits will be beneficial. Material resulting from the side channel dredging could be used to extend sandbar habitat at the downstream end of the island. Enhancements may include reforestation of the bank line with a buffer strip at least 100 ft. wide. Secondary channels, as well as wetland areas on the interior of Maple Island could be enhanced to provide additional off channel habitats. A portion of the material resulting from side channel dredging could be used to create ridges for hardwood planting. Allow natural hydraulic processes act, wherever possible, to create swales.

D.14 **CRAIN'S CHUTE RM 105.7-104.4**

This chute has an average width of approximately 75 feet, ranging from 25 - 100 feet. A smaller side channel connects with the chute at the upstream end. Bathymetry indicates the bottom elevations of these chutes range from about 0 to +10 feet LWRP. Some depth diversity is present within the side channels. The substrate is predominately mud and sand. Two wooden pile dikes (Dike Nos. 105.0 and 104.7 R) are located within the chute. Approximately 600 acres of non-leveed floodplain habitat, most of which is forested, is located within and adjacent to the project area (RM 106 -103). A series of wetlands (scour holes or borrow pits) are located immediately riverward of the levee within a 400 ft wide strip of timbered wetlands.

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at 'high energy' areas to create scour holes will increase depth diversity. Selective dredging to remove large sediment deposits will be beneficial. Pile dikes in the chute will be retained and where possible improved

The existence of these side channels is the result of river hydrodynamic forces interacting with river training structures (i.e. wooden pile and stone filled dikes). This phenomenon should be thoroughly investigated to determine the morphologic and hydrodynamic characteristics necessary to create islands and side channels. Results from this investigation could then be applied to river reaches with the appropriate characters to develop side channel complexes elsewhere within the system, especially within those reaches in which side channel habitat is limited.

D.15 **LIBERTY CHUTE RM 103.1-100.1**

The side channel behind Rockwood Island, Liberty Chute, is 375-1000 feet wide, with an average width of approximately 550 feet. The side channel behind Liberty Island, just downstream of Liberty Chute, is 200-400 feet wide, with an average width of 250 feet. Bathymetry in both chutes indicates the average bottom elevation is approximately +0 feet LWRP, ranging from about -30 to +10 feet LWRP. Good depth diversity exists within these side channels. Substrate is predominately sand and mud; some woody structure is present within the chute. There is a rock dike (not a complete closure) at the upstream end of the chute, a rock closing structure at the lower end, and three wooden pile dikes located within the side channels (1 behind Rockwood Island and 2 behind Liberty Island. A deep scour hole (>30 ft deep LWRP) has been created below the internal rock closure (Dike No. 101.1 L). Moderately deep holes (>20 deep LWRP) have been created below two of the pile dikes. Approximately 2500 acres of non-leveed floodplain habitat, about half of which is forested, is located within and adjacent to the project area (RM 103-99).

Rehabilitation of the side channels may be accomplished by reducing the amount of bed load entering the chutes and increasing the amount of flow. Encouraging the development of a sinusoidal flow pattern through the chute by using alternating hard points (stone or wood or both), or by modifying existing rock closing structures will increase depth diversity. Selective dredging within the chutes to remove large sediment deposits will be beneficial. Pile dikes in the chutes will be retained and where possible improved. Material resulting from side channel dredging could be used to extend sandbar habitat at downstream end of the islands.

D.16 JONES CHUTE RM 98.4-95.0 R

The project area consists of two side channels. The side channel behind Liberty Bar is 50-400 feet wide, with an average width of approximately 120 feet. Jones Chute is 225-600 feet wide, with an average width of approximately 350 feet. Bathymetry in both chutes indicates the average bottom elevation in Liberty Bar Chute is approximately +9 feet LWRP, ranging from about +5 to +20 feet LWRP. The average bottom elevation in Jones Chute is approximately +4 feet LWRP, ranging from about -20 to +18 feet LWRP. Fair depth diversity exists within these side channels. Substrate is predominately sand and mud; little woody structure is present within the chute. There is a rock dike (not a complete closure) at the upstream end of the chute and a rock closing structure in the mid-portion of Jones Chute. Deep scour holes (>30 ft deep LWRP) have been created below these rock structures. Two moderately deep holes (>20 deep LWRP) have been created in upper Jones Chute by Dike No. 97.0 R. Approximately 2000 acres of non-leveed floodplain habitat, less than half of which is forested, is located within and adjacent to the project area (RM 99 -94).

Rehabilitation of the side channels may be accomplished by reducing the amount of bed load entering the chutes and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at 'high energy' areas to create scour holes will increase depth diversity. Selective dredging to remove large sediment deposits will be beneficial. Material resulting from side channel dredging could be used to extend sandbar habitat at downstream end of island.

D.17 RIVER MILE 93.8 THROUGH 73.8

This reach of the MMR contains no side channels or off channel habitat. Three to four side channels will be considered for construction in this area. This could be accomplished by strategically locating a dike field (or a series of chevron dikes) off bank, near the main channel boarder. The dike field would be allowed to naturally fill with material or, alternately, dredge material would be placed into the field to initiate the island creation process. The elevation of the island in relation to the hydrograph will determine if woody vegetation will successfully colonize the island. Some of the islands could be raised to sufficient elevation to allow growth of woody vegetation while others may be held at the bare sand stage. Other options for side channel or off channel habitat will also be explored in this area.

D.18 COTTONWOOD SIDE CHANNEL RM 79.0-77.5 R

Cottonwood side channel is located along the right descending bank between river miles 79.0 – 77.5. Gravel deposits, both along the main navigation channel and along the side channel bank, characterize the side channel. The substrate of the side channel is cobble/gravel/bedrock and includes moderate amounts of sand. There are no closing structures upstream, downstream, or within the side channel. Shallow gravel/sand bars extend from the island to the mainland upstream and downstream of the side channel. At low river stages these become emergent and limit access by boat.

Cobble/gravel substrate types are valuable and infrequent in this reach of the river. This side channel and island contains one of the larger areas of this valuable substrate in the lower 80 miles of the Mississippi River. This side channel is one of only two in the lower 80 miles that has no artificial obstructions above, below, or within.

Continue conservation efforts and increase monitoring. No rehabilitation or enhancement measures proposed at this time.

D.19 CRAWFORD CHUTE RM 73.9-71.5L

Crawford Towhead side channel is located along the left descending bank at approximately river miles 74 – 71.5. The side channel currently accepts water at high river stages only. The side channel is dissected by closing structures and has a wing dike upstream of the inlet and upstream of the outlet. This side channel is part of a larger complex of off-channel remnant sloughs and borrow areas. The entire complex, including the side channel proper, extends from the Big Muddy River in Illinois, downstream, to a point across the river from Trail of Tears State Park in Missouri (a distance of about 12 river miles). The re-establishment of flow throughout the side channel at average to lower river stages could provide many wildlife benefits. It will provide valuable off channel habitat for refugia and reproduction and may be one of the more important areas for primary productivity in the lower 80 miles of the river. An increase in depth diversity and wetted edge within the side channel, along the island on the main channel border, and in the floodplain (riverside of levee) is desirable.

Rehabilitation of this side channel may be accomplished by establishing flow at average to low river stages. Notch dikes within the side channel and along the island in the channel border area to increase connectivity, encourage island creation, and redistribute substrate to encourage exposure of cobble/gravel material beneath the sand.

D.20 VANCIL TOWHEAD RM 69.0-67.4 L

Vancil Towhead side channel is located along the left descending bank at approximate river miles 69.0 – 67.4. The side channel currently accepts water only at high river stages. This side channel is part of the larger complex of side channels, off-channel remnant sloughs, and borrow areas mentioned earlier in the discussion of Crawford Towhead.

Rehabilitation of the channels may be accomplished by reestablishing flow at average to low river stages. Notching, installation of hard points and dredging all may be required to improve flow at lower river stages. Enhancement measures consist of incorporating this area into a larger habitat enhancement effort, which would include side channels, channel border area, and floodplain (area to levee).

D.21 PICAYUNE CHUTE RM 60.8-54.7L

Picayune side channel is located along the left descending bank between river miles 61 – 56.5. The side channel has a wing dike above the inlet and a notched closing structure across the outlet. There are three remnant wooden pile dikes, a low water road spanning the side channel connecting the Illinois bank to the island, a rock closing structure, and a rock spur dike. The inlet becomes isolated from the main river by a large sand plug (an extension of the island) at river stages below +7 LWRP. The side channel contains deep water throughout its length with moderately good depth diversity, a few small sandbars, and a small amount of woody structure. The low water road and stone closing structure begin to dissect the side channel at river stages of +17 LWRP and below.

Rehabilitation of this side channel includes notching of the upper closing structure to improve flow at lower river stages while preventing bed load from entering the side channel. Additional woody structure will be beneficial.

D.22 SCHENIMANN CHUTE RM 59.0-57.0R

Schenimann Chute side channel is located along the right descending bank between river miles 62.5 – 56.5. The side channel is unique in that it has an interior tributary on the upper end, which drains hundreds of acres of wooded upland. The tributary (Bainbridge Creek), is a wet weather stream and may be inundated by the river under high stages. The side channel is dissected by closing structures, which create four isolated chambers. The first chamber is the longest and is characterized by the confluence of Bainbridge Creek, two old pile dike structures, and a connection to the main river at stages as low as 8 feet (Cape Girardeau gage). The second chamber is slightly shorter and very sandy, with the exception of the plunge pool below the structure dividing chambers 1 and 2 (some gravel), and above the structure dividing chambers 2 from 3 (silty). The second chamber also contains an inlet from the main river that enters about mid-way and a pile dike just below this inlet. The third chamber is the shortest of the four, uniform in depth , and has no internal structures or unique features. The fourth and final chamber becomes disconnected from the main river at stages below +6 LWRP. This chamber is divided mid-way by a pile dike and becomes dry below the dike during low river stages. A permanent pool exists above the dike. The substrate is mostly sand.

The lack of connectivity to the main river and the shallow to absent water conditions create harsh environments for its inhabitants. Rehabilitation of the side channel can be accomplished by re-establishing connectivity between the side channel chambers and the main river, as well as between the individual chambers themselves. Depth and substrate diversity and woody structure are needed.

D.23 **MARQUETTE CHUTE RM 51.0-47.0L**

Marquette side channel is located along the left descending bank between river miles 51.0 and 47. The side channel has a wing dike above the inlet, a notched closing structure across the inlet, and a wing dike that extends nearly 2/3 of the way across the outlet. The notch in the closing structure across the inlet is unique in that it apparently reaches all the way to the river bed thereby allowing flow at most river stages. Three remnant wooden pile dikes exist within the side channel. A wing dike exists approximately mid-way through the side channel. A notched closing structure disconnects the lower 1/3 of the side channel. Water passes through this notch when the river stage is greater than +11 LWRP. The side channel contains vast amounts of sand both as aquatic substrate and as island extensions, which do not become inundated at flood stage (+27 LWRP). The upper 1/3 of the side channel becomes dry at river stages below +5 LWRP. At these lower stages it is possible to walk from the Illinois mainland, across the side channel and island, to the banks of the Mississippi. The middle portion of the side channel maintains moderately deep water at low river stages. The plunge pool below the internal closing structure remains deep at low river stages. The side channel becomes shallow and sandy downstream of the plunge pool. During low flows this area may become dry, disconnecting the side channel from the main channel. Because of the closing structure at the inlet and the emergent sand at the outlet, the side channel becomes disconnected from the main river at average to low river stages. The side channel is on the inside of a sharp bend, more accurately described as a split flow region. Without training structures, the side channel would capture much of the river's flow and the navigation channel would be compromised.

Rehabilitation of the side channel can be accomplished by redirecting more flow into the side channel without introducing additional sediment or compromising the navigation channel. Increase depth diversity (currently it's deep or it's shallow but not a lot in between) and substrate diversity and add woody structure. Connect the plunge pool below the internal closing structure to the main river channel to allow access to this deep-water over wintering habitat.

D.24 SANTA FE CHUTE RM 40.4-35.0L

Santa Fe Chute side channel is located on the left descending bank at approximate river miles 39.5 – 34.4. There is a wing dike immediately upstream of the inlet, a closing structure across the inlet, and a wing dike across 2/3 of the outlet of the side channel. A remnant secondary channel enters Santa Fe Chute at the upper end, but water enters this chute only during high river stages. Cobble/gravel substrate is present at the upper end of the chute, but the predominant substrate type is sand. The upper 1/3 of the side channel is relatively deep, while the middle of the side channel is very shallow and sand, silt, and some gravel become exposed during average to low river stages. The lower portion of the side channel is also shallow. A deep cut was dredged after the 1993 flood near the outlet of the chute. As of this writing, the cut has mostly filled in. A sand bar spans the entire width of the side channel just above the dredge cut. This bar connects the Illinois mainland to Santa Fe Island (the mainland and island are also connected just below the inlet closing structure by emergent sand). In recent years wing dikes were added throughout the upper 2/3 of the side channel in an attempt to encourage thalweg sinuosity and depth diversity. Nine dikes were constructed in an alternating configuration. They were built to half bank height in two different phases spanning three years of construction. The closing structure across the inlet of the side channel begins to emerge at moderately high river stages. At +17LWRP, the closing structure disconnects the side channel from the main channel. The dikes constructed within the side channel appear to be creating scour holes off their tips, however much of the side channel remains very shallow. The dredge cut provided needed deepwater habitat, but proved to be much shorter lived than originally expected. Little to no water remains in over half this side channel during average to low river stages. While there is some degree of substrate diversity, the lack of depth diversity and woody structure remain a concern.

Rehabilitation measures include completion of the dike construction to original engineered specifications. Re-establish connectivity between the side channel and the main river channel at average to low river stages. Through the use of hard points or other suitable structures, increase depth diversity and create deep-water habitat accessible to fish for over wintering.

D.25 BILLINGS ISLAND, POWERS ISLAND RM 35.6-31.2R

Billings Island side channel complex is located on the right descending bank at approximate river mile 34.3 – 32.8. It is composed of two distinct side channels, one immediately upstream of the other, both of which are disconnected from the main river channel by a large sand bar. The upstream side channel has a dike immediately upstream of the inlet and one immediately downstream of the outlet. The second side channel has a dike immediately upstream of the inlet (same dike that is located at the outlet of the first side channel) and a dike immediately downstream of the outlet. No structures exist through the interior of either side channel. Substrate composition is primarily silt/sand. Little woody structure is present in the upstream side channel. Some woody material may be found in the downstream side channel. Both side channels are characterized by poor depth diversity and little to no diversity in structure, substrate, or bank type. During average to lower river stages, a sand bar is exposed at the inlet of the first side channel disconnecting it from the river. A high elevation sand shelf is present in the channel border area between the two side channels. This shelf limits access at average to moderately high river stages. A high sand shelf is also present downstream of the outlet of the second side channel. The lower channel appears to have a higher bed elevation than the upper side channel and is not accessible by boat except during high water.

Rehabilitation includes efforts to increase diversity of depth, structure, and substrate. Encourage flow into side channel at average to lower river stages. Through notched dikes or other appropriate measures, create a secondary channel which would disconnect large channel border sand island from side channel island creating least tern nesting habitat (isolating sand bar to reduce predation).

D.26 **BUMGARD CHUTE AND ISLAND RM 31.0-29.0L**

Bumgard side channel is located on the left descending bank at approximately river mile 31 – 29.7. It is one of only two side channels in the lower 80 miles of the river that is not disconnected from the river at its inlet by a closing structure. There is a dike immediately upstream of the inlet and two hard points in the interior of the side channel. Substrate composition of the side channel and the island is predominately cobble/gravel/sand. The hard points create small scours off their tips, however, the remainder of the side channel is shallow and the lower end becomes dry at average to lower river stages. Gravel extends below the dike above the inlet to the island, prohibiting access to the side channel at lower river elevations. Water velocity in this side channel can be high during average to high flows (recorded in excess of 1.4 m/s). Gravel accumulations upstream and sand downstream disconnects this side channel from the main channel during low river stages. Woody structure is scarce and depth diversity is moderately poor.

Rehabilitation of the side channel can be accomplished by encouraging depth diversity through the installation of hard points or notching of existing dike structures. Dredging to reconnect the lower end of the side channel to the main channel at lower river stages and addition of woody material would be beneficial. Material resulting from this dredging operation could be used to extend sandbar habitat at the downstream end of the island.

D.27 **BUFFALO ISLAND RM 26.3-24.5 R**

This chute has an average width of approximately 320 feet, ranging from 240 to 600 feet. There is a small secondary channel traversing the upstream tip of the island.

Bathymetry indicates the average bottom elevation of the chute is approximately +2 feet LWRP and ranges from about -25 to +20 feet LWRP. There is fair depth diversity with the side channel. Substrate is sand and mud. There is a rock dike (Dike No. 26.1R) located at the upstream end of the chute and a rock closing structure (Dike No. 24.8R) at the lower end. A pair of deep scour holes (>30ft. deep) has been created below the internal rock closure. Approximately 1500 acres of levee free floodplain habitat, most of which is agricultural, is located within and adjacent to the project area (RM 27 to 24).

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at "high energy" areas to create scour holes will increase depth diversity within the chute. Additional woody structure and selective dredging to remove large sediment deposits will also be beneficial. The small secondary channel could be enhanced to provide additional off channel areas and/or high quality wetlands.

D.28 **BROWN'S BAR RM 24.5-21.8L**

This side channel (divided flow) is 400-1200 feet wide, with an average width of approximately 810 feet. Bathymetry indicates the average bottom elevation of the primary (left) channel of the chute is approximately +1 feet LWRP, ranging from about -30 to +21 feet LWRP. The right channel has an average bottom elevation of approximately +20 feet LWRP, ranging from about +14 to +25 feet LWRP. A small (50 ft wide) secondary channel is located just upstream of the chute and there are two other secondary channels located within the chute. Moderately good depth diversity exists within the side channel ranging from deep scour holes to sand bar habitat. Substrate is mostly sand. A stone filled dike with spur (Dike No. 24.4 L) is located at the upstream end of the chute, Dike No.21.9 L is located at the downstream end of the chute. There are two stone closures located within the chute (Dike Nos. 23.8 and 22.3 L), which roughly divides the chute in thirds. A deep (>-30 ft LWRP) scour hole is located below the lower closure. There is a wooden pile dike located in the lower 'compartment'. The land adjacent to the chute is unprotected floodplain, most of which is agricultural. The forested area is located within and adjacent to the project area. Trees along approximately 1600 feet of the left bank have been lost or removed.

Rehabilitation of the side channels may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Use of hard points or other suitable structures to increase depth diversity will be beneficial to aquatic resources. Woody structure and selective dredging to remove some sand deposits would also be beneficial. Material resulting from side channel dredging could be used to extend sandbar habitat on downstream end of islands. Enhancement of this area would include reforestation of denuded areas along the bank-line with at least a 100 ft wide buffer strip. A portion of the material resulting from side channel dredging could be used to create ridges for hardwood planting. Allow natural hydraulic processes act, wherever possible, to create swales.

D.29 **THOMPSON CHUTE RM 15.7R**

This chute has been cut off from the river by the landowners and is not available for habitat enhancement.

D.30 **SISTER CHUTE RM 14.4-11.9**

The chute lies behind two islands: Island Nos.28 and 29. The chute has an average width of approximately 250 feet, ranging from about 150 to 625 feet. There is a secondary channel located between the islands. Bathymetry indicated the average bottom elevation of the chute is approximate +6 LWRP and ranges from about -17 to +20 feet LWRP. There is fair depth diversity within the channel. Substrate is sand and mud. There is a rock dike with a spur dike (Dike No. 14.5 R) located just above the upstream end of the chute and two rock closing structures and a wooden pile dike (Dike No. 13.4R) within the chute. The land adjacent to the chute is levee free floodplain, most of which is agricultural. Some forested area is located within and adjacent to the project area, mainly associated with the islands.

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at "high energy" areas to create scour holes will increase depth diversity. Additional woody structure and selective dredging to remove large sediment deposits will be beneficial. Material resulting from the dredging operations could be used to extend sandbar habitat on downstream end of the island. The secondary channel could be enhanced to provide additional off channel areas and/or high quality wetlands.

D.31 **BOSTON BAR CHUTE RM 10.2-7.6 L**

The chute has an average width of approximately 250 feet, ranging from about 125 to 550 feet. There are two secondary channels located just upstream of the island. Bathymetry is not available, but field observations indicate that the average bottom elevation is about +5 feet LWRP, ranging from about -5 to +10 LWRP. Substrate is sand and mud. There is a rock dike (Dike No. 10.1L) located at the upstream end of the chute and a rock closing structure (Dike No. 7.9L) near the lower end of the chute. Approximately 2000 acres of levee free floodplain habitat, most of which is agricultural, is located within and adjacent to the project area.

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at "high energy" areas to create scour holes will increase depth diversity. Additional woody structure and selective dredging to remove large sediment deposits will also be beneficial. Material resulting from dredging may be used to extend sandbar habitat on the downstream end of the island. The secondary channels could be enhanced to provide additional off channel areas and/or high quality wetlands.

D.32 <u>ANGELO CHUTE RM 5.2-1.3 L</u>

The chute has an average width of approximately 715 feet, ranging from about 450 - 1300 feet. There is a secondary channel located just downstream of the upstream end of the chute. Bathymetry indicates the average bottom elevation of the chute is approximately +2 feet LWRP and ranges from about -44 to +17 feet LWRP. Substrate is sand and mud. There is a rock dike with a spur dike closure (Dike No. 5.2 L) located at the upstream end of the chute and a rock closing structure (Dike No. 4.2 R) with a wooden pile dike core (much of which is currently exposed) within the chute. Approximately 2500 acres of levee free floodplain habitat, most of which is agricultural, is located within and adjacent to the project area (RM 5 - 1).

Rehabilitation of the side channel may be accomplished by reducing the amount of bed load entering the chute and increasing the amount of flow. Selective placement of hard points (wood, rock, or both) or modification of existing structures at 'high energy' areas to create scour holes would increase depth diversity. Additional woody structure and selective dredging to remove large sediment deposits will also be beneficial. The pile dike within the chute will be retained and improved, if possible.

APPENDIX A
MAPS

Copies of the maps were not included in the A&M report but are available upon request.

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APPENDIX B
COST ESTIMATES

COST ESTIMATES

Estimated Average Costs Per Side Channel*

Pre-Monitor	30.0
Real Estate Costs	50.0
Engineer Design, Plans and Specifications	200.0
Construction Costs	1000.0
Dredging Costs	200.0
Monitor During Construction	30.0
Post Monitor	30.0
Total Estimated Cost Per Side Channel	1540.0

Estimated Average Annual Costs*

Two Side Channels	3080.0
Base Monitoring (in addition to ongoing LTRM effort)	200.0
Annual Evaluation and Progress Report	25.0
PM Costs (admin, coordination, procurement, etc.)	165.0
Total Annul Estimated Cost	3470.0

Total Estimated Cost of the Side Channel Plan*

Estimated Average Annual Cost	3470.0
Completion Estimated in 15 Years (2 side channels per year)	x 15
Total Estimated Cost	52050.0**

* Costs in thousands (000) of dollars.

** Costs do not include enhancement activities on upland sites.

The 15-year target for completion is dependant upon availability of adequate funding.

APPENDIX C
MICRO MODELING

MICRO MODELING

Micro Modeling is a newly developed, cost effective hydraulic river engineering technology used by engineers, scientists, environmentalists, teachers, landowners and navigation industry representatives for the purpose of resolving some of the major issues that surround our nation's rivers and streams. Micro Modeling is extremely small-scale physical sediment transport modeling of a river or stream. River Engineers use these models to replicate the hydraulic mechanics of flowing water and sediment in a river on an area the size of a normal tabletop.

The theory behind sediment transport modeling on a micro scale is simple. It is a fact that small streams behave very similar to large rivers. A river or stream, no matter how large or small, is a body of flowing water and sediment. The mechanics of moving water and sediment remain similar, whether it's a small creek, or the Mississippi River. Therefore, a small stream can actually be described as a model of a larger river.

Successful Micro Modeling mission accomplishment has alleviated the financial burden of more expensive mediums of modeling used in the past, and many taxpayer dollars have been saved. Traditional river modeling used by the Corps in the past was performed on a large scale at the Waterways Experiment Station in Vicksburg, Mississippi. These models, about the size of a football field, provided excellent results but were very costly to build and operate and would take years to finalize a study.

Due to the very small scale Micro Models are studied at, they are relatively inexpensive to build and operate. Furthermore, results from the models can be obtained in just a few short months. Micro Models are composed of four innovative design components: the model insert, the table top sized hydraulic flume, the automated operating system which controls the flow of water and sediment, and the data collection system. Each component serves dependently upon the other to function as one unit.

The model inserts, which define the river, stream, or lake under study, are constructed of modern day plastic composites including acrylic, polystyrene, urea, and laminate. The inserts are built to extremely high tolerances of scales so that accurate and reproducible measurements during model testing can be made. The inserts are placed within the tabletop-sized hydraulic flume and filled with plastic sediment sand-like particles.

The hydraulic flume is made of waterproof marine grade plywood. The flume is built to withstand the added weight of water and sediment, as well as people leaning on the model while participating in hands-on experiments. The flume houses a water and sediment reservoir, a pump, a magnetic flow meter and an industrial process control valve. The top of the flume is adjustable in any direction by the use of rotational jacks located within the cavity of the flume.

The operating system, which consists of customized computer hardware and software, was developed to control the simulation of water and sediment through the model. The system is designed to input water and sediment particles through the model automatically and in equilibrium. This means that the rise and fall of the water level and the sediment load is the same at both the entrance and exit of the model reach at all times. The operating system employs graphic software and instrumentation, which electronically controls a process control valve and monitors a magnetic flow meter. The system enables the operator to simulate a rise and fall of water levels similar to an actual river or stream.

The data collection system employs a state of the art three-dimensional laser scanner that is used to collect the contours of the changing bed sediment in the model. The laser is an extremely accurate measuring device, which collects hundreds of thousands of data points over the length of the model. The data points are used to create computer generated topographic survey maps. Engineers compare these model survey maps to topographic surveys of the actual riverbed being studied.

One of the greatest advantages provided by a Micro Model is the ability to convey highly complex hydraulic concepts to non-technical, non-engineering clients and partners. Engineers use the dynamic hydraulics of the model to demonstrate these concepts and allow the engineer, the biologist, the farmer, the towboat pilot, the landowner, etc., to communicate with each other in an effective and efficient manner. Because of this benefit, partners from all agencies and groups can remain intimately involved from the beginning of a project to its conclusion. Everyone has the opportunity to test their ideas in the model with the ability to touch and observe the effects they create. Ideas that produce positive effects are further tested scientifically by experienced river engineers. The model results are presented to all the partners with a formulated group solution as the ultimate goal.

Micro Modeling has many satisfied customers from a wide variety of interest groups. Many of its customers consist of environmental resource agencies, environmental interest groups, navigation industry representatives, landowners, government and private engineers, biologists, scientists etc. These customers have had the opportunity to physically participate in Micro Model studies by personally viewing and being able to manipulate the model. This has allowed the customer a greater understanding of river mechanics and therefore created a median by which government engineers and their previously adversarial groups could build a bridge to understand each other. Creating a harmonious relationship between the customer and producer was the first step in developing a product that the customers and users can be satisfied with. Micro Modeling technology has enabled the lines of communication to open and has formed relationships that were previously nonexistent.

Since 1994, a variety of Micro Model studies have been conducted and completed at the Applied River Engineering Center in St. Louis, Missouri. The time and cost savings of using a Micro Model is even more significant over the length of a few years. Using Micro Modeling technology, 16 studies have been completed at a cost of around $1 million. If these studies had been conducted using the traditional large models, the costs would have exceeded $20 million, and most of the studies would not yet be complete.

Micro Modeling has been used to study possible environmental enhancement measures to three side channels on the Middle Mississippi River and one side channel on the Lower Mississippi River. Designs conceived from the Micro Models have been built in two of the side channels and construction is scheduled for the remaining two side channels. Micro Model methodology has also been used to study many other environmental projects on the Upper Mississippi River, the Missouri River, and the White River in Arkansas.

APPENDIX D
MIDDLE MISSISSIPPI RIVER HISTORICAL INFORMATION

A Natural History of the Middle Mississippi River
by

Susan E. Corvick and Robert A. Hrabik

In 1993, the Upper Mississippi River Conservation Committee (UMRCC) issued a call for action report, "Facing the Threat: An Ecosystem Management Strategy for the Upper Mississippi River." The report identified environmental problems in the Upper Mississippi River (UMR) and challenged the President, Congress, federal agencies, and states to develop a "scientifically sound ecosystem management strategy for the UMR" by 2000 and implement the strategy over the ensuing fifty years.

Given the information-oriented mission of the Long Term Resource Monitoring Program, staff at the Open River Field Station took an active role in developing a plan for the unimpounded open river reach of the UMR. This reach, known as the Middle Mississippi River (MMR), is that segment between the confluence's of the Missouri and Ohio Rivers. The committee formed in 1994 to develop the ecosystem management strategy for the MMR was named the Middle Mississippi River Ecosystem Management Work Group (work Group).

During the first meeting of the work group, it became apparent that virtually no background information had been assembled on the natural environment of the MMR. Some members believed that without this information, a comprehensive ecosystem management strategy could not be developed. Work group members began gathering information, but soon realized the time needed to adequately address this task was greater than anyone could justify. The work group then approached the UMRCC to cosponsor an investigation into the natural history of the MMR, which they agreed to, and the project began in 1997. Since then, we have been gathering accounts describing the MMR environment from the point of European discovery, roughly 1600 AD, to the present. We separated our research into three phases; two dedicated to gathering material and one to writing the history.

Our work began by studying Carl J. Ekberg's translation of Nicolas de Finiels' 1803 manuscript, *An Account of Upper Louisiana*. Finiels, a French engineer, was employed by the Spanish government at various times from 1797 to 1818 to develop and oversee a number of projects throughout the Louisiana Territory. Finiels made the observations that would later appear in his *Account* as he traveled up the Mississippi River to St. Louis in early 1797. He also produced a detailed map of the MMR valley, drawn during 1797 – 1798. Both are generally considered to be excellent sources of late 18th-century physical information for our area of investigation and provide us with the necessary background to design our research plan.

Finiels' manuscript and map proved to be very helpful, as did Ekberg's and William Foley's editing of *An Account of Upper Louisiana*. The book's accompanying notes and bibliography familiarized us with standard texts used to conduct preliminary historical research into our subject. As we consulted these sources, we became familiar with scholars who conducted extensive research upon the same or related topics. We collected a large amount of information from these sources, as well as from numerous manuscript collections, journal and magazine articles, government documents, newspapers, maps, drawings, photographs, and oral interviews.

Particularly informative were two series edited by Rueben Gold Thwaites, *The Jesuit Relations and Allied Documents*, 1610-1791 (73 volumes) and *Early Western Travels, 1748-1846* (32 volumes). The first series contained correspondence and reports generated by Jesuit missionaries during their service in North America. A number of these documents were very descriptive of the Mississippi River and its environment. The second was a compilation of some of the diaries held by the State Historical Society of Wisconsin. We examined those containing descriptions of the MMR and related plants, animals, and human activity. Several of the diaries contained within this series were published in book-length format in recent years.

Other sources we found useful in locating information about the early European presence in the MMR were: Philip Pittman's *The Present State of the European Settlements on the Mississippi* (1765-1768), Thomas Hutchins' *A Historical Narrative and Topographical Description of Louisiana and West Florida* (published 1784), Georges-Victor Collot's *A Journey in North America* (1796), Gilbert Imlay's *A Topographical Description of the Western Territory of North America* (published 1798), and Henry M. Brackenridge's *Views of Louisiana* (published 1798). We frequently used material contained in the writings and sources of Clarence W. Alvord, Carl J. Ekberg, William E. Foley, John Francis McDermott, and Abraham P. Nasatir, all of whom conducted extensive research on our subject.

River guides (e.g. the *Navigator*, *Western Pilot*, and *James River Guide*) and drawings, panoramas, and lithographs of the period are also informative. These visual sources, particularly useful in our effort to understand how the MMR changed through time, must be interpreted with caution, particularly the drawings and lithographs that may have been romanticized for the intended audience. Even so, most are highly detailed and many were generated by individuals employed by a government or commercial entity or who had a scientific interest in the surroundings they were recording.

Throughout our research we looked for primary documents to use as sources in our natural history project. We gathered material from manuscript collections held at the Missouri Historical Society, Missouri State Archives, Western Historical Manuscripts Collection, and other repositories. We found that these descriptive letters and diary excerpts echoed the accounts that appeared in the publications we reviewed.

We increasingly relied upon journal articles and government documents to locate information relative from 1875 to the present and were not disappointed by the amount of material available referencing this time period. Journal articles were particularly useful in determining the validity of some of the very early accounts and maps of the MMR. Government documents provided insight into various government agencies' relationship to the MMR by detailing a particular organization's responsibility to both the general public and the environment.

We discovered a large amount of material relative to the MMR held in libraries and archives throughout the world. Although empirical scientific data on MMR resources is rare prior to the 1960's, the variety and richness of descriptive information encountered so far surprised us. The sources listed in this report represent only a fraction of the material accumulated during our research. Analyses of historical and current scientific information will shed new light on how the MMR has changed over time. As we review the material in preparation for writing our manuscript, we will look for recurrent themes to help us understand the natural history of the MMR.

RESTORATION OF THE MIDDLE MISSISSIPPI RIVER

BY THE ARMY ENGINEERS

CLAUDE N. STRAUSER, P.E., L.S.
CHIEF, POTAMOLOGY SECTION, ST. LOUIS DISTRICT
HYDROLOGIC AND HYDRAULICS BRANCH
APRIL 1978

The Middle Mississippi River (between the mouths of the Ohio and Missouri Rivers) was narrow and deep as the eighteenth century drew to a close, but this was soon to change. The Louisiana Purchase of 1803 was to have a dramatic and nearly irrevocable influence on the navigability of this mighty river. From the founding of St. Louis in 1764 until the beginning of the nineteenth century, the Mississippi River at St. Louis was deep and narrow. As John Bond stated in his book, The East St. Louis, Illinois Waterfront, the river at St. Louis in 1780 was so narrow that British soldiers and Indians enroute to attack the Village of Cahokia, Illinois, fired their muskets across the river and rattled the roofs of St. Louis houses. This same book also says that before Piggot's Ferry went into operation in 1797, the narrowness of the river permitted travelers to verbally summon a boat from the other side. One such traveler in 1787 was "Danny" Boone, son of Daniel Boone. Tradition says that young Boone rode down to the Illinois shore and gave the customary call: "O-o-over!" He was eventually picked up and taken across the river.

American dominion over the Mississippi Valley resulted in the westward migration of pioneers from the eastern portion of the United States. The small village of St. Louis, Missouri, began to flourish and soon became the gateway to the West.

A new era in the life of the Village of St. Louis began in 1817 when the first steamboat arrived at the St. Louis levee. This steamboat was the Zebulon M. Pike. The life of this small community was forever changed after this momentous occasion. The City of St. Louis grew from a population of 16,000 in 1840 to over ten times this amount in 1860. Annual steamboat arrivals grew from 3 to over 3,600 in the period from 1817 to 1858. (See photo of the St. Louis levee front in 1858). This tremendous migration of people to the Mississippi Valley put heavy pressure on the area's natural resources, primarily the bountiful supply of timber.

Timber, from along the banks of the Mississippi River, was used for fuel on the steamboats and lumber for construction of settlements. Some trees, which were in imminent danger of falling into the river, were removed by the Army Engineers before they became deadly hazards to the wooden hulled steamboats. Also great forests of timber were cleared from the rich alluvial bottoms for agricultural purposes. In 1848, a traveler named Henry Lewis, wrote that the "steamboats on the Mississippi all burn wood, and such are the immense quantities destroyed in this manner that, had not nature provided an inexhaustible supply, some other fuel would have had long since to take its place." As the timber from bank lines of the river was being removed, the banks became less stable and began to deteriorate rapidly. The river width increased from an average of 3600 ft. in 1821 to an average of 5300 ft. in 1888. A report written to the Chief of Engineers by Captain O. H. Ernst in 1880 described this river deterioration. Captain Ernst had just finished comparing a recently obtained survey to a prior survey when he wrote the following:

"One of the most important developments of this survey is the evidence which the present position of the shore lines affords, that the stability of the banks has decreased with the settlement of the country and the clearing away of the forests. Weakened banks permit more rapid erosions, give the river greater width, and therefore less depth, and the navigation is injured. The fact that the river has materially widened within the last 60 years is generally acknowledged by those best informed. And if this widening process is still going on it is evident that the navigation is still further deteriorating. An examination of the shore line shows that in every case where cleared fields along a caving bank are interrupted by a patch of wood, the latter projects out into the river. It is easy to believe that the binding quality of the roots, and the protection formed by the fallen trees at the foot of the bank should have this effect. Wooded banks yield finally, of course, but the rate of erosion is so slow that the river has time to build up on the opposite side, and there is no increase of width."

"The facts lead to the belief not only that the navigation has been deteriorating in the past, but that the process is still going on, and will increase in rapidity as further clearings are made, and that, unless energetic measures are adopted to replace the guards established by nature and removed by man, the day will come when the navigability of the river for vessels that now use it will be destroyed."

One of the maps submitted with this report is shown in Figure 1. This map graphically shows the instability of the deforested bank lines.

In the 1880's, the Army Engineers began a bold, almost impossible, task of obtaining and maintaining a dependable navigation channel on the Middle Mississippi River, by attempting to restore the river to a condition that had previously existed. As stated in 1880, by Ernst, "it is pretty well established that there was in former years a depth of water throughout the navigable channel at the lowest stage at least equal to what we shall endeavor to obtain by our works." As Mark Twain said in his book, Life on the Mississippi, "the military engineers have taken upon their shoulders the job of making the Mississippi over again - a job transcended in size by only the original job of creating it."

After many years of progress on the navigation project and the associated studies, planning, and analysis of results by the Army Engineers, we now have a river that is very nearly the same as it was in the early part of the nineteenth century. The average width of the Middle Mississippi River was change from 5300 ft. in 1888 to an average width of 3200 ft. in 1968 (as compared to 3600 ft. in 1821).

In a recent report conducted by Colorado State University for the St. Louis Engineer District, a comparison of surface area, island area and riverbed area of the Middle Mississippi River between Jefferson Barracks Bridge (mile 168.7) and the Ohio River (mile 0.0) were shown (Table 1).

TABLE 1, SURFACE AREAS (SQ. MI.)

Year	Surface Area	Island Area	Riverbed Area
1821	109	14	95
1888	163	35	128
1968	100	17	83

As can be seen, the goal of returning navigability to the Middle Mississippi River has resulted in restoring the river of today to approximately the conditions present in the early nineteenth century.

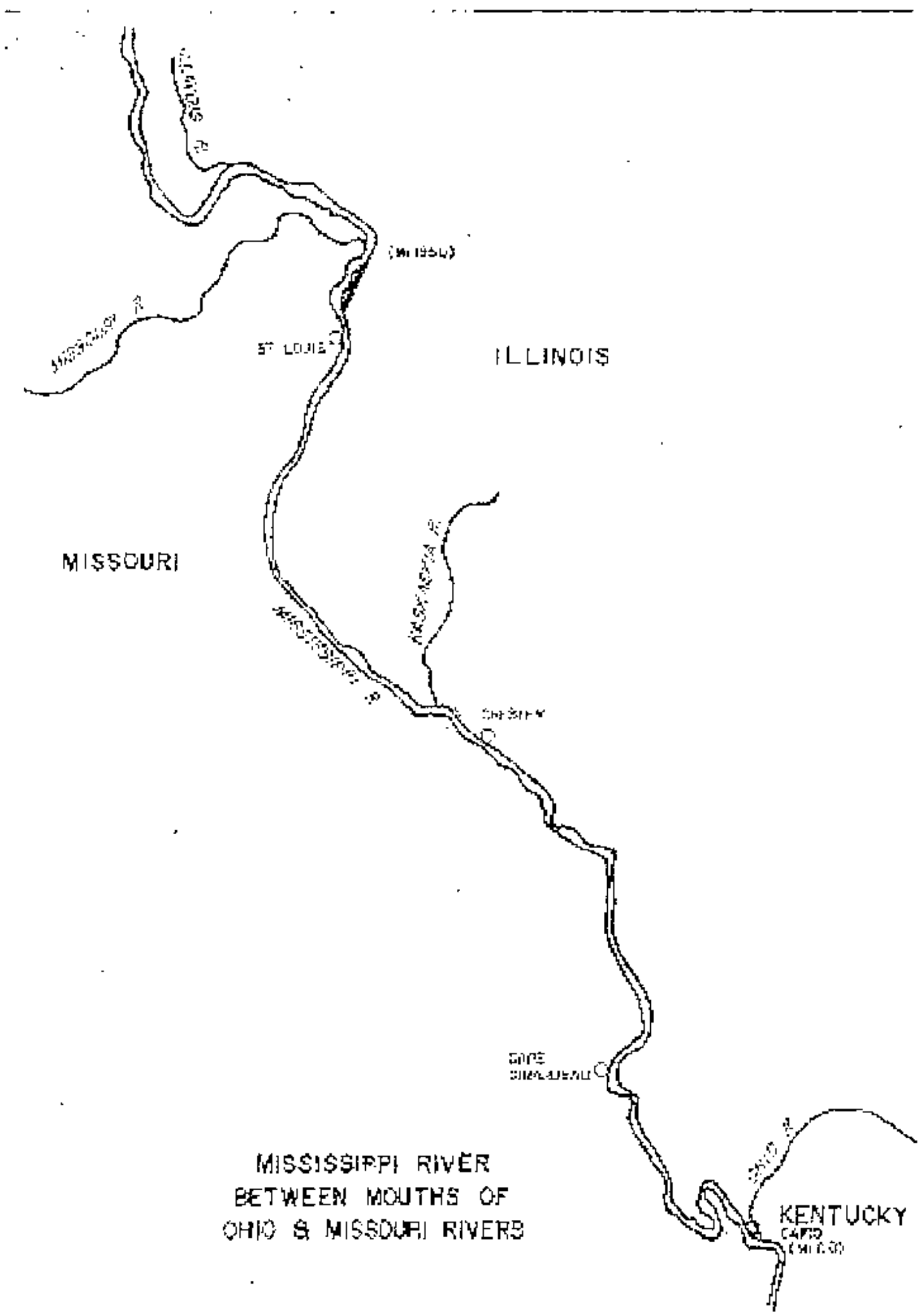
Another aspect of the river that needs to be addressed is the length of the main channel of the Mississippi River between the mouth of the Ohio and Missouri Rivers. This can best be illustrated by Figure 2. This information was developed for the St. Louis Engineer District by the Institute of River Studies located at the University of Missouri at Rolla.

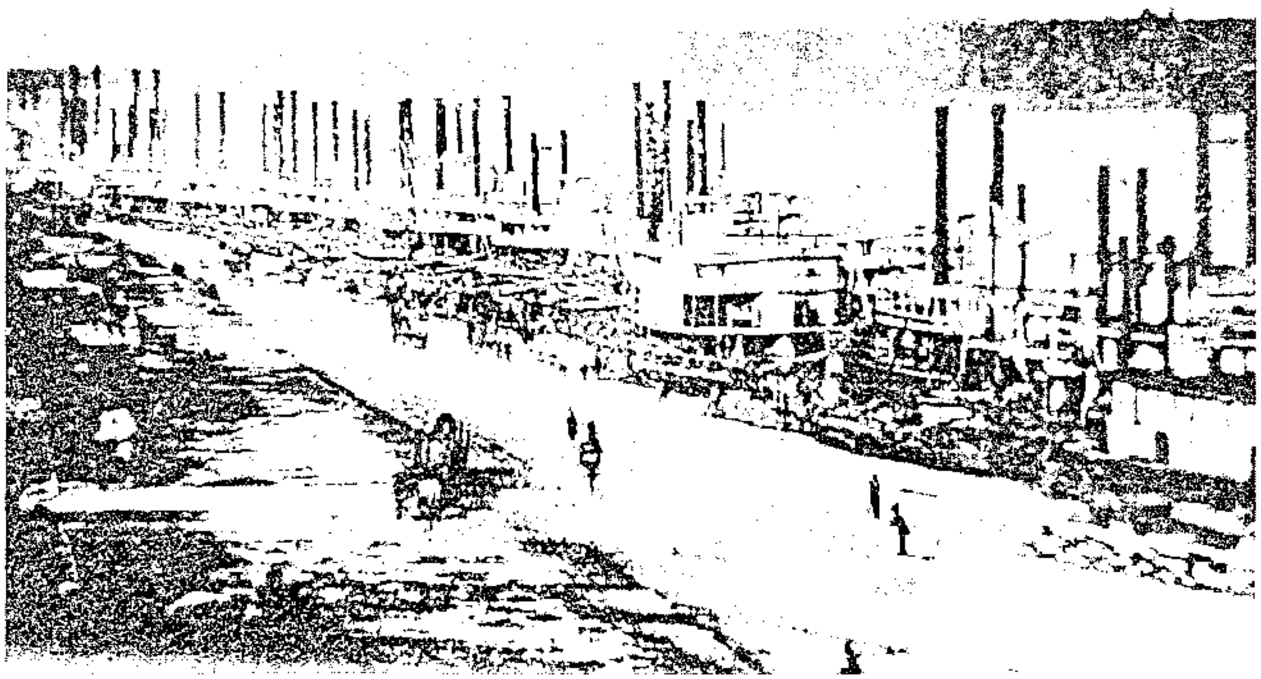
Figure 2 shows how channel length has varied since 1821. In 1974, the river length is nearly the same as it was in 1821. The shortening of the river between 1881 and 1899 was caused by a natural cut-off during the flood of 1881. A conscientious effort has been made by several generations of river engineers to restore the length of the river to its original condition.

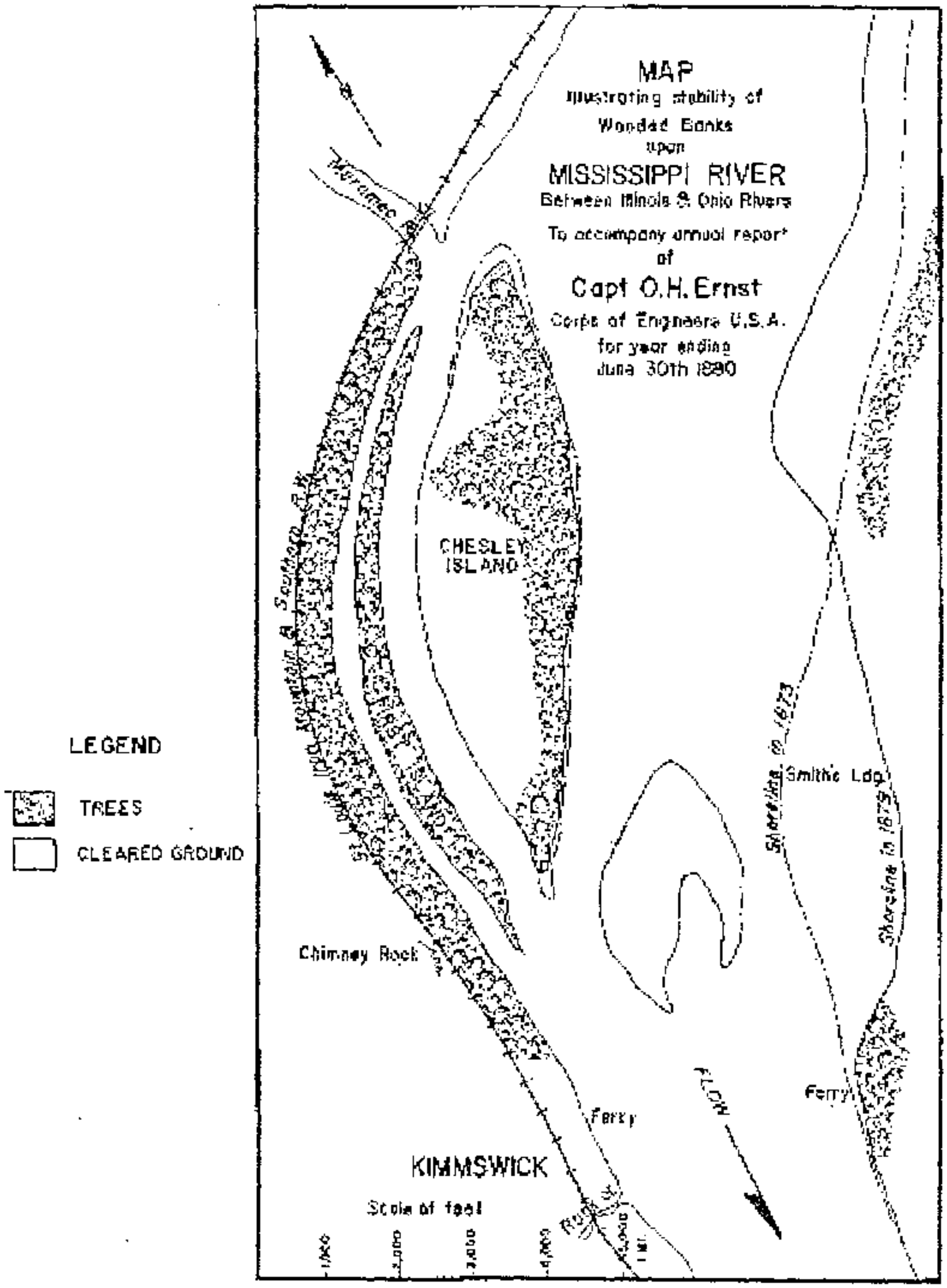
All of the above is the result of a policy established in 1875 by Colonel James H. Simpson: "A permanent improvement must of necessity be designed and executed in entire harmony with the natural laws of the river. To reconstruct the stream according to conditions imposed or assumed can be done successfully if we know all the facts and relations which enter into the problem. The omission of one may be fatal to success: hence all arbitrary changes are to be avoided. But nature overlooks nothing, and we may confidently assume that the position and direction of the river at any time is the resultant of all the forces, and consequently, is a concrete expression of the law of the stream, which we may modify and preserve, but may not safely destroy or radically change."

The uncontrolled exploitation of the timber resources during the period of time from the early 1800s to the late 1800's nearly created an irrevocable loss of navigation in the Middle Mississippi River.

The work of obtaining and maintaining a dependable navigation system on the Middle Mississippi River by the Army Engineers has been, and continues to be, a work of conservancy. The Middle Mississippi River of the early nineteenth century and the Middle Mississippi River of today are essentially the same.


MISSISSIPPI RIVER
BETWEEN MOUTHS OF
OHIO & MISSOURI RIVERS
ILLINOIS
MISSOURI
KENTUCKY
ST LOUIS
OHIO R





MAP
Illustrating stability of
Wooded Banks
upon
MISSISSIPPI RIVER
Between Illinois & Ohio Rivers
To accompany annual report
of
Capt O.H. Ernst
Corps of Engineers U.S.A.
for year ending
June 30th 1890
CHESLEY
ISLAND
Smith's Ldg.
Chimney Rock
Ferry
Ferry
FLOW
KIMMSWICK
Scale of feet
LEGEND
TREES
CLEARED GROUND

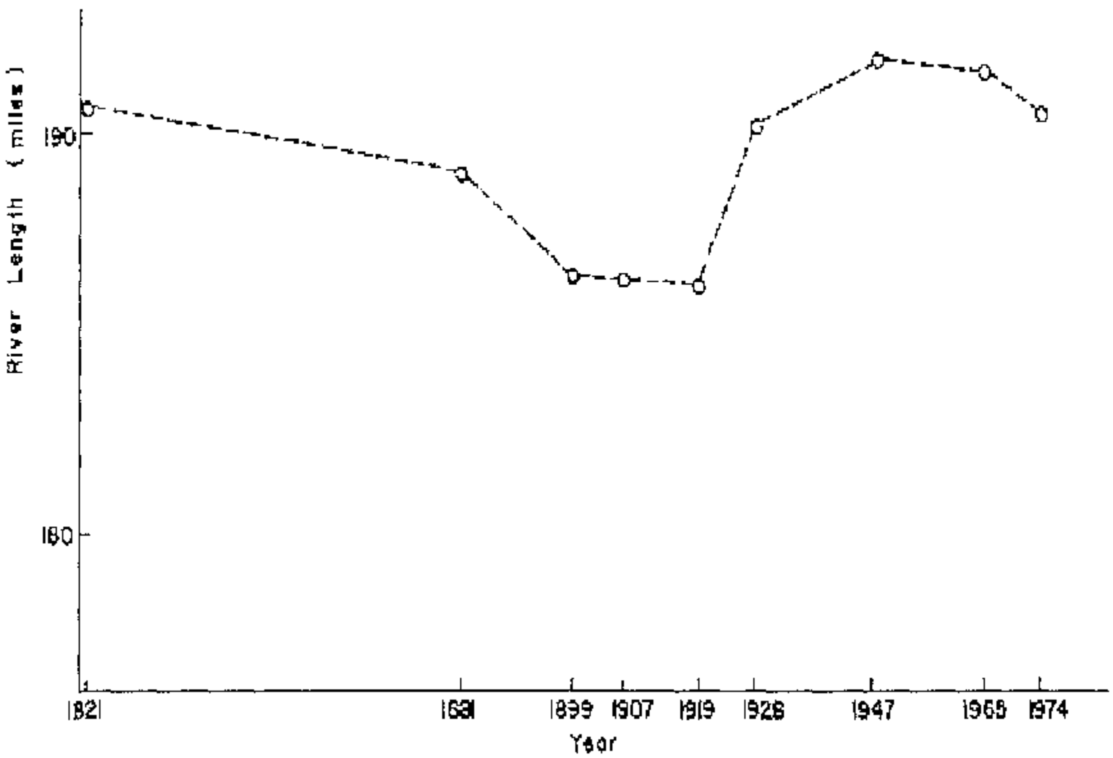


Figure 2: Length of the Main Channel of the Mississippi River Between the Mouth of the Ohio and Missouri Rivers for Selected Years

EXERPTS FROM:

A JOURNEY
IN
NORTH AMERICA

BY VICTOR COLLOT,
Late General in the French service, and Governor of Guadeloupe.

PARIS,
PRINTED FOR ARTHUR BERTRAND, BOOKSELLER,
No. 25, RUE HAUTHEFEUILLE.

1826

CHAPTER XV

Before WE speak of the Mississippi, that great artery of North America, it is necessary to make an observation.

Obliged, on leaving the Ohio and entering the Mississippi, to ascend a part of this last river, in order to gain the Missouri; and anxious to give a successive view of objects such as we beheld them, our account of the Mississippi will necessarily be interrupted; that is to say, we shall first treat of the Mississippi from the Ohio to the Missouri, and shall not resume our account of that river as far as New Orleans, till we have finished our expedition into the country of the Illinois and the Missouri.

We began our course on the Mississippi the second of August. This day was one of the hottest we had felt in North America: Fahrenheit's thermometer had risen to ninety-seven. An hatchet exposed to the sun during an hour had acquired such a degree of heat, that we could not hold it in our hands. The wind was south, and the weather thick and hazy.

Immediately on entering the Mississippi, and after doubling the northern point which separates the water of this river from those of the Ohio, we passed on the left a great sand-bank, called in the language of the country *batture*, formed by this last river. The sand-bank is long, flat, and covered with young poplars. At this point both sides of the river are low and swampy, and we saw nothing on the horizon which indicated that there were any lands more elevated within a certain distance. For this reason the right side of the river, opposite to the mouth of the Ohio, will never be proper for the construction of any works, unless at an expense which would be useless in a country that is yet a desert.

Three miles from the mouth of the Ohio, in ascending the river, is an island on the left, called Buffalo Island, which is about a mile in length, well wooded, and high, with a blackish soil. We observed on both sides of the river, ranks of willows, all of the same height, resembling the finest Lombardy poplars, and arranged with so much symmetry that each tree seemed placed at equal distances, which viewed from the water produced a most beautiful effect.

After doubling Buffalo Point, we reached, at the distance of half a mile, Elk Island, which is newly formed. The willows we saw on this spot were not more than from two to three years growth. Both passages are equally good; nevertheless, when the waters are low, and in going up the river, the right side is to be preferred, leaving the island on the left.

We rowed by Elk Island a mile, and a mile and a half higher we reached on the right Pointe a la Perche, so called on account of the great quantity of willows with whit it is bordered; these willows are still loftier than those we have just mentioned, some of them being sixty feet in height.

Between Elk Island and Pointe a la Perche the current is more gentle than from this island to the mouth of the Ohio, where it is so strong that we proceeded scarcely more than a mile in two hours; and this with such difficulty, that the best Canadian rower could not handle his oar more than a quarter of an hour without resting.

Half a mile higher that Pointe a la Perche, we reached on the right Charpon Islands: these are three in number and they follow each other in succession; each is about a mile long, including the canals by which they are separated. The lands continue low and swampy to a very great distance on both sides, but they are of fine quality having from twelve to eighteen feet of vegetable earth.

Three miles above these islands we reached Courcy Islands: these are four in number, and occupy a space of two miles. The towing line is used for these three miles (the towing line is made use of when the waters are low and the sand banks dry: in high waters, or when the banks are steep, this mode is impracticable).

Before we reached Courcy Islands, we passed between two great banks, in order to gain the right side, leaving the islands on the right. This is the only side practicable for the towing line, the other being perpendicular and encumbered with trees, which renders this passage extremely difficult. With a line of fifty fathoms, though the waters are low, we bound no bottom.

Immediately after passing the last of Courcy Islands, we steered to the left, in order to avoid a very dangerous sandbank; there is a passage on the right, but the current is so strong, that it is practicable only in descending the river.

In crossing over, we met with a disagreeable accident: our boatmen, exhausted in striving to master the current, stopped on a sudden, when the boat drove with such violence and with so much force on a stump, which broke in its ribs, that we had only time to throw ourselves on the nearest of one of the islands, where we passed the rest of the day to repair the damage.

We learned with certainty, on leaving the Ohio, that from thence to the Missouri, we could never proceed faster than three leagues in a day, and sometimes only two. Although our boat had twenty oars, the rapidity of the current, the immense quantity of trees heaped together on both sides of the river, and which sometimes filled half its bed; the transversal position of these trees, which changes the current of the river, and increases its rapidity, render this navigation very difficult and dangerous: we were continually in the alternative of breaking on the trees, or striking on the sandbanks.

We estimated the current of the river in this place at six or seven miles an hour, and often nine in channels formed by the islands. The country continues to be low and swampy.

We proceeded nine miles and reached the English Island, called by the Canadians Great Courcy Islands, and by the Indians Taiouwapeti. These island occupy a space of six miles, and are twelve in number, ranged in groups of different sizes, and each affording a passage: it is, however, safest to leave them all on the right; not only because the current is less strong, but that nearly six miles are gained by taking the channel on the left. The navigation for Little Courcy Island hither is good: the banks which are formed between them, and which are dry, make it a very easy for towing.

We saw a great quantity of game of every kind on these islands, roebucks, bears, and buffaloes; we killed one of the latter. From the mouth of the Ohio to this spot we found neither creek nor river, nor saw any source whatever.

After passing the English Islands, we perceived that the lands begin to rise, and cease to be swampy; the soil nevertheless, is poor, being either rocky or gravelly, missed with reddish earth. At a Distance we perceived a chain of heights, called Taiouwapeti Mountain, which runs north and south, parallel to the river.

The whole of the quarter is covered with vines of the large kind, which differs, however, from that which we found in the forth, the wood not being so thick; the fruit is less, of a deeper red and sweeter: these vines climb to the tops of the loftiest trees.

At half a mile distance from the last of the English Islands, we found on the left side a chain of rock, called the Little Chain. We kept to the right, and two miles higher we found a second, called the Great Chain, which extends into the middle of the river, and is a mile in length. The rocks that form this last chain being detached from each other, leave a number of small passages, which, although perilous, may be passed with less danger, aided by a good pilot, than the channel altogether on the right, where there is a current so strong, that it cannot be stemmed without much loss of time and considerable efforts, while amidst the rocks the water is almost stagnant.

After passing the Great Chain of rocks, keeping constantly to the left, the navigation continues gentle and easy. We sometimes proceeded a mile and an half an hour.

Here the ground on both sides rises in gentle slopes, and is no longer swampy; it is a mixture of rocks, gravel, and good soil. We beheld at intervals small rivulets, which take their sources in the heights of Taiouwapeti. The quality of their waters is very inferior to that of the river.

The banks of the river are extremely dangerous in this place, from the quicksands which often shift, and on which no one can step without the risk of being swallowed up; our hunter had nearly perished in this manner, and was saved only by placing his fowling piece in a cross direction, when we instantly threw out cords and hawled him on board the vessel. These quicksands may easily be known by their luster, which have the polish of glass, and by their humidity which resists the hottest beams of the sun.

We proceeded six miles, and reached, on the left side, Cape a la Cruche: it is a very elevated and perpendicular point, in front of which, and level with the water, is a nest of rocks which extends to some distance, and which is very dangerous. These rocks may easily be distinguished by the breakers.

The navigation during these six miles is good, if care be taken to keep onn the left side.

Having reached Cape a la Cruche, we crossed a part of the river to gain an island on the opposite side, which is bordered by a great sandbank, very conveniently situated for towing. We thus avoided a very strong current on the left and which begins after doubling Cape a la Cruche.

Three miles above Cape a la Cruche, we passed on the left the small island of La Ferriere.

Towards four o'clock in the afternoon, we perceived in the horizon a kind of white riband of great length, which was a flock of pelicans, called by the Canadians *great throats*, coming from the north in their passage to the southward. They begin to arrive in this latitude, in the month of June, as the cold approaches. In the month of December, therefore, an innumerable quantity are seen at New Orleans, where they generally pass the winter, and hatch their young. These birds travel always in flocks; when they reach any great river, they range themselves all in one line, their heads turned against the stream, and thus suffer themselves to be carried down: they swallow all the fish that some in their way, and deposit them in the great bag. When the river is too narrow to contain a whole flock, they place themselves in a line of two deep: they prefer the Mississippi and the Missouri to every other river, on account of their muddy waters.

At the distance of a mile and an half above the island of La Ferriere, we reached Cape Girardot. We kept to the left side, to take advantage of a very strong eddy that reaches from this last island to Cape Girardot, which is the first military point on the river, from the mouth of the Ohio; both sides being wither swampy or broken by rocks.

Cape Girardot, on the contrary, is a block of granite, covered with a vegetable earth, about a foot in depth; it commands the whole river, which by means of a point, or very considerable alluvion, on the opposite side, is narrowed to the breadth of a mile at most. In order to avoid the shallows with which this alluvion is surrounded, all vessels that pass are obliged to keep very near the right side, which is within half cannon shot of the Cape.

The upper part of the block or eminence A, is commanded by no height; that part which fronts the river is steep and inaccessible; the large and deep defile surrounds it to the north and east: on the south is a gentle declivity, which finishes in low and sometimes marshy lands. The foot of the cliff affords shelter and excellent mooring for vessels.

Cape Girardot is, therefore, so situated as to supply what is wanting on the right bank of the Mississippi, at the point which corresponds to the mouth of the Ohio. Placed at forty-three miles and half only above its mouth, this point command whatever issues from that river, and covers perfectly on this side the place of St. Louis, from which it could receive succour in twenty-four hours. This leads us to think that the true station of the gallies is at this spot, where there is a fort respectable enough to protect them.

The river in great floods rises here as high as seventy feet.

In one of the villages of the Loups which I visited whilst I remained at Cape Girardot, I found a white who had formed an establishment. This planter in clearing had destroyed a settlement of beavers: on examining, with the proprietor, the devastation which had been made in the swelling and dikes of these industrious animals, we were struck with the appearance of one among those we had killed, the skin of which was totally without hair, and his body covered with scars. I conjectured at first that this was the effect of some malady natural to this species of animal: but my host, to whom I made the remark, informed me, that he was the slave of the family, and that a similar one was found in almost ever habitation of the beavers.

"In each family," said he, "there is one, which on his entrance into the world is destined to be the slave. The most servile and laborious occupations are his lot; among which is that of serving as a traineaü for the conveyance of wood. When the beavers have resolved on cutting wood, and it remain only to be carried off, the slave takes the stick between his fore feet; the free beavers, seizing him by the tail, drag him in this manner, nor is he permitted to quit his hold till he reaches home."

If this be a fact, and I relate it with the same simplicity that it was recounted to me, it is not astonishing that the body of this anima should be scarified an deprived of its hair, by the continued friction he must have undergone, when dragged through briars, over stones and rocks. This at least is certain, that the beaver I saw was without hair, and covered with scars both old and newly made.

At the distance of half a mile from Cape Girardot, and on the left side, is a creek which is almost dry during the summer; and half a mile higher is the island Du Verrier, which we left on the right. The navigation during this mile is easy, but the island being very large, and narrowing the bend of the river, there is a very strong current on both channels. We quitted the left side, and crossed to gain the island, which is surrounded with banks, that facilitate the use of the towing line. The left side of the river, independently of its extreme rapidity, is also filled with a considerable quantity of drift wood, which chokes up half the channel; but these kinds of obstacles are but momentary; the next year they may totally disappear, and may probably embarrass some other point of the river.

After rowing by the island Du Verrier, which is two miles long, and proceeding three miles further, we reached False Bays, situated on the right side; we crossed again a part of the river, to gain a great sandbank which is dry, and where the current is less strong. We left on the right, a mile from False Bays, an island without a name, which has been only formed within these two years. Two miles and an half above this island, we passed another on the right, of which the name is also unknown.

The current during these last two miles and an half is moderate, and the navigation easy; we kept to the right side, which is bordered with flat rocks, and convenient for mooring boats. A mile above this last island, perpendicular rocks rise on the right bank to the height of two hundred feet: the left side, on the contrary, is swampy.

We rowed the length of a mile along this iron rampart, and reached on the same side Marl River (Riviere de Glaise), which is full of clay of this nature. The river is about forty or fifty yards wide at its mouth, runs through low and swampy lands, and is almost dry during the summer.

Four miles above, and on the same side, Apple River (Riviere aux Pommes) empties itself. This river is from eighty to ninety yards in breadth at its mouth, and though its water are low in dry seasons, there is nevertheless enough for the navigation of canoes.

Directly opposite to Apple River, Mud River (Riviere aux Vases) flows into the Mississippi. Its mouth is concealed by a very considerable island, which forms two passages; the first, in ascending the river, is the best. This river is navigable sixty miles for canoes, during the whole year; the country through which it flows is extremely fertile, but swampy to a great distance.

Four miles above Mud river, and on the right side of the Mississippi, is the Tower; a name given to a great mass of rocks, at nearly fifty yards distance from the right bank. Its round form, insulated situation, and lofty height, led the first navigators to give it this appellation. This rock offers nothing curious excepting the immense quantity of birds of every kind to which it affords an asylum. Six weeks previous to our arrival here, an American family, composed of twelve persons, were all massacred. They had taken their station, on the left side of the river. Soon after their landing, two Chickasaws came to visit them with a friendly air, asking them for provisions and rum, which were given to them, and they appeared to go away highly satisfied. But at daybreak a troop of twenty Indians fell upon this unfortunate family, and massacred men, women, and children without mercy. These murders are very common, and are committed almost always by Indians proscribed and driven from their tribes for robbery or some bad action; the vagabonds then wander through the woods, and rob and kill all they meet. These depredations are in general committed by the Chickasaws; sometimes, however, massacres take place by way of reprisal. If an Indian be killed by a White, as soon as the news reaches the tribe, the whole nation swears vengeance, and that the same quantity of blood which has been taken shall be shed: after which, the first White that presents himself, whether a stranger or no, becomes their victim. When such attacks are to be apprehended, it is prudent to encamp in one of the small islands, after having well examined it; or what is still better, to anchor always at a little distance from the shore. To this precaution, which we cannot too strongly recommend to those who travel in these deserts, we owe the preservation of our own lives.

Leaving the Tower, we proceeded three miles and an half, and reached Winged Island (Isle aux Ailes), which we left on the right. In this space there are several eddies on the left side, which favor the ascent of the river; the current is very strong on the right.

Four miles and an half above Winged Island is Five Men Cape (Cap des cinq Hommes), situated on the left side. It is known by the long line of rocks which precedes it, and which though joined to the bank, extends far into the river. These rocks form very violent currents, but beyond them the navigation becomes smooth and easy.

Three miles above Five Men Cape are Dung Islands (Isles a la Merde); these are four in number, and extend nearly three miles. We passed them on the left, and half a mile higher we reached the river St. Mary, situated on the same side. Opposite its mouth is a little island called Perch Island (Isle a la Perche), which we left on our right.

A mile and an half above Perch Island, we reached the island of Kaskaskias.

From Five Men Cape the navigation is good, and even easy, but care must be taken when at Perch Island, to cross the river and gain the right side, where the current is much more gentle than on the left.

A mile above the island of Kaskaskias, we reached the mouth of the river which bears this name.

The appearance of the country from Cape Girardot to this place, varies but little; every where we find small rocky heights, intersected by vallies, which are often overflowed. Excepting Cape Girardot, the whole of this country, from the Ohio to Kaskaskias, is uninhabited.

The river Kaskaskias is nearly on hundred and twenty yards broad at its mouth, and affords in every season a gentle and safe navigation for all kinds of boats. The village of Kaskaskias, situated ten miles from the mouth of the river, is the first settlement in the country of the Illinois.

From Kaskaskias to Salt River is reckoned ten miles; from thence to St. Genevieve four; from St. Genevieve to Fort Chartres twenty; to Joachim River eighteen; to Marimeck river fifteen; to the village of Carondelet fifteen; to St. Lewis ten; and to the Missouri River four.

The whole navigation from the river Kaskaskias is excellent, and traverses a country very well inhabited, called the Illinois.

RECAPITUATION OF THE DISTANCES
FROM THE MOUTH OF THE OHIO TO THAT OF THE MISSOURI

From the mouth of the Ohio to	Miles
Buffalo Island	3
Its length	1
Elk Island	1/2
Its length	1
Point a la Perche	1 1/2
Charpon Islands	1/2
Their length	3
Courcy Islands	3
Their length	2
English islands	9
Their length	6
Little chain of rocks	1/2
Great chain	2
Cape a la Cruche	6
Island a la Ferriere	3
Cape Girardot	1 1/2
Island du Verrier	1
Its length	2
False Bays	3
Marl River	5 1/2
Apple River	4
The Tower	4
Winged Island	3 1/2
Five Men Cape	4 1/2
Dung Islands	3
Their length	3
River St. Mary	1
Kaskaskias Island	1 1/2
Salt River	10
St. Genevieve	4
Fort Chartres	20
Joachim river	18
Marimeck River	15
Carondelet village	15
St. Lewis	10
The Mouth of the Missouri	5
	176 1/2

The most valuable information which we acquired during this short passage, respecting the navigation of this river, as well from our own observations as the different accounts which we could procure, was, that whatever talents, patience, and courage may be exercised in undertaking this expedition, there are obstacles which will forever render it impossible to obtain either charts or any certain details respecting the course of this river, which can server either as a guide or instruction to travelers.

The Mississippi has not only the inconvenience of being of an immense extent, of winding in a thousand different directions, and of being intercepted by numberless islands; its current is likewise extremely unequal, sometimes gentle, sometime rapid; at other times motionless; which circumstances will prevent, al long as both sides remain uninhabited, the possibility of obtaining just data with respect to distances. But an insurmountable obstacle will always be found in the instability of the bed of this river, which changes every year: here a sharp point becomes a bay; there an island disappears altogether. Further on, new islands are formed, sandbanks change their spots and directions, and are replaced by deep channels; the sinuosities of the river are no longer the same: here where it once made a bend it now takes a right direction, and there the straight line becomes a curve: here ravages and disorders cannot be arrested or mastered by the hand of man, and it would be extreme folly to undertake to describe them, or pretend to give a faithful chart of this vast extent of waters, as we have done of the course of the Ohio, since it would not only be useless but dangerous. It is for these reasons that we shall confine ourselves, as we proceed, to general ideas with respect to the navigation of this river, and treat in detail only of the most striking military points situated on its current. If from the Ohio to the river Kaskaskias we have deviated from this rule, it is because that part of the river is reckoned the most difficult, and also varies less on account of the two chains of heights which bounds its banks, and which fix and master its course.

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