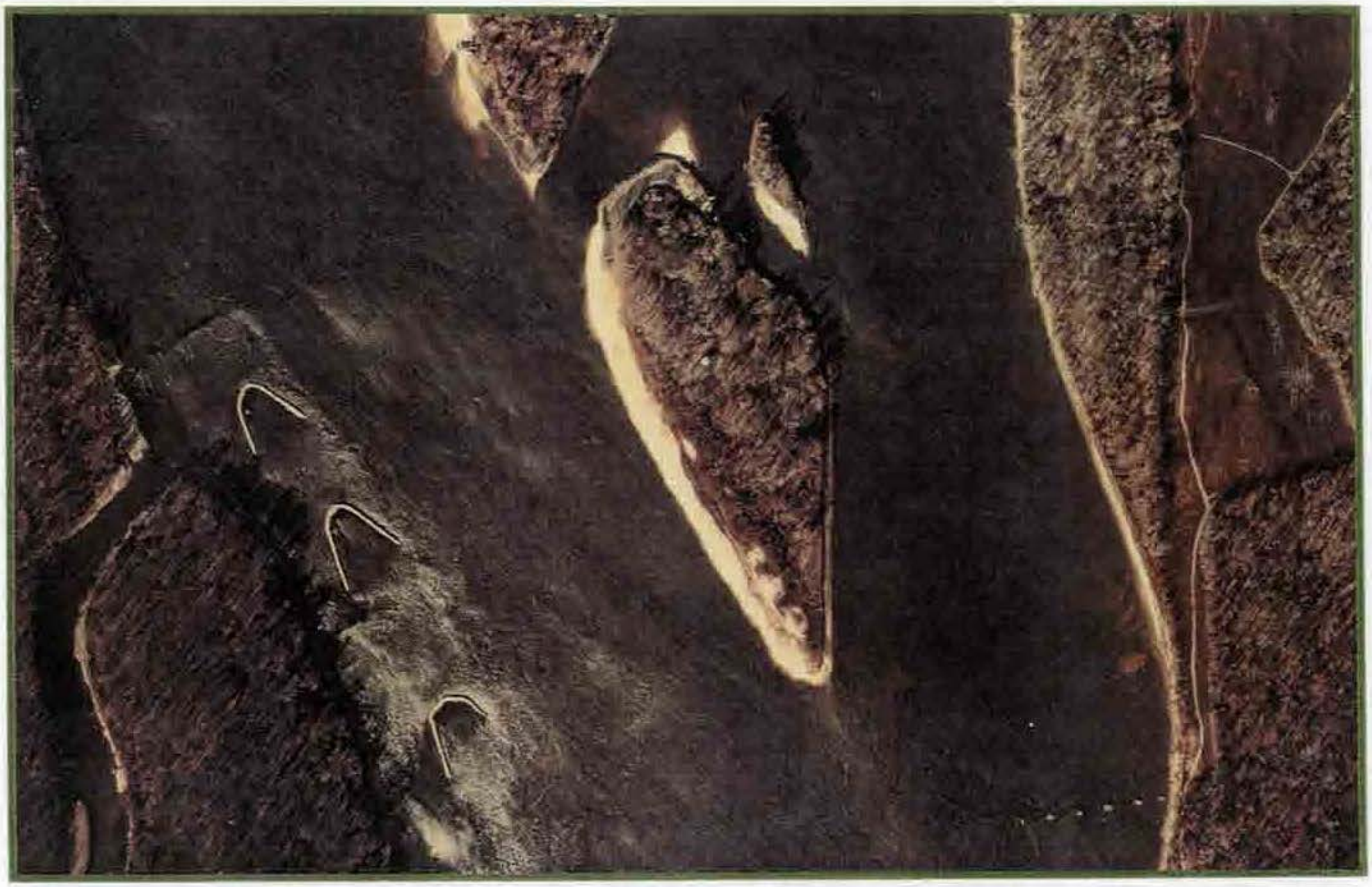
MELVIN PRICE LOCKS AND DAM

UPPER MISSISSIPPI RIVER BASIN
MISSISSIPPI RIVER MISSOURI AND ILLINOIS

PROGRESS REPORT 1999



DESIGN MEMORANDUM NO. 24
AVOID AND MINIMIZE MEASURES

US Army Corps
of Engineers
ST. LOUIS DISTRICT

"Good engineering enhances the environment"

MAY 2000

Cover photo

Aerial photo of the chevron dike field and multiple roundpoint structures (MRS) in Pool 25. The photo was taken on December 20, 1999. The chevron dike field was constructed in 1998 and 1999. The MRS was constructed in 1998. Both innovative river training structures were built by the A&M program. Fieldwork at both sites has shown that the structures are providing useful and valuable fish habitat.

AVOID AND MINIMIZE MEASURES

DESIGN MEMORANDUM #24

1999 PROGRESS REPORT

MELVIN PRICE LOCKS AND DAM
MISSISSIPPI RIVER - MISSOURI AND ILLINOIS

Prepared By:

U.S. Army Engineering District- St. Louis

1222 Spruce Street

St. Louis, Mo. 63103-2833

April 2000

Avoid and Minimize
Environmental Impacts Program
St. Louis District - Mississippi Valley Division
1999 Progress Report

Executive Summary

In 1992, the St. Louis District agreed to establish an Avoid and Minimize Program (A&M) 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 1999 focused on previously started work, including the placement of revetment and stub nose dikes in Sante Fe chute (RM 39.5-35.0L) and the completion of an additional one and a half chevron dikes in Pool 25 (RM 266). Biological monitoring work on the chevron dike field and the multiple roundpoint structures (MRS) in Pool 25 found that fish were using the structures and that they were creating valuable habitat. The chevron dikes appear to be providing needed overwintering habitat fish. The rare blue sucker and several species of catfish continue to be collected around the MRS structures.

In 1998, the A&M team decided to focus effort on improving fish passage through locks and dams. This work began at Lock and Dam 25 in 1999. Results from that monitoring effort showed that fish movement through gates occurs during open river and that the opportunity for fish passage increases as discharge and water levels rise. Fish movement when the gates are in the water, even at low head conditions, was not detected. Gate manipulation scenarios to increase fish passage were devised for implementation in 2000.

Results of the Bolters Bar micromodel study were released in 1999. Recommendations at this chronic dredge site included placement of four chevron dikes, removal of some remnant dikes, and creation of a deflector dike, all along the right descending bank.

A report summarizing an extensive 1989 unionid collection effort on the middle river was completed. This previously unavailable information will be used as a planning aid on future A&M side-channel improvement projects.

The final report on fish assemblages in Saint Genevieve Bend (RM 120-118) was finished in 1999. This site was sampled with a rock hopper bottom trawl prior to placement of bendway weirs in September 1997. Six species of fish were collected including one sicklefin chub, a candidate for federal threatened and endangered species status. The rock hopper provided effective at sampling along the main channel border, but ineffective at sampling in the main channel.

Pre-construction survey and fish sampling of two dike modification sites in the middle river were completed. These sites, at the confluence with the Ohio River and at the weir field at Greenfield Bend (RM 4), will be surveyed and sampled again after modification. Information gained at these sites will aid future A&M dike implementation projects.

Two progress reports on the monitoring of effects of Environmental Pool Management (EPM) in Pool 25 were completed. The report on waterfowl food production found that a number of species of plants, including smartweed and chufa, responded to the 1999 drawdown. Avian use surveys found waterfowl spent the majority of time foraging in the shallow water areas where vegetation was produced by EPM. The report on fish use of vegetation produced by EPM found that fish numbers and species were higher in vegetated areas than in non-vegetated areas. Low dissolved oxygen rates were noted in some vegetated areas. Vegetation along island edges had a greater number of species than did vegetation in backwater areas. Stranding of fishes was noted at several locations. Stranding may have been a function of lower than usual summer pool water levels. These water levels were a function of an unusually high hydrograph. Earlier spring sampling found that fish were using the residual vegetation produced by EPM in 1998

A report summarizing benthic invertebrate data collected in association with river training structures and in areas without structures was completed. This report concluded that the rock used in river training structures, increases species diversity and richness. Concrete rubble placed in the river was also found to increase diversity and richness. Chevron dikes were shown to increase habitat diversity, not only by the placement of rock, but also by an increase in substrate diversity behind the structures.

The fourth year of the middle Mississippi River pallid sturgeon habitat use study was in 1999. Twelve fish were implanted with sonic tags. Based on the tracking work, pallid sturgeon 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 showed negative selection of areas in the main channel, downstream of wing dams and upstream of wing dams. Pallid sturgeon showed no selection, negative or positive, for bendway weirs.

The 2000 A&M budget is expected to be $1 million. Proposed construction activities in 2000 include completion of the Pool 24 chevron dike field and construction of a notched closing structure behind Cottonwood Island (RM 289). Monitoring work will include continued sampling at the chevron dike and multiple roundpoint structures and testing of gate manipulation scenarios at Lock and Dam 25 to facilitate fish passage.

Avoid and Minimize
Environmental Impacts Program
St. Louis District - Mississippi Valley Division
1999 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 O&M 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 on recommended measures. The planning and implementation team consist 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, collect data as part of a monitoring program, develop materials for grant funds, and donate time to develop alternatives for construction of measures at the Applied River Engineering Center located at the District Service Base. This team meets at least once a year (often more) 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 year's reports, and Design Memorandum 24, are available from the St. Louis District.

1999 A&M Program Activities

A&M 1. 1999 Construction. Construction in 1999 focused on completing previously started work. In 1997 the A&M program constructed six alternating stub dikes in Sante Fe Chute (rm 39.5-35.0). Based on the original micromodel results, nine alternating dikes with opposite bank revetment were to be constructed in the sidechannel to create both a sinuous channel and off-channel deep water habitat. In 1999, the final three stub dikes and opposite bank revetment were constructed. Chevron dike work (RM 266.2-265.8) in Pool 25 was also completed. Work at the site began in 1998 with the construction of one and a half chevron dikes. An additional one and a half chevrons were constructed in 1999, bringing the total chevron dike count at the site to three. This dike field is illustrated on the cover of the progress report. Plans call for one more chevron dike to be constructed at this site at a yet undetermined date.

A&M 2. Chevron dike monitoring. As mentioned, the A&M program constructed three chevron dikes in Pool 25 of the Mississippi River (RM 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 266.0 were surveyed on 4 August 1999 and 13 December 1999. The M.V. Boyer was used to collect bathymetry, velocity, and hydroacoustic fisheries data.

Fish were using the chevron dikes during both sampling trips. The upper and middle dikes showed a marked increase in fish density from the August to the December survey. 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. 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 to provide. Having been constructed one year later than the upper two chevron dikes, the lower chevron dike has had only one 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.

The August survey showed that fish were using all three of the chevron dikes, though fish densities were lower than in December. Continued monitoring will show if the August density numbers were higher than expected densities outside of open river conditions. The chevron dikes provide a slack-water refuge from the higher open river flow. Consequently, it is possible that a higher number of fish were using the dikes than would have been during normal pooled summer conditions. Previously sampling work by IDNR found that fish use chevron dikes throughout the year. Monitoring at the site will continue in 2000. Presently a summer and a winter sample are scheduled. Detailed survey results are available in Appendix A.

A&M 3. Multiple Roundpoint Structure Monitoring. To be completed Appendix B

A&M 4. 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 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. Over 25 species of fish in the Upper Mississippi exhibit migratory behavior.

Lock and Dam 25 consists of a lock chamber, three 100-foot wide roller gates, fourteen 60-foot wide tainter gates, and a 2500-ft overflow section. Monitoring work was 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. First year goals were to collect velocity and fish data, document the movement of fish through gate bay 17, and develop gate management scenarios to test in 2000. Hydroacoustic fisheries equipment and current velocity profiling equipment were mounted in gate bay 17 and sampling was conducted at ten foot intervals across the gate bay. Gate bay 17 was sampling for 10 days. Eight and a half of those days were at open river conditions. Sampling commenced on 10 April and ended on 13 May.

679 fish were counted moving through gate bay 17. Fish movement appeared to be correlated with gate opening. Fish movement was the greatest during the first day of open river (10 April), averaging about 2.3 fish per minute. On 11 April, the lower 2-foot of the dam gates were placed back in the water. During that day fish movement dropped to .02 fish per minute or about one fish every 100 minutes. The gates were removed from the water on 12 April and remained out of the water until 17 August. Seven days of sampling at open river in late April and early May resulted in fish movement rates ranging from .26 to .64 fish per minute.

Gate bay 17 provides a unique fish passage opportunity at open river. As water level, flows, and discharge increase, velocities actually decrease in gate bay 17. This decrease is related to the crosscurrent flows created by the overflow dike directing downstream flows back towards the lock and dam gates. As these flows cross the end of the lock and dam structure they come in contact with the downstream flows above gate bay 17. The strength of the crosscurrent flows shields gate bay 17 from downstream flows, creating a slackwater eddy. This effect is most exaggerated just before the overflow dike is topped.

Examination of fish prolonged swimming speed finds that most fish species can traverse flows less than 2 feet per second. As flows rise above 2 feet per second the number of fish species that appear to be able to pass decreases. Four feet per second is the upper end of swimming speeds for Mississippi River fish. In gate bay 17, on April 10, the first day of open river, flows less than 4 feet per second were seen 56% of the time. Flows less than 2 feet per second were present 10% of the time. On April 21, water levels had risen 6 feet from the elevation on April 10, discharge had increased 77,000 cfs, and the overflow area was topped. On that date 92% of the velocities were below 4 ft per second and 45% of the velocities were below 2 ft per second.

First year results indicate that opportunity for fish passage appears greatest during open river conditions. Movement opportunities outside of open river are probably very limited. Monitoring in 2000 will focus on creating hydraulic conditions to extend or create open river conditions outside of the "normal" period of open river, and exploring structural alternatives to extenuate the effects in gate bay 17. Gate management scenarios are being developed to maintain pool conditions while allowing gate 17 to remain open.

A&M 5. Fish and Wildlife Effects of Environmental Pool Management. 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 waterfowl as water levels rise. The District is exploring ways to further enhance EPM but lacks basic information on fish and waterfowl use of the EPM created vegetation. In 1999, Southern Illinois University-Carbondale began two studies to determine the response of waterfowl, aquatic invertebrates, fish and water quality to wetland vegetation produced by EPM (Appendix C).

5A. Effects of water level management on waterfowl food production in Pool 25, Upper Mississippi River. The objectives of this study are to 1) characterize the plant community associated with water level management and estimate seed biomass production, 2) quantify the aquatic invertebrate population response to increased macrophyte production, and 3) characterize avian use of habitats produced by water level management.

Vegetation community data were collected during 24-25 July and 13 August 1999, beginning three weeks after drawdown. Seed biomass data were collected on 3, 10, and 11 September 1999, approximately 3 weeks after reflooding. The aquatic macroinvertebrate populations were monitored at both devegetated and vegetated sites during the fall of 1999. Waterfowl surveys were conducted between 27 February and 23 April 1999. Observations of waterfowl behavior were conducted during March and April 1999 from duck blinds present within the study area.

Preliminary plant community study results indicate that EPM continues to produce a plant community comprised mainly of moist-soil species that provide food for waterfowl. Little zonation in species distribution suggests relatively uniform availability of food resources in the study area.

Invertebrate samples from the fall of 1999 are currently being processed. When these data are available, comparisons between 1999 and 1998 data will be made to see if differences in relative abundance exist between plots and years. If abundance is significantly lower in non-vegetated plots than the vegetated plots, the differences might be attributable to EPM. Further analysis of invertebrate data will focus on differences in taxa abundance between plots.

Waterfowl using vegetated areas spent a majority of time foraging in shallow water areas, suggesting that they are using resources produced by drawdown. However, the infrequency of dabbling ducks in open water may not be an appropriate indicator of the importance of vegetation produced by EPM. Behavioral observations planned for the spring of 2000 will incorporate the devegetated plots from the invertebrate experiment to characterize the use of shallow open water areas.

5B. Fish Response to Water-level Manipulation: Mississippi River Pool 25. This study has four objectives: 1) examine fish use of vegetated and non-vegetated areas, 2) determine if increases in the forage fish base benefits adult fish, 3) determine the benefit of residual vegetation to young fishes, and 4) monitor the effect of vegetation on water quality and zooplankton.

Fish sampling prior to pool management in 1999 found that fish were using the residual vegetation produced by pool management in 1998. Buffalo, sunfishes, white bass, redhorse, and drum were among the species collected.

Four sites in Pool 25 were sampled after the 1999 summer pool drawdown of 29 June to 12 August. Vegetated and non-vegetated areas were sampled at each site from late August to middle October. Fish abundance and the number of fish species were significantly higher in the vegetated plots. Fish abundance and species present also were related to location of the vegetation. Abundance and number of species were lowest in the extensive, shallow backwater areas and higher in the vegetation along island edges. Early results showed the occurrence of low dissolved oxygen (DO) at some vegetated sites. Low DO values were presumed to be caused by low atmospheric mixing and plant decomposition. Backwater sites were dominated by fish like the common carp and mosquitofish, which are tolerant of low oxygen levels. Channel shiners and spotfin shiners dominated island edge vegetation. In both cases, young-of-the-year and juvenile fish dominated samples. Overall, sixteen species of fish were collected. Stranding of fish and mussels in isolated pools during drawdown were noted. Stranding may have been a function of lower than usual summer pool water levels. These water levels were a function of an unusually high hydrograph. Sampling work is scheduled to continue in 2000.

A&M 6. Middle Mississippi River Pallid Sturgeon Habitat Use Project. In 1999, the A&M program continued for the fourth 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.

Twelve additional pallid sturgeon were obtained from commercial fishers and implanted with sonic transmitters during year four. Ten of the fish had high character index values, one was in the hybrid overlap range and one was in the hybrid range. Seventeen other pallid sturgeon were examined but not implanted with transmitters due to their small size. Only one fish implanted with a sonic transmitter during years one through three was relocated during year four.

A total of 184 relocations of the study fish were made from 13 November 1995 to 31 December 1999. 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 39% of all relocations. Main channel border and below wing dam habitat were used by the fish 26% and 14% percent of all relocations respectively. Twenty-six 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 10%), however the main channel was still used most often (43%). Main channel and main channel border habitat were used 82% of the time once water temperatures rose above 4°C.

Habitat availability analysis indicates that the study area was approximately 65% main channel, 11% main channel border, 1% downstream island tips, and the other 23% of habitat types being related to river training structures. The sturgeon showed positive selection for, in rank order: main channel border, downstream of island tips, between wing dams, and the tips of wing dams. The fish showed a negative selection for, in rank order, main channel, downstream of wing dams, and upstream of wing dams. Late information not published in the SIU-C 1999 progress report found that pallid sturgeon were neither selecting nor avoiding bendway weir habitat. More detailed results are available in Appendix D.

A&M 7. Benthic invertebrate assemblages associated with recently constructed river training structures on the Mississippi River. The A&M program has been monitoring benthic invertebrate use of river training structures since 1994. Monitoring sites have included chevron dikes, established bendway weir fields, new bendway weir fields, and areas without structures. In 1999 all of this information was compiled into a summary report. The report describes the overall ecological benefits and impacts of the experimental training structures that the A&M program has constructed. The underlying objective of the report was to determine if benthic invertebrate species richness increased due to the construction of river training structures in the Upper and Middle Mississippi River.

Benthic invertebrates were collected from chevron dikes near RM 289.5 in 1994, 1995, and 1996, from bendway weirs near RM 164 in 1996, and from bendway weirs near RM 30 in 1996. Benthic invertebrate samples were also collected from Mississippi River substrate around chevron dikes in 1994, 1995, and 1996, near proposed training structures at RM 265.7 and 250.2 in 1996, and downstream of bendway weirs near RM 20 in 1996. Because rock structures appeared to provide invertebrate habitat, rubble from the demolition of a lock and dam 26 I-wall (RM203) was left in the river and monitored for colonization in the summers of 1996, 1997, and 1998.

With an increase in habitat heterogeneity, benthic invertebrate species richness and diversity tend to increase. These results shows that rock structure, regardless of whether or not it is a channel maintenance structure, does indeed provide additional habitat heterogeneity. The study also showed that even a slight increase in heterogeneity of habitat can increase diversity and richness. The study showed that species composition in chevron dike interiors, both within the substrate and on the rocks were different than those on the exterior of the dikes, resulting in a much higher species richness at RM 289.5. Chevron dikes also maintain side channel flow, reducing backwater sedimentation that generally occurs in standard dike fields.

Bendway weirs are in a much harsher, high flow environment, but also provide refugia and habitat heterogeneity. In this study, more taxa were found and diversity was higher within weir fields then in substrate without the weirs at RM 20. In addition, habitat heterogeneity not only within the weir field, but also across the channel may increase because the weirs are designed to modify and stabilize substrate, allowing debris to accumulate. This stabilization across the channel may prove to provide habitat above and beyond that provided by simply adding rock over a period of time, though more study is needed. A copy of the report is found in Appendix E.

A&M 8. Middle Mississippi River Mussel Report. The St. Louis District, during a period of low water in the winter of 1988 and spring of 1989, conducted a broad unionid survey of the middle Mississippi river. This work was conducted at side-channel, backwater, and borrow pits sites along the middle river. In 1999, the A&M program had a summary report created from that data (Appendix F). This report will assist the A&M program as it continues to examine side-channel improvement projects in the middle river. Results of the survey found 2,536 specimens of 19 native unionid species. Eighteen species were collected from 24 side-channels sampled, while 12 species were found in four borrow sites surveyed. The three most abundant species were the giant floater (*Anadonta grandis*), fragile papershell (*Leptodea fragilis*), and the pink papershell (*Potamilus ohiensis*) which made up 87.5% of the total number of specimens collected. Twenty-six native species are reported to occur in the middle river.

A&M 9. Bolters Bar Micro Model Study. The St. Louis District's Applied River Engineering Center micro-modeled an area of repetitive maintenance dredging in Pool 26 (rm 227-222). This reach, the Bolters Bar reach, is one of the most often dredged areas in the St. Louis District. Over 3.9 million cubic yards of material has been dredged in the reach in the last 18 years, at a cost of over $5.1 million. Preliminary results of that micro-model study were included in the A&M 1998 Progress Report. Those results were finalized in a 1999 status report (Appendix G). The recommended plan includes the placement of four chevron dikes along the right descending bank. Although traditional dike structures also produced favorable results, chevron dikes were chosen for because of their environmental benefits. The chevron dikes should also stabilize the dredge material placed behind the structures, which will likely result in the creation and use of recreation beaches in that reach. Other recommendations included removal of some remnant dikes, and creation of a deflector dike, all along the right descending bank.

A&M 10. Evaluation of fish assemblages near the Ste. Genevieve Bend, Mississippi. A final report on the fish sampling work at Ste. Genevieve Bend was completed in 1999. The draft copy of this report was included in the 1998 progress report. Rock Hopper bottom trawling was conducted in and near the main channel of the Ste. Genevieve Bend on August 1997. This work was to determine the presence of fish species in these habitats prior to a placement of bendway weirs and to determine if this sampling method is a potentially valuable collection technique in the open river. Weirs were placed in the bend in September 1997. The study serves as a baseline in this area for comparison of fish collection data after the bendway weirs were completed. The full report is in Appendix H.

The fish collection technique appeared to work relatively well outside the main channel on the inside bend (80% of fish captures) but was not as effective in the main channel or main channel border. In fact no fish were captured in two trawls taken in the outer bend of the main channel. Thirty-five fish of 6 species were collected during 8 trawl runs. Species included sicklefin chub *(Macrohybopsis meeki)*, common carp *(Cyprinus carpio)*, channel catfish *(Ictalurus punctatus)*, blue catfish *(Ictalurus furcatus)*, mooneye

(Hiodon tergisus), and shovelnose sturgeon *(Scaphirhynchus platorynchus)*. Although very few fish were captured in the main channel, the only sickle fin chub (Federal candidate species) collected in the effort was in the main channel. Relatively large numbers of shovelnose sturgeon were collected within the inside bend of the navigation channel. Both adults and young-of-year blue catfish and shovelnose sturgeon were captured at the site. It is likely that these two species spawn within the Ste. Genevieve bend vicinity.

The report mentions that the Rock Hopper trawling method was ineffective in strong currents (> 1m/s) as well as dangerous. One potentially effective method of sampling this type of habitat would be to collect data using hydroacoustic equipment. This method would provide a way to collect total fish biomass and size structure estimates, and could be combined with trawling efforts to estimate species composition of the area.

A&M 11. Fish Habitat Sampling Prior to Channel Modifications on the Open River. St. Louis District conducted survey work and fish sampling at two sites proposed for river channel modification. The sites, Greenfield Bend (RM 4) and the bend near the Ohio River confluence (RM 0) will also be surveyed after channel modification. Information gained at these two sites will aid with future A&M dike implementation projects.

11A. Ohio River Confluence Site. New river channel modification structures have been proposed to be added or existing structures modified near RM 0 on the right descending bank of the Mississippi River. Specifically, dike 1.3 on the right bank (R) is to be extended out to the end of dike .8(R) and raised to 15 foot STL (Saint Louis gauge) and sloped up to high bank (HB). Dike .8(R) is planned to also be raised to 15 foot STL at the end and sloped up to HB. At RM .6(R) and RM .3(R) two new dikes of the same elevations as above are planned to be newly constructed, extending out to a line between dikes .1(R) and .8(R). These structures have been proposed in order to widen the navigation channel at the bend where 17 collisions and 3 groundings involving tows have occurred in the last 18 years.

Fish sampling using a modified otter trawl was completed along a sandbar on the inside bend of the Mississippi River across the river from the Ohio River mouth on 13 and 14 September 1999. Sampling was conducted along the entire sandbar at depth intervals of 5 feet, 10 feet, 15 feet and 20 feet. Sampling was conducted with the current. Numbers and species of fish collected included the following: 601 channel catfish *(Ictalurus punctatus)*, 182 speckled chub *(Macrohybopsis aestivalis)*, 79 blue catfish *(Ictalurus furcatus)*, 84 freshwater drum *(Aplodinotus grunniens)*, 17 shovelnose sturgeon *(Scaphirhynchus platorynchu)*, eight gizzard shad *(Dorosoma cepedianum)*, three white bass *(Morone chrysops)*, two silverband shiners *(Notropis shumardi)*, one emerald shiner *(Notropis atherinoides)*, one striped bass *(Morone saxatilis)*, one goldeye *(Hiodon alosoides)*, one sauger *(Stizostedion canadense)*, and one sicklefin chub *(Macrohybopsis meeki)*. Most fish were captured in trawls completed at the 5 and 10-foot intervals.

On 23 September, the M.V. Boyer surveyed the area. Bathymetry, velocity, substrate, and hydroacoustic fisheries information was collected at that time. Substrate appeared to be mostly sand at the middle and lower part of the sandbar, however gravel was picked up in the net on the upper part of the bend. The hydroacoustic data showed that the substrate occurring on the upper end of the site was a coarser material than substrate on the downstream end. Post construction monitoring of bathymetry, velocity, substrate, and hydro acoustic fisheries information are planned to be completed by the M.V. Boyer. Trawl sampling is also planned to be completed.

11B. Greenfield Bend Site. New river channel modification structures were proposed for the Greenfield Bend area. Specifically, two new bendway weirs are proposed to be placed upriver from the existing weir field at RM 4.2 and at RM 4.0. These are being considered due to encroachment of a point bar into the navigation channel on the inside bend.

Sampling was performed at Greenfield Bend on 27 and 28 September 1999. Sampling methods were the same as at the Ohio Mouth site. The bathymetry of the site was quite varied, from very shallow gently sloping bottom, to a very sharp drop off into a 95 ft thalweg hole. In fact, sampling at the middle section of the point bar was deleted because very steep slope conditions made using an otter trawl impractical. Because of river substrate conditions, including snags and substrate type, only three successful trawl hauls were completed on the upper part of the point bar at 10, 15, and 20 feet intervals. One unsuccessful trawl (snag) was attempted at the five-foot interval of the upriver portion of the bar, and one other unsuccessful trawl (snag) was completed at the 10-foot interval of the down river portion of the point bar. No other sampling was attempted at this site.

Fish species collected included speckled chub, shovelnose sturgeon, channel catfish, a blue catfish and one stonecat. The stonecat was collected in the unsuccessful trawl over the cobble substrate on the upper transect. Stonecats are not widely distributed throughout the river, occurring primarily in areas with both flow and rocky crevices. Its capture points to the uniqueness of this site. Contrary to the poor sampling results, the site appeared to have diverse habitat, and a change to sampling methods more appropriate for the site (i.e. seines and trammel nets) could reveal a more diverse group of fishes.

The M.V. Boyer surveyed the area on 23 September. Bathymetry, velocity, substrate, and hydroacoustic fisheries information was collected at that time. Based on field observations, it appears that a large continuous area of gravel substrate exists off the ends of the weirs. The hydroacoustic equipment indicated that there was a substantial number of fish using the deep hole off the end of the last weir. It appears that configuration of the sandbar shelters the hole from most channel flows. Post construction monitoring of bathymetry, velocity, substrate, and hydro acoustic fisheries information are planned to be completed by the M.V. Boyer. Fish sampling is also planned to be completed, however the methods used to capture fish may be changed.

FY 2000 A&M Program

The FY 2000 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 24. At this time, the program is expected to be extended till 2007 to offset the annual differences in funding. Proposed construction activities in 2000 include completion of the chevron dike field above Cottonwood Island (RM 289) and construction of a notched closing structure behind Cottonwood Island in Pool 24. The original plan called for five chevron dikes at the head of Cottonwood Island. Three of the chevron dikes were built in 1993. The remaining two chevron dikes will be constructed in 2000. In addition, the notched closing structure will be built behind Cottonwood Island to decrease sedimentation in the sidechannel. Some of the biological monitoring work to be done in 2000 includes continued sampling at the chevron dike and multiple roundpoint structures and testing of gate manipulation scenarios at Lock and Dam 25 to increase fish passage. Other work in 2000 includes replacing the A&M mooring buoy below Lock and Dam 25, moving the existing buoy to a location below Lock and Dam 22 and finalizing a plan for the creation, protection, and enhancement of open river side channels.

Avoid & Minimize Team

Dave Busse	Corps of Engineers- Project Manager
T. Miller	Corps of Engineers- Technical Manager
Bob Clevinstine	U.S. Fish and Wildlife Service
Joyce Collins	U.S. Fish and Wildlife Service
Dick Steinbach	U.S. Fish and Wildlife Service
Karen Westphall	U.S. Fish and Wildlife Service
Chuck Surprenant	U.S. Fish and Wildlife Service
Tommy Seals	Brown Water Towing (RIAC)
Ed Henleben	ORGULF Transport (RIAC)
Lauren Ward	American Land Conservancy
John Killion	American Land Conservancy
Butch Atwood	Illinois Department of Natural Resources
Gordon Farabee	Missouri Department of Conservation
Ken Dalrymple	Missouri Department of Conservation
Ken Brummett	Missouri Department of Conservation
Bob Hrabik	Missouri Department of Conservation - LTRM
Jenny Frazier	Missouri Department of Conservation - LTRM
Dave Herzog	Missouri Department of Conservation - LTRM
Stan Michaelson	Missouri Department of Conservation
Wayne Porath	Missouri Department of Conservation
Mike Schroer	Missouri Department of Conservation
Mark Haas	Missouri Department of Conservation
Roger Myhre	Corps of Engineers - MVS
John Boeckmann	Corps of Engineers - MVS
Mike Thompson	Corps of Engineers - MVS
Stan Ebersohl	Corps of Engineers - MVS
Dan Erickson	Corps of Engineers - MVS
Dave Gordon	Corps of Engineers - MVS
Steve Redington	Corps of Engineers - MVS
Red Mezo	Corps of Engineers - MVS
Lloyd Coakley	Corps of Engineers - MVS
Rob Davinroy	Corps of Engineers - MVS
Claude Strauser	Corps of Engineers - MVS
Jerry Rapp	Corps of Engineers - MVS
Brian Johnson	Corps of Engineers - MVS
Eric Laux	Corps of Engineers - MVS
Leonard Hopkins	Corps of Engineers - MVS
Maryetta Smith	Corps of Engineers -MVD

APPENDIX A.

1) 1999 Summary report on Pool 26 (river mile 266R) chevron dike sampling, U.S. Army Corps of Engineers, St. Louis District.

2) Cottonwood Island Chevron Dike Fisheries Evaluation Update, Illinois Department of Natural Resources, May 2000

1999 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 recently 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 1998) found that a variety of fishes are using this habitat. The chevron dikes at 266.0 have never been sampled. Chevron dikes have not been sampled in the winter, but it is expected that the area behind the chevron dike provides valuable fish over-wintering habitat.

Sampling to Date: The three chevron dikes at 266.0 were sampled on 4 August 1999 and 13 December 1999.

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 461 fish per acre behind the top chevron dike to 576 fish per acre behind the lower chevron dike. The average density behind the middle chevron dike was 570 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 2,601 and 1,828 for the middle and upper 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.

Table 1. Chevron sampling data from 1999.

	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
Middle Chevron inside	8-4-99	11	402	27.2	Open river
Lower Chevron inside	8-4-99	7	406	27.2	Open river
Upper Chevron inside	12-13-99	9	1823	5	Normal pool
Middle Chevron inside	12-13-99	9	2590	5	Normal pool
Lower Chevron inside	12-13-99	4	0	5	Normal pool
Upper Chevron below	12-13-99	6	0	5	Normal pool
Middle Chevron below	12-13-99	5	0	5	Normal pool
Lower Chevron below	12-13-99	4	0	5	Normal pool
Upper Chevron outside	12-13-99	5	0	5	Normal pool
Lower Chevron outside	12-13-99	5	40	5	Normal pool

Conclusions: Fish were using the chevron dikes during both sampling trips. The upper and middle dikes showed a marked increase in density from the August 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. 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 one 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 sample showed that fish were using all three of the chevron dikes. Further fieldwork should show if the August density numbers were higher than expected densities outside of open river conditions. Because the chevron dikes provide a slack-water refuge from the higher open river flow, it is possible that a higher number of fish were using the dikes than would have been expected during normal pooled summer conditions. Based on the results from Atwood (1998) you would expect fish to be using the dikes year round.

Monitoring at the site will continue in 2000. Presently a summer and a winter sample are scheduled.

References:

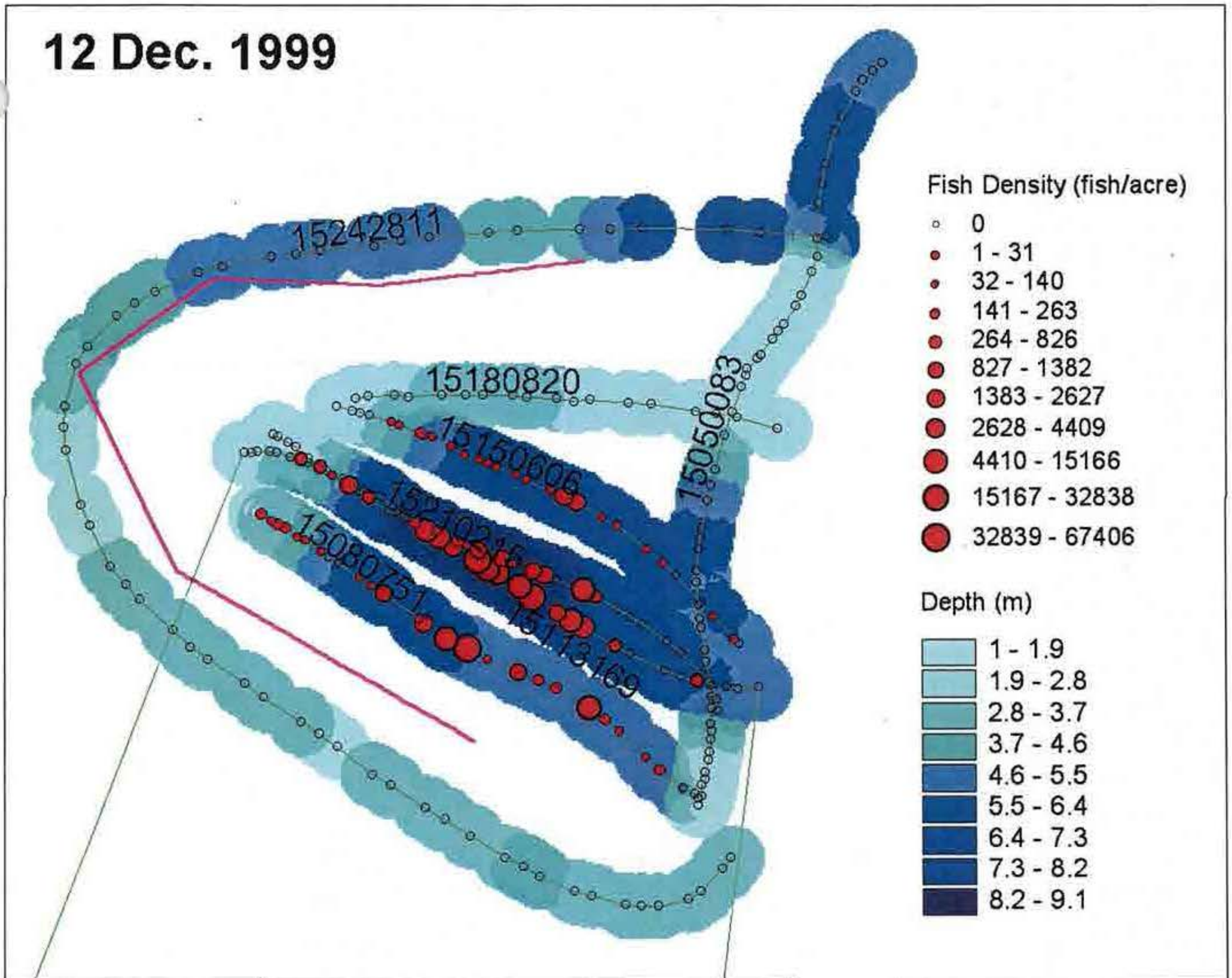
Atwood, E.R. 1998. Cottonwood Island Dike Fisheries Evaluation Update. Prepared for U.S.

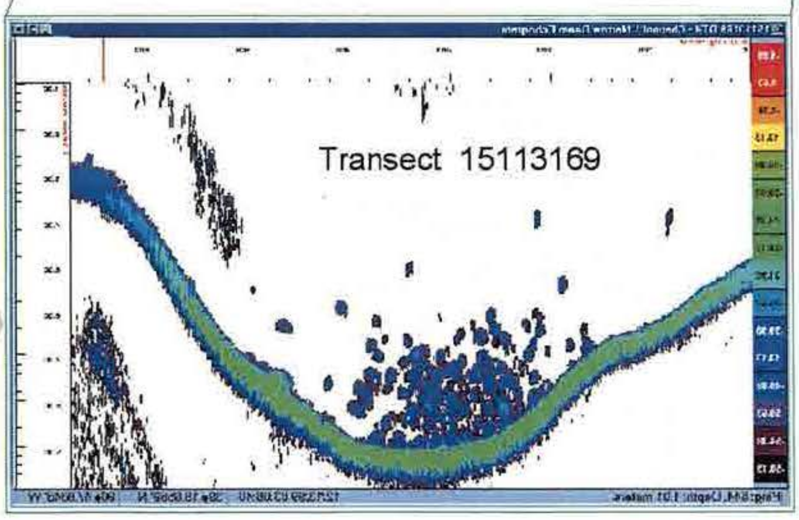
Army Corps of Engineers, St. Louis District. 19 pp.

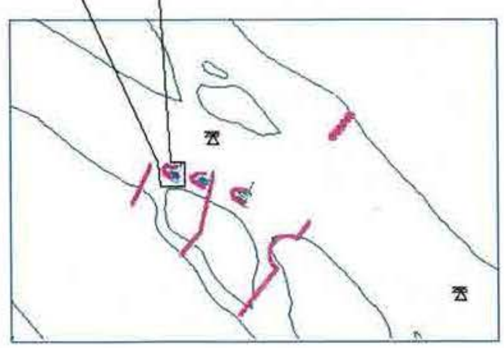
Submitted: 10 March 2000
Revised: 29 March 2000

Brian Johnson, Fishery Biologist
US Army Corps of Engineers, St. Louis District
Planning, Programs, and Project Management Division
Environmental and Economics Branch, Environmental Section

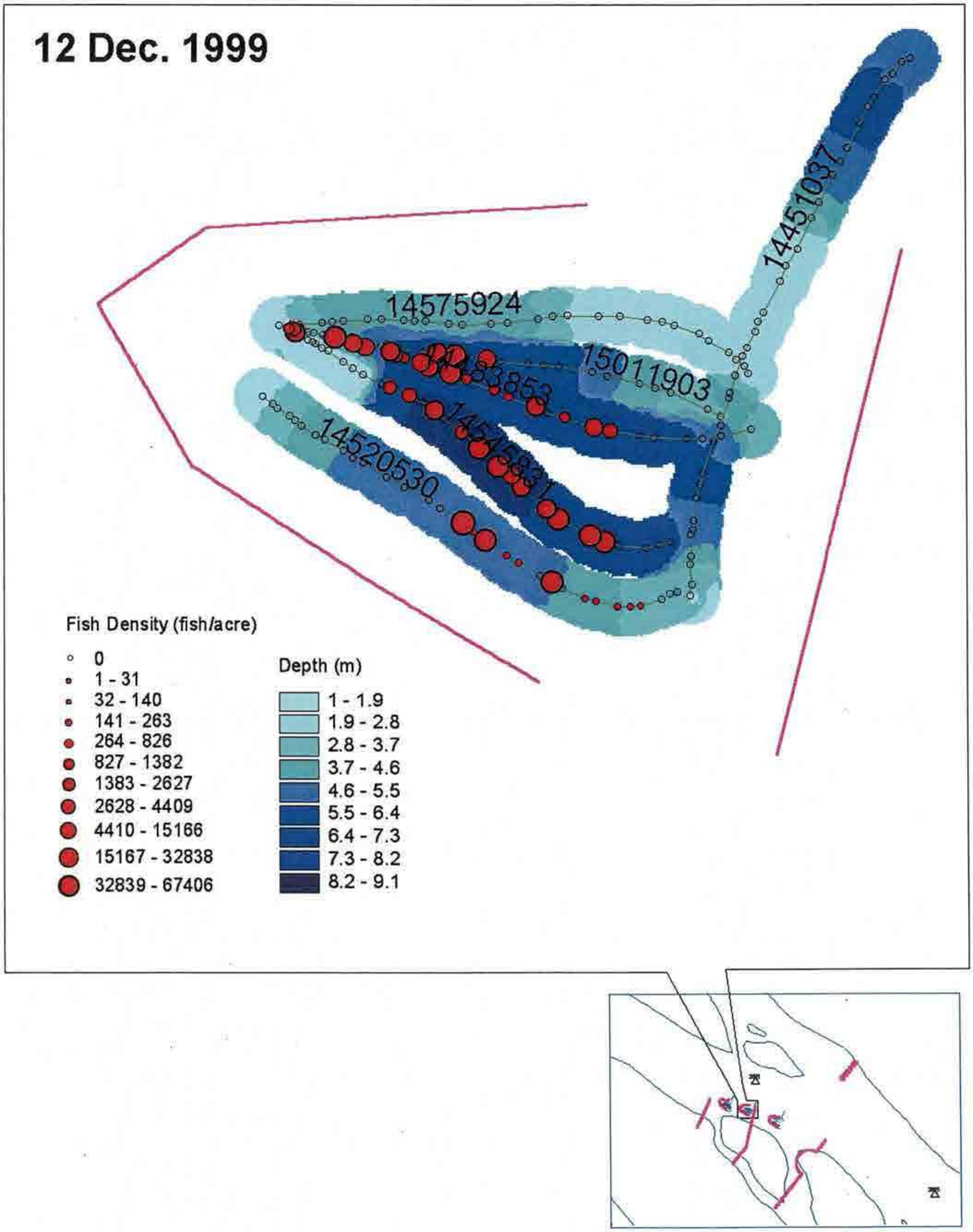
Upstream Chevron



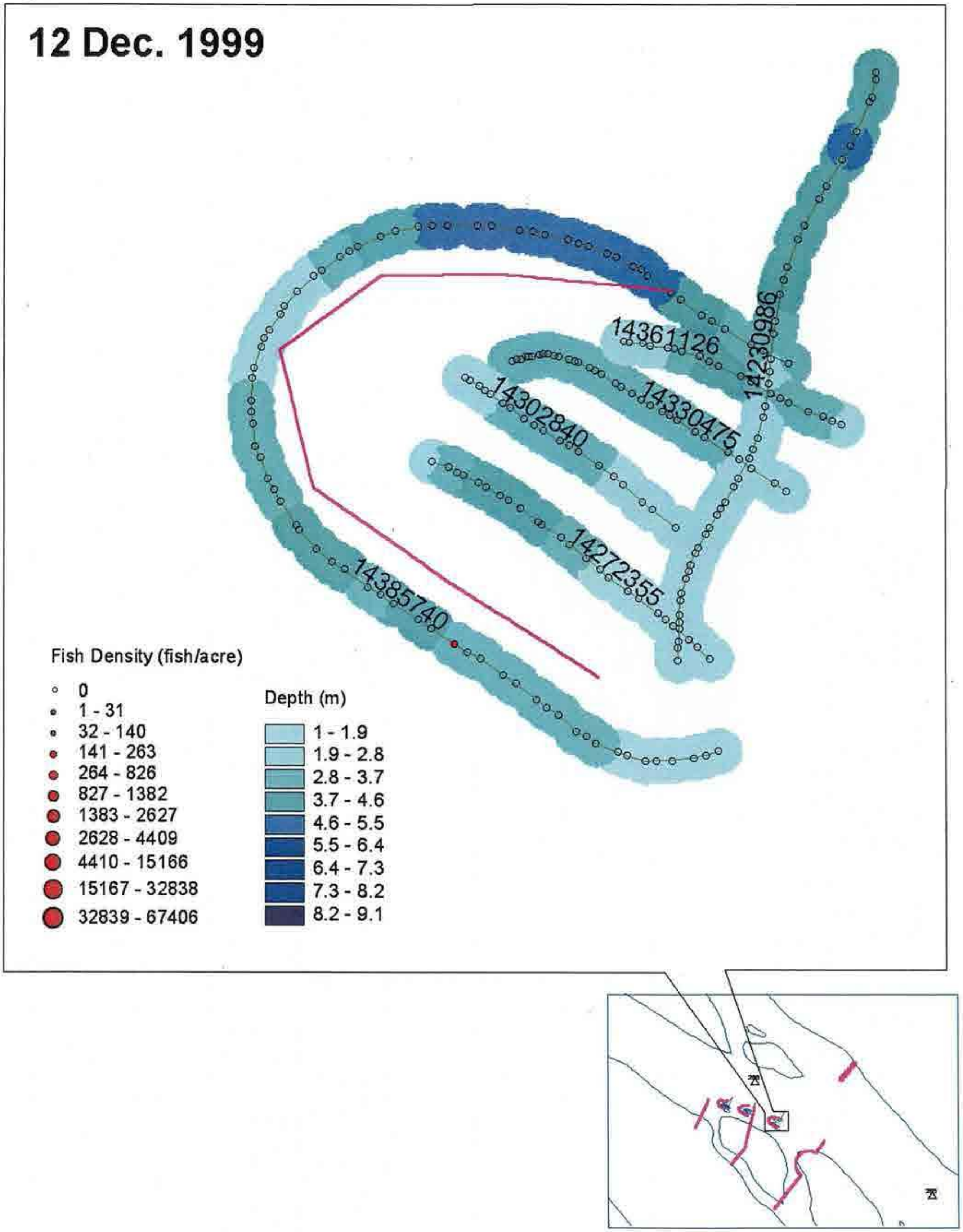


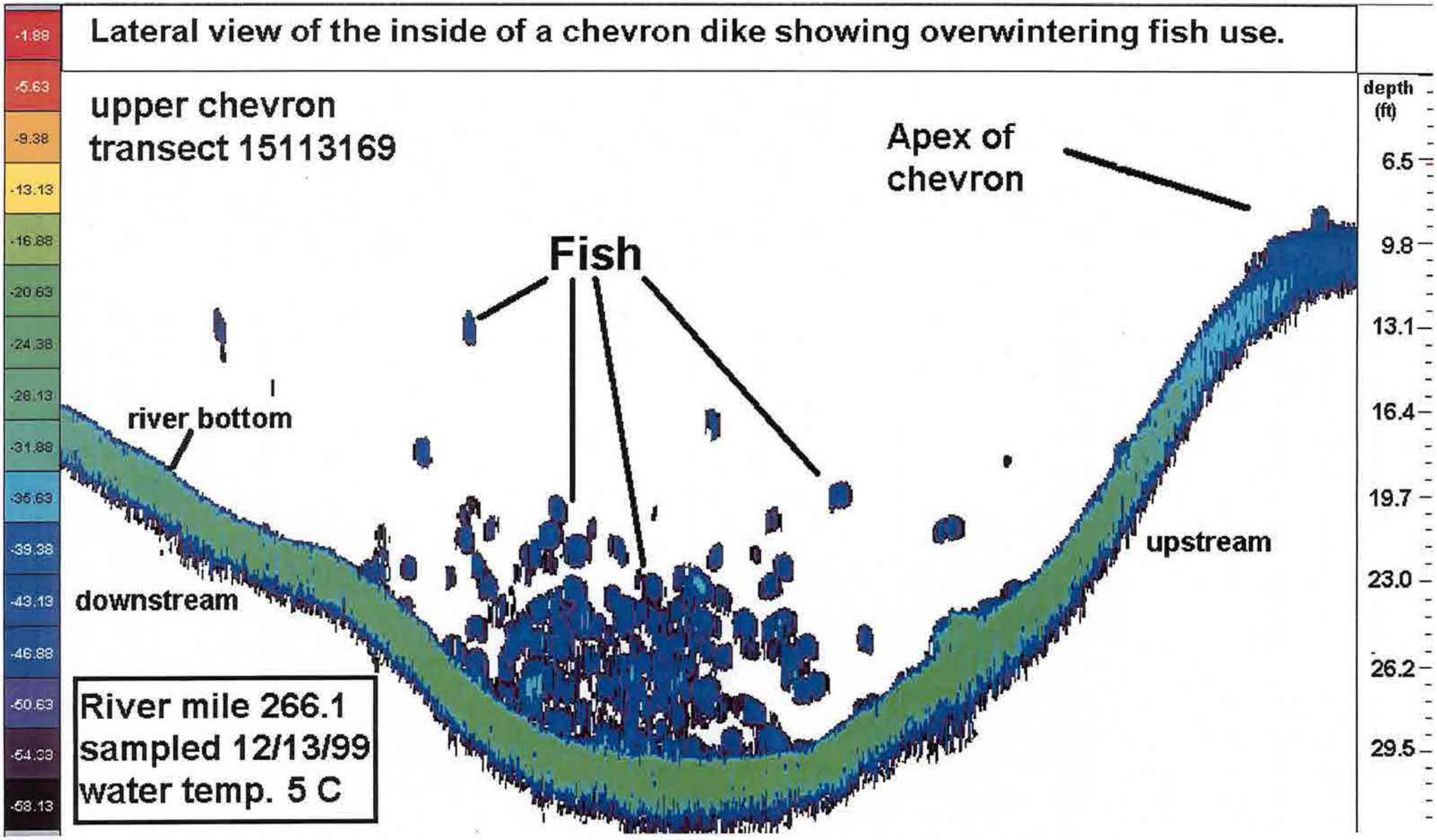


Middle Chevron

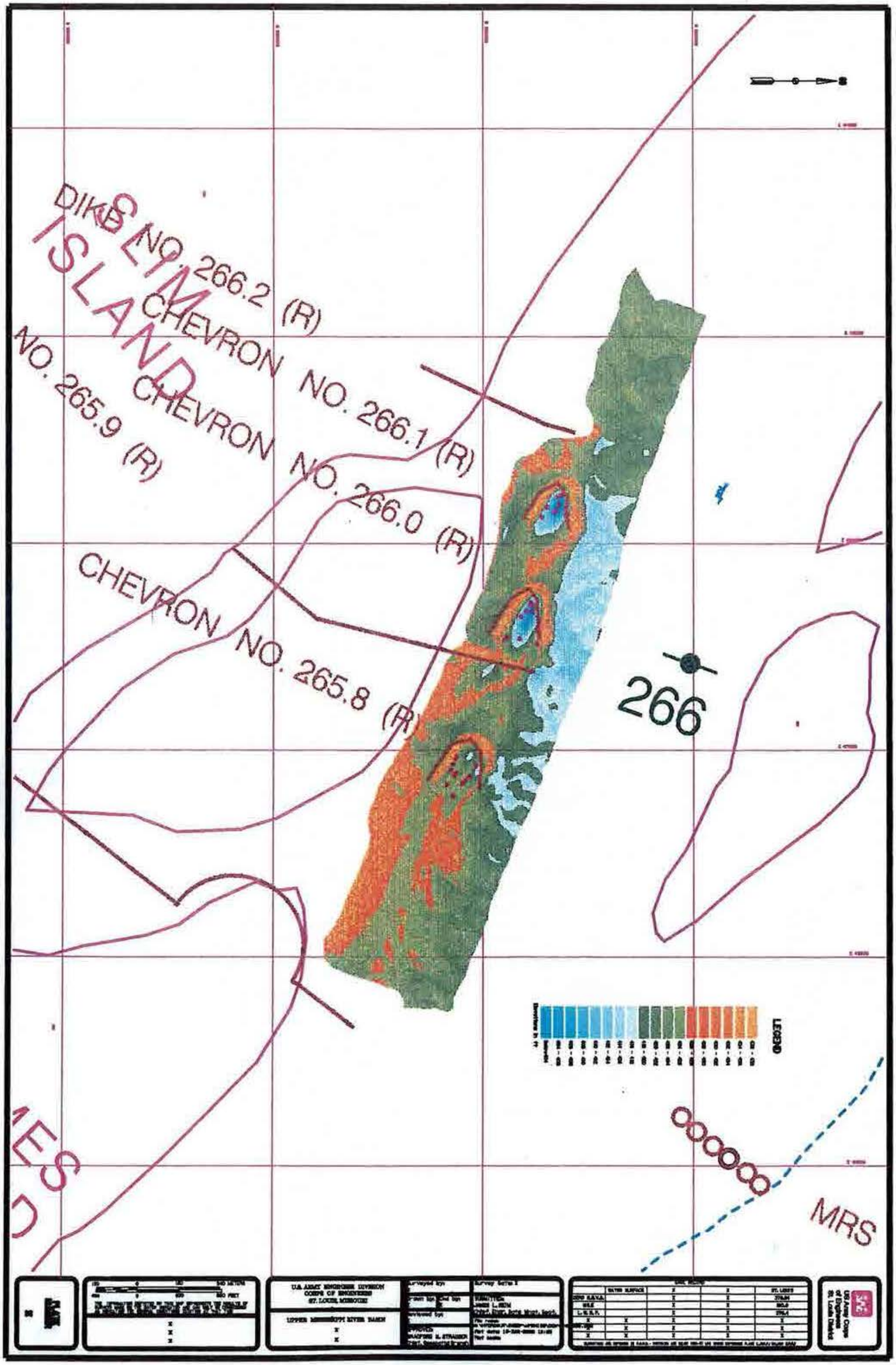


Downstream Chevron





Lateral view of the inside of a chevron dike showing overwintering fish use.
upper chevron
transect 15113169
Apex of
chevron
Fish
river bottom
downstream
upstream
River mile 266.1
sampled 12/13/99
water temp. 5 C
depth
(ft)
6.5
9.8
13.1
16.4
19.7
23.0
26.2
29.5
-1.88
-5.63
-9.38
-13.13
-16.88
-20.63
-24.38
-28.13
-31.88
-35.63
-39.38
-43.13
-46.88
-50.63
-54.38
-58.13



DIKE NO. 266.2 (R)
CHEVRON NO. 266.1 (R)
CHEVRON NO. 266.0 (R)
NO. 265.9 (R)
CHEVRON NO. 265.8 (R)
ISLAND
266
MRS
LEGEND

Cottonwood Island Chevron Dike
Fisheries Evaluation Update

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

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

May 2000

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 Chevrons since October 1993. The upstream and downstream most chevrons have been sampled, along with a small backwater slough at Drift Island as a control site. In 1998 two additional control sites (Head of Bay Island and main channel border along Cottonwood Island, adjacent to the upper chevron) were sampled to evaluate 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.

Methods

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 an 18' welded aluminum boat. The electrodes are approximately 5' apart, project about 6' off the bow and project to a water depth of about 4', 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, measured, checked for abnormalities and disease, and 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 6153 fishes representing 53 species have been collected during 985 minutes of electrofishing (93.70 fish/15 ef min). When these data are summarized by habitat type (inside, outside, Drift Is.) over all sampling periods (Table 2), the highest catch rate was observed inside the chevrons (135.21 fish/15 min EF), followed by Drift Island Slough (78.64 fish/15 min EF) and outside the chevrons (74.10 fish/15 min EF). The number of species collected was also highest inside the chevrons (41 species) [Table 2], followed by Drift Island Slough (36 species) and outside the chevrons (29 species). Table 3 summarizes fish collections from all sites sampled to date.

When the number of species collected per site are compared (Figure 1), the highest species richness was observed from inside the upper chevron (37 species) followed by Drift Island

Slough (36 species), lower inside and upper outside (28 species), Head of Bay Island (25) 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 137.08 fish/15 min EF, followed by lower inside (130.94 fish/15 min) and Drift Island Slough (97.59 fish/15 min) [Figure 2]. These data suggest that the habitat types created inside the chevron dikes are holding more individual fishes and more fish species per unit area than either the habitat immediately outside of the chevrons or the slough habitat.

A similar picture emerges when the catch rates by site of selected individual fish species 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, but higher (and similar) 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).

A broader and more holistic view, however, is to look at chevrons in their entirety, with habitats inside and outside as an interacting, integrated whole. When observed from this perspective, as a single habitat unit or a chevron dike field, we notice that of the 54 species collected so far in this study effort, 48 are associated with chevrons (Table 2).

An examination of the length frequencies of selected fishes collected from the vicinity of the chevrons (inside and outside) and Drift Island Slough helps illustrate the similarities and differences in the fish populations inhabitating these two habitat types. For instance, although smallmouth buffalo densities associated with the chevrons are considerably less than those in Drift Island Slough, the size range observed for this species is greater in the vicinity of the chevrons than in the slough and it appears chevrons are providing higher quality nursery habitat for these fishes than is the slough habitat (Figures 11 and 12). Largemouth bass and bluegill densities are also much higher in Drift Island Slough and the size ranges are also greater (Figures 13, 14, 15 and 16). Similar to smallmouth buffalo, the proportion of juvenile largemouth bass and bluegill observed in the vicinity of the chevrons is higher than those associated with the slough, probably indicating the favorable juvenile habitat conditions provided inside the chevrons.

It's also interesting to look at the density and size differences between lotic fish species collected inside and outside the chevrons, such as channel catfish and white bass, and may help illustrate possible biotic interactions between the inside and outside chevron habitat types.

The channel catfish catch rate was more than 3.5 times higher along the outside of the chevrons than inside (Table 2), suggesting higher densities outside. The size structure of channel catfish collected inside and outside indicates similar sized fishes are utilizing both areas (Figures 17 and 18). The catch rate data coupled with the length frequency data suggests that adult fish are residing most often outside the chevrons and occasional move into the inside. The purpose of such movement is unknown, but at least two possibilities exist: 1) channel catfish use the inside as a temporary resting place from high current velocities experienced on outside, and 2) they are utilizing the slightly higher density of forage fishes and slighter different macroinvertebrate assemblage (Ecological Specialists, Inc 1997) found inside.

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 fish, while the most of those fish collected on the outside of the chevrons were one year or older, suggesting, again the interior habitat is providing valuable nursery habitat for young fishes.

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	Lower Chevron Inside	9
14-Oct-93	Lower Chevron Outside	9
14-Oct-93	Upper Chevron Inside	9
14-Oct-93	Upper Chevron Outside	9
21-Jul-95	Drift Island Slough	60
02-Aug-95	Upper Chevron Inside	14
02-Aug-95	Upper Chevron Outside	14
12-Sep-95	Lower Chevron Inside	16
12-Sep-95	Lower Chevron Outside	16
12-Sep-95	Upper Chevron Inside	16
12-Sep-95	Upper Chevron Outside	16
11-Oct-95	Upper Chevron Inside	14
11-Oct-95	Upper Chevron Outside	14
12-Aug-96	Drift Island Slough	60
14-Aug-96	Lower Chevron Inside	15
14-Aug-96	Lower Chevron Outside	15
14-Aug-96	Upper Chevron Inside	15
14-Aug-96	Upper Chevron Outside	15
09-Sep-96	Drift Island Slough	15
09-Sep-96	Lower Chevron Outside	15
09-Sep-96	Upper Chevron Inside	15
09-Sep-96	Upper Chevron Outside	15
08-Oct-96	Drift Island Slough	15
08-Oct-96	Lower Chevron Outside	15
08-Oct-96	Upper Chevron Inside	15
08-Oct-96	Upper Chevron Outside	15
16-Jul-97	Lower Chevron Inside	15
16-Jul-97	Lower Chevron Outside	15
16-Jul-97	Upper Chevron Inside	10
16-Jul-97	Upper Chevron Outside	10
04-Aug-97	Drift Island Slough	60
26-Sep-97	Upper Chevron Inside	15
26-Sep-97	Upper Chevron Outside	15
12-Jun-98	Cottonwood MCB	20
12-Jun-98	Lower Chevron Inside	15
12-Jun-98	Upper Chevron Inside	15
12-Jun-98	Upper Chevron Outside	20
06-Aug-98	Drift Island Slough	60
17-Aug-98	Lower Chevron Inside	15
17-Aug-98	Lower Chevron Outside	15
17-Aug-98	Upper Chevron Inside	15
17-Aug-98	Upper Chevron Outside	15
14-Oct-98	Head of Bay Island	20
14-Oct-98	Upper Chevron Inside	15
14-Oct-98	Upper Chevron Outside	15
25-Aug-99	Drift Island Slough	60
26-Aug-99	Head of Bay Island	15
26-Aug-99	Upper Chevron Inside	15
26-Aug-99	Upper Chevron Outside	15
23-Sep-99	Head of Bay Island	20
23-Sep-99	Upper Chevron Inside	12
23-Sep-99	Upper Chevron Outside	12
	Total effort to date	985

Table 2. Compostition of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes study area, 19

	Chevron Inside		Chevron Outside		Chevron Total		Drift Is. Slough		All Stations	
sampling effort (min)	280		300		580		330		910	
Species	N	N/15min	N	N/15min	N	N/15min	N	N/15min	N	N/15min
Shortnose gar	4	0.21	0	0	4	0.10	3	0.14	7	0.12
Longnose gar	0	0.00	0	0.00	0	0.00	5	0.23	5	0.08
Bowfin	0	0.00	0	0.00	0	0.00	21	0.95	21	0.35
American eel	0	0.00	2	0.10	2	0.05	0	0.00	2	0.03
Skipjack herring	1	0.05	0	0.00	1	0.03	0	0.00	1	0.02
Gizzard shad	786	42.11	153	7.65	939	24.28	281	12.77	1220	20.11
Threadfin shad	1	0.05	0	0.00	1	0.03	0	0.00	1	0.02
Mooneye	0	0.00	3	0.15	3	0.08	0	0.00	3	0.05
Goldfish	1	0.05	0	0.00	1	0.03	0	0.00	1	0.02
Carp	36	1.93	97	4.85	133	3.44	106	4.82	239	3.94
Bighead carp	1	0.05	0	0.00	1	0.03	1	0.05	2	0.03
Silver carp	0	0.00	0	0.00	0	0.00	1	0.05	1	0.02
Carp x Goldfish	0	0.00	0	0.00	0	0.00	1	0.05	1	0.02
Central stoneroller	0	0.00	1	0.05	1	0.03	0	0.00	1	0.02
Suckermouth minnow	5	0.27	0	0.00	5	0.13	0	0.00	5	0.08
Silver chub	7	0.38	11	0.55	18	0.47	9	0.41	27	0.45
Spotfin shiner	82	4.39	174	8.70	256	6.62	3	0.14	259	4.27
Red shiner	6	0.32	15	0.75	21	0.54	0	0.00	21	0.35
Bluntnose minnow	4	0.21	2	0.10	6	0.16	1	0.05	7	0.12
Bullhead minnow	420	22.50	28	1.40	448	11.59	38	1.73	486	8.01
Emerald shiner	344	18.43	588	29.40	932	24.10	1	0.05	933	15.38
Silverband shiner	1	0.05	0	0.00	1	0.03	0	0.00	1	0.02
River shiner	46	2.46	28	1.40	74	1.91	0	0.00	74	1.22
Bigmouth shiner	0	0.00	1	0.05	1	0.03	0	0.00	1	0.02
Sand shiner	6	0.32	14	0.70	20	0.52	0	0.00	20	0.33
Mimic shiner	64	3.43	31	1.55	95	2.46	1	0.05	96	1.58
Spottail shiner	4	0.21	0	0.00	4	0.10	0	0.00	4	0.07
Shiner spp.	13	0.70	0	0.00	13	0.34	0	0.00	13	0.21
Bigmouth buffalo	17	0.91	0	0.00	17	0.44	106	4.82	123	2.03
Smallmouth buffalo	59	3.16	25	1.25	84	2.17	224	10.18	308	5.08
Black buffalo	1	0.05	0	0.00	1	0.03	9	0.41	10	0.16
Unidentified Carpsucker	14	0.75	0	0.00	14	0.36	0	0.00	14	0.23
Quillback	14	0.75	0	0.00	14	0.36	1	0.05	15	0.25
River carpsucker	73	3.91	1	0.05	74	1.91	19	0.86	93	1.53
Spotted sucker	0	0.00	0	0.00	0	0.00	2	0.09	2	0.03
Shorthead redhorse	4	0.21	9	0.45	13	0.34	2	0.09	15	0.25
Golden redhorse	3	0.16	0	0.00	3	0.08	0	0.00	3	0.05
Channel catfish	29	1.55	109	5.45	138	3.57	33	1.50	171	2.82
Flathead catfish	4	0.21	91	4.55	95	2.46	26	1.18	121	1.99
Freckled madtom	0	0.00	1	0.05	1	0.03	0	0.00	1	0.02
Mosquitofish	15	0.80	0	0.00	15	0.39	41	1.86	56	0.92
Brook silverside	1	0.05	0	0.00	1	0.03	0	0.00	1	0.02
White bass	32	1.71	14	0.70	46	1.19	3	0.14	49	0.81
Yellow bass	0	0.00	1	0.05	1	0.03	0	0.00	1	0.02
Black crappie	5	0.27	0	0.00	5	0.13	104	4.73	109	1.80
White crappie	2	0.11	0	0.00	2	0.05	40	1.82	42	0.69
Largemouth bass	36	1.93	5	0.25	41	1.06	80	3.64	121	1.99
Smallmouth bass	0	0.00	4	0.20	4	0.10	0	0.00	4	0.07
Warmouth	1	0.05	0	0.00	1	0.03	8	0.36	9	0.15
Green sunfish	52	2.79	7	0.35	59	1.53	2	0.09	61	1.01
Bluegill x Green sunfish	1	0.05	0	0.00	1	0.03	0	0.00	1	0.02
Bluegill	133	7.13	18	0.90	151	3.91	669	30.41	820	13.52
Redear sunfish	0	0.00	0	0.00	0	0.00	1	0.05	1	0.02
Orangespotted sunfish	56	3.00	0	0.00	56	1.45	231	10.50	287	4.73
Sauger	3	0.16	0	0.00	3	0.08	1	0.05	4	0.07
Logperch	1	0.05	1	0.05	2	0.05	2	0.09	4	0.07
Mud darter	0	0.00	0	0.00	0	0.00	1	0.05	1	0.02
Freshwater drum	136	7.29	48	2.40	184	4.76	70	3.18	254	4.19
Total number fish collected	2524	135.21	1482	74.10	4006	103.60	1730	78.64	5736	94.55
Number of species collected	41		29		48		36		54	

Table 3. Summary of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes study area, 1993 - 1999.

	Chevrons				Control sites			
	Lower inside	Lower outside	Upper inside	Upper outside	Drift Is. Slough	Head of Bay Is.	MCB	All Stations
sampling effort (min)	85	100	195	200	330	55	20	985
Species								
Shortnose gar	0	0	4	0	3	1	0	7
Longnose gar	0	0	0	0	5	0	0	5
Bowfin	0	0	0	0	21	0	0	21
American eel	0	0	0	2	0	0	0	2
Skipjack herring	0	0	1	0	0	1	0	1
Gizzard shad	215	41	571	112	281	6	5	1220
Threadfin shad	1	0	0	0	0	0	0	1
Mooneye	0	0	0	3	0	0	0	3
Bighead carp	1	0	0	0	1	0	0	2
Silver carp	0	0	0	0	1	0	0	1
Goldfish	0	0	1	0	0	0	0	1
Carp	7	27	29	70	106	37	4	239
Carp x Goldfish	0	0	0	0	1	0	0	1
Central stoneroller	0	0	0	1	0	1	0	1
Suckermouth minnow	3	0	2	0	0	0	0	5
Silver chub	0	2	7	9	9	0	0	27
Spotfin shiner	52	57	30	117	3	20	3	259
Red shiner	1	5	5	10	0	21	0	21
Bluntnose minnow	1	0	3	2	1	0	0	7
Bullhead minnow	114	7	306	21	38	5	1	486
Emerald shiner	119	194	225	394	1	46	3	933
Silverband shiner	1	0	0	0	0	0	0	1
River shiner	20	13	26	15	0	0	2	74
Bigmouth shiner	0	0	0	1	0	0	0	1
Sand shiner	0	1	6	13	0	0	0	20
Mimic shiner	5	8	59	23	1	2	2	96
Spottail shiner	0	0	4	0	0	0	0	4
Shiner spp.	0	0	13	0	0	0	0	13
Bigmouth buffalo	10	0	7	0	106	7	0	123
Smallmouth buffalo	27	8	32	17	224	1	2	308
Black buffalo	1	0	0	0	9	2	0	10
Quillback	5	0	9	0	1	0	1	15
River carpsucker	30	0	43	1	19	0	3	93
Carpsucker spp.	0	0	14	0	0	0	0	14
Spotted sucker	0	0	0	0	2	0	0	2
Shorthead redhorse	0	4	4	5	2	4	5	15
Golden redhorse	1	0	2	0	0	1	1	3
Channel catfish	8	56	21	53	33	10	2	171
Flathead catfish	3	27	1	64	26	1	0	121
Freckled madtom	0	0	0	1	0	0	0	1
Mosquitofish	0	0	15	0	41	1	0	56
Brook silverside	0	0	1	0	0	0	0	1
White bass	14	5	18	9	3	5	1	49
Yellow bass	0	1	0	0	0	0	0	1
Black crappie	3	0	2	0	104	5	0	109
White crappie	0	0	2	0	40	1	0	42
Largemouth bass	11	0	25	5	80	4	0	121
Smallmouth bass	0	1	0	3	0	0	0	4
Warmouth	0	0	1	0	8	0	0	9
Green sunfish	4	0	48	7	2	0	0	61
Bluegill	23	4	110	14	669	23	1	820
Redear sunfish	0	0	0	0	1	0	0	1
Orangespotted sunfish	23	0	33	0	231	3	0	287
Bluegill x Green sunfish	0	0	1	0	0	0	0	1
Sauger	0	0	3	0	1	0	0	4
Logperch	0	0	1	1	2	0	0	4
Mud darter	0	0	0	0	1	0	0	1
Freshwater drum	39	18	97	30	70	10	4	254
Total number fish collected	742	479	1782	1003	2147	218	40	6153
Number of species collected	28	19	37	28	36	25	16	53

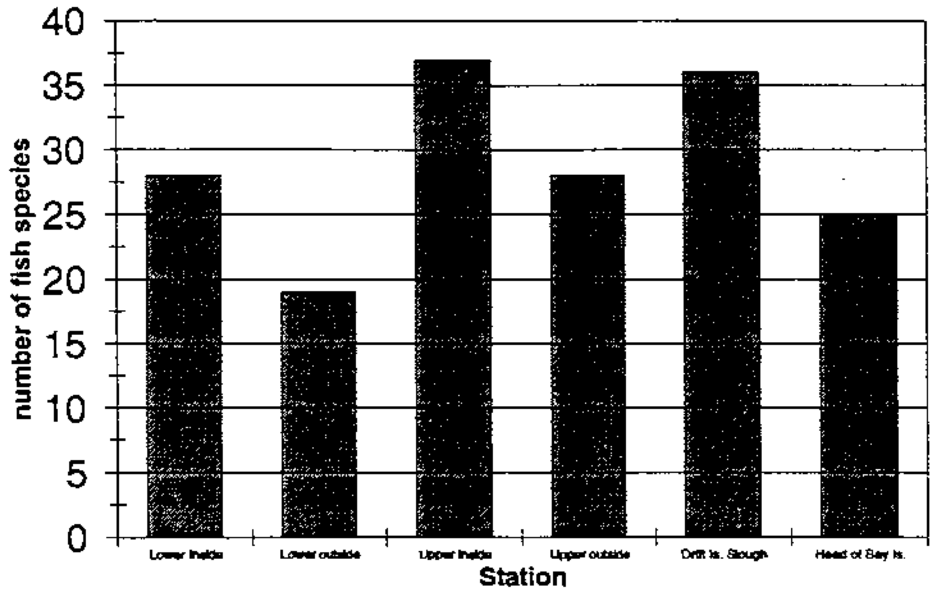


Figure 1. Total number of fish species collected with electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

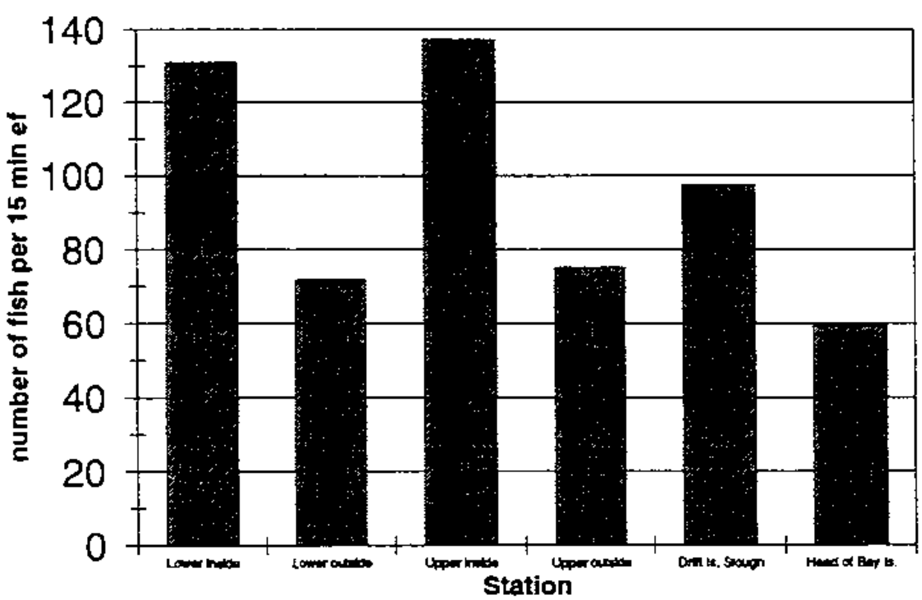


Figure 2. Total number of fish collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

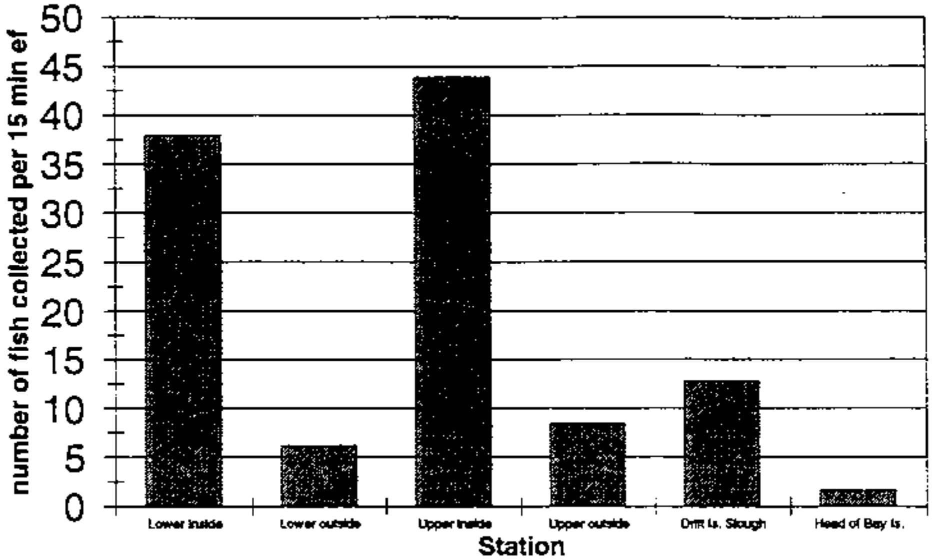


Figure 3. Total number of gizzard shad collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999

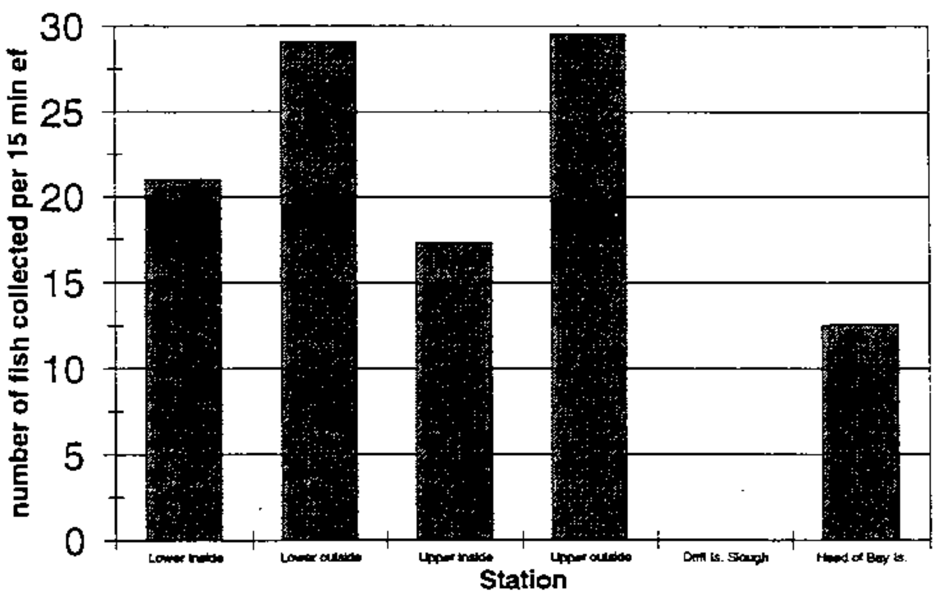


Figure 4. Total number of emerald shiner collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

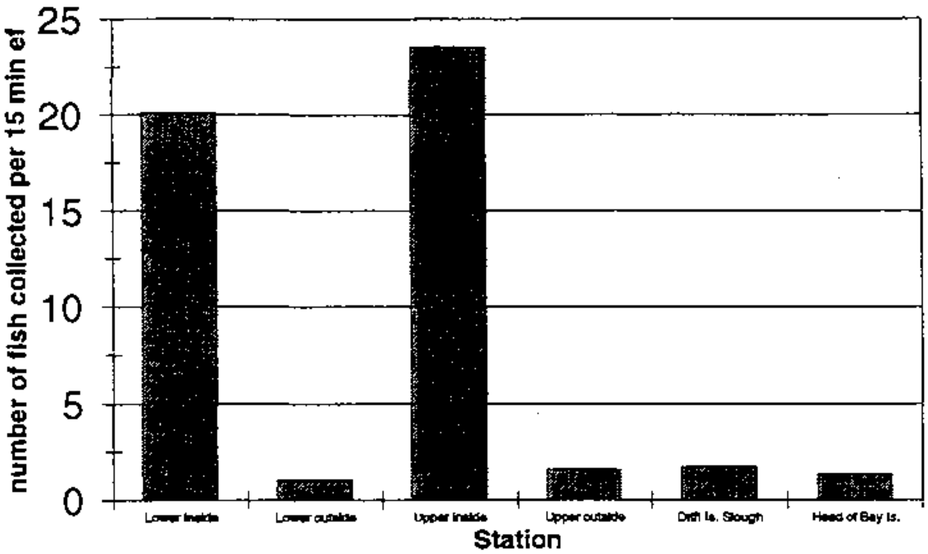


Figure 5. Total number of bullhead minnow collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

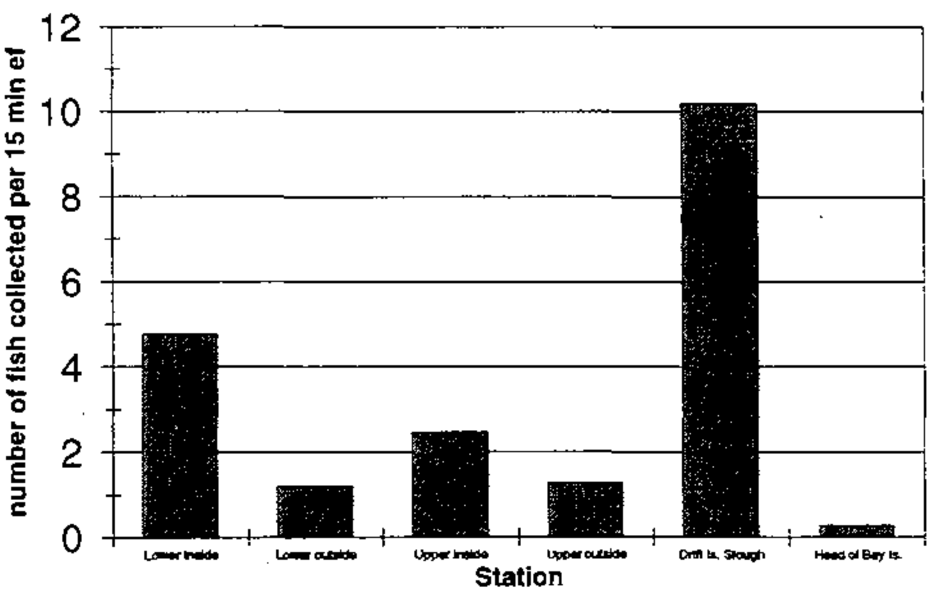


Figure 6. Total number of smallmouth buffalo collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

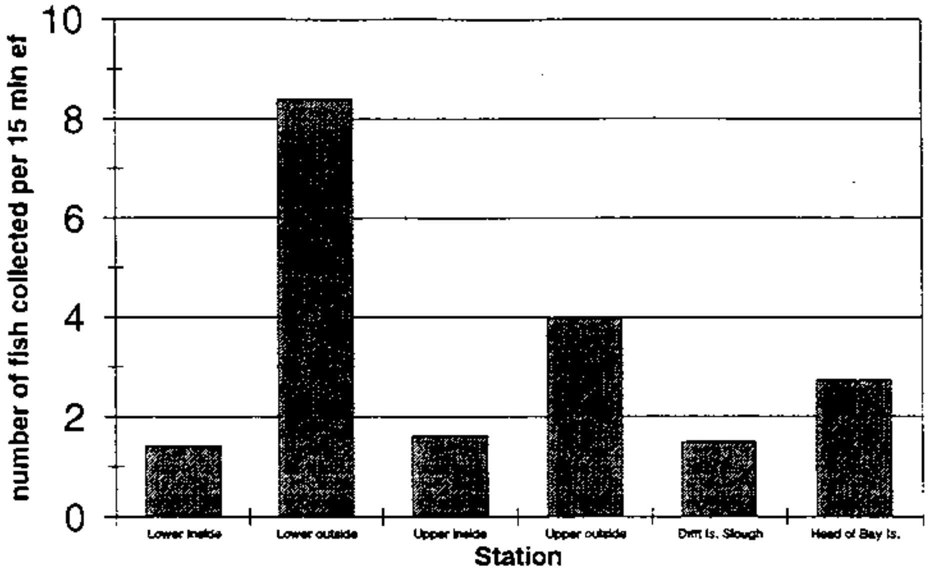


Figure 7. Total number of channel catfish collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

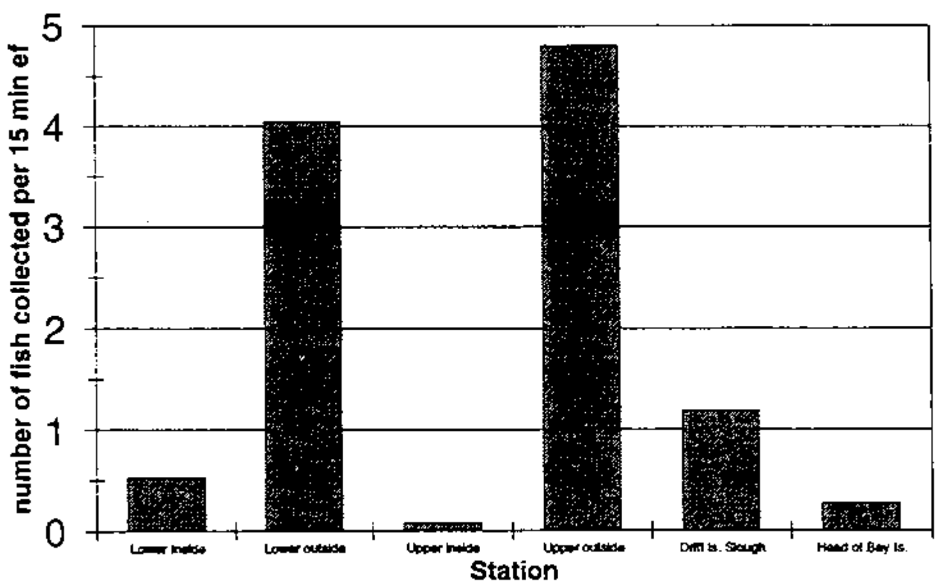


Figure 8. Total number of flathead catfish collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

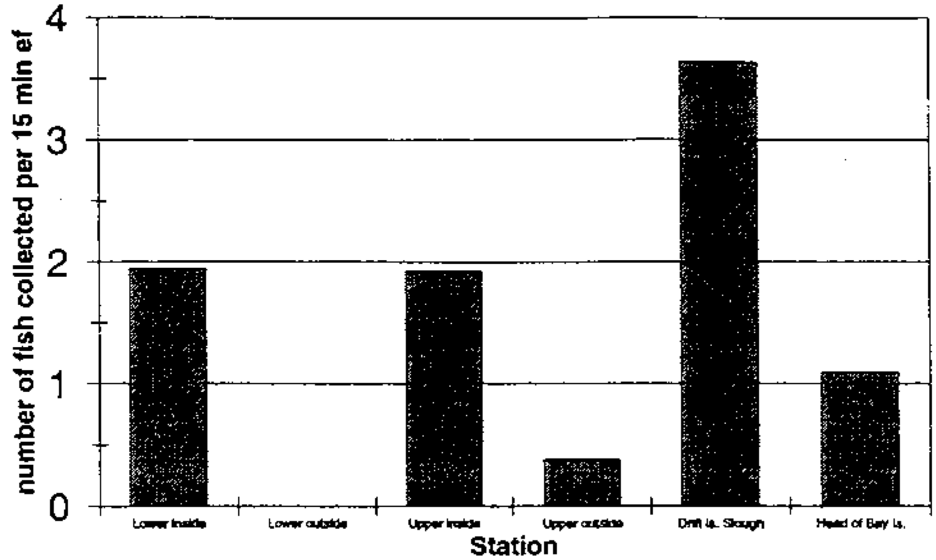


Figure 9. Total number of largemouth bass collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

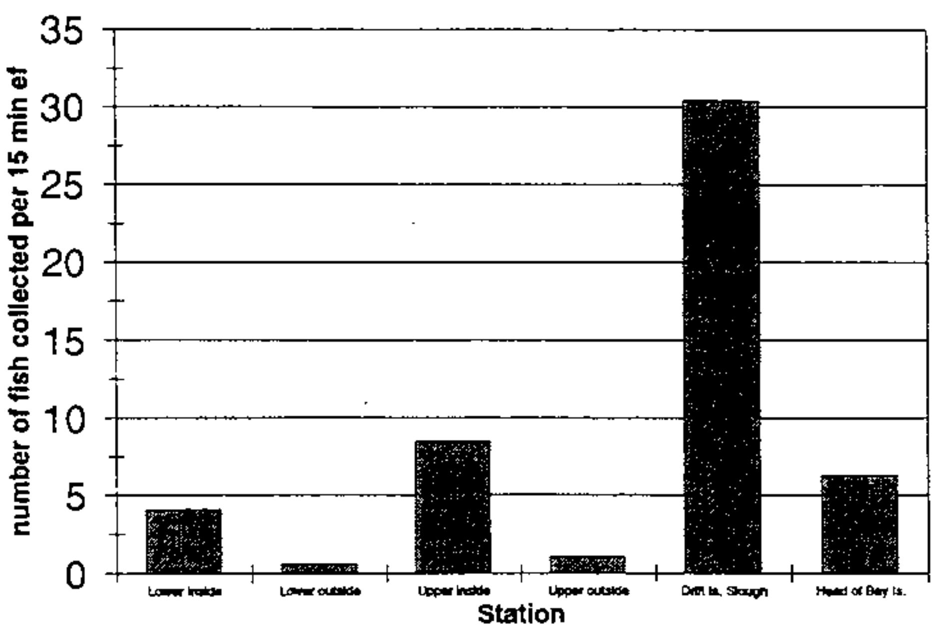


Figure10. Total number of bluegill collected per 15 min of electrofishing at Cottonwood Island Chevrons, Drift Island Slough and Head of Bay Island, 1993 - 1999.

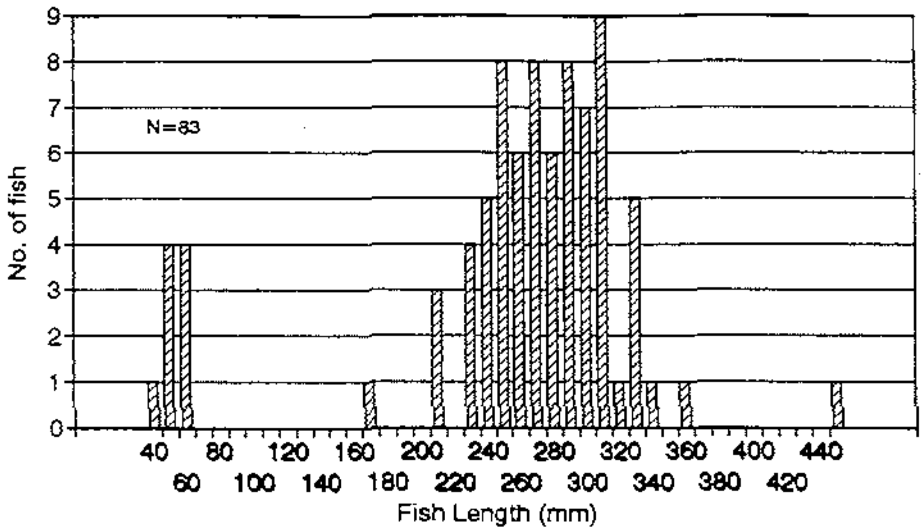


Figure 11. Length frequency of smallmouth buffalo collected inside and outside of Cottonwood Island chevron dikes, 1993 - 1998.

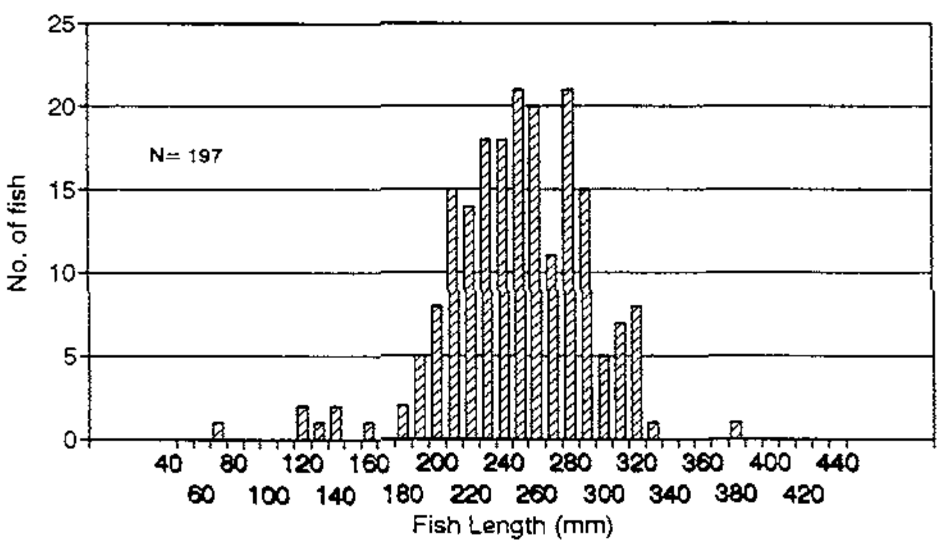


Figure 12. Length frequency of smallmouth buffalo collected at Drift Island Slough, 1993 - 1998.

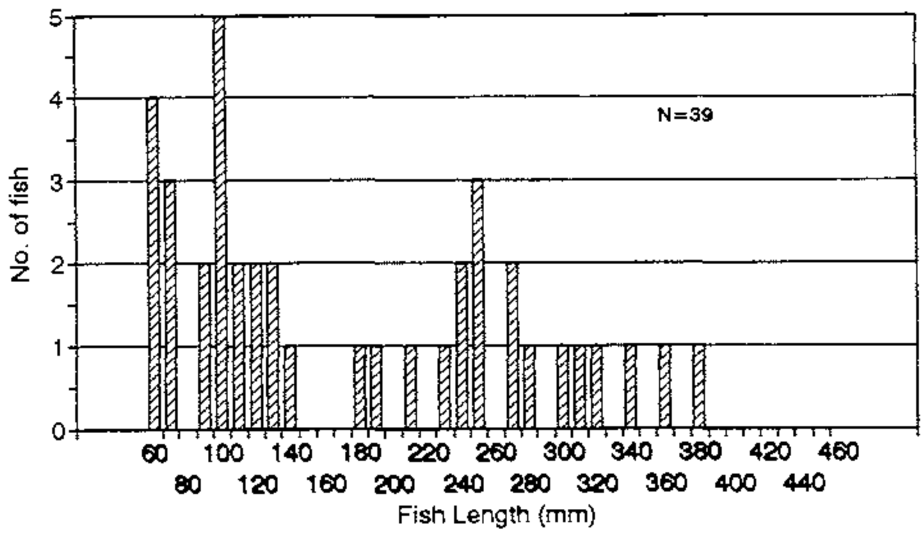


Figure 13. Length frequency of largemouth bass collected inside and outside of Cottonwood Island chevron dikes, 1993 - 1998.

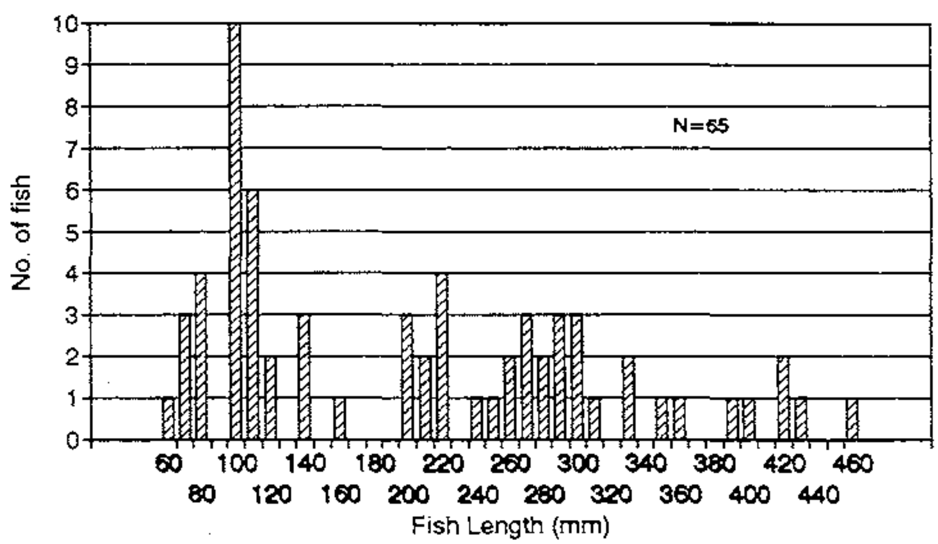


Figure 14. Length frequency of largemouth bass collected at Drift Island Slough, 1993 - 1998.

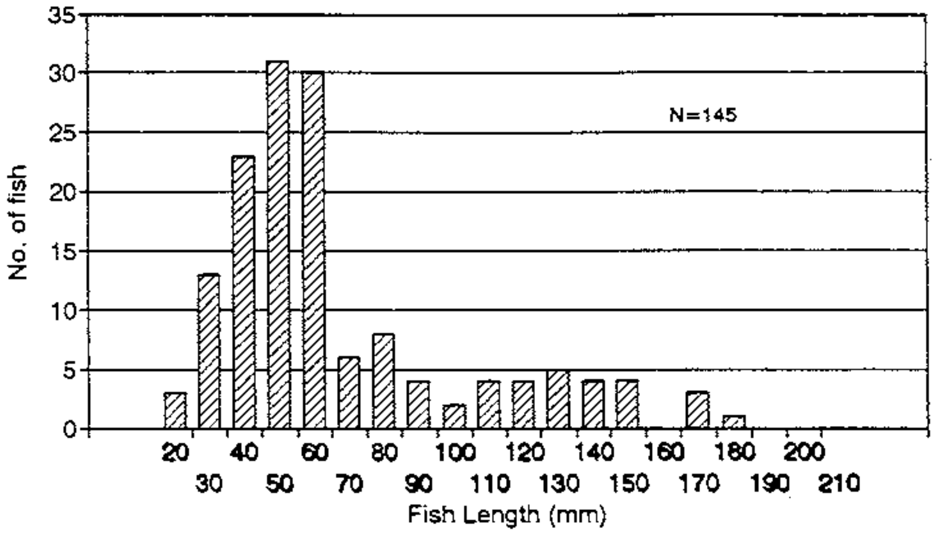


Figure 15. Length frequency of bluegill collected inside and outside at Cottonwood Island chevron dikes, 1993 - 1998.

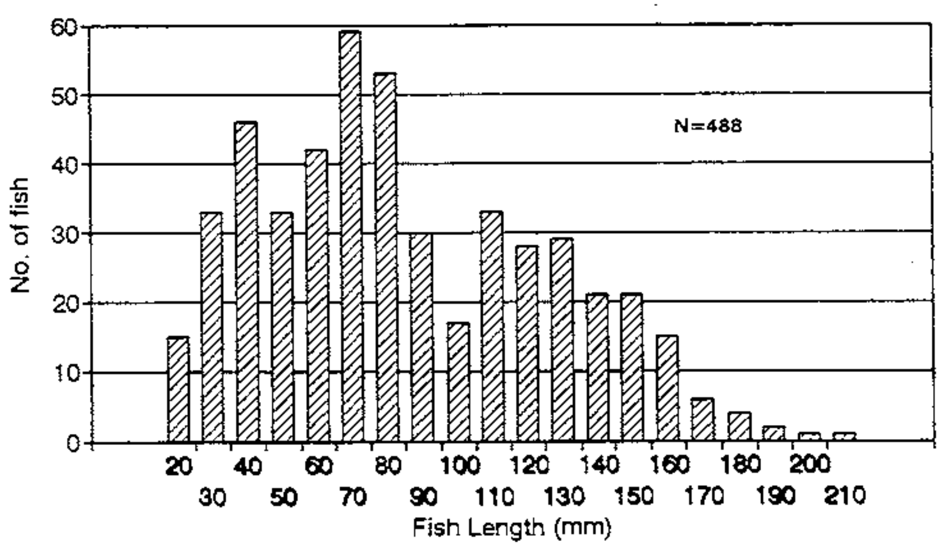


Figure 16. Length frequency of bluegill collected at Drift Island Slough, 1993 - 1998.

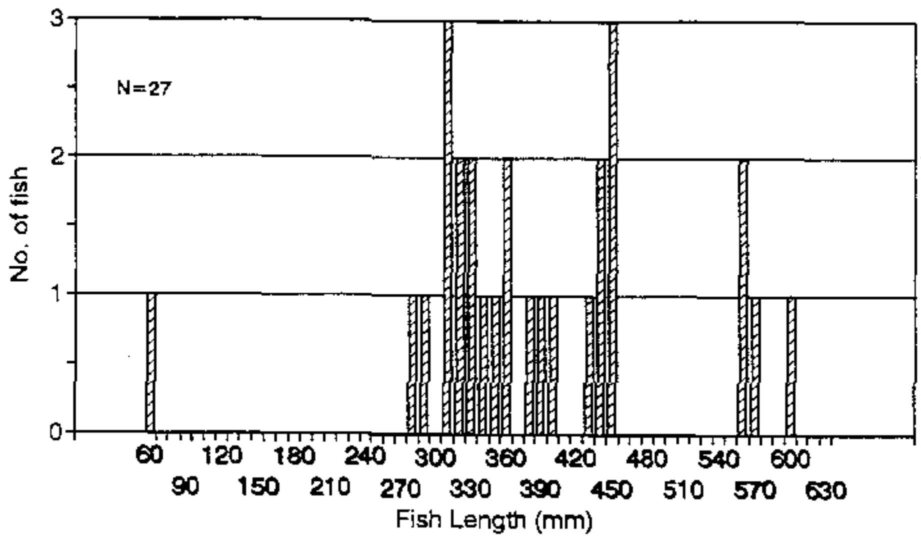


Figure 17. Length frequency of channel catfish collected inside at Cottonwood Island chevrons, 1993 - 1998.

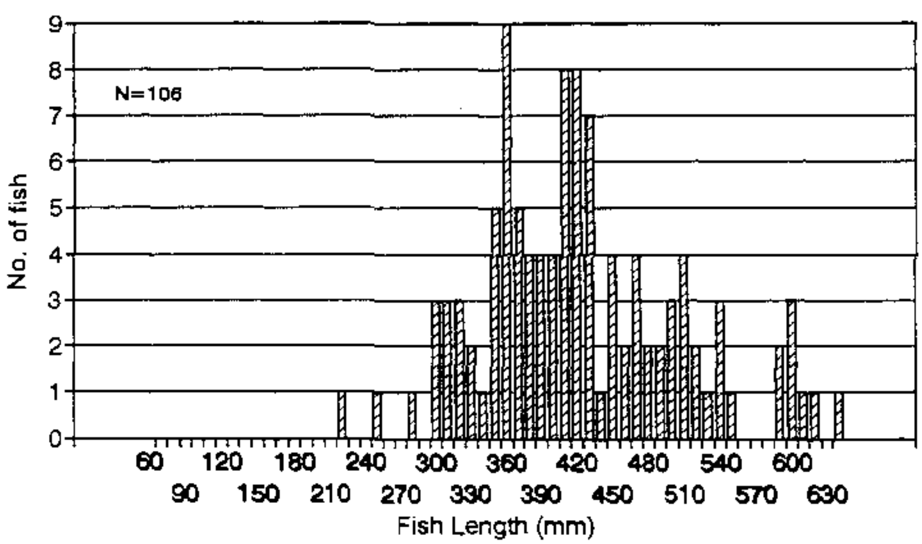


Figure 18. Length frequency of channel catfish collected outside at Cottonwood Island chevrons, 1993 - 1998.

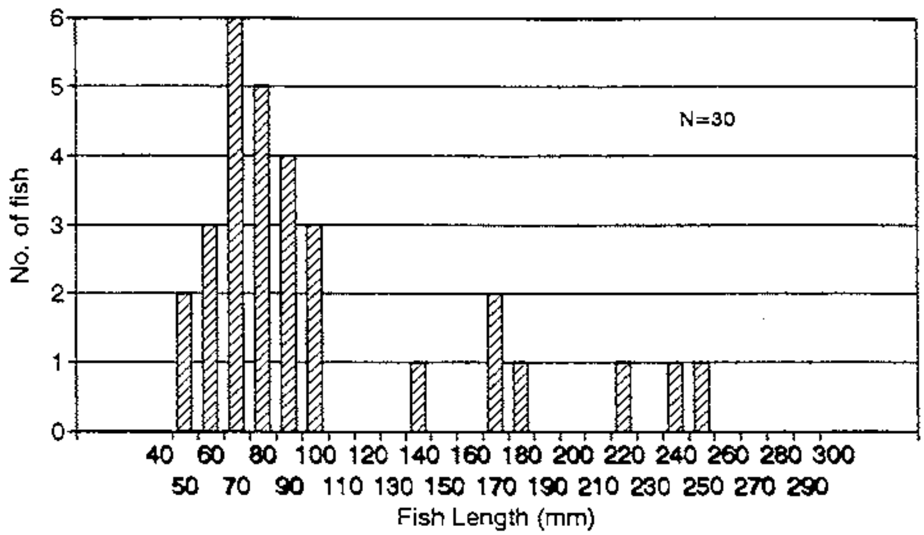


Figure 19. Length frequency of white bass collected inside at Cottonwood Island chevrons, 1993 - 1998.

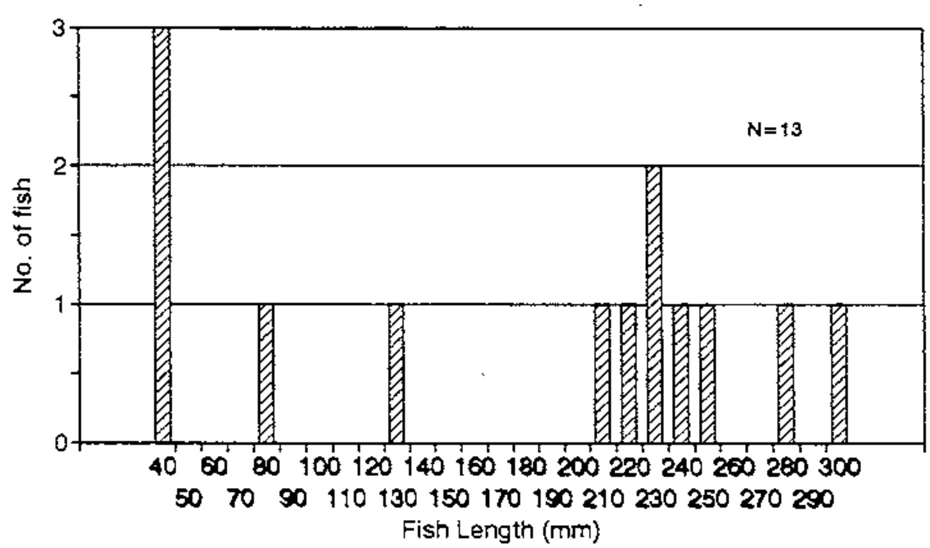
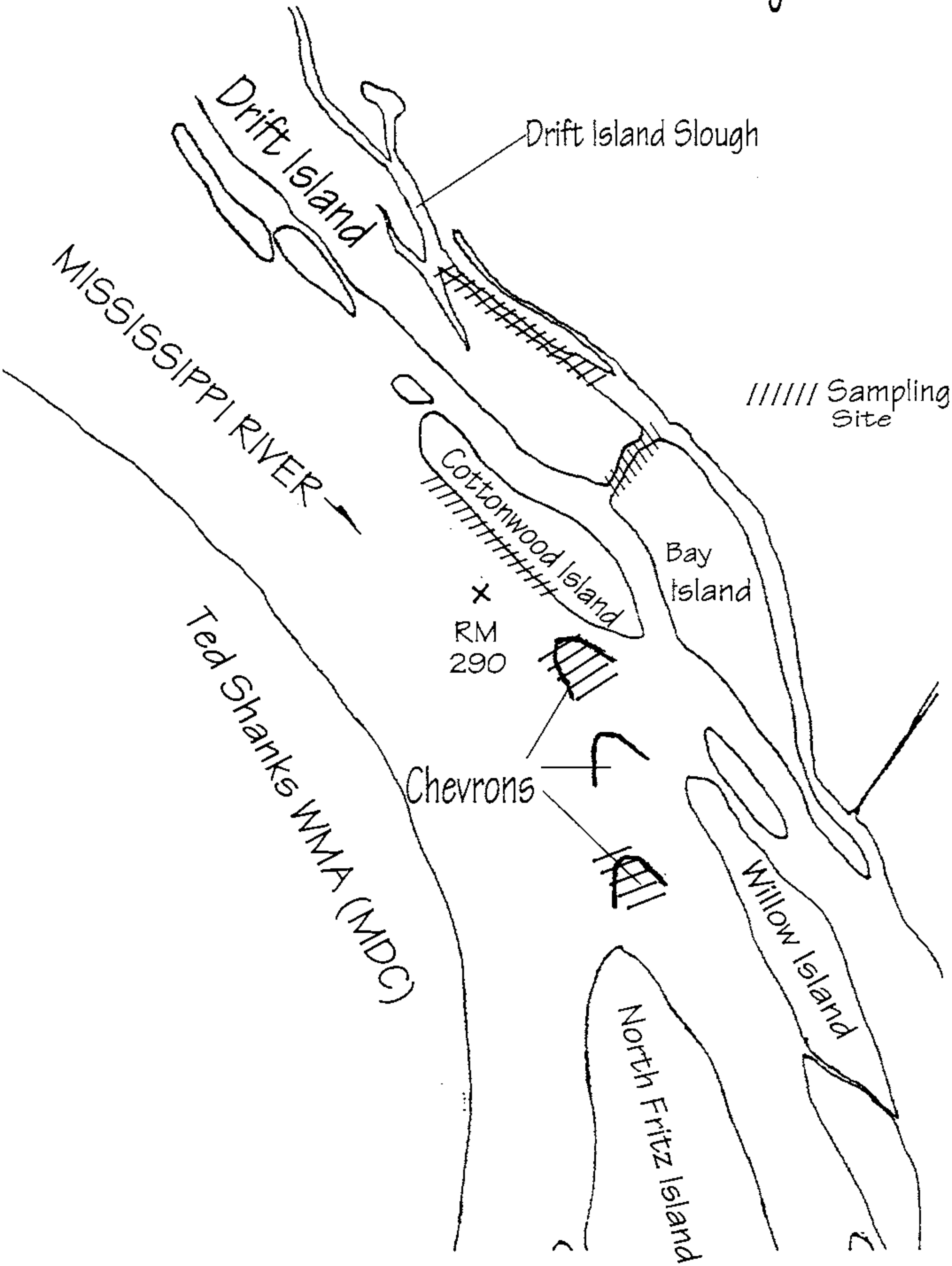
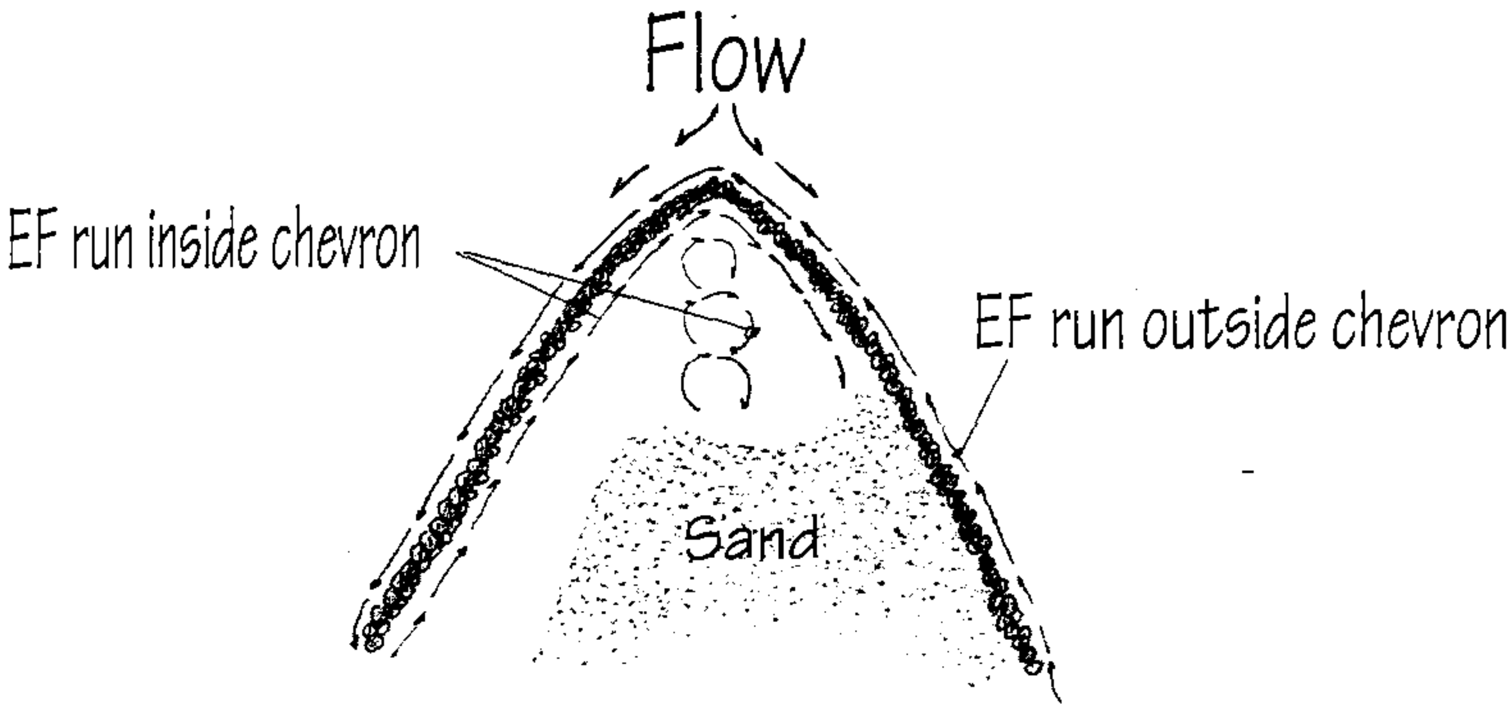


Figure 20. Length frequency of white bass collected outside at Cottonwood Island chevrons, 1993 - 1998.

Cottonwood Island Chevron Dike Study Area



Typical Chevron Electrofishing Runs



APPENDIX B.

Multiple Round Point Structures Preliminary Fisheries Evaluation, Illinois Department of Natural Resources, May 2000

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 Rivers Program

May 2000

Introduction

The Illinois Department of Natural Resources, Division of Fisheries, Boundary Rivers Program has collected four fish samples with A.C. electrofishing (EF) on the Multiple Round Point Structures constructed by the St. Louis District, Corps of Engineers at Mississippi River mile 256.6L, in 1998 and 1999 (Figure 1). 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 in attempt to capture stunned fishes originally out of range.

Results and Discussion

A total of 256 fish representing 16 species (44.14 fish/15min ef) were collected on the four sampling runs (87 minutes total) [Table 2]. Gizzard shad and emerald shiner were the most frequently collected species, followed by flathead catfish and channel catfish.

The length frequency distributions of the flathead and channel catfishes collected in the sampling effort indicate that both young of year and older individuals of these species are utilizing these structures .

A notable species collected in this effort is the blue sucker. This big river species is presently uncommon 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 each of the four sampling runs seem to indicate that these fishes are seeking the habitat conditions provided by these structures.

Conclusion

The data collecred in this preliminary 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, once more common in the river.

Table 1. Sampling dates and electrofishing effort for Pool 25 Multiple Round Point Structures.

Sampling date	Electrofishing effort (min)
18-Aug-98	22
15-Oct-98	15
07-Sep-99	20
22-Sep-99	30
Total	87

Table 2. Composition of fishes collected with A.C. electrofishing at Pool 25 Multiple Round Point Structures, 1998-1999.

Species	Number	No./15min ef
Gizzard shad	58	10.00
Carp	20	3.45
Red shiner	1	0.17
Emerald shiner	81	13.97
Mimic shiner	4	0.69
Smallmouth buffalo	6	1.03
Blue sucker	9	1.55
Shorthead redhorse	10	1.72
Channel catfish	14	2.41
Flathead catfish	37	6.38
Stonecat	1	0.17
White bass	1	0.17
Green sunfish	2	0.34
Bluegill	1	0.17
Slenderhead darter	1	0.17
Freshwater drum	10	1.72
Total number	256	44.14
Number species	16	

APPENDIX C.

Environmental Pool Management

1) 1999 Progress Report - Effects of water level management on waterfowl food production in Pool 25, Upper Mississippi River. Southern Illinois University Carbondale, Cooperative Wildlife Research Laboratory.

2) 1999 Progress Report - Fish and water quality responses to nonpersistent wetland vegetation produced via Environmental Pool Management in Pool 25 of the Upper Mississippi River. Southern Illinois University Carbondale, Fisheries Research Laboratory.

Progress Report: January 1999-December 1999

Project: Effects of water level management on waterfowl food production in Pool 25, Upper Mississippi River.

Objectives:

1) Characterize the plant community associated with water level management and estimate seed biomass produced.

2) Quantify the aquatic invertebrate population response to increased macrophyte production.

3) Characterize avian use of habitats produced by water level management.

Funding Source: U.S. Army Corps of Eng., U.S. Fish & Wildl. Serv., Coop. Wildl. Res. Lab.

Principal Investigator: Bruce D. Dugger

Graduate Research Assistants: Jamie C. Feddersen

INTRODUCTION

Since the late 1800's, anthropogenic influences on the Mississippi River ecosystem have substantially changed system structure and function. To increase habitat availability, the Upper Mississippi River Conservation Committee (UMRCC) and United States Army Corps of Engineers (USACE) developed a water level management plan to increase the health of the Mississippi River ecosystem by enhancing fish and wildlife habitat while maintaining a 9-ft. navigation channel. The management plan, called Environmental Pool Management (EPM), endeavors to increase the production of aquatic macrophytes in Pools 24, 25, and 26 by lowering pool water levels 0.2 - 1.0 m to expose mudflats.

Intensive evaluation of the plant and invertebrate communities responding to EPM has not been conducted. The goal of this study is to quantify the plant food resources produced by water level drawdowns on Pool 25 of the Mississippi River and evaluate invertebrate and avian response to these resources.

This report is a summary of activities for calendar year 1999 and contains preliminary findings, which may be subject to future modifications and revisions. To prevent the issuing of misleading information, persons wishing to quote from any of this report, to cite it in bibliographies, or to use it in other forms should first obtain permission from the Director of the Cooperative Wildlife Research Laboratory.

STUDY AREA

The study is being conducted in Pool 25 (Fig. 1), 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). Study sites are located in side channel and backwater areas of Jim Crow Island, Turner Island, and the Batchtown State Fish and Waterfowl Management Area, hereafter referred to as Batchtown. Earlier work indicates water drawdowns resulted in increased macrophyte abundance at all 3 sites (Wlosinski et al. unpubl. data).

ACTIVITIES (01 Jan - 31 Dec 1999)

Plants

Objective 1: Characterize the plant community associated with water level management and estimate seed biomass produced.

Vegetation composition data were collected beginning 3 weeks post-drawdown, during 24-25 July and 13 August 1999. Sixteen transects were placed perpendicular to the shoreline and followed an elevation gradient. A single 0.5-m^2 sample plot was placed along the transect at locations that corresponded to 5, 20, 35, 50, and 75-cm water depth, relative to full pool (434.0 ft NGVD). For each species in each plot we recorded species composition, percent cover, and stem density. Nomenclature follows Scott and Wasser (1980) and Mohlenbrock (1986).

Preliminary results of vegetation composition (Fig. 2) indicate 15 species responded to river drawdown. Based on percent occurrence, the most common species were smartweeds (*Polygonum* spp.; 93%), barnyardgrasses (*Echinochloa crusgalli* and *E. muricata;* 80.3%), and chufa (*Cyperus esculentus;* 76%). Chufa had the highest stem density ($\bar{x}$ = 22.3 stems/$0.5m^2$; Fig. 3), followed by smartweed and barnyardgrass ($\bar{x}$ = 10.4 and $\bar{x}$ = 8.5 stems/$0.5m^2$, respectively). In general, percent occurrence was not influenced by plot elevation (Fig. 4).

Seed biomass data were collected on 3, 10, and 11 September 1999, beginning approximately 3 weeks post reflood. We quantified seed biomass using techniques developed by Laubahn and Fredrickson (1992). Seed biomass production of smartweeds, barnyardgrass, chufa, and rice cutgrass (*Leersia oryzoides*) was estimated to be 4,144 kg/ha. Chufa and smartweeds comprised the majority of the biomass (2,998 kg/ha and 1,038 kg/ha, respectively).

Invertebrates

Objective 2: Quantify the aquatic macroinvertebrate population response to increased macrophyte production.

Nektonic sampling.-- During 1999, we processed all samples collected in 1998 from our plots designated to-be-devegetated (TBD) and to-remain-vegetated (TRV) during fall 1998 (Prog. Rep. Oct.-Dec. 1998). Organisms were identified using Pennak (1989) and Merritt and Cummins (1996). Annelids were identified to class, Crustaceans to order or family, Mollusks and Insects to family.

Fifty-one different taxa were identified in nektonic samples collected at Turner Island and Jim Crow Island in 1998 (Table 1). We identified 39 and 45 taxa in TBD and TRV plots, respectively. Mean abundance per sample did not differ between TBD plots ($\bar{x}$ = 318.17/1,497.15 cm^3) and TRV plots ($\bar{x}$ = 302.61/1415.09 cm^3, $n = 36$, $F = 0.10$, $p = 0.7565$).

Benthic sampling.--Fifteen different taxa were identified in benthic samples collected at Turner Island and Jim Crow

Island. Number of taxa identified in TBD versus TRV plots was 12 and 15, respectively. Mean abundance per sample did not differ between control ($\bar{x}$ = 62.00) and treatment plots ($\bar{x}$ = 46.50, n = 36, F = 0.01, p = 0.9106).

To-be-devegetated plots were treated with a commercial herbicide on 13 July 1999, 2 weeks post drawdown, and every 2 weeks until reflood occurred to prevent vegetation establishment within the treatment plots. The devegetated plot simulated substrate conditions prior to water-level drawdowns occurring on Pool 25, (i.e. no management). The TRV plots did not have herbicide applied and are intended to represent current conditions in drawdown areas of Pool 25.

On 4 October 1999 we collected 9 nektonic samples and 9 benthic samples in each of 4 vegetated and 4 devegetated plots (n = 144). These samples are currently being processed to compare against the 1998 samples.

Waterfowl

Objective 3: Characterize avian use of habitat produced by water level management.

Nine surveys were conducted between 27 February - 23 April 1999. We conducted surveys from the bow of a boat in all main channel, side channel, and backwater areas downstream of Jim Crow Island and in vegetated areas of Batchtown. Surveys of the slough on Jim Crow Island and the impoundment on Turner Island were conducted on foot. A route was chosen to minimize flushing birds to areas not yet surveyed. Wind speed (km/h), wind direction, air temperature (°C), precipitation, and percent cloud cover (10% interval) were recorded prior to beginning surveys. Total number, species, and location (vegetation vs. open water) of waterfowl were noted during each survey period.

Fifteen species of waterfowl were observed throughout the survey period (Table 2). Although we have yet to analyze these data, when combining all surveys, it is clear more birds were observed in vegetation (35,838) than in open water (2,404). In vegetated areas, mallards/American black ducks (*Anas platyrhynchos/Anas rubripes*) and northern pintails (*A. acuta*) were most abundant (18,432 and 16,420, respectively). American wigeon (*A. americana*) was the only species observed in the vegetation not observed in open water. Compared to dabbling ducks, diving ducks were more abundant in open water. Lesser scaup (*Aythya affinis*) was the most abundant species in open water (1,102) and the only species not observed in vegetation.

Waterfowl behavior observations were conducted during March-April 1999. Activity-budgets of spring migrating waterfowl were documented using focal-switch observations (Losito et al. 1989). Focal individuals were observed from 15 to 30 minutes and behaviors were recorded at 10-second intervals. Observations were conducted from duck blinds present within the study area using a 20-60x spotting scope.

We collected 36.4 hours of time activity budget data, 32.0 hours in vegetated areas and 4.5 hours in non-vegetated areas. Combining all data, waterfowl spent 39% of their time feeding and 32% loafing (Table 3). Based on 29.6 hours of observation, dabbling ducks in the vegetation fed 41% of the time and loafed 30% of the time. Diving ducks in the open water (3.35 observation hours) spent 56% of their time loafing and only 14% of their time feeding. Mallards observed in vegetation (*n* = 26, 19.85 observation hours) spent similar amounts of time feeding, 31% as they did loafing, 39%. Pintails (*n* = 25, 11.43 observation hours) spent more time feeding, 50%, than they did loafing, 26%. Ideally we wanted a more even distribution of observations between vegetated and non-vegetated areas; however, dabbling ducks rarely occurred in non-vegetated areas.

DISCUSSION AND PROSPECTUS

Plants

Preliminary results indicate EPM continues to produce a plant community comprised mainly of moist-soil species that provide food for waterfowl. Percent occurrence for barnyard grasses and chufa in our study were similar to those reported by Wlosinski et al. (unpublished data) but was twice as high for smartweeds. These changes may not reflect temporal changes in the plant community but rather differences in sampling techniques. Little zonation in species distribution suggests a relatively uniform availability of food resources in the Batchtown area.

Invertebrates

The results of the first phase of the invertebrate experiment are encouraging. Preliminary analysis suggest there was no difference in total abundance and number of taxa between experimental plots for both sampling techniques prior to treatment with herbicide. We are currently processing samples collected in fall 1999, after the herbicide treatment. When these data become available comparisons will be made with the 1998 data to see if differences in relative abundance exist between plots and years. If abundance is significantly lower in non-vegetated plots than vegetated plots we may be able to attribute these difference to the macrophyte response to EPM. Additional analyses of the invertebrate data will focus on differences in abundance of a taxon between plots.

Waterfowl

Waterfowl surveys indicate use of vegetated areas predominantly by dabbling duck species. Waterfowl using vegetated areas spent a major portion of their time foraging in shallow water areas suggesting they are using plant and invertebrate resources produced by the drawdown. However, low numbers of dabbling ducks in open water may not be an appropriate indicator of the importance of the vegetation produced by EPM. Dabbling ducks feed in relatively shallow water (Bellrose 1976) and their paucity in open water may reflect their inability to effectively feed in relatively deeper water. Behavioral observations during spring 2000 will incorporate the devegetated plots from the invertebrate response experiment to characterize use of shallow open water areas.

Further investigations will include comparing historical data from aerial surveys conducted by Illinois Natural History Survey to identify differences in numbers of waterfowl using Batchtown before and since the inception of EPM. If EPM has improved habitat conditions in Batchtown we predict a significant increase in the abundance of waterfowl between pre- and post-EPM. This will assist us in developing conclusions to the efficacy of EPM in producing quality food resources to migrating waterfowl.

LITERATURE CITED

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, PA. 540pp.

Cummins, K. W. 1973. Trophic relations of aquatic insects. Annual Review of Entomology. 18:183-206.

Laubahn, M. K. and L. H. Fredrickson. 1992. Estimating seed production of common plants in seasonally flooded wetlands. Journal of Wildlife Management 56:329-337.

Losito, M. P., R. E. Mirarchi, and G. A. Baldassarre. 1989. New technique for time-activity studies of avian flocks in view-restricted habitats. Journal of Field Ornithology 60:388-396.

Merritt, R. W. and K. W. Cummins. 1996. An introduction to the aquatic insects of North America. Third Edition. Kendall/Hunt Publishing Co. Dubuque, Iowa. 862pp.

Mohlenbrock, R. H. 1986. Guide to the vascular flora of Illinois. Southern Illinois University Press. Carbondale, Illinois. 507pp.

Pennak, R. W. 1989. Fresh-water invertebrates of the United States. Third Edition. John Wiley and Sons, Inc. New York, New York. 628pp.

Scott, T. G. and C. H. Wasser. 1980. Checklist of North American Plants for wildlife biologists. The Wildlife Society Publication. 58pp.

Table 1. Invertebrate taxa identified in nektonic and benthic samples collected from paired-plots on Jim Crow Island and Turner Island, Pool 25, Upper Mississippi River, October 1998.

	Jim Crow Island		Turner Island	
Taxa	**Nektonic**	**Benthic**	**Nektonic**	**Benthic**
Aeshnidae	X			
Araneidae	X		X	
Arctiidae	X			
Asellidae	X	X	X	X
Baetiscidae	X			
Belostomatidae	X		X	
Cambaridae	X		X	
Carabidae	X			
Ceratopogonidae	X	X	X	
Chironomidae	X	X	X	X
Cladocera	X	X	X	X
Coenagrionidae	X		X	
Copepoda	X	X		
Cordulegastridae			X	
Corixidae	X	X	X	X
Cossidae	X		X	
Culicidae	X		X	
Dolichopodidae			X	
Empididae	X		X	
Gammaridae	X		X	
Gerridae	X			
Gryllidae	X			
Gyrinidae	X		X	
Haliplidae	X		X	
Hebridae	X		X	
Hirudinea	X			
Hydrometridae	X		X	
Hydrophilidae	X	X	X	X
Hydroptilidae	X			
Lestidae	X			
Libellulidae	X			
Lycosidae	X		X	
Lymnaeidae	X	X	X	X
Macroveliidae	X	X	X	
Naucoridae	X			

Table 1. Continued.

	Jim Crow Island		Turner Island	
Taxa	**Nektonic**	**Benthic**	**Nektonic**	**Benthic**
Nematoda	X	X	X	X
Noteridae			X	
Oligochaeta	X	X	X	X
Ostracoda	X	X	X	X
Physidae	X	X	X	X
Pisauridae	X		X	
Planorbidae	X	X	X	
Saldidae	X	X	X	
Scelionidae			X	
Sciomyzidae	X			
Sisyridae	X		X	
Staphylinidae			X	
Stratiomyidae	X		X	
Tabanidae			X	
Talitridae			X	
Tipulidae			X	

Table 2. Total waterfowl observed during 9 surveys (27 Feb - 23 April 1999) on lower Pool 25, Upper Mississippi River.

	Habitat		
Species	Vegetation	Open water	Total
Canada goose	236 (77%)	70 (23%)	306
American wigeon	30 (100%)	0 (0%)	30
Blue-winged teal	123 (86%)	20 (14%)	143
Gadwall	67 (63%)	40 (37%)	107
Green-winged teal	378 (89%)	46 (11%)	424
Mallard/American black duck	18,432 (98%)	444 (2%)	18,876
Northern pintail	16,420 (99%)	167 (1%)	16,587
Northern shoveler	57 (66%)	30 (34%)	87
Wood duck	22 (65%)	12 (35%)	34
Canvasback	38 (68%)	18 (32%)	56
Lesser scaup	0 (0%)	1,102 (100%)	1,102
Redhead	20 (24%)	65 (76%)	85
Ring-neck duck	15 (4%)	390 (96%)	405
Total	35,838 (94%)	2,404 (6%)	38,242

Table 3. Percent time devoted to foraging and loafing by waterfowl using Pool 25, Upper Mississippi River during spring 1999.

	Vegetation		Open Water	
Species	Feeding	Loafing	Feeding	Loafing
Green-winged teal (*n* = 11)	42	13	–	–
American wigeon (*n* = 5)	91	0	–	–
Gadwall (*n* = 3)	0	64	–	–
Mallard (*n* = 26)	31	39	–	–
Northern pintail (*n* = 25,3)	51	25	43	36
Northern shoveler (*n* = 3)	8	80	–	–
Canvasback (*n* = 2)	–	–	0	59
Lesser Scaup (*n* = 2)	–	–	1	67
Ring-neck duck (*n* = 3)	–	–	32	46
Redhead (*n* = 2)	50	14	–	–

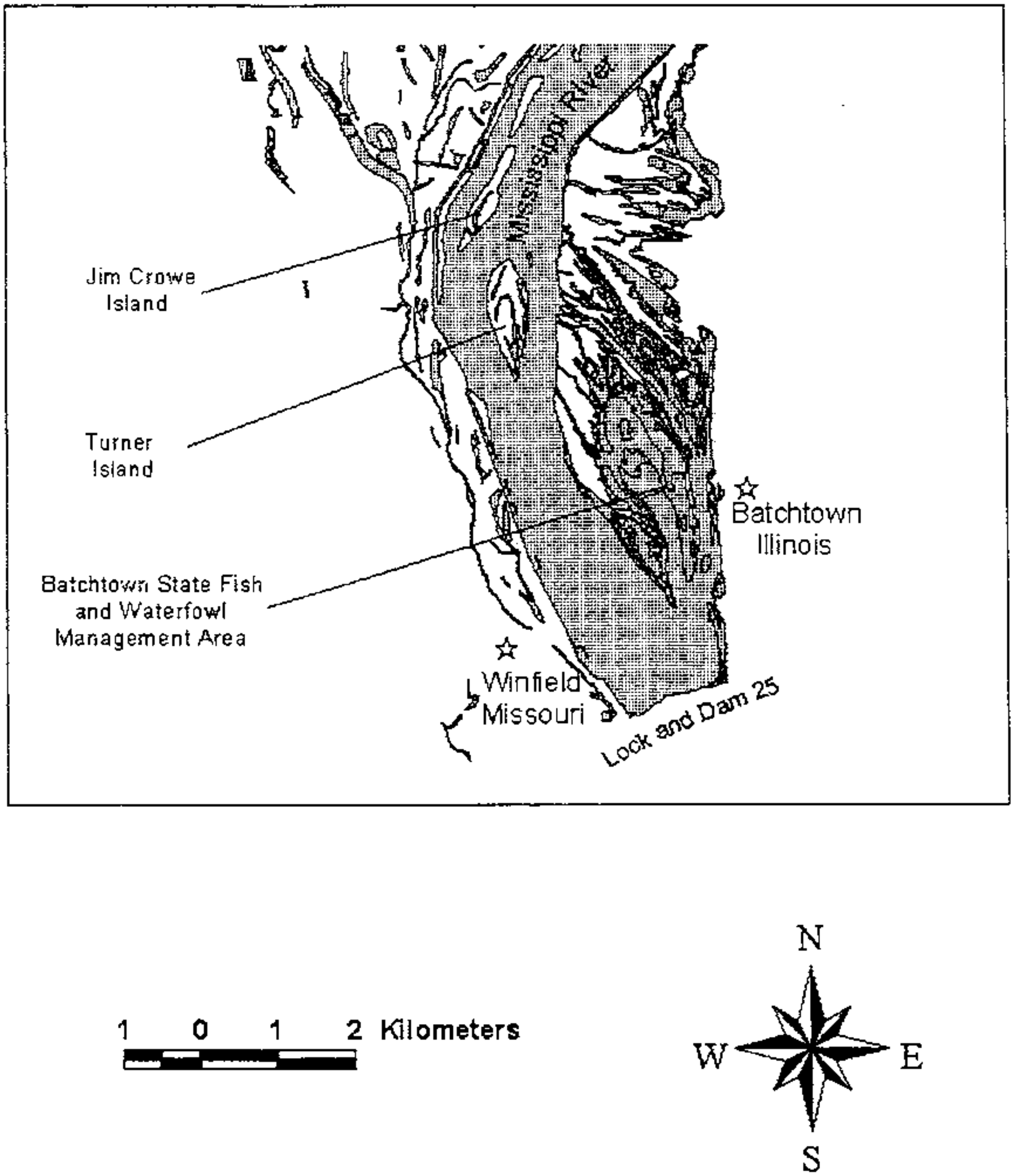


Figure 1. Lower reach of Pool 25, Upper Mississippi River.

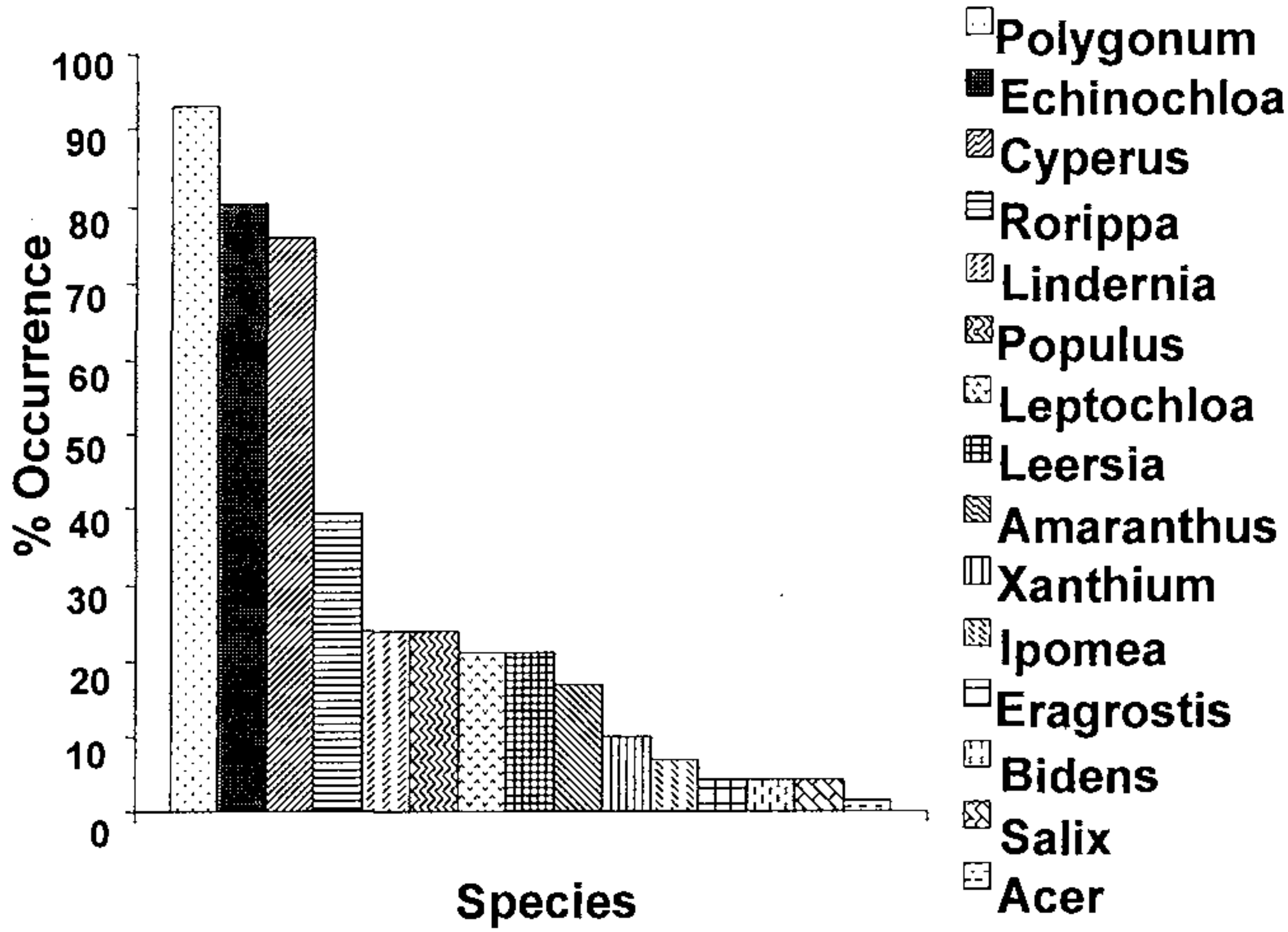


Figure 2. Percent occurrence of plant species in the Lower Reach of Pool 25, Upper Mississippi River, 1999.

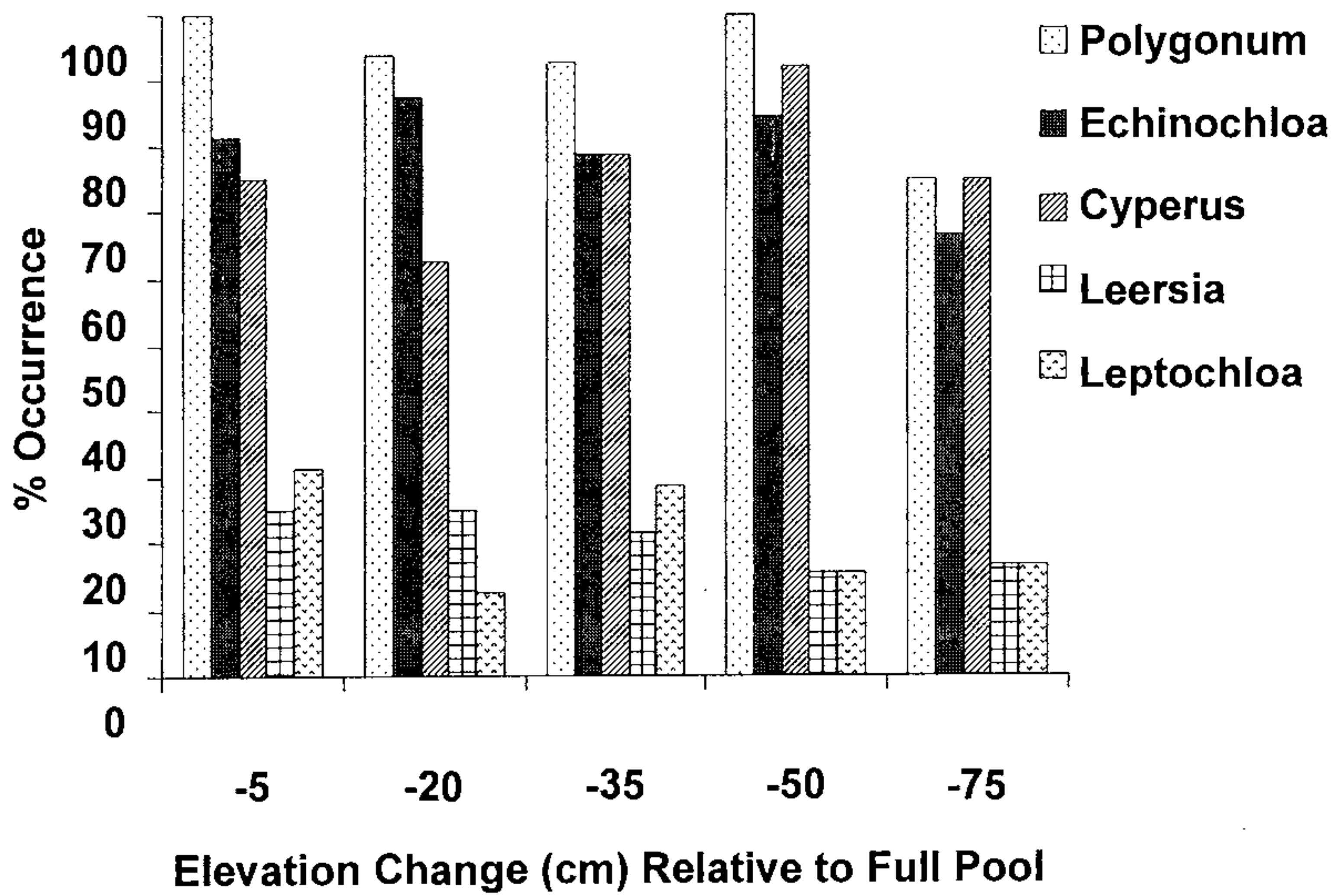


Figure 3. Percent occurrence of plant species along an elevation change (relative to full pool) in the Lower Reach of Pool 25, Upper Mississippi River, 1999.

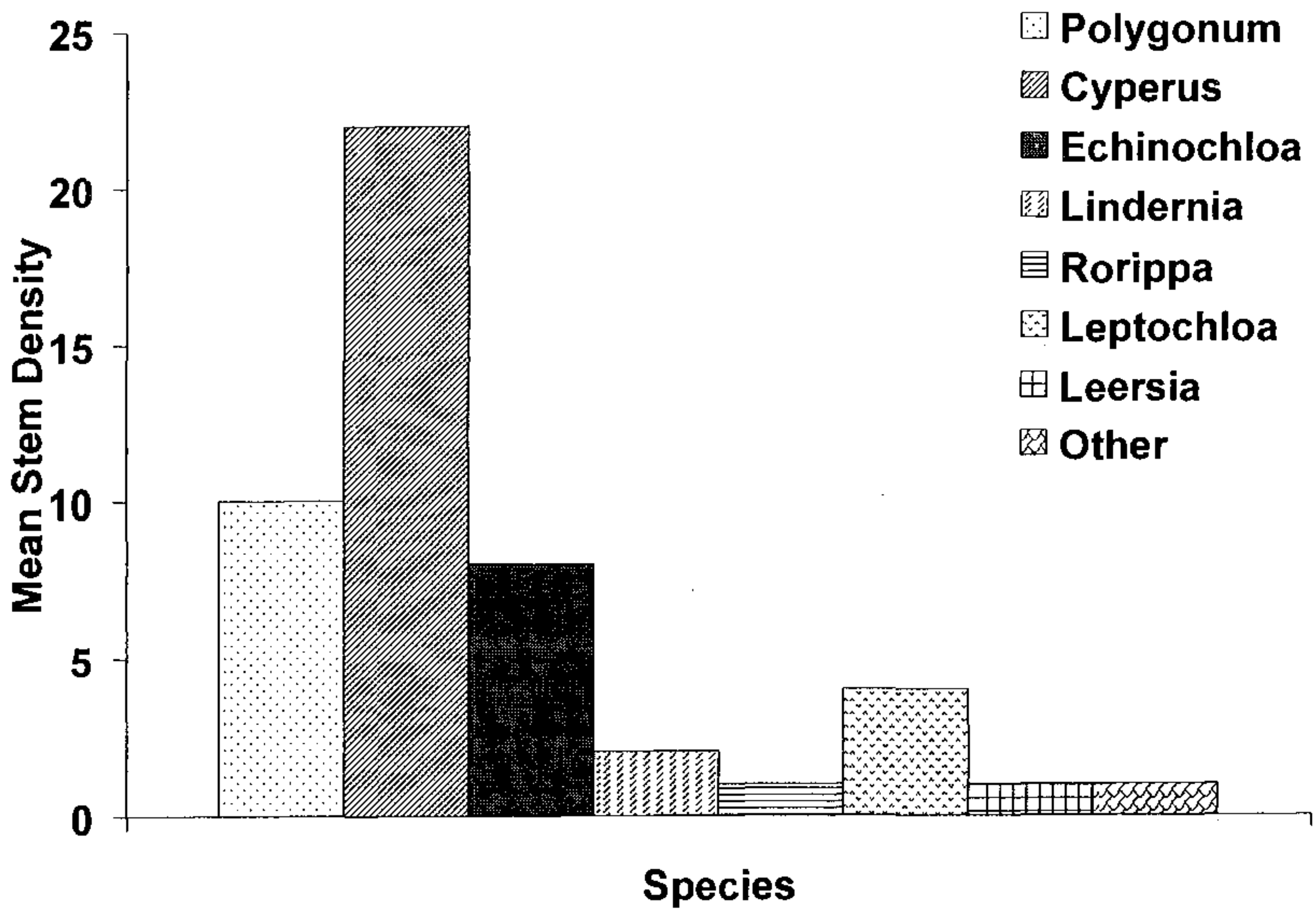


Figure 4. Mean stem density (no. stems/0.5 m^2) of plants species in the Lower Reach of Pool 25, Upper Mississippi River, 1999.

Progress Report: January 1999-December 1999

Project: Fish and water quality responses to nonpersistent wetland vegetation produced via Environmental Pool Management in Pool 25 of the Upper Mississippi River.

Objectives:

1. Examine fish use of nonpersistent vegetation with seine and popnet samples from vegetated and experimentally devegetated plots.
2. Sample adult fish in vegetated areas to determine benefits of increased food availability (e.g., forage fish) due to vegetation production.
3. Study benefits to young fish of residual vegetation in spring.
4. Monitor the effects of vegetation on water quality and zooplankton.

Funding Agencies: St. Louis District, U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service

Principal Investigators: Robert J. Sheehan and Brooks M. Burr

Graduate Research Assistant: Reid Adams

Introduction

Water levels in Pool 25 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, 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). Herein, "drawdown" is synonymous with the maximum drawdown which generally follows spring floods. Under current operating procedures, the St. Louis District has no control over the timing or magnitude of the drawdown that follows spring open river conditions. However, some flexibility in how water levels are managed may be realized during the return of the river to the target pool elevation. Since 1994, the time period conducive to management has ranged from approximately 38 to 57 days during the summer months.

The major goal of Environmental Pool Management (EPM) is to maintain relatively low, stable water levels following drawdown in the spring. The management scheme prolongs the dry phase during the growing season of backwaters located primarily 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 (Dalrymple et al. 1996).

Many studies document fish interactions with aquatic macrophytes in lakes, reservoirs, and small streams (Dibble et al. 1996), and Janecek (1988) reported 107 fish species in the Upper Mississippi River utilize aquatic plants for reproduction, nursery habitat, cover, and as feeding grounds. Environmental Pool Management on Pools 24, 25, and 26 produces nonpersistent, emergent, wetland vegetation consisting mainly of millet, chufa, and smartweeds (pers. comm. J.H. Wlosinski, U.S. Geological Survey, and J. Feddersen, Cooperative Wildlife Research

Laboratory, SIUC). Seine hauls in vegetated and adjacent nonvegetated areas in Pools 24, 25, and 26 during fall of 1997 demonstrated EPM-induced vegetation was providing habitat for small forage fish, particularly the emerald shiner, *Notropis atherinoides* (Heidinger et al. 1998). Our main objective was to quantify fish use of EPM-induced vegetation versus nonvegetated areas having similar depths and water velocities; therefore, differences in use could be directly related to the presence or absence of vegetation.

Activities

In conjunction with the SIUC Cooperative Wildlife Research Laboratory, four study sites were chosen in Fall of 1998: Jim Crow Island, Turner Island, and two sites within the Batchtown State Wildlife Management Area (Batchtown East and Batchtown West). A vegetated plot and a plot to be devegetated ($400m^2$) during summer 1999 were designated at each site. This enabled a comparison of vegetated and devegetated plots within a range of riverine habitats: viz., a semi-isolated slough, an island tip, and an extensive backwater area.

<u>Spring 1999</u> - prior to drawdown

Four sampling trips were made after ice-out to determine if young, newly hatched fish were using residual vegetation (if it existed) as nursery habitat. Moderate amounts of residual vegetation remained in the sites, but the amount of attached stems/detritus remaining, particularly in Batchtown, was substantially reduced due to the combination of thawing ice and scouring spring flood waters. Three complete bouts of sampling were conducted at each site/plot combination from 21 May - 15 June. Water quality, zooplankton, and fish samples were collected each trip. Five fish samples were taken in each plot (vegetated and plot designated to be devegetated) with a 1-m long, 500-μm mesh larval fish seine. Additional fish samples were taken in the plots with a 1.6-mm mesh seine. Fish samples have been rough sorted and await identification, along with zooplankton samples. Preliminary examination indicated the vegetated areas, particularly on Jim Crow and Turner Island, provided nursery habitat for many young fish, including the following genera: *Lepisosteus*, *Hiodon*, *Dorosoma*, *Carpiodes*, *Ictiobus*, *Moxostoma*, *Morone*, *Lepomis*, *Percina*, and *Aplodinotus*. Additional fish samples were collected near Stag Island and within Batchtown for comparison with study sites.

Summer 1999 - following maximum drawdown

The four study sites (Jim Crow Island, Turner Island, Batchtown East, and Batchtown West) were visited following maximum drawdown to prepare devegetated plots. All plots to be devegetated were cleared of woody debris, and vegetation remaining from the previous year was removed on 7 July. With the assistance of Ken Dalrymple (Missouri Department of Conservation) and Jamie Feddersen (SIUC Cooperative Wildlife Research Laboratory) one plot at each site was treated with Rodeo® herbicide on 13 July with a backpack sprayer. Two additional applications were made on 24 July and 13 August. Prior to reflood, devegetated plots were completely devoid of vegetation. Our goal was to achieve devegetated plot sizes of 400 m^2, and we sprayed an additional 5 meters around the perimeter to minimize an edge bias during fall sampling. Also, 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. Additional spraying was not required to attain the desired conditions at Jim Crow Island.

We noted the stranding of many fish in isolated pools within the Batchtown area. Fish were probably initially isolated in late June, during the maximum drawdown that followed open river conditions. These fish were trapped in deep channels that traverse Batchtown during periods of high flow. Thousands of dead fish were observed on 24 July, encompassing at least 11 species, mostly YOY channel catfish (*Ictalurus punctatus*) and river carpsucker (*Carpiodes carpio*). The cause of death was probably extremely high midday water temperatures and low dissolved oxygen. The deep channels also contained many stranded mussels (*Amblema plicata*, *Quadrula sp.*, and *Megalonaias nervosa*) that were easy prey for raccoons (pers. observation by R. Adams, J. Feddersen, and K. Dalrymple).

Fall 1999 - following reflood

Water quality, zooplankton, and fish were sampled at each site and plot on five sampling trips from 28 August to 14 October. Vertically integrated zooplankton samples, ranging from the water surface to 10 cm above the substrate, were taken in triplicate from each plot using a modified littoral sampling tube (Pennak 1962) and preserved in 5% buffered formalin. These samples have not been processed, but zooplankton was not conspicuous to the unaided eye in the field or in sample containers. Dissolved oxygen, pH, water temperature, conductivity, turbidity, and water depth were recorded at a minimum of two stations per plot each sampling trip. Dissolved oxygen and water temperature were measured near the surface and bottom when depth exceeded 30 cm. Water velocity was negligible in all plots during sampling.

Vegetated and devegetated plots tended to have similar water depth, water temperature, pH, and conductivity, but dissolved oxygen and turbidity varied among plots (Table 1); although, statistical analyses have not yet been conducted. Higher turbidity was consistently recorded in the devegetated plots, but vegetated plots tended to have lower dissolved oxygen. Dense vegetation at Batchtown East, Batchtown West, and Turner Island resulted in dissolved oxygen values (below 4 mg/L) that are generally limiting to fish (Table 1). Low dissolved oxygen within the vegetation was probably due to a combination of low atmospheric mixing and the oxygen demand of decomposing plant material. Low dissolved oxygen in the vegetation was a chronic problem at Batchtown East throughout our fall sampling. Dissolved oxygen values became more favorable to fish at Batchtown West and Turner Island when plants began to senesce and wind/wave action opened the vegetation allowing mixing to occur. Dissolved oxygen was also monitored at the deep outer edge of the vegetated plots throughout fall and found to be similar to concentrations in the devegetated plot.

Corresponding with water quality measurements, fish were sampled with a 3.66-m seine, having a mesh size of 1.6 mm, and 1-m^2 popnets constructed of 1.6-mm mesh netting. Plots were sampled each trip with three popnets left overnight and triggered the next day for a total of 120 popnet samples. Two seine hauls, each 10 m long, were made in devegetated plots, and five kicksets were made in vegetated plots each trip. 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 the area immediately in front of the seine was "kicked" vigorously. Seine hauls were also made along the deep outer edge of the vegetation and kept separate from other samples. Mean number of species and relative abundance were calculated from replicate popnet samples in a respective plot per trip and analyzed using Analysis of Variance tests (ANOVA). Seine hauls and kicksets within a respective plot per trip were pooled into one sample for analysis. Seine and popnet samples have been processed for three of the five sampling trips. The overall model was a three-way ANOVA with Site, Plot, and Capture Method as independent variables and either mean number of species or fish abundance as dependent variables. These analyses did not include fish captures at the deep outer edge of the vegetation. Though analysis of available data are preliminary, the following results are indicative of overall trends.

Sixteen species, including nine members of the family Cyprinidae, were collected with popnets and seine hauls in the vegetated and devegetated habitats (Table 2). Collections were dominated numerically by the channel shiner, *Notropis wickliffi*. Based on 7, 214 fish, mean number of species captured and fish abundance were significantly higher in vegetated plots for both capture methods ($P < 0.001$). Also, species richness and abundance were higher in seine samples in comparison with popnet samples ($P < 0.001$). For both dependent variables, Site was a significant factor, and the Site X Plot interaction had a significant effect on mean number of species. Post-hoc analyses indicated that higher numbers of fish and species were collected at Jim Crow Island and Turner Island, and there was no difference between vegetated and devegetated plots in mean number of species collected at Jim Crow (Student Neuman-Keuls test).

Fish samples reflected macrohabitat differences among sites. Fish abundance and mean number of species were lowest at Batchtown West and Batchtown East, sites in the extensive, shallow backwater area comprising the majority of vegetation acreage in Pool 25. Vegetated plots at these sites were dominated by species tolerant of low dissolved oxygen such as mosquitofish (*Gambusia affinis*) and common carp (*Cyprinus carpio*) (Table 2). Vegetation production was very high in 1999, and further research is needed to determine the extent of low dissolved oxygen concentrations during years of more typical vegetation densities. Smaller patches of EPM-induced vegetation present on Turner Island and Jim Crow Island had less of a dissolved oxygen problem and provided suitable habitat for more fish. Vegetation on Turner Island harbored young-of-the-year of numerous species, including channel shiners and spotfin shiners (*Cyprinella spiloptera*). Total length has been recorded on every specimen, and length frequency distributions of common species will be compared among sites and plots.

Electrofishing was conducted on 14 October 1998 and 21 October 1999 in Batchtown and adjacent to Turner Island and Jim Crow Island to sample large fishes. Gizzard shad (*Dorosoma cepedianum*), river carpsucker (*Carpiodes carpio*), buffalofishes (*Ictiobus* spp.) and common carp (*Cyprinus carpio*) were the most abundant fishes collected in Batchtown based on 2.5 hrs of electrofishing (Table 3). Turner Island and Jim Crow Island samples were comprised mostly of gizzard shad and common carp (Table 4). The low number of piscivores captured near the vegetation has impeded documentation of direct benefits of increased forage fish availability.

Current Trends and Considerations

By influencing reproduction and recruitment processes, water level management (Midpool control point management and Environmental Pool Management) can affect the fish community composition of Mississippi River pools, since fish species may respond differently to a particular hydrologic regime. Spring spawning species, already facing restricted access to quality floodplain habitat, may suffer from a shortened spawning season if drawdown is too early in the year. Year-class strength will also be affected if the drawdown strands or forces newly hatched young from backwater nursery areas before they are fully prepared for life in river channel habitats. Reproduction of centrarchids in late spring/early summer is known to be detrimentally impacted by fluctuating water levels during nest building (Kohler et al. 1993; Raibley et al. 1997), and recruitment will be further impacted by subsequent stranding or reduced access to backwaters following drawdown. In fall, the young of some species (particularly late summer spawners) will probably benefit substantially from the presence of newly flooded vegetation whose growth and density depends on drawdown parameters. The influence of macrohabitat and vegetation characteristics on ambient water quality may allow some young fish to utilize more of the vegetated acreage than others. At latitudes where water temperatures lower than 4 ^{0}C are experienced by YOY fish in winter, the availability of suitable overwintering habitats is a major determinant of recruitment (Sheehan et al. 1990). As a response to critically low water temperatures, some fish bury in substrates (Crawshaw et al. 1982, Cunjak 1986). Residual vegetation and resulting detrital layers may aid recruitment of some species by providing favorable overwintering habitat. Water level management affects fish communities through many potential avenues of influence on recruitment processes throughout the year.

Trends in fish response to the hydrologic regime of 1999 are apparent, although not all data have been processed. Maximum drawdown was reached on approximately 29 June, and water levels generally remained below 430 ft until reflooding began 12 August. The summer hydrologic regime exposed mudflats in lower Pool 25 for extended periods of time and was very successful in producing nonpersistent vegetation. Based on quantified sampling and two collection methods in fall, more species and a higher abundance of fish were found in the nonpersistent vegetation compared to similar areas devoid of vegetation. These fish were mainly young-of-the-year and recently hatched cyprinids. The young of late spawning channel shiners, spotfin shiners, and river shiners heavily utilized vegetation on Turner Island as nursery habitat, therefore benefiting from the presence of vegetation. Unlike most other species, mosquitofish and juvenile common carp were able to utilize vegetated areas with low dissolved oxygen in Batchtown. Including aforementioned cyprinids, these species appeared to be the main benefactors of increased nursery habitat attributable to the presence of vegetation.

Maximum drawdown typically corresponds to the final receding of spring flood waters, and the timing is very crucial to recruitment of spring and early summer spawning fishes. Similar to Pool 25 drawdowns in 1994 - 1996, the drawdown of 1999 began in early to mid June. Evidence of reproduction by many spring spawning fishes was found prior to the 1999 drawdown at Jim Crow Island, Turner Island, and within Batchtown. After maximum drawdown, we found substantial numbers of YOY fish stranded in the slough on Jim Crow Island and within Batchtown. Stranding may have been exacerbated in summer 1999 because water levels had to be held abnormally low due to elevated discharges upstream. Further research is needed to assess recruitment losses due to the stranding of young within backwaters during maximum drawdown. Also, it is not clear if the young are being forced from nursery areas prematurely.

The response of nest-building centrarchids to water level management (Midpool control point management and EPM) in Pool 25 is unclear at this time. During our spring 1999 sampling of the designated study sites and additional backwaters on Stag Island and within Batchtown, we found very little evidence of reproduction by *Lepomis*, *Micropterus*, or *Pomoxis*. Extensive fall 1999 sampling resulted in the capture of very few centrarchids; samples were dominated by the orangespotted sunfish (*Lepomis humilis*) which is reported to be tolerant of a wide range of environmental conditions, including fluctuating water levels (Robison and Buchanan 1988). Very few *Pomoxis* and no *Micropterus* were collected during seining of shallow shorelines in Pools 24, 25, and 26 in fall of 1997 (Heidinger et al. 1998). Observed trends may be due to a low number of adults in the population, low survivorship of young, or spawning failure due to fluctuating water levels during reproduction (Raibley et al. 1997). Environmental Pool Management reduces water level fluctuations following maximum drawdown, but suitable spawning and rearing habitat may not be available when water levels are below full pool. Additional data collection and analysis of historical collections are needed to determine the effect of water level management on centrarchids in Mississippi River pools.

Although Environmental Pool Management was only partially implemented in 1999, we did document benefits to fish of the presence of nonpersistent vegetation (which is produced when EPM is practiced). Other aspects of EPM that may influence fish reproduction and early life history need to be studied. When EPM is implemented, the impact of dampening water level fluctuations following maximum drawdown in spring is not clear. For instance, rising water levels may rescue or provide relief to fish and mussels stranded in off-channel habitats after drawdown by restoring benign water quality conditions. On the other hand, additional fish may enter the habitats during reconnection, exacerbating the fish stranding problem. Further study of how fish respond to water level fluctuations, including a determination of controlling water elevation (elevation upon which the habitat becomes reconnected with the main river) for important off-channel areas in lower Pool 25, is needed. Water level fluctuations in lower reaches of pools due to tilting are known to impact the biotic communities of these habitats (Sparks 1995; Theiling et al. 1996). Data further describing the extent of this problem are needed. Environmental Pool Management appears to benefit some fish, but more research is needed to determine how it can be optimized for both fish and waterfowl.

Literature Cited

Crawshaw, L.I., D.E. Lemons, M. Parmer, and J.M. Messing. 1982. Behavioral and metabolic aspects of low temperature dormancy in the brown bullhead, *Ictalurus nebulosus*. Journal of Comparative Physiology 148:41-47.

Cunjak, R.A. 1986. Winter habitat of northern leopard frogs, *Rana pipiens*, in a southern Ontario stream. Canadian Journal of Zoology 64:255-257.

Dalrymple, K.L., E. Atwood, D. Busse, and C.N. Strauser. 1996. Environmental pool management status report. Proceedings of the Upper Mississippi River Basin Committee, Cape Girardeau, MO, March 5-7, 1996.

Dibble, E.D., K.J. Killgore, and S.L. Harrel. 1996. Assessment of fish-plant interactions. Transactions of the American Fisheries Society 16:357-372.

Heidinger, R.C., B.M. Burr, and R.J. Sheehan. 1998. Water level manipulation/vegetation project: Mississippi Pools 24, 25, and 26. Final Report to the U.S. Army Corps of Engineers, St. Louis District.

Janecek, J.A. 1988. Literature review on fishes interaction with aquatic macrophytes with special reference to the Upper Mississippi River System. Upper Mississippi River Conservation Committee, Fish Section, Rock Island, Illinois.

Kohler, C.C., R.J. Sheehan, and J.J. Sweatman. 1993. Largemouth bass hatching success and first-winter survival in two Illinois reservoirs. North American Journal of Fisheries Management 13:125-133.

Pennak, R.W. 1962. Quantitative zooplankton sampling in littoral vegetation areas. Limnology and Oceanography 7:487-489.

Raibley, P.T, T.M O'Hara, K.S. Irons, K.D. Blodgett, and R.E. Sparks. 1997. Largemouth bass size distributions under varying annual hydrological regimes in the Illinois River. Transactions of the American Fisheries Society 126:850-856.

Robison, H.W. and T.M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville.

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

Sparks, R.E. 1995. Need for ecosystem management of large rivers and their floodplains. Bioscience 45:168-182.

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

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

Table 1.

Water quality values in vegetated (Veg) and devegetated (DeVeg) plots at four sites in Pool 25 of the Mississippi River. Means, with ranges in parentheses, 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)	44.8 (38.0-49.0)	42.1 (33.0-51.0)	53.5 (39.0-66.0)	55.3 (45.5-64.0)	27.3 (21.5-35.0)	28.5 (19.0-39.0)	24.5 (16.0-28.0)	27.5 (26.5-32.0)
Temperature (^{0}C)	21.4 (18.5-27.9)	22.3 (17.0-29.6)	20.7 (16.2-25.8)	21.1 (17.3-25.6)	23.1 (17.0-31.0)	23.2 (16.5-32.1)	21.7 (16.7-28.5)	21.9 (16.7-27.2)
Dissolved Oxygen (mg/L)	6.2 (0.9-10.9)	8.2 (5.9-10.0)	2.6 (1.1-4.4)	5.7 (4.3-8.1)	8.7 (5.7-12.3)	10.2 (5.8-12.7)	6.8 (0.7-14.1)	8.6 (6.3-11.4)
pH	7.8-8.7	8.1-8.7	7.4-8.0	7.8-8.4	8.2-9.1	8.0-8.7	7.3-8.8	8.3-8.8
Conductivity (μmhos/cm)	400-450	400-460	300-454	300-439	400-469	400-480	300-450	300-410
Turbidity (NTU)	56.6 (14-100)	64.6 (21-100)	17.9 (4-56)	51 (20-72)	26.7 (4-54)	56.9 (8-100)	65.6 (8-100)	84.7 (31-100)

Table 2.

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 three sampling trips during fall 1999.

	Batchtown West		Batchtown East		Jim Crow Island		Turner Island	
Species	Veg	DeVeg	Veg	DeVeg	Veg	DeVeg	Veg	DeVeg
Dorosoma cepedianum	1	0	0	0	0	0	1	0
Ctenopharyngodon idella	0	0	0	0	169	18	0	0
Cyprinus carpio	217	3	60	0	69	112	57	0
Cyprinella spiloptera	25	1	58	7	58	45	998	12
Notemigonus crysoleucas	1	0	0	0	0	0	0	0
Notropis atherinoides	55	220	15	94	5	49	7	246
Notropis blennius	0	0	0	0	0	0	63	0
Notropis wickliffi	1	8	0	12	93	73	2104	51
Pimephales notatus	0	0	0	0	1	0	0	0
Pimephales vigilax	0	0	0	2	0	0	2	2
Carpiodes carpio	0	1	0	1	0	1	0	0
Ictalurus punctatus	0	0	0	0	0	0	1	1
Gambusia affinis	144	1	103	0	1491	355	52	0
Labidesthes sicculus	0	0	0	7	0	0	0	0
Lepomis humilis	5	25	2	3	0	1	3	1
Lepomis macrochirus	0	0	0	0	0	0	1	0
Totals:								
Number of Species	8	7	5	7	7	8	11	6
Fish Abundance	449	259	238	126	1886	654	3289	313

Table 3.

Electrofishing results from the Batchtown State Wildlife Management Area 1998-1999. 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 Sunfish	*Lepomis macrochirus*	4	0
Orangespotted Sunfish	*Lepomis humilis*	4	1
Warmouth Sunfish	*Lepomis gulosus*	1	0
Freshwater Drum	*Aplodinotus grunniens*	2	0

Table 4.

Electrofishing results from Turner Island and Jim Crow Island in October 1998. Numbers are based on 30-min electrofishing runs at each site.

Common Name	Scientific Name	Jim Crow Island	Turner Island
Skipjack Herring	*Alosa chrysochloris*	0	1
Gizzard Shad	*Dorosoma cepedianum*	14	88
Common Carp	*Cyprinus carpio*	6	10
Grass Carp	*Ctenopharyngodon idella*	0	1
Emerald Shiner	*Notropis atherinoides*	3	2
River Carpsucker	*Carpiodes carpio*	1	0
Smallmouth Buffalo	*Ictiobus bubalus*	1	0
Channel Catfish	*Ictalurus punctatus*	2	2
White Bass	*Morone chrysops*	0	2
Bluegill Sunfish	*Lepomis macrochirus*	1	2
Orangespotted Sunfish	*Lepomis humilis*	0	1
Freshwater Drum	*Aplodinotus grunniens*	2	3

APPENDIX D.

1999 Progress Report Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University Carbondale, Fisheries Research Laboratory.

Middle Mississippi River Pallid Sturgeon Habitat Use Project

Robert J. Sheehan, Roy C. Heidinger,

Paul S. Wills, Keith L. Hurley, and Miguel Nuevo

Fisheries Research Laboratory and Department of Zoology

Southern Illinois University

Carbondale, IL 62901-6511

Year 4

Annual Progress Report

January 2000

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 fourth year of the study (October 1998 through December 1999). Goal 1 during year 4 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 preliminary 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 of Goal 2 was to collect substrate samples from the site. Objective B of Goal 2 was to attempt to collect sturgeon eggs at this site during the reported spawning season using a benthic dredge specifically designed for this purpose.

Goal 3 during year 4 was to continue refinement of the character index equation created during year 1. Objective A of Goal 3 was to publish a field guide for the application and interpretation of the character index so that others working with pallid sturgeon could use it effectively. Objective B of Goal 3 was to evaluate the character index using the data base of meristics and morphometrics collected from pallid sturgeon, shovelnose sturgeon, and putative hybrids captured throughout their sympatric geographic range.

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 was used in Years 2, 3, and 4 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 15.2-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 – Preliminary observations on habitat of sturgeon spawning site near Chester, Illinois

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

The site is located on the western shore (Missouri Shore) of the Mississippi River directly below the automobile bridge at Chester, Illinois. 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 on three occasions during the spring of 1999 on 4 April 1999, 14 May 1999, and 17 May 1999 to collect eggs from the alleged spawning site using a benthic egg dredge. Water temperature during this sampling period was between 14.5° C and 20° C. The benthic egg dredge consisted of a heavy metal sled onto which was attached a 250 □m 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 sampling attempt consisted of five deployments of the dredge. Each dredge deployment covered approximately 50 linear meters of river bed.

Goal 3 -Character Index Value: Field Guide and Evaluation

The objectives of Goal 3 were to publish a field guide for the character index (CI), and to evaluate the character index's discriminative ability.

The ability of two indices, the character index (CI) and the morphometric character index (mCI), to distinguish between pallid sturgeon, shovelnose sturgeon and hybrids was evaluated using Discriminate Functions Analysis (DFA). Jackknifed classification was used to reduce the bias that individual specimens have on prediction of group membership. Output of the DFA includes graphs depicting clustering of individuals, and the percentage of *a priori* group membership assignments made by the CI or mCI that match the DFA classifications. The assumption made in the classification analyses was that group membership assignments based on the DFA were correct for comparisons. The five morphometric ratios (OB/IB, HL/IB, HL/MIB, IL/IB,and IL/MIB), and two meristic (AFC and DFC) were used as characters for the DFA analysis of the CI and for examining regional differences. The five morphometric ratios alone were used as characters for the DFA analysis of the mCI.

A total of 257 *Scaphirhynchus* including pallid sturgeon, shovelnose sturgeon and hybrids, were collected from throughout the sympatric range of the pallid sturgeon and the shovelnose sturgeon with the help of other pallid sturgeon researchers and members of the Pallid Sturgeon Recovery Team (Figure 2). Index values were calculated for each of these specimens and they were then classified into one of five groups; shovelnose sturgeon, shovelnose-overlapping hybrids, non-overlapping hybrids, pallid-overlapping hybrids, and pallid sturgeon (Figure 3). A total of 222 of these specimens included fin ray count data, and were used to evaluate the CI. All 257 specimens were used to evaluate the mCI. A separate DFA was calculated for 77 specimens classified as pallid sturgeon by the CI in order to explore whether any clustering, related to regional differences, was apparent that would limit the indices use throughout the sympatric range of pallid sturgeon and shovelnose sturgeon.

Results

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

Twelve additional pallid sturgeon were obtained from commercial fishers and implanted with sonic transmitters during Year 4. Ten of the fish had high character index (CI) values (Sheehan et al. 1997a), one was in the pallid sturgeon hybrid overlap range, and one was in the hybrid range (Tables 2, 3 and Figure 3). Two of the 12 fish implanted with a transmitter (3334 and 6—9) were confirmed to be females with eggs during the implantation surgery.

Seventeen other pallid sturgeon were examined but not implanted with sonic transmitters due to their small size (Table 4). Nine of these fish had a scar at the base of the left pectoral fin, and one carried a Missouri Department of Conservation (MDOC) floy tag. The scarred fish were 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.

Only one fish implanted with a sonic transmitter during years 1-3 was relocated during Year 4. This may be due to the fact that transmitters implanted during earlier study years had reached the end of their battery life. Contacts from seven pallid sturgeon were added to the study data during Year 4. The following analysis is a synopsis of all relocation data gathered throughout Years 1, 2, 3, and 4 of this project.

Habitat Associations

A total of 184 relocations of the study fish were made from November 13, 1995 to December 31, 1998. These 184 contacts were all made during daylight hours. Approximately 2655 miles of tracking effort were exerted during the four years of this study to accumulate these relocations. Most tracking effort was expended between river miles 81 and 151 (Figure 4). 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 39% of all relocations. The MCB and WDB habitats were used during 26% and 14% of all contacts, respectively. All other habitats comprised 1% to 9% of all relocations (Figure 5).

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 10%, respectively). However, the MCL (49%) was still used most often (Figure 6). 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 (54%) and the MCB (28%) together comprised 82% of all relocations (Figure 7).

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 11% of the relocations during the spring (Figure 8). Use of the MCB (26%) habitat remained similar to most other seasons. Use of the WDB habitats increased greatly during the spring at 36% of the contacts. The ITD (16%) and WDD (11%) habitats were also used (Figure 8). It is notable, however, that the number of contacts during this period was low (n = 19) 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 9). The ITD, WDT, and WDB habitats were also used at 3%, 10%, and 3%, respectively.

During the summer (surface water temperatures over 20 °C), habitat associations were diverse and resembled the overall habitat associations. The WDT macrohabitat saw its heaviest use during the summer months at 13%. The major habitats of use during the summer were the MCL (27%), MCB (32%), ITD (10%), and the WDB areas (16%) (Figure 10).

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 (88.5% of all relocations) in water with maximum depths from 3 to 12 m (Table 5). The study sturgeon were primarily found in the MCL and MCB habitats, where depths in this range are common.

Fifty-nine substrate samples were taken at points where pallid sturgeon were relocated. Study fish were found over sand substrates 80.4% of the time (n = 41) (Table 6). Sturgeon were found over sand/gravel substrates 9.8% of the time (n=5). Fish were located over mud/silt substrates 5.9% of the time (n = 3). The mean surface velocity measurement taken at points where pallid sturgeon were relocated was 0.51 m/s (SD=0.25).

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 11).

Strauss's selectivity index values (L_i) ranged from -0.2158 to 0.1504 (Figure 12). 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 = 154.90, 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 12).

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 7). However, only two habitats showed a change in direction of 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)(Figure 13).

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 8). Selection direction did not change for any habitat during the three discharge regimes (Figure 14). 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 2334 (with 2 contacts) was located along a 0.4-mi stretch of river. In contrast, pallid sturgeon 384 was located along a 72.2-mi stretch of river in 6 contacts (Table 9). The mean observed home range was 18.5 mi. 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 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.

Nineteen of the 27 fish implanted with a transmitter were relocated at least one time during the four years of this study. The longest period of contact on a fish to date was fish 2237 at approximately 19 months (Figure 15). The observed movements of each of these fish are depicted in Figures 16-34. Figure 35 provides annual discharges from 1 January 1996 through 30 September 1999 of the study period.

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

The substrate samples taken below the automobile bridge at Chester, Illinois 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.

Goal 3 -Character Index Value: Field Guide and Evaluation

Field Guide

A field guide (Sheehan et al. 1999) was published for the character index. The field guide also discusses a new index that was developed in a manner similar to the original except that only morphometric ratios were used as predictors (i.e., meristic characters were dropped from the regression equation). This second index, the morphometric character index (mCI), was developed in response to field workers desire to avoid collection of fin ray counts, that can be difficult under some circumstances. A copy of the field guide is included with this report. The field guide was printed on water resistant paper and distributed to researchers working with pallid sturgeon.

Evaluation of the Character Indices

The DFA analysis indicated that 90.0% of fish classified as pallid sturgeon by the CI were consistent with classifications made by the jackknifed classification procedure (Table 10). Ten fish were shifted out of the pallid sturgeon group and reclassified as pallid-overlapping hybrids. No fish from the other groups were reclassified as pallid sturgeon.

Examination of the plot of the first two canonical variables produced by the DFA revealed that individuals classified as pallid sturgeon by the CI clustered distinctly from individuals classified as shovelnose sturgeon (Figure 36). The individuals classified as shovelnose-overlapping hybrids, non-overlapping hybrids, and pallid-overlapping hybrids form a third cluster in between the shovelnose sturgeon and pallid sturgeon clusters with shovelnose-overlapping hybrids nearer the shovelnose sturgeon cluster, pallid-overlapping hybrids nearer the pallid sturgeon cluster, and hybrids in the middle.

The DFA analysis indicated that 89.7% of fish classified as pallid sturgeon by the mCI were consistent with classifications made by the jackknifed classification procedure (Table 11). Nine fish were shifted out of the pallid sturgeon group and reclassified as pallid-overlapping hybrids. Three fish from the pallid-overlapping hybrid group were reclassified as pallid sturgeon. No fish from the other three groups were reclassified as pallid sturgeon.

Examination of the plot of the first two canonical variables produced by the DFA revealed that individuals classified as pallid sturgeon by the mCI clustered distinctly from individual classified as shovelnose sturgeon (Figure 37). The individuals classified as shovelnose-overlapping hybrids, non-overlapping hybrids, and pallid-overlapping hybrids form three clusters with shovelnose-overlapping hybrids nearer the shovelnose sturgeon cluster, pallid-overlapping hybrids nearer the pallid sturgeon cluster, and hybrids in the middle.

Examination of the plot of the first two canonical variables produced by the DFA based on sampling region revealed that pallid sturgeon from all regions form a single cluster with only minor regional sub-clustering (Figure 38).

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 (20%), 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 an 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 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 as their confidence intervals all fall above zero. 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 11). 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 18.5 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 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 36). 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 - Preliminary 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 preliminary observations. This line of investigation, however, may be important in locating sites and identifying habitat characteristics needed for spawning.

Goal 3 –Character Index Value: Field Guide and Evaluation

Both the CI and the mCI classified more than 89% of pallid sturgeon correctly based on the DFA, and thus can provide reliable means for differentiating them from shovelnose sturgeon and hybrids. In cases where a higher degree of assurance is needed in identification, such as hatchery programs, using fish that aren't near the overlap zones would be advisable. The DFA analysis showed widely separate clusters for pallid sturgeon and shovelnose sturgeon with hybrids clustering in the intermediate area. This evidence supports the validity of the pallid sturgeon as a species, and the contention that they are hybridizing with shovelnose sturgeon in the natural setting. The lack of distinct regional clustering of pallid sturgeon based on CI identifications indicates that the CI is a viable tool for identification of pallid sturgeon throughout their geographic range. Geographic specificity has been an impediment to the application of other identification indices proposed in the past.

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.

Literature Cited

Bailey, R. M., and F. B. Cross. 1954. River sturgeons of the American genus Scaphirhynchus: Characters, distribution, and synonymy. Papers of the Michigan Academy of Science, Arts, and Letters 39:169-208.

Bramblett, R. G. 1996. Habitats and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers, Montana and North Dakota. Doctoral dissertation. Montana State University - Bozeman, Montana.

Campton, D. E., A. L. Garcia, B. W. Bowen, and F. A. Chapmen. 1995. Genetic evaluation of pallid, shovelnose, and alabama sturgeon (*Scaphirhynchus albus*, *S. platorynchus*, and *S. suttkusi*) based on control region (D-loop) sequences of mitrochondrial DNA. Final report. Cooperative Agreement No. 14-48-0006-94-929.

Carlson, D. M. and W. L. Pflieger. 1981. Abundance and life history of the lake, pallid, and shovelnose sturgeons in Missouri. Final Report. Endangered Species Project SE-1-6, Missouri Department of Conservation, Jefferson City.

Carlson D. M., W. L. Pflieger, L. Trial, and P. S. Haverland. 1985. Distribution, biology, and hybridization of *Scaphirhynchus albus* and *S. platorynchus* in the Missouri and Mississippi rivers.

In S. Doroshov (ed) Sturgeon Symposium. Environmental Biology of Fishes 14:51-59.

Clancey, P. 1990. Fort Peck Pallid Sturgeon Study. Annual Report F-16-10. U.S. Army Corps of Engineers, Omaha, Nebraska.

Dryer, M. P. and A. J. Sandvol. 1993. Recovery plan for the pallid sturgeon (*Scaphirhynchus albus*). U.S. Fish and Wildlife Service, Denver. 55 pp.

Erickson, J. D. 1992. Habitat selection and movement of pallid sturgeon in Lake Sharpe, South Dakota. Master Thesis. South Dakota State University - Brookings, South Dakota.

Helms, D. 1974. Shovelnose sturgeon, Scaphirhynchus platorynchus, in the navigational impoundments of the upper Mississippi River. Tech. Series. Iowa State Conservation Commission 74-3. 68pp.

Hunter, C. J. 1991. Better trout habitat: a guide to stream restoration and management. Island press, Washington D.C.

Kallemeyn, L. W. 1983. Status of the pallid sturgeon (*Scaphirhynchus albus*). Fisheries 8:3-9.

Kentz, S. and M. Dryer. 1996. Character index for pallid and shovelnose sturgeon. Technical notes. Number: 1:96. Missouri River Fish and Wildlife Management

Assistance Office, U.S. Fish and Wildlife Service, Bismarck, North Dakota.

Lechowicz, M. J. 1982. The sampling characteristics of electivity indices. Oecologia 52:22-30.

May, B., C. C. Krueger, and H. L. Kinkaid. 1997. Genetic variation at microsatellite loci in sturgeon: primer sequence homology in *Acipenser* and *Scaphirhynchus*. Canadian Journal of Fisheries and Aquatic Sciences (in press).

Mayden, R. L. and B. R. Kuhajda. 1997. Threatened fishes of the world: *Scaphirhynchus albus* (Forbes & Richardson, 1905)(Acipenseridae). Environmental Biology of Fishes 48:420-421.

Moos, R. E. 1978. Movement and reproduction of shovelnose sturgeon, *Scaphirhynchus platorynchus,* in the Missouri River, South Dakota, Vermillion. 216pp.

Phelps, S. R. and F. W. Allendorf. 1983. Genetic identity of pallid and shovelnose sturgeon (*Scaphirhynchus albus* and *S. platorynchus*). Copeia 1983:696-700.

Sheehan, R. J. and M. Konikoff. In press (1998). Wetlands and fisheries resources of the Mississippi River. Pp 628-647 *in* S. K. Majumdar, E.W. Miller, and F. P. Brenner, Wetlands and Associated Systems. Pennsylvania Acadamy of Science, Harrisburg, Pennsylvania.

Sheehan, R. J., R. C. Heidinger, P. S. Wills, M. A. Schmidt, G. A. Conover, and K. L. Hurley. 1997a. Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University at Carbondale. Annual performance report. Carbondale, Illinois.

Sheehan, R. J., R. C. Heidinger, P. S. Wills, M. A. Schmidt, G. A. Conover, and K. L. Hurley. Guide to the pallid sturgeon shovelnose sturgeon character index (CI) and morphometric character index (mCI). SIUC Fisheries Bulletin No. 14. Southern Illinois University at Carbondale, Carbondale, Illinois.

Sheehan, R. J., R. C. Heidinger, K. L. Hurley, P. S. Wills, and M. A. Schmidt. 1997b. Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University at Carbondale. Annual performance report. Carbondale, Illinois.

Sheehan, R. J., W. M. Lewis, L. R. Bodensteiner, M. Schmidt, E. Sandberg, and G. Conover. 1994. Winter habitat requirements and overwintering of riverine fishes. Southern Illinois University at Carbondale. Final performance report F-79-R-6. Carbondale, Illinois.

Sheehan, R. J., W. M. Lewis, L. R. Bodensteiner, D. E. Logsdon, and P. S. Wills. 1990. Winter habitat requirements and overwintering of riverine fishes. Project Completion Report (190 pp) to the Illinois

Department of Conservation. Cooperative Fisheries Research Laboratory, Southern Illinois University, Carbondale, Illinois.

Sheehan, R. J. and J. R. Rasmussen. 1993. Large Rivers. Pp 443-466 *in* C. Kohler and W. Hubert, editors. Inland Fisheries Management in North America. American Fisheries Society. Bethesda, Maryland.

Strauss, R. E. 1979. Reliability estimates for Ivlev's electivity index, the forage ratio, and a proposed linear index of food selection. Transactions of the American Fisheries Society 108:344-353.

Watson, J. H. and P. A. Stewart. 1991. Lower Yellowstone River pallid sturgeon study. Montana Department of Fish, Wildlife, and Parks, Helena.

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 2. Length, weight, character index values, and source of pallid sturgeon implanted with a sonic transmitter and released into the Middle Mississippi River during Year 4 (October 1998 through December 1999).

Transmitter Number	Date	Weight (g)	Length (mm) Total	Standard	Fork	Character Index Value	Source
239	10/27/98	--	652	697	783	-1.65	Jim Beuschel
2264	10/27/98	--	576	646	653	-2.00	Jim Beuschel
2273	10/31/98	2363.6	744	799	878	-1.75	John Booth
5--10	1/21/99	1909.0	725	770	853	-0.48	John Booth
338	3/29/99	1636.4	730	782	859	-1.21	Mike Duboise
7--8	3/30/99	1318.2	673	723	802	-1.92	Jim Beuschel
6--9	4/1/99	3273.0	836	877	959	-1.35	John Booth
3334	4/1/99	3227.3	836	888	975	-1.93	John Booth
284	4/3/99	3136.4	817	864	967	-1.50	John Booth
257	4/19/99	1590.9	672	719	806	-0.26	Gene Esker
248	4/26/99	1545.5	712	762	855	-0.71	Gene Esker
2363	12/29/99	1454.5	695	742	820	-2.08	Jim Beuschel

Table 3. Meristic and morphometric measurements of pallid sturgeon implanted with a sonic transmitter and released into the Middle Mississippi River during Year 4. All measurements are in millimeters. OB = outer barbel mean length, IB = inner barbel mean length, HL = head length, MIB = mouth to inner barbel distance, and IL = interrostrum length.

Transmitter								Fin Ray Counts		Ventral
Number	IB	IB	OB	OB	MIB	IL	HL	Anal	Dorsal	Scutes
239	26	26	61	59	32	93	208	37	26	None
2264	19	17	50	51	31	82	181	41	25	None
2273	34	33	93	96	42	97	240	41	25	Few
5–10	48	46	79	82	41	84	208	39	26	None
338	35	33	63	63	37	98	208	40	27	None
7–8	22	22	60	58	38	104	221	39	26	None
6–9	47	45	112	116	47	112	256	41	26	Few
3334	27	33	87	84	49	114	260	40	25	Few
284	44	41	110	110	43	111	249	40	26	None
257	36	36	55	57	32	80	188	33	24	Many
248	36	40	81	82	40	86	207	39	24	Few
2363	29	25	62	61	31	104	225	41	28	None

Table 4. Meristic and Morphometric measurements for the pallid sturgeon captured in the Middle Mississippi River during Year 4 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)	OB/IB	HL/IB	HL/MIB	IL/IB	IL/MIB	Fin Ray Counts Anal	Fin Ray Counts Dorsal	Ventral Scutes
595	1045.5	3.17	10.46	6.10	4.51	2.63	36	24	Few
602	909.1	1.74	6.35	5.97	2.87	2.70	41	28	None
564	772.7	2.14	9.51	6.77	4.27	3.04	39	25	None
520	727.3	2.35	8.22	5.07	3.73	2.30	--	--	None
515	590.9	2.07	7.81	6.22	3.58	2.85	39	29	None
515	636.4	2.41	8.15	6.68	3.66	3.00	39	24	Few
632	1090.9	2.39	7.63	6.87	3.56	3.20	41	29	None
593	863.6	2.28	8.84	7.31	3.72	3.08	38	24	Few
623	954.5	2.31	7.85	6.38	3.65	2.97	42	34	None
554	727.3	2.26	8.87	6.65	3.90	2.92	39	28	None
541	681.8	3.92	13.00	5.45	6.15	2.58	39	26	None
612	1090.9	1.94	5.74	5.56	2.42	2.34	38	23	Many
558	727.3	2.39	7.51	6.34	3.39	2.86	39	26	None
507	545.5	2.33	7.38	5.54	3.43	2.57	40	27	None
548	681.8	2.09	8.00	7.33	3.68	3.38	40	27	None
545	681.8	2.45	7.71	5.59	3.52	2.55	39	27	Few
584	300.0	2.28	8.93	8.35	4.19	3.91	39	27	None

Table 5. Maximum water depths at locations where pallid sturgeon were found.

Depth (m)	Contacts	Percent
<3	9	5.0
3 - 6	41	22.7
6 - 9	66	36.5
9 - 12	53	29.3
12 - 15	9	5.0
15 - 18	1	0.6
>18	2	1.1

Table 6. Substrate type at locations where pallid sturgeon were found in the Middle Mississippi River.

Substrate Type	Observations	Percentage
Mud/Silt	3	5.9
Sand	41	80.4
Course Sand	1	2.0
Sand/Gravel	5	9.8
Gravel	1	2.0

Table 7. 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	187.96	6	12.59
4-10	33.95	6	12.59
10-20	230.80	6	12.59
20+	194.99	6	12.59

Table 8. 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	99.08	6	12.59
Medium	102.58	6	12.59
High	297.18	6	12.59

Table 9. Range of river miles over which individual pallid sturgeon were contacted.

Transmitter Number	River Mile[1]		Number of Observations[2]	Miles
	Upstream	Downstream		
7-8[3]	117.5	117.5	1	0
2273	105.5	105.6	1	0.1
5-10[3]	103.3	104.0	2	0.7
239	117.5	119.5	1	2
456	103.8	106.0	2	2.2
267	113.7	118.0	15	4.3
2237	117.5	126.0	8	8.5
366	107.6	117.3	19	9.7
2264	108.7	119.9	6	11.2
249	108.6	120.5	21	11.9
276	130.4	142.3	1	11.9
294	123.8	142.5	18	18.7
357	95.5	118.4	23	22.9
3334	81.7	110.3	3	28.6
2588	109.1	141.7	17	32.6
465	106.8	142.0	11	35.2
339	106.3	141.7	5	35.4
375	98.2	142.3	12	44.1
384	32.3	104.5	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 10. Jackknifed DFA Reclassification of individuals identified using the CI (CI Taxon) (n=222)(S=shovelnose sturgeon; OS= shovelnose-overlapping hybrid; H=hybrid; OP= pallid-overlapping hybrid; and P=pallid sturgeon).

CI Taxon	% Correct	Number Classified into Group By DFA					N by CI
		S	OS	H	OP	P	
Shovelnose	78.8	52	12	2	0	0	66
S-Overlap	60.0	1	6	3	0	0	10
Hybrid	34.5	0	7	10	12	0	29
P-Overlap	52.9	0	0	8	9	0	17
Pallid	90.0	0	0	0	10	90	100
N by DFA		53	25	23	31	90	222

Table 11. Jackknifed DFA Reclassification of individuals identified using the mCI (mCI Taxon) (n=257)(S=shovelnose sturgeon; OS= shovelnose-overlapping hybrid; H=hybrid; OP= pallid-overlapping hybrid; and P=pallid sturgeon).

		Number Classified into Group by DFA					
mCI Taxon	% Correct	S	OS	H	OP	P	N by CI
Shovelnose	81.5	22	5	0	0	0	27
S-Overlap	94.1	2	48	1	0	0	51
Hybrid	93.8	0	2	45	1	0	48
P-Overlap	86.4	0	0	3	38	3	44
Pallid	89.7	0	0	0	9	78	87
N DFA		24	55	49	48	81	257

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, WDB = between wing dams, ITD = downstream island tip.

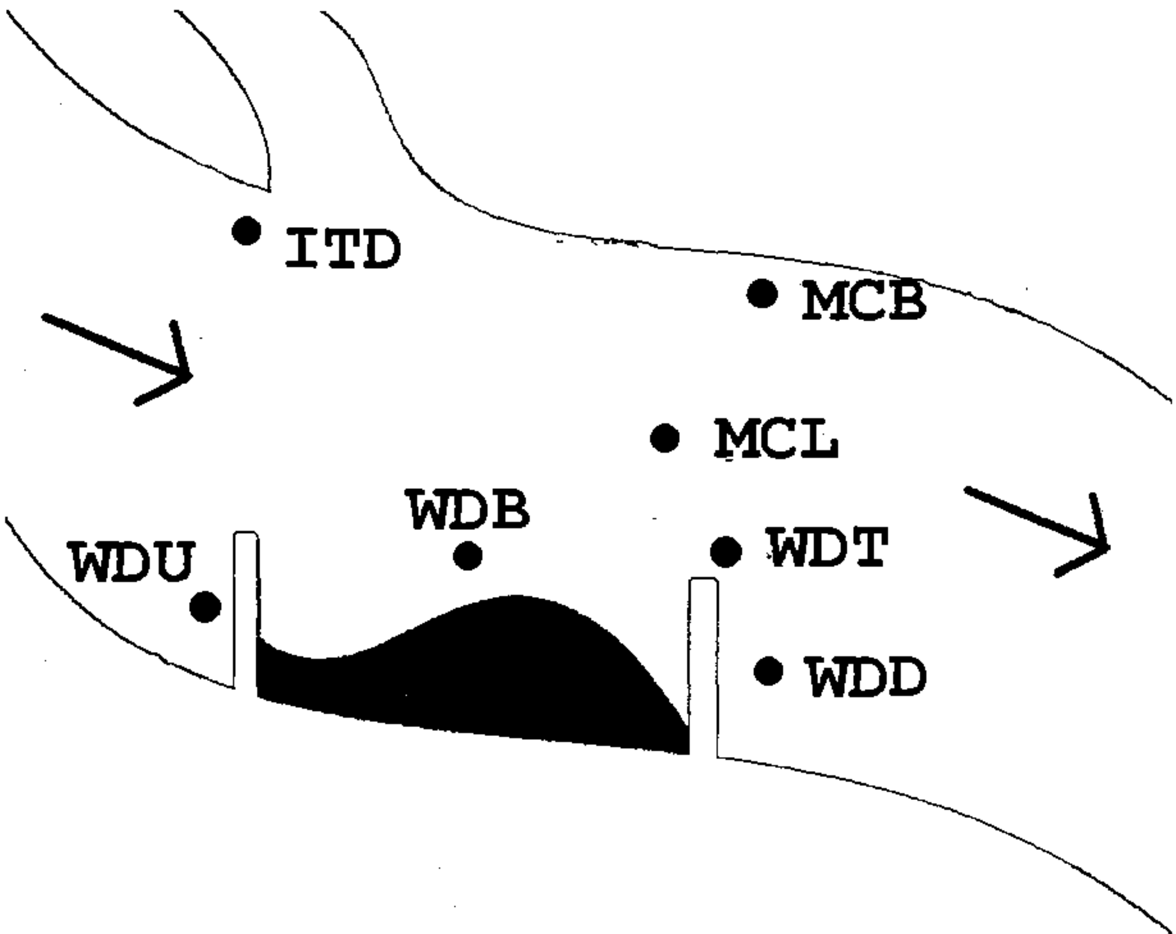


Figure 1. Areas (black circles) where pallid sturgeon, shovelnose sturgeon, and their hybrids were collected to evaluate discriminative ability of the character index (CI) and morphometric character index (mCI).

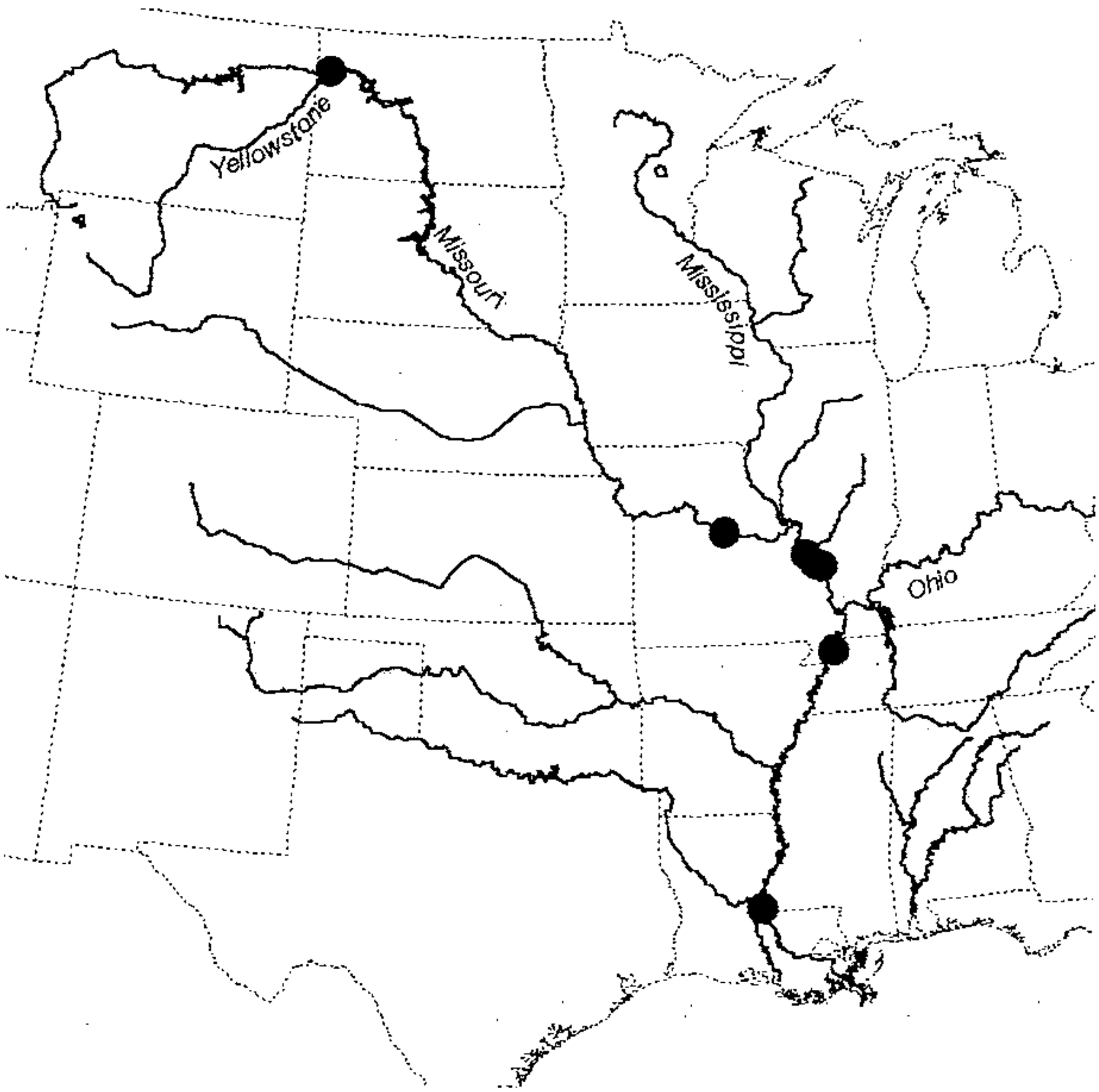


Figure 3. Character index (CI) values for pallid sturgeon captured from the Middle Mississippi River. Diamonds represent sturgeon surgically-implanted with a sonic transmitter. Triangles represent presumed pallid sturgeon that were not implanted with a sonic transmitter. Circles represent shovelnose sturgeon specimens from the Middle Mississippi River. Ranges were calculated from pallid, hybrid, and shovelnose sturgeon collected by Carlson and Pflieger (1983) and used in the development of the CI.

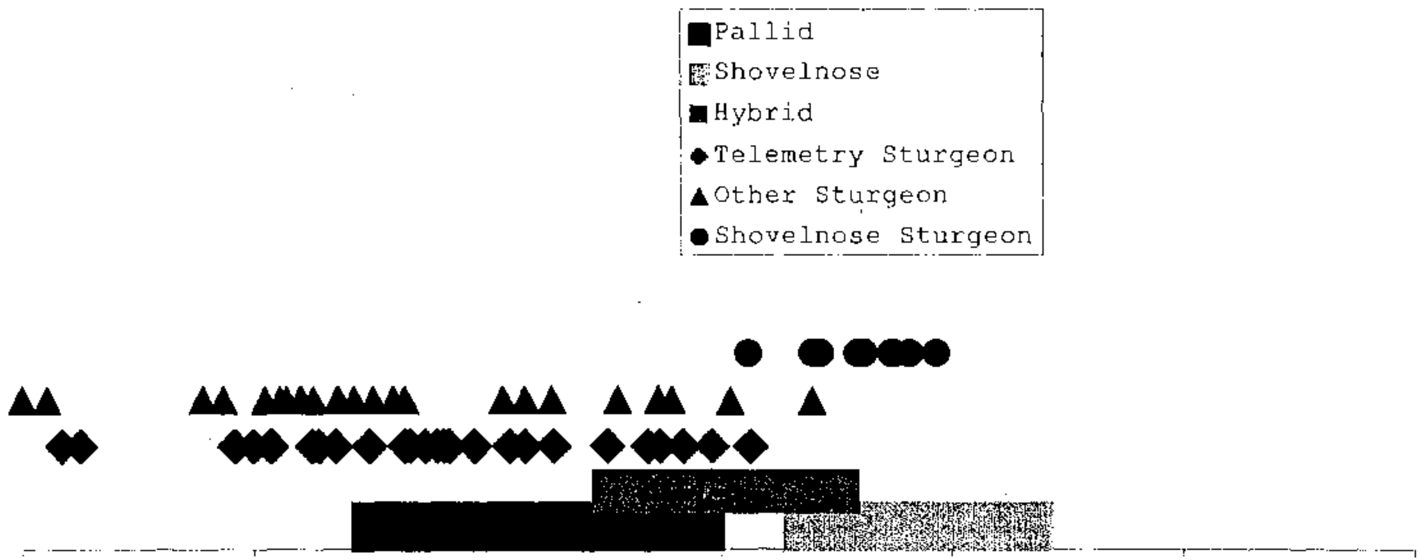


Figure 4. Tracking effort expressed as the frequency that each river mile in the study area was tracked from November 1995 through December 1999.

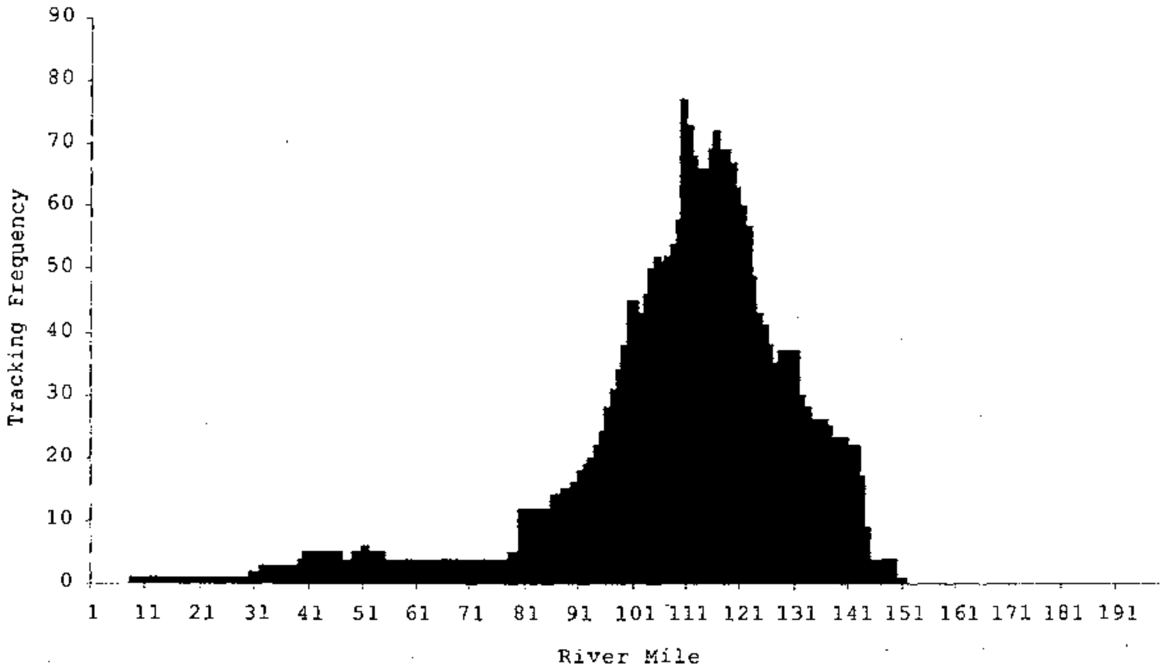


Figure 5. Pallid sturgeon habitat associations in the middle Mississippi River from November 1995 through December 1999. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 184.

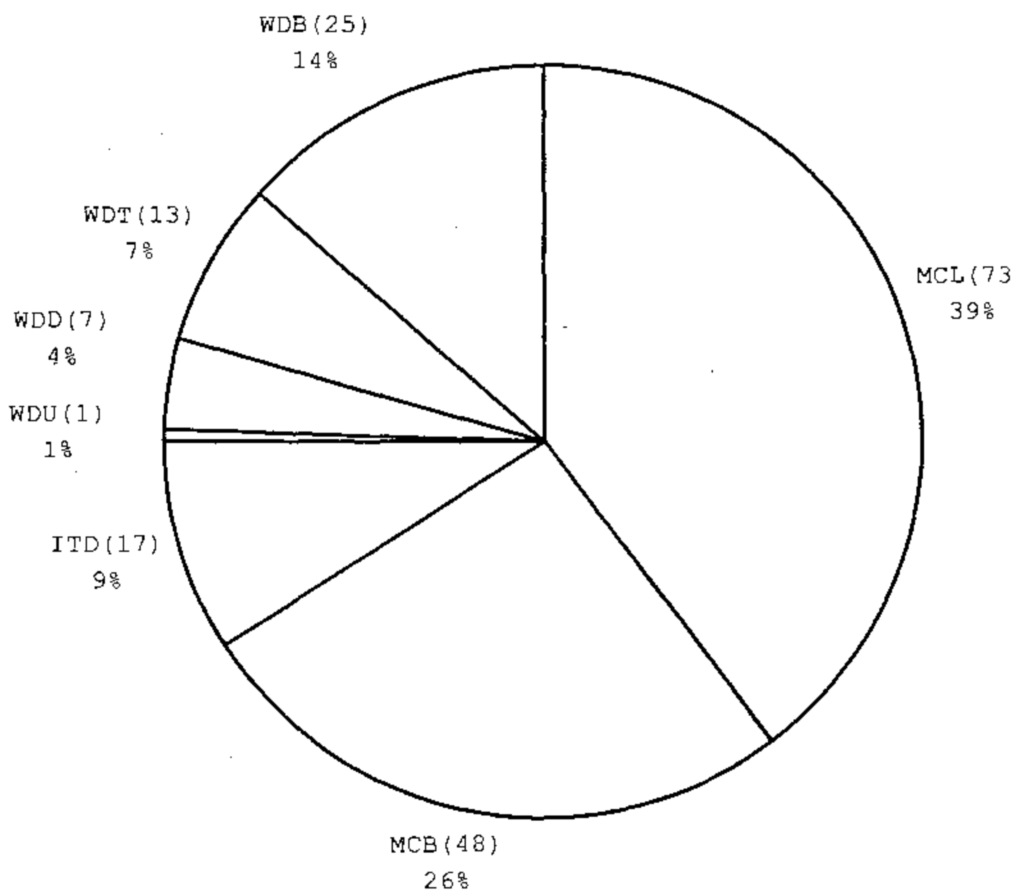


Figure 6. Pallid sturgeon habitat associations at surface water temperatures at or below 4° C in the middle Mississippi River from November 1995 through December 1999. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N =42.

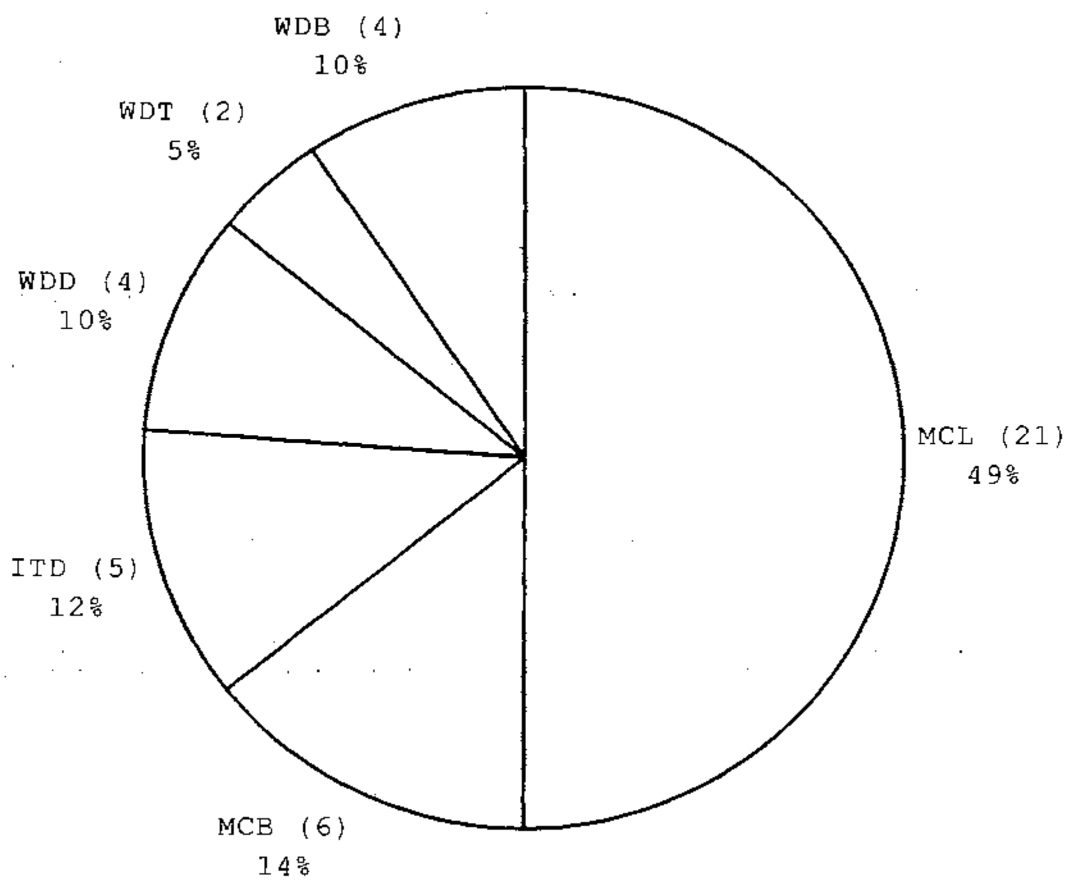


Figure 7. Pallid sturgeon habitat associations at surface water temperatures at or above 4° C and below 10° C in the middle Mississippi River from November 1995 through December 1999. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 32.

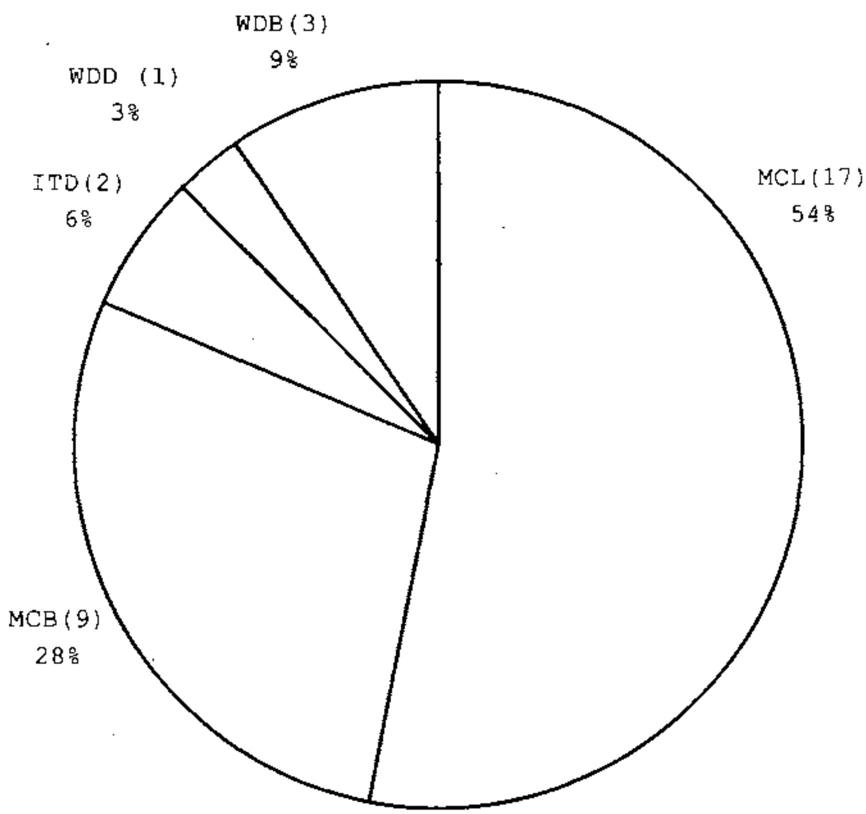


Figure 8. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River during spring months during 1996-1999. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 19.

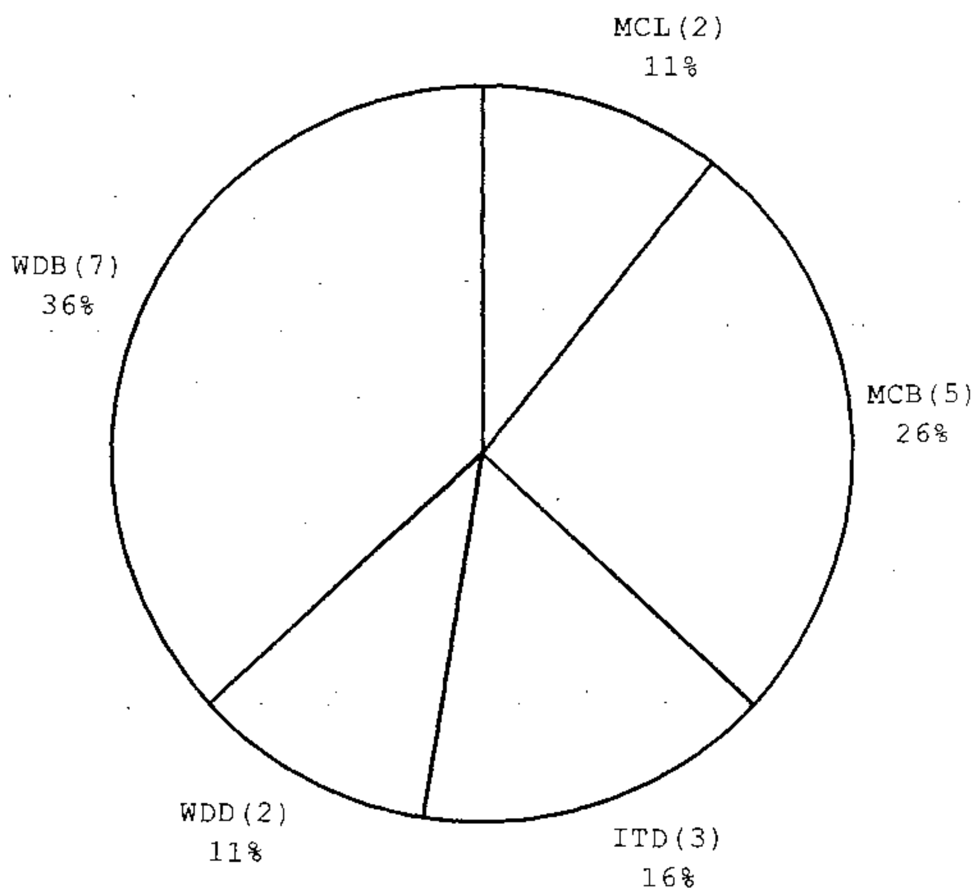


Figure 9. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River during fall months of 1995-1999. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 29.

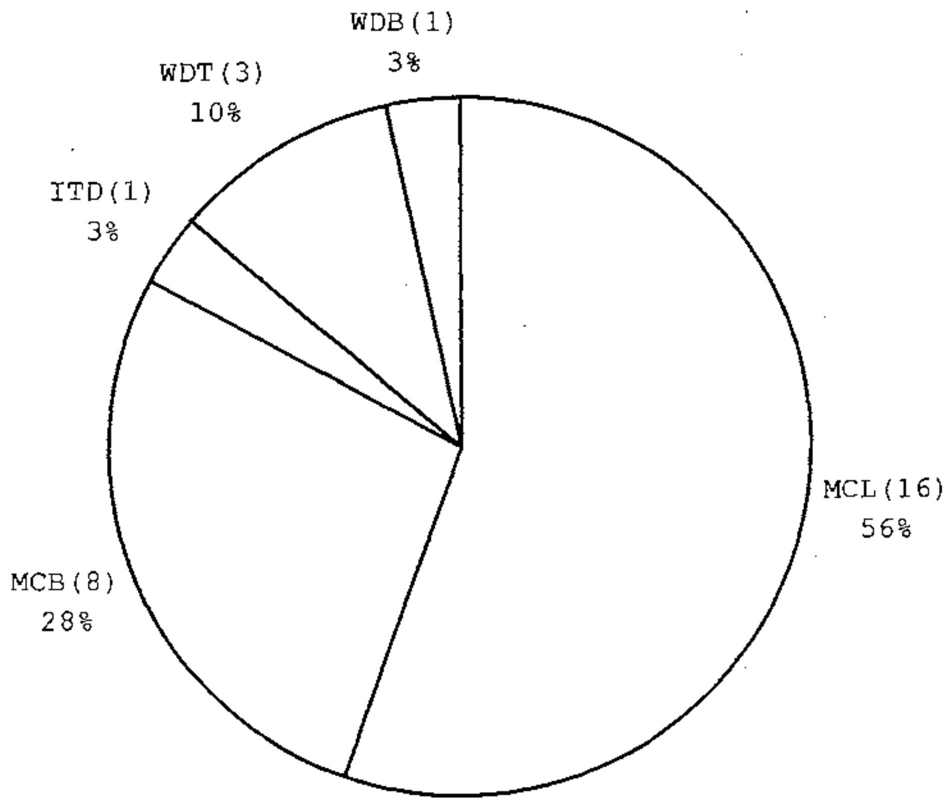


Figure 10. Pallid sturgeon habitat associations at surface water temperatures at or above 20° C in the middle Mississippi River from November 1995 through December 1999. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 62.

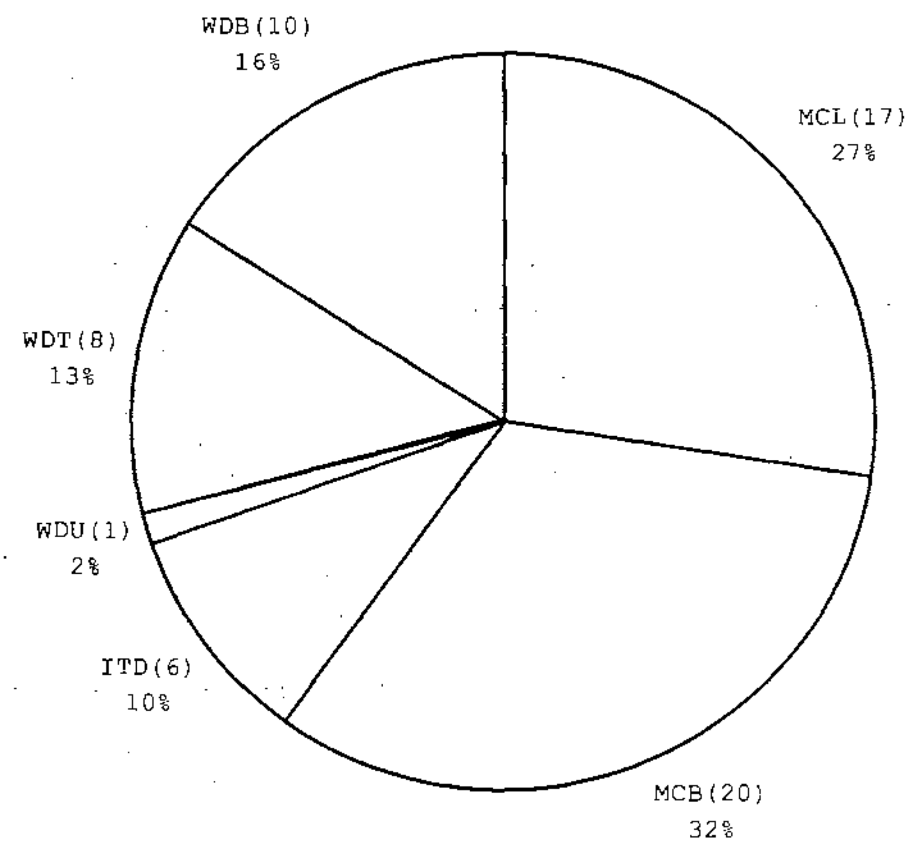


Figure 11. Habitat availability in the Middle Mississippi River expressed as a percentage. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip.

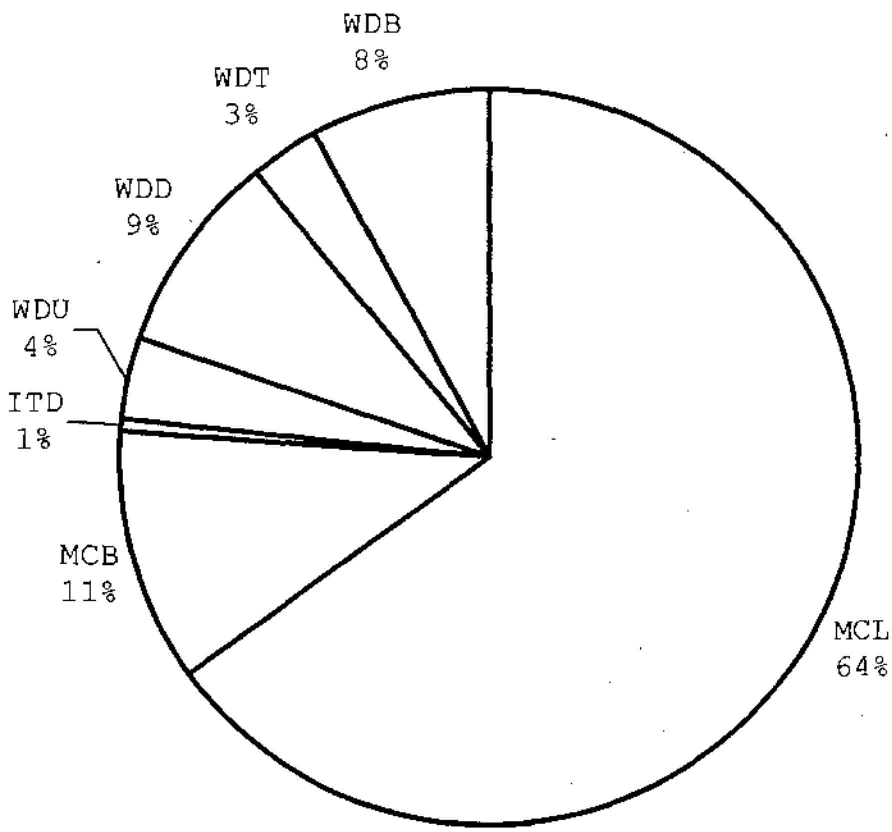


Figure 12. Strauss's linear selectivity index (L_i) values for each macrohabitat. Positive values represent selection for a habitat while negative values represent selection against a habitat. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing 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).

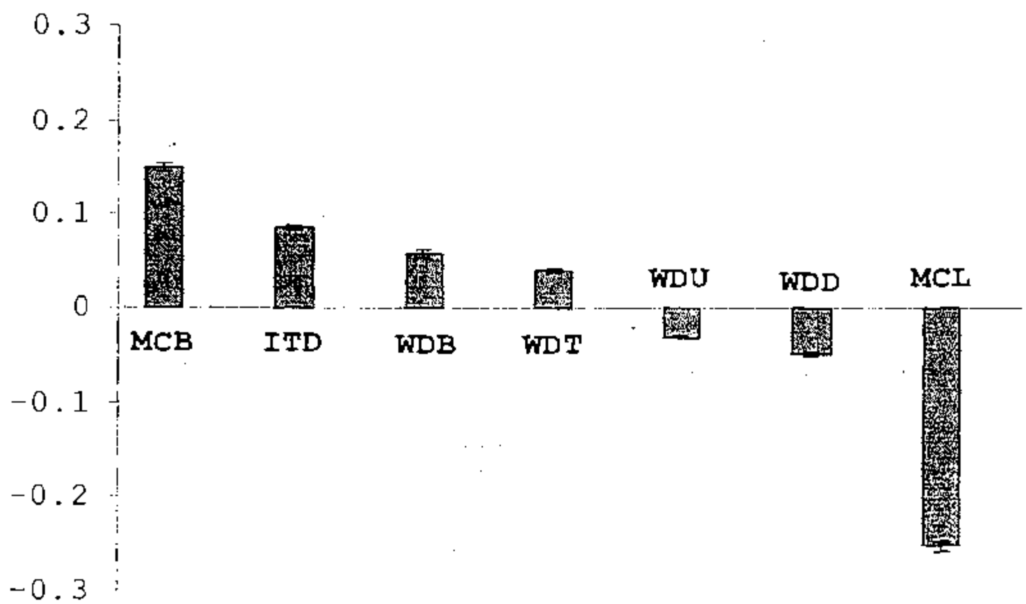


Figure 13. Strauss's linear selectivity index (L_i) values for each macrohabitat by temperature regimes (°C). Positive values represent selection for a habitat while negative values represent selection against a habitat. Error bars represent 95% confidence interval. MCL = main channel, MCB = main channel 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).

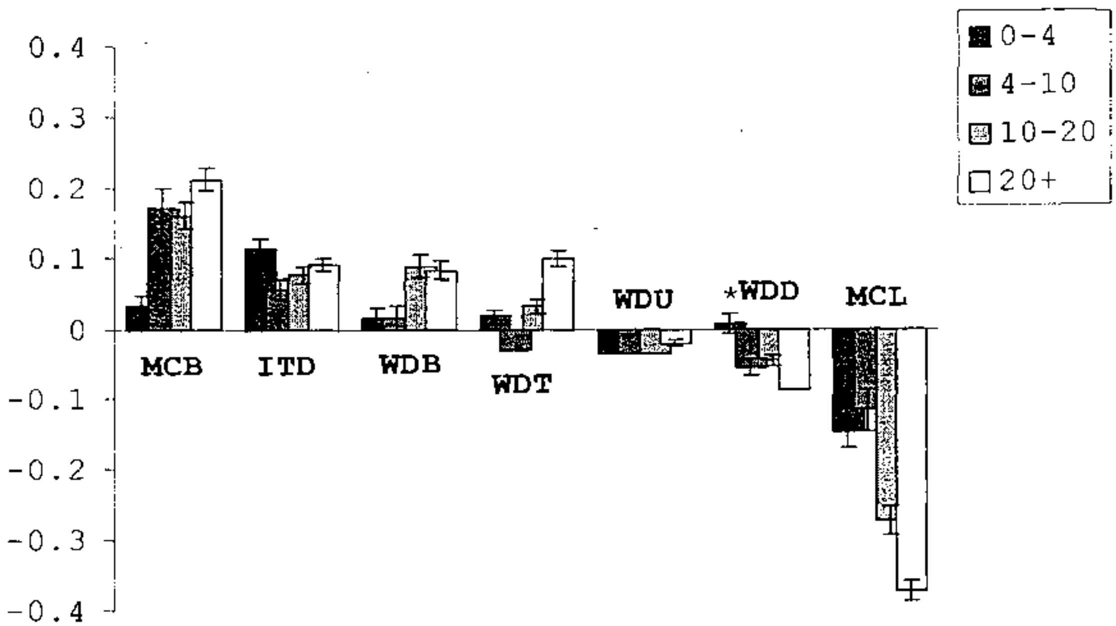


Figure 14. Strauss's linear selectivity index (L_i) values for each macrohabitat by discharge regimes. Positive values represent selection for a habitat while negative values represent selection against a habitat. Error bars represent 95% confidence interval. MCL = main channel, MCB = main channel border, 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).

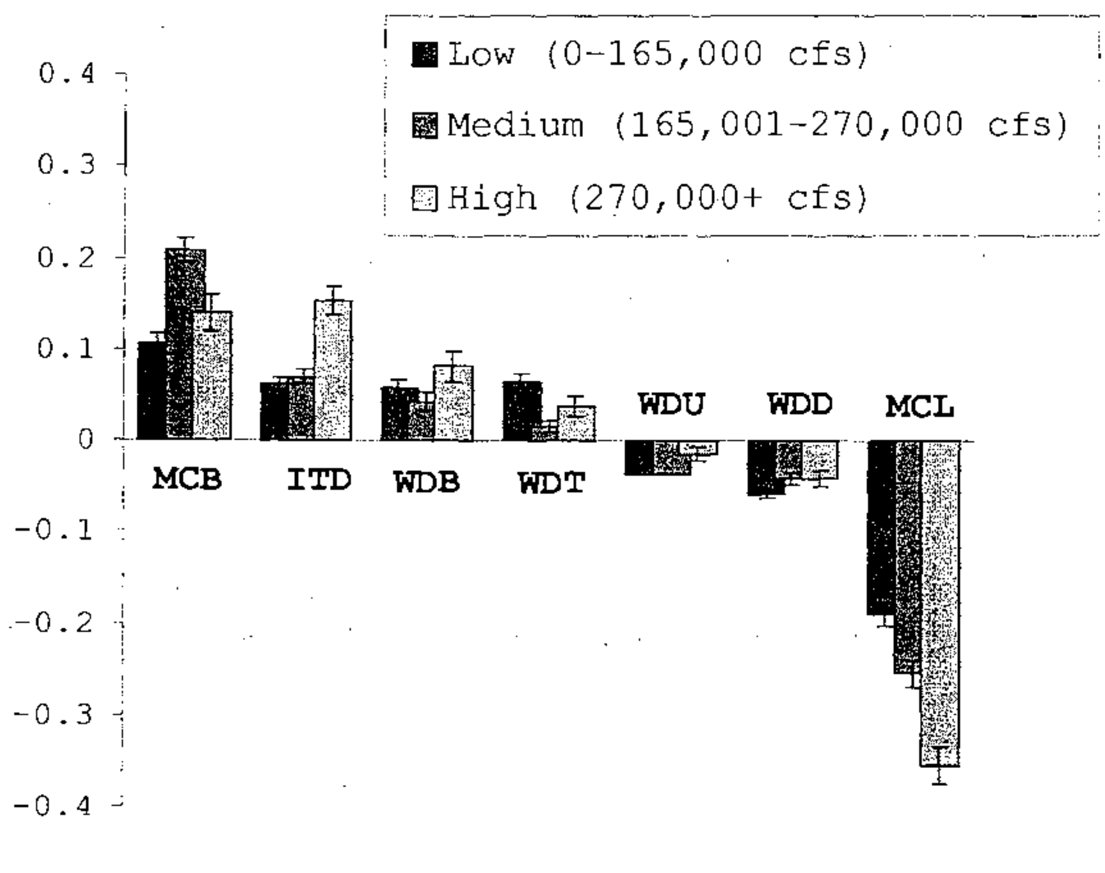
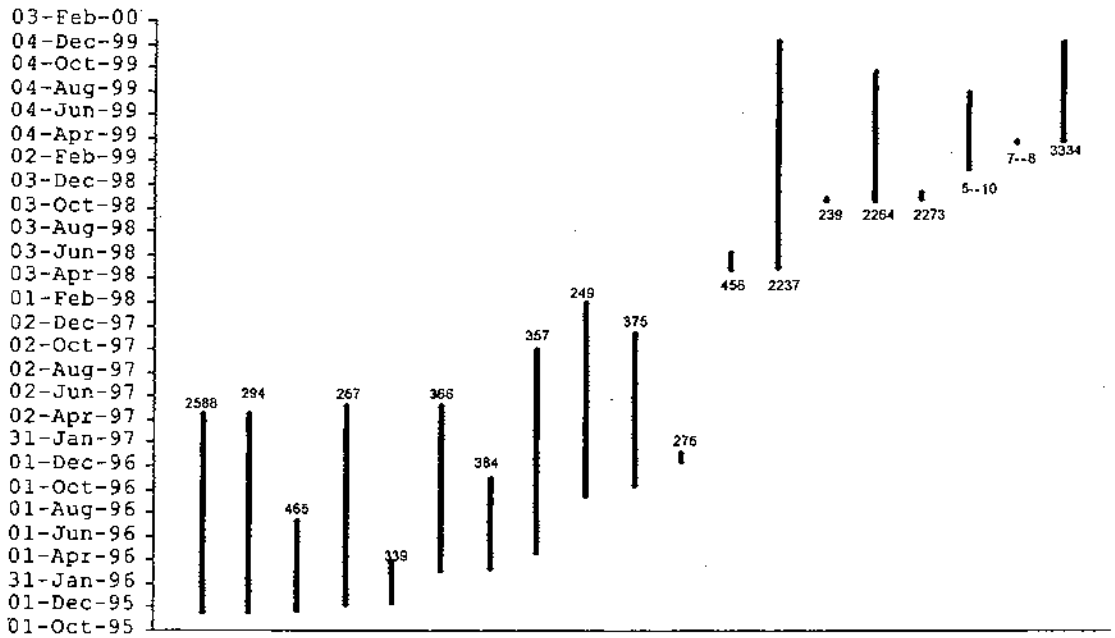


Figure 15. Contact period (date of release to last contact date) for each fish with at least one post-release contact from October 1995 through December 1999.



Pages Missing

The published 1999 A & M Report did not include figures 16 - 34 of this report

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.

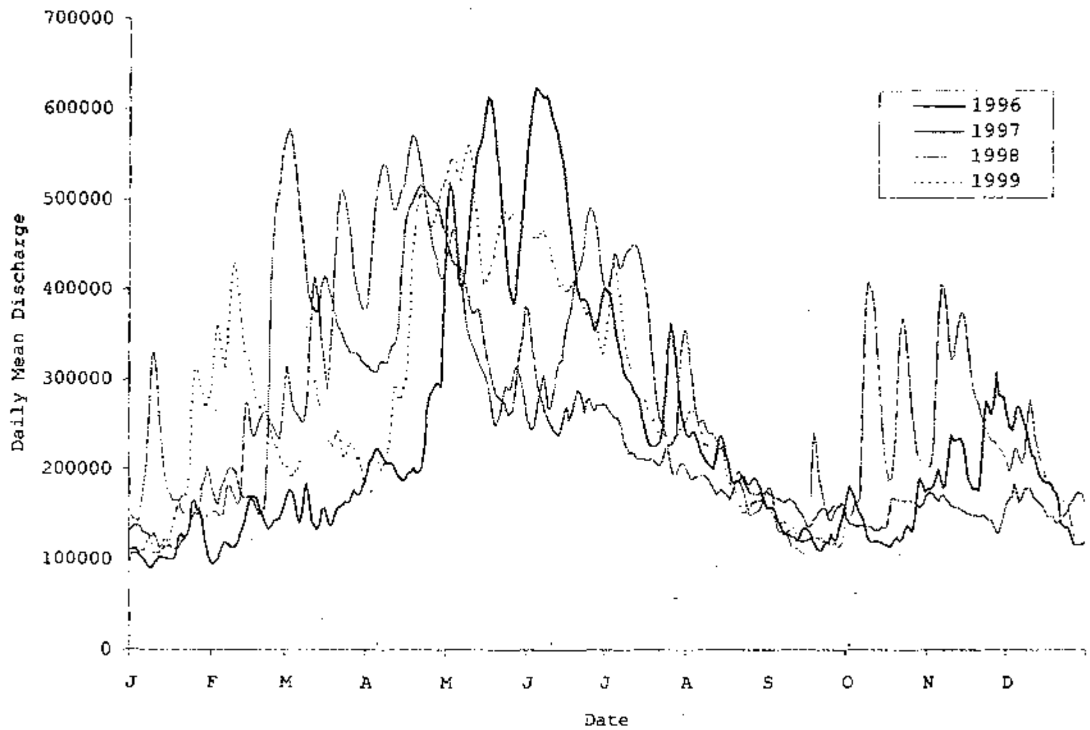


Figure 36. Plot of the first two canonical variables generated by the DFA analysis of *Scaphirhynchus* specimens, including shovelnose sturgeon, pallid sturgeon, putative hybrids, collected from throughout the sympatric geographic range. Symbols indicate the *a priori* identifications made by the character index (CI).

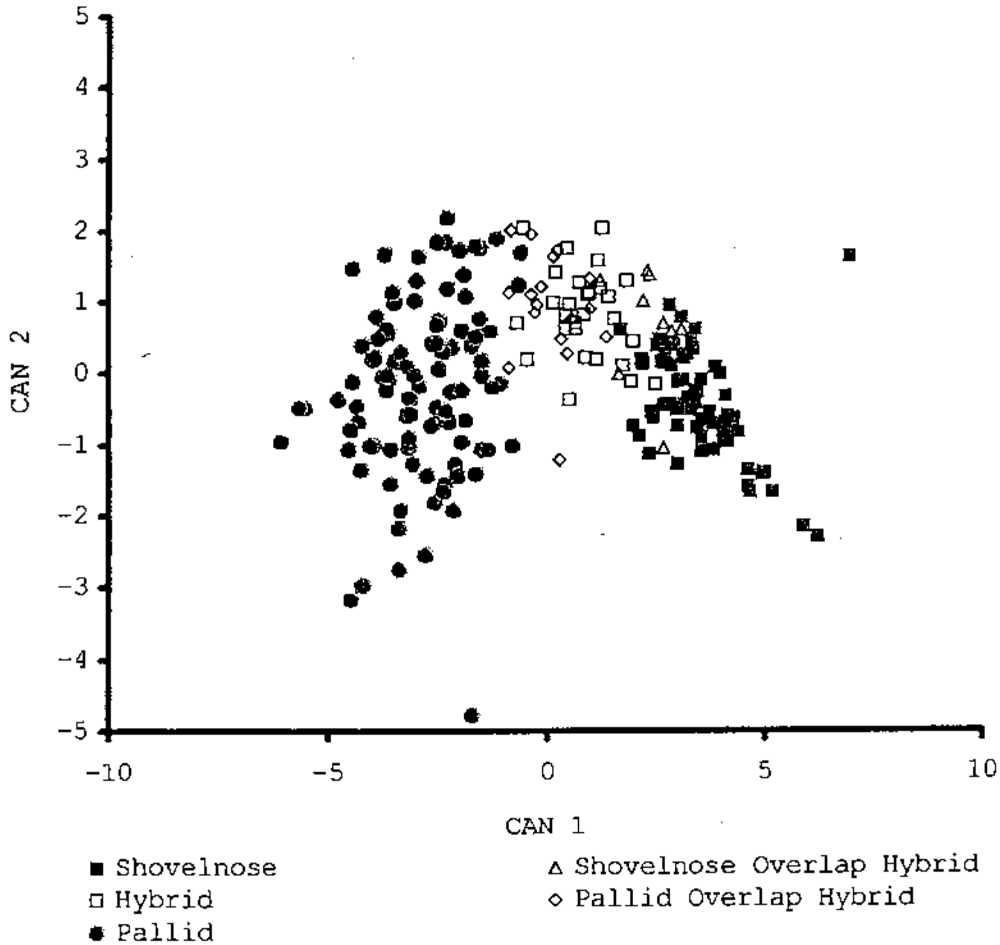


Figure 37. Plot of the first two canonical variables generated by the DFA analysis of *Scaphirhynchus* specimens, including shovelnose sturgeon, pallid sturgeon, putative hybrids, collected from throughout the sympatric geographic range. Symbols indicate the *a priori* identifications made by the morphometric character index (mCI).

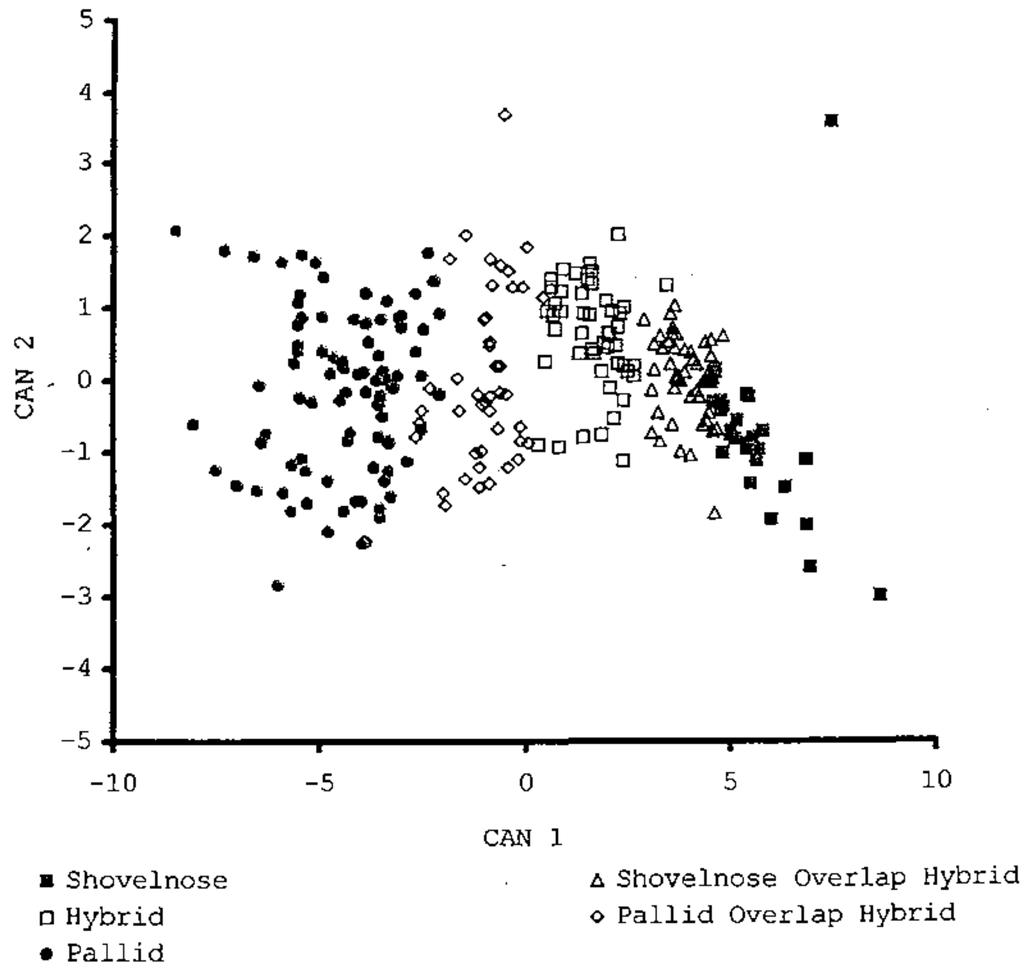
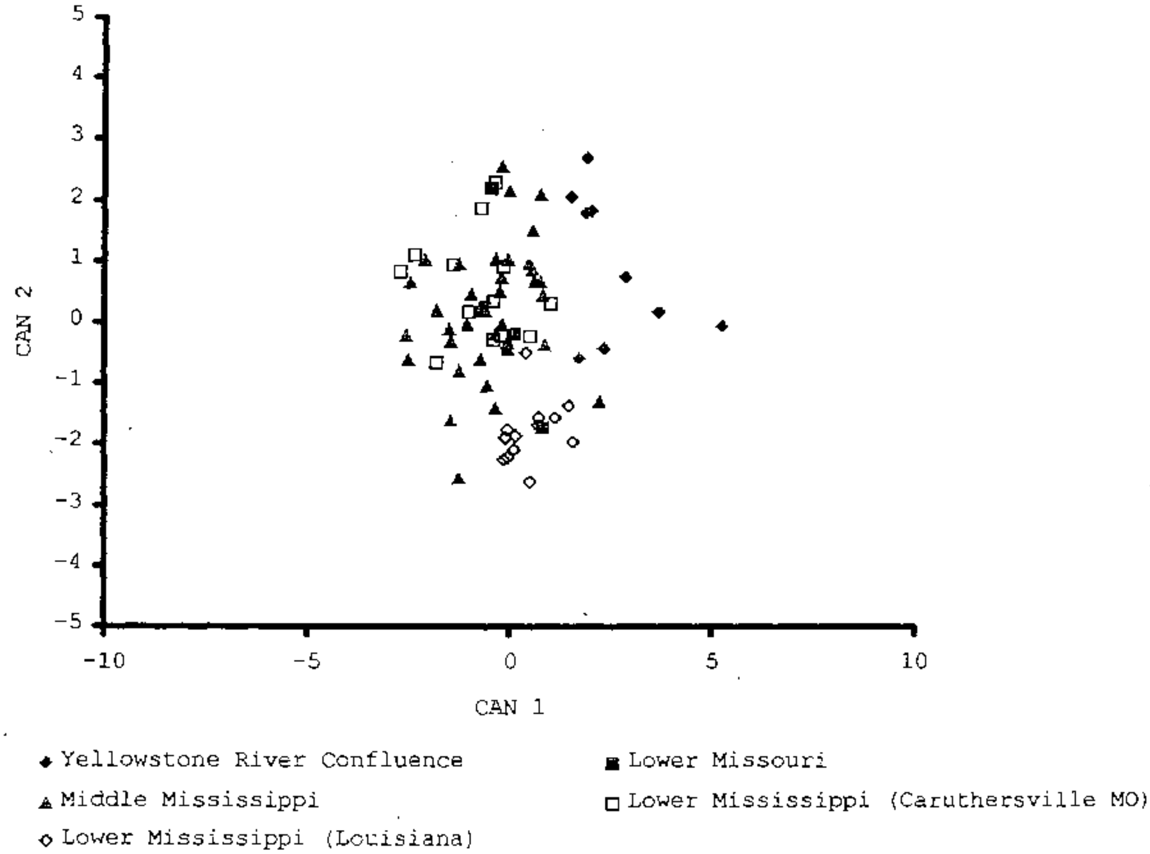


Figure 38. Plot of the first two canonical variables generated by the DFA analysis of pallid sturgeon collected from throughout the geographic range. Symbols indicate the region of specimen origin.



Cited and Related Literature

Bailey, R.M., and F.B. Cross. 1954. River sturgeons of the american genus *Scaphirhynchus*: Characters, distribution, and synonomy. Papers ot the Michigan Academy of Science, Arts, and Letters 39:69-208.

Carlson, D. M. and W. L. Pflieger. 1981. Abundance and life history of the lake, pallid, and shovelnose sturgeons in Missouri. Final report. Endangered Species Project SE-1-6, Missouri Department of Conservation, Jefferson City.

Carlson, D.M., W.L. Pflieger, L. Trial, and P.S. Haverland. 1985. Distribution, biology, and hybridization of *Scaphirhynchus albus* and *S. platorynchus* in the Missouri and Mississippi rivers. Environmental Biology of Fishes 14:51-59.

Sheehan, R. J., and R. C. Heidinger, P. S. Wills, M. A. Schmidt, G. A. Conover, and K. L. Hurley. 1997. Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University at Carbondale. Annual performance report. Carbondale, Illinois.

SIUC Fisheries Bulletin No. 14

Guide to the Pallid Sturgeon Shovelnose Sturgeon Character Index (CI) and Morphometric Character Index (mCI)

Fisheries Research Laboratory,
Southern Illinois University,
Carbondale, Illinois 62951-6511

Guide to the
Pallid Sturgeon Shovelnose Sturgeon
Character Index (CI) and Morphometric
Character Index (mCI)

Robert J. Sheehan
Roy C. Heidinger
Paul S. Wills
Michael A. Schmidt
Greg A. Conover
Keith L. Hurley

SIUC Fisheries Bulletin No. 14

Fisheries Research Laboratory, Southern Illinois
University, Carbondale, Illinois 62901-6511

1999

further refined, and ranges of values for the CI and mCI will most probably diminish.

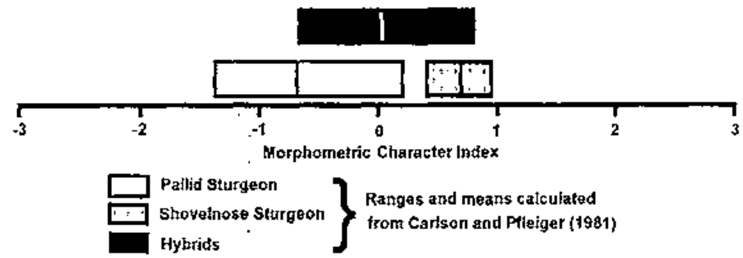


Figure 6. Ranges of mCI values

Table 4. Ranges of mCI values

Sturgeon Type	mCI Range	Mean mCI
Pallid	-1.34 to 0.22	-0.69
Hybrid	-0.70 to 0.83	0.03
Shovelnose	0.41 to 0.97	0.71

parental species and the hybrids. Designation of a hybrid within the overlap range must be made with caution since the fish used to calculate the CI and mCI were more subjectively identified as hybrids or pure species by Carlson and Pfleiger (1981). Specimens that score more strongly negative or more strongly positive can be assumed to be pallid sturgeon or shovelnose sturgeon, respectively, with a higher degree of certainty. Such specimens would be more suitable for applications such as brood stock for artificial propagation of the two species.

The ranges of CI and mCI values for pallid sturgeon (Figures 5 and 6; Tables 3 and 4) are based on the relatively small number of specimens examined by Carlson and Pflieger (1981). We have obtained pallid sturgeon specimens from the Middle Mississippi River (Sheehan et al. 1997) with CI and mCI values more negative than the ranges provided herein. As the specimen data base increases, there will be a tendency for the ranges to increase. On the other hand, once genetic methods are developed to definitively determine the proper placement of *Scaphirhynchus* specimens into appropriate taxa, the multiple regression equations can be

Table of Contents

Character Index Interpretation

The character Index values quantify the strength of pallid or shovelnose characteristics of a sturgeon. Generally speaking, the more positive the CI or mCI the more shovelnose-like the sturgeon (Figures 5 and 6; Tables 3 and 4). Conversely, the more negative the CI or mCI value the more pallid-like the sturgeon. Note that a zone of overlap exists between the

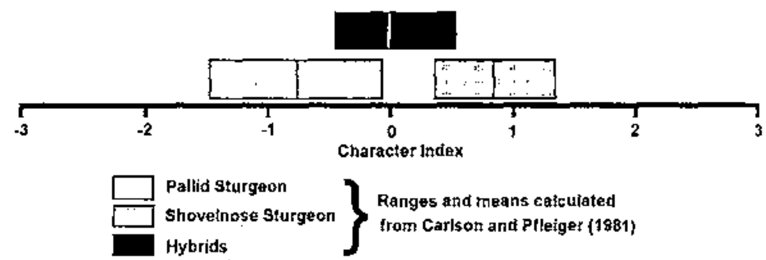


Figure 5. Ranges of CI values

Table 3. Ranges of CI values.

Sturgeon Type	CI Range	Mean CI
Pallid	-1.48 to -0.09	-0.86
Hybrid	-0.45 to 0.51	-0.02
Shovelnose	0.37 to 1.33	0.82

$$CI = 6.11 + 0.00000235(\boldsymbol{DFC}) - 0.177(\boldsymbol{AFC}) - 0.703(\boldsymbol{OB/IB}) - 1.424(\boldsymbol{HL/IB}) + 1.389(\boldsymbol{HL/MIB}) + 2.878(\boldsymbol{IL/IB}) - 3.258(\boldsymbol{IL/MIB})$$

($n=30$, $r^2=0.7898$, $p \leq 0.0001$)

$$mCI = 2.655 - 0.844(\boldsymbol{OB/IB}) - 0.749(\boldsymbol{HL/IB}) + 1.292(\boldsymbol{HL/MIB}) + 1.874(\boldsymbol{IL/IB}) - 3.776(\boldsymbol{IL/MIB})$$

($n=30$, $r^2=0.6980$, $p \leq 0.0001$)

Introduction

Pallid sturgeon (*Scaphirhynchus albus*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) are native to the Mississippi River. A number of studies (e.g., Carlson et al. 1985) suggest that these two species are hybridizing in the Mississippi River, based on the meristic and morphometric characteristics of sampled specimens. However, natural, interspecific hybridization has yet to be confirmed in *Scaphirhynchus;* currently, no genetic technique is available that discriminates among pallid sturgeon, shovelnose sturgeon, and their hybrids.

Pallid sturgeon and shovelnose sturgeon are morphologically similar, making it difficult for the untrained observer to distinguish between them. The potential for hybrid sturgeon to appear in collections makes identification of specimens even more problematical. There is a need to develop methods to identify *Scaphirhynchus* specimens, based on the best available information, for field studies and artificial propagation programs.

Carlson and Pflieger (1981) reported meristic and morphometric characteristics for sturgeon specimens they categorized as pallid sturgeon, shovelnose sturgeon, or hybrids. This information has been used by us to develop two indices that quantitatively describe how Carlson and Pflieger (1981) placed specimens into the three categories. The indices are in the form of multiple regression analysis equations that can be programmed into a hand-held calculator. We have found them useful for tentatively identifying *Scaphirhynchus* specimens in the field (Sheehan et al. 1997).

The Character Index (CI) uses two meristics (dorsal and anal fin ray counts) and 5 morphometric ratios. We developed the second index, the morphometric Character Index (mCI), because the pallid sturgeon is an endangered species, and it is sometimes difficult to count fin rays in live specimens. The mCI uses only the 5 morphometric ratios. We recommend use of the CI whenever possible. Accurate fin ray counts can be obtained from live specimens using our methods with practice, and the CI provides a stronger predictive equation. We have also developed a computer program, the Character

The CI and mCI, and their Calculation

Multiple regression techniques were used to develop predictive models with weighted characteristics that statistically account for the variability observed in characteristics for presumptive pallid sturgeon, shovelnose sturgeon, and their hybrids. The models were developed from data presented by Carlson and Pflieger (1981) for sturgeon taken from the Middle Mississippi River. These models were derived by assigning five morphometric ratios (OB/IB, HL/IB, HL/MIB, IL/IB, IL/MIB) and two meristics in the case of the CI (AFC and DFC) as independent variables in multiple regression analyses. The variable, taxon, was treated as the dependent variable in the regression analysis with pallid sturgeon coded as -1, hybrids as 0, and shovelnose as 1 (Note: The taxon identifications were as determined in Carlson and Pflieger (1981)). The CI and mCI values are generated by entering each of the appropriate meristic values and/or morphometric ratios into the equations:

Morphometric Ratios

Five morphometric ratios are calculated by simple division of the various morphometrics (Table 2).

Table 2. Morphometric ratios.

Ratio	Abbreviation
Outer Barbel / Inner Barbel	OB/IB
Head Length / Inner Barbel Length	HL/IB
Head Length / Mouth-To-Inner-Barbel Distance	HL/MIB
Interrostrum Length / Inner Barbel	IL/IB
Interrostrum Length / Mouth-To-Inner-Barbel Distance	IL/MIB

Index Calculator (CIC), to aid in calculating and interpreting CI values. The program can be used in the field if a laptop computer is available.

Characters Used for the Index

Five morphometric ratios, derived from seven morphometrics (Figure 1; Table 1) and two meristics (dorsal and anal fin ray counts) are needed to calculate a CI value.

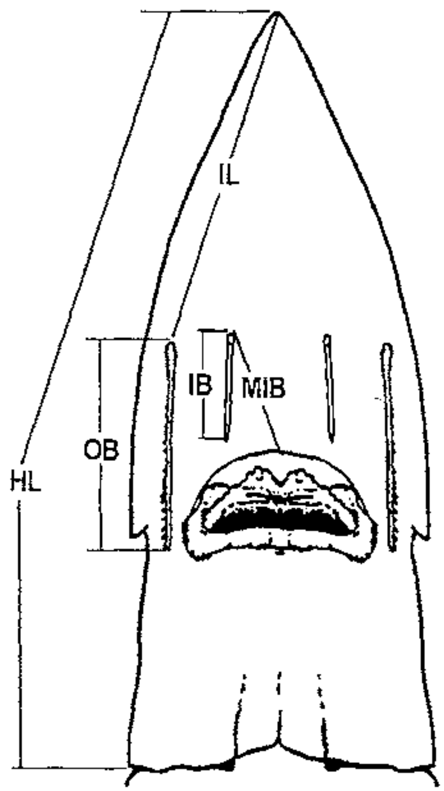


Figure 1. Morphometric measurements.

close to each other. Count several times until a consistent count is achieved.

Anal Fin Ray Count (AFC): Counts are made in the same manner as the dorsal ray counts. Once again all fully formed and rudimentary rays are counted, but the preanal plate at the anterior edge of the fin is not.

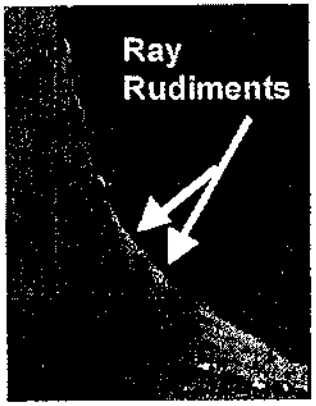


Figure 3. Ray rudiments. Note the predorsal plate (light triangular region) to the right of the ray rudiments.

edge of the fin (Figure 3). The fully formed rays can be distinguished from surrounding tissue by their segmentation (Figure 4). It is necessary to use a pointed stylus, such as a pen, to keep track of position while counting. It is helpful to have an assistant hold the fish by its caudal peduncle while counting, especially if the specimen is large. If the fish's head is left in a tub of water it will generally remain calm during the counting process. It is very helpful to count with a light source (e.g., the sun or flashlight) positioned so that the fin is backlit. Care should especially be taken at the anterior and posterior ends of the fin where rays can be very

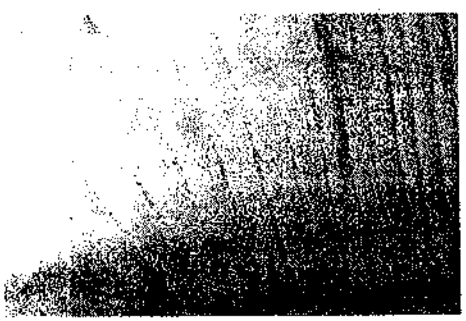


Figure 4. Detail of fin showing segmentation of rays.

Table 1. Characters needed to calculate the CI and mCI

Character	Abbreviation
Inner Barbel Lengths	IB
Outer Barbel Lengths	OB
Mouth-To-Inner Barbel Distance	MIB
Interrostrum Length	IL
Head Length	HL
Dorsal Fin Ray Count	DFC*
Anal Fin Ray Count	AFC*

* not used for the mCI

Meristics and morphometric measurements (detailed individually below) are taken using methods similar to Bailey and Cross (1954). Some measurements are simplified to ease data collection in the field. All Measurements are taken to the nearest millimeter using calipers.

Inner Barbel Lengths (IB): Inner barbels are measured *from* the anterior point of insertion *to* the tip. Each barbel should be flattened against the ventral surface of the rostrum facing toward the posterior of the fish. Both barbels are measured and their average length used for calculation (conspicuously damaged barbels are not used for the calculation).

Outer Barbel Lengths (OB): Outer barbels are measured *from* the anterior point of insertion *to* their tip. Each barbel should be flattened against the ventral surface of the rostrum facing toward the posterior of the fish. Both barbels are measured, and their average length used for calculation (conspicuously damaged barbels are not used for the calculation).

Mouth-To-Inner Barbel Distance (MIB): This measurement is taken *from* the midline of the edge of the cartilaginous ridge anterior to the proboscis (mouth) *to* the anterior insertion of the right inner barbel. The edge of the cartilaginous ridge can be felt with the tip of the calipers.

Interrostrum Length (IL) (a.k.a Nose to outer barbel): This measurement is taken *from* the tip of the rostrum *to* the anterior insertion of the right outer barbel.

Head Length (HL): The head is measured in two increments due to the maximum length of a standard set of calipers. The first increment extends *from* the tip of the rostrum *to* the extent of the calipers measurement ability (this point can be marked temporarily by gently pressing the point of the caliper into the flesh creating an indentation). The second increment extends *from* the point where the prior measurement ended *to* the posterior margin of the operculum. The sum of these measurements is the head length.

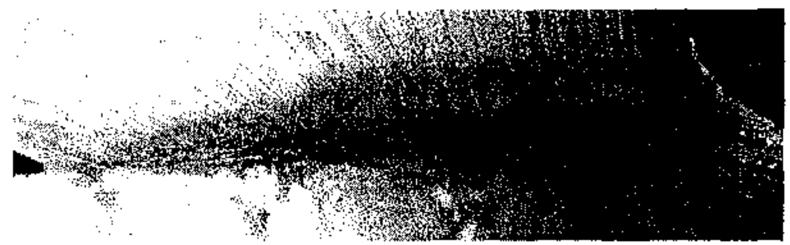


Figure 2. Base of the dorsal fin showing unbranched rays.

Dorsal Fin Ray Counts (DFC): A count is made of all the rays in the dorsal fin. The count is made at the base of the fin where the rays ***have not begun to branch*** (Figure 2). Both the fully formed rays throughout the fin and the rudimentary rays at the anterior end of the fin are counted; care should be taken not to count the predorsal plate at the anterior

APPENDIX E.

Draft Report - Benthic invertebrate assemblages associated with recently constructed river training structures on the Mississippi River.

Prepared for U.S. Army Corps of Engineers, St. Louis District by Ecological Specialists Inc.

Benthic invertebrate assemhlages associated with recently constructed river training structures on the Mississippi River

Heidi L. Dunn[1] and Brian L. Johnson[2]

[1]Ecological Specialists, Inc.

114 Algana Ct.

St. Peters, MO 63376

Ecologists@aol.com

[2]St. Louis District Army Corps of Engineers

Environmental and Economic Analysis Branch

1222 Spruce St.

St. Louis, MO 63103-2833

DRAFT

ABSTRACT

Construction and invertebrate monitoring of experimental chevron dikes (Mississippi River Mile [MRM] 289.5) and bendway weirs (MRM 164 and 30) was part the Avoid and Minimize (A & M) Program to mitigate the possible environmental impacts of increased navigation traffic in the upper Mississippi River resulting from construction of the second lock at the Melvin Price Locks and Dam. The monitoring objective was to determine if benthic invertebrate species richness was increased near the river training structures compared to the river substrate. Benthic invertebrates were collected from chevron dikes (MRM 289.5; rock baskets), bendway weirs (MRM 164 and MRM 30; rock baskets, buoy rocks, and weir rocks), and I-wall rubble (MRM 203; rock baskets) between 1994 and 1998. Samples were also collected from substrate around and within chevron dikes, near proposed training structures at MRM 265.7 and 250.2, downstream of bendway weirs (MRM 20), and riverward of I-wall rubble. Principal Component Analysis (PCA) and comparison of species richness, diversity and composition were used to determine the relationship of macroinvertebrate communities in the study area.

The study area (MRM 289.5 to MRM 20) appears to support a species rich invertebrate community, as 238 taxa were collected. PCA analysis resulted in a continuum of samples along both axes rather than distinct clusters, and axes were significantly correlated with substrate, structure, position, and season (Factor 1), and river mile (Factor 2). Rock, whether alone or associated with a training structure, increased habitat and invertebrate assemblage heterogeneity. Additionally, species richness in substrate within dikes and near rubble tended to be higher than in areas without these structures. With time, substrate and therefore invertebrate assemblage heterogeneity should increase within the river cross section containing the training structure.

INTRODUCTION

The U.S. Army Corps of Engineers (USACE) established the Avoid and Minimize (A & M) Program to mitigate the possible environmental impacts of increased navigation traffic in the upper Mississippi River resulting from construction of the second lock at the Melvin Price Locks and Dam (USACE, 1992). Through coordinated efforts of USACE, U.S. Coast Guard, U.S. Fish and Wildlife Service, Illinois Department of Natural Resources, Missouri Department of Conservation, and the towing industry, 43 A & M measures were identified in four categories:

A. Operations of the locks and navigation channel.

B. Measures related to towing operations.

C. Measures related to induced development.

D. Measures to rectify impacts.

Eight measures were selected for implementation:

A- 3. Designate lock approach waiting area or provide special mooring sites.

A-10. Reduce open water dredge material disposal by creating beaches.

A-11. Reduce open water dredge material disposal through wetland creation.

A-13. Place dredge material in the thalweg.

A-16. Continue dike configuration studies (i.e., notched dikes, chevrons and bullnose dikes).

A-17. Place off-bank revetment on islands.

A-19. Monitor bendway weirs.

B- 8. Study reduction of tow waiting times.

Since 1994, the USACE St. Louis District (SLD) has monitored invertebrate use of experimental chevron dikes (Mississippi River Mile [MRM] 289.5) and bendway weirs (MRM 164 and 30) as part of the A & M Program (Figure 1).

The SLD introduced the idea of chevron dikes to the River Regulatory Team in 1991, and built a prototype of three chevron dikes in a particularly troublesome spot in Pool 24, near MRM 289.5 in 1993 as part of Measure A-16 (Figure 2). This area consists of a split channel with a point bar encroaching on the thalweg. Annual dredging was required and dredge material was disposed in the open water of the channel border along the left descending bank. Establishing chevron dikes in this area diverts flow into the thalweg while allowing flow into the side channel and reducing open water dredge disposal (USACE, 1992). The dike structures should provide substrate for invertebrate colonization, and food and cover for fish. When dredging is needed, material would be placed behind the dikes, creating islands. After islands have formed and are colonized by vegetation, they should reduce barge wave impacts on nearby islands and riverbanks. Subsequently, experimental roundpoint dikes were constructed near MRM 265.7 in 1998, one chevron dike was constructed near MRM 250.2 in 1996, and three chevron dikes were constructed near MRM 266.0 in 1998 (Figure 1).

The bendway weir concept consists of a series of level-crested submerged rock weirs built around a bend to increase the effective width of the Mississippi River navigation channel by scouring the channel at the outer edge and reducing point bar development on the inner side of the bend (USACE, 1992). The weir field is submerged, adding stable bottom structure, creating complex flow patterns, reducing velocity and turbulence on the outside bends, and reducing channel degradation (USFWS, 1992). SLD has constructed 17 bendway weirs as part of measure A-19 since 1990. A prototype weir field was constructed in 1990 near Dogtooth bend, nine weirs were constructed around Price's Bend (MRM 30) in 1991, and five weirs were constructed at the Carl Baer Bendway, near MRM 163.5 in April 1996 (Figure 1).

Epilithic communities in the unmodified river would have been found on woody debris, on boulders in rapids, and on cobble sediments of the river bed, but are now confined mostly to wing dams, revetted banks, other channel-training structures (Sauer and Lubinski, 1999) and unionid beds (Beckett *et al.*, 1996). Although recent river training structures were built to reduce channel maintenance needs, they should also enhance fish and benthic resources (USFWS, 1992).

The objective of this study was to determine if benthic invertebrate species richness increased due to the construction of river training structures in the upper Mississippi River.

METHODS

Benthic invertebrates were collected from chevron dikes near Mississippi River mile (MRM) 289.5 in November/December 1994, May/June and August/September 1995, and August/September 1996; bendway weirs near MRM 164 during July/August/September 1996; and bendway weirs near MRM 30 during August 1996 (Figure 1; Table I). Benthic invertebrate samples were also collected from Mississippi River substrate around chevron dikes in November 1994, June and September 1995, and September 1996; near proposed training structures at MRM 265.7 and 250.2 in April 1996; and downstream of bendway weirs near MRM 20 in August 1996 (Figure 1; Table I). Since rock structures appeared to provide invertebrate habitat, rubble from the 1996 demolition of the Lock & Dam 26 I-wall (MRM 203) was left in the river. Rubble was monitored for invertebrate colonization in July/August 1996, June/July 1997, and June/July 1998. Mississippi River substrate riverward of the rubble was sampled in July 1997 and July 1998 (Figure 1; Table I).

Field Methods

Chevron dikes (MRM 289.5)

Rock baskets were used to sample the epilithic community of chevron dikes. Artificial samplers have been criticized because they may not reflect natural substrate, and collected animals may not represent the native community (Anderson and Mason, 1968). However, they appear to be the best method of sampling difficult habitats, such as large rock (Dickson *et al.*, 1971; Hall, 1982; Ciborowski and Clifford, 1984).

Baskets were constructed from one-half of a standard minnow trap. Each basket was filled with 35 rocks of approximately the same size. Baskets were covered with 6mm hardware cloth secured with plastic ties. Baskets were anchored to the dikes and were allowed to colonize for 30 days. Baskets were scooped out of the water with a standard sieve bucket (no. 30 mesh) to prevent animal loss. The baskets and animals retained in the sieve were placed into an 11L bucket.

Inundated areas within each dike and substrates surrounding dikes were sampled with a standard ponar ($0.05m^2$). Surrounding substrate samples were from a variety of flow and substrate conditions.

Samples were rinsed in a standard sieve bucket (no. 30), and the remaining invertebrates, debris, and substrate were rinsed into a 1L jar.

MRM 265.7 and MRM 250.2

Substrate samples were collected within the left descending channel border, downstream of a small island near MRM 265.7, and within the left descending channel border between Willow Bar Island and the navigation channel near MRM 250.2 in April 1996. At the time of sampling, round point dikes and chevron dikes were proposed at MRM 265.7 and 250.2, respectively. The objective of sampling was to characterize the invertebrate assemblage prior to construction. Ten samples were collected with a standard ponar, sieved in a standard sieve bucket and rinsed into a 1L jar. Subsequently, round point dikes were constructed near MRM 265.7, and three and one chevron dikes were constructed at MRM 266 (right descending bank) and 250.2 (left descending bank), respectively.

I-wall rubble (MRM 203)

Rock baskets were used to sample the epilithic community in the I-wall rubble. Rock baskets were constructed as described above, deployed in the rubble, and allowed to colonize for 30 days. Twelve rock baskets were attached to the shoreward lock wall on the Illinois side of the river and placed onto the Lock and Dam 26 I-wall rubble near MRM 203. The contour of the river bottom from the remaining lock wall to the I-wall rubble was observed with a depth finder, and the rock baskets were released where the bottom elevation was highest (presumably on the remaining I-wall and rubble). The samplers were placed in approximately 9m of water, and distributed upstream to downstream within the I-wall rubble.

Twelve samplers were deployed in an effort to obtain ten samples in 1996, and eight samples in 1997 and 1998 for analysis. Baskets were attached to the remaining lock wall with 3.2mm galvanized steel cable, and bolted to an eye-bolt in the lock wall. Cinder blocks were used to hold the cable at the base of the lock wall and the rock baskets within the I-wall rubble.

Baskets were deployed 25 July 1996 and retrieved 23 August 1996, deployed 26 June 1997 and retrieved 25 July 1997, and deployed 17 June 1998 and retrieved 22 July 1998 for a colonization period of at least 30 days in all three years. All 12 baskets were retrieved in 1996 and 1997, and 10 and 8, respectively, were randomly selected for analysis. In 1998, high discharge occurred between basket setting and retrieval, and drifting debris became entangled in the cables securing the baskets to the I-wall. Only four baskets were retrieved in 1998.

Visual examination upon retrieval revealed substantial macroinvertebrate colonization of all 12 samplers in 1996 and 1997, and moderate colonization of all four samplers in 1998. Baskets were scooped out of the water with a standard sieve bucket to prevent animal loss. The baskets and animals retained in the sieve were placed into an 11L bucket.

A standard ponar ($0.05m^2$) was used to sample the macroinvertebrate community in river substrate riverward of the I-wall rubble in 1997 and 1998. Samples were collected parallel to each set of three rock basket samplers, but in the river channel adjacent to the I-wall rubble. Samples were rinsed in a standard sieve bucket (no. 30), and the remaining invertebrates, debris, and substrate were rinsed into a 2L jar.

Bendway weirs (MRM 164, MRM 30, MRM 20)

Bendway weirs are completely submerged and are located in areas with swift current, rendering sampling of epilithic communities difficult. A variety of methods were used at the MRM 164 site; rock baskets, buoy anchors, and weir rocks (Table I). In an effort to duplicate methods used at chevron dikes, rock baskets were constructed as above, attached to buoy anchors to hold them stationary and deployed in the weir field. However, only four of the 18 deployed baskets were retrieved intact, and one of these was devoid of animals apparently as a result of sedimentation.

Buoy anchors, which are approximately 680kg (1500lb), 0.9 x 0.9 x 0.3m concrete blocks with reinforced rebar eyes on the top and one side for lifting, were considered an appropriate artificial substrate for weir rock sampling, because of their size and similarity to weir rocks. Groups of three buoy anchors were placed on and adjacent to three of the five weirs near MRM 164 with the assistance of the USACE M. V. Pathfinder. Sample retrieval was attempted after 35 days of colonization, however retrieval success was low. Several buoy anchor cable lines became entangled with lines from other samplers and with bottom debris, or were buried in the sediment, causing dangerous tension in the cable lines and forcing abandonment of ten buoy anchors. Recovery of buoy anchors was highest closer to the bank (75%), with only 33% of the buoy anchors placed furthest from the bank retrieved. Overall, 17 of the 26 deployed buoy anchors were retrieved, but 11 of those were apparently sand blasted or had been buried, and only six yielded macroinvertebrate scrape samples. Samples were scraped from the rock surface with the highest colonization and within the area of a $0.0929m^2$ ($1ft^2$) Surber sampler. To ensure minimal damage to the animals, a 10% nitric acid solution spray was used to dislodge macroinvertebrates and their cases from the rocks. The animals were lightly brushed and rinsed into the sampler, and transferred to 1L plastic jars.

Since rock baskets and buoy anchors proved less than successful, 14 scrape samples were collected from weir rocks at both MRM 164 and MRM 30. Weir rocks were collected with a clam shell dredge on a USACE SLD work barge powered by the USCACE MV Pathfinder. A scrape sample was collected from rock surfaces with the greatest macroinvertebrate colonization using a 0.15m (6in) diameter ($0.018m^2$) sampling frame, 10% nitric acid spray to dislodge the animals from the surface, and a pan to catch the falling debris. Samples were washed into plastic 1L jars.

In addition to sampling in the weir field, ten concrete buoy anchors were placed near MRM 164, in a bendway without weirs, upstream of the weir field. The objective was to obtain comparable samples within and upstream of the weir field to assess the weir field's influence on species composition and colonization rate. Buoy anchors were attached with cable to red nun buoys, and deployed parallel to and approximately 61m (200ft) from the left descending bank. All ten buoy anchors from the upstream bendway were retrieved after 27 days. Scrape samples were collected as previously described for weir rock scrapes ($0.018m^2$).

Substrate samples were collected from Thompson's Bend (MRM 20). A clamshell dredge on the USACE SLD work barge powered by the USACE MV Pathfinder was used to collect $0.57m^3$ ($0.75yd^3$)

of sand and gravel substrate from the river bottom. A subsample of substrate was collected with a petite ponar (0.024m^2). Samples were collected at approximately 91.5m (300ft) intervals along transects and washed into plastic 2L jars.

All samples were preserved in 10% formalin stained with rose bengal and transported to the laboratory for processing.

Laboratory

Each sample was rinsed through a no. 30 sieve to remove preservative and a portion was placed in a white pan. Samples with many animals were subsampled. Animals were sorted from debris with the aid of a magnifying lamp or dissection microscope, and placed in scintillation vials containing 75% alcohol. Abundant groups (chironomids, oligochaetes, trichopterans, and ephemeropterans) were sorted into separate vials.

Sample debris was searched until all animals were retrieved. The remaining debris was rinsed into the original sample container, preserved in 75% alcohol, and marked with the sorters initials and sorting date.

To ensure sorting efficiency, 10% of the remnant samples were reprocessed, including at least one per sorter and one per sampling method. If the total number of animals in the remnant sample or subsample was less than 10% of the total number of animals sorted from the original sample or subsample, the sorting effort was accepted. If the above criteria were not met, samples were resorted and rechecked until quality assurance criteria were met or exceeded. Sorting efficiency was over 99% for all samples and no resorting was required.

A Folsom sample splitter was used for all subsampling. Very large samples (>500 animals) were split before sorting. However, only samples relatively free of entangling debris (biasing the subsample) were split, and all rare and large animals were removed (fish, anisopterans, non-hydropsychid caddisflies) before splitting. Samples (or fractions thereof) were split into at least four subsamples, and two subsamples were processed and checked against each other to ensure unbiased splits. The total number of sorted animals identified per sample was at least 250, and, if available, in proportions of 50 to 100 chironomids and oligochaetes, 70 trichopterans, and 70 ephemeropterans per sample. Unprocessed subsamples were preserved in 75% alcohol, labeled appropriately, and stored.

To determine splitting efficiency and individual estimate accuracy, at least two subsample fractions were processed for each split sample. The number of individuals, as well as the similarity in taxa, were compared between the two subsamples. Counts between fractions were within 20% and percent similarity ($PSC=100-0.5\Sigma|a_i-b_i|$) between fractions exceeded 90% for all split samples.

Animals were identified to lowest practical taxon, species in most cases. Chironomids and oligochaetes were mounted in CMC-10 mounting media and identified using a compound microscope. Other animals were identified with the aid of a dissection scope.

Several representatives of some groups, such as hydropsychid caddisflies and heptageniid mayflies, were early instars and could only be accurately identified to family. Likewise, most tubificid oligochaetes could not be identified due to sexual immaturity.

During the identification and enumeration process, a reference collection of all taxa was prepared. Reference specimens were preserved in 75% alcohol and labeled with name, date, location of collection and identifying biologist. The reference collection was checked by a second biologist.

Data analysis

The primary sampling objective was to evaluate taxonomic composition within training structures and substrates, rather than invertebrate density. Therefore, scrape samples were not randomly collected from weir rocks and buoy anchor rocks, but were biased toward the highest macroinvertebrate density area on the recovered rock surfaces. The rate of invertebrate colonization depends on numerous factors including invertebrate drift (Waters, 1964; Townsend and

Hildrew, 1976; Ciborowski and Clifford, 1984), substrate (Kirk and Perry, 1992; Smock, 1996), distance from colonizing source (Sheldon, 1977; Kirk and Perry, 1992; Smock, 1996), density of nearby invertebrate communities (Hare, 1995), detritus accumulation (Rabeni and Minshall, 1977; Culp *et al.*, 1983), and species specific colonization rates (Sheldon, 1977; Ciborowski and Clifford, 1984; Peckarsky, 1986; Smock, 1996), and artificial substrates are unlikely to yield an accurate representation of density (Casey and Kendall, 1997). Density estimates for rock baskets are further hindered by the inability to accurately quantify rock surface area. Rock texture also affects colonization, as more textured rock tends to provide more refugia from physical disturbance and area for attachment (Clifford *et al.*, 1992), and buoy anchors are smoother than weir rock. Total density and density of particular taxa in artificial samplers and in scrap samples, therefore, may not accurately reflect density of rock structures. Whereas, parameters such as taxonomic composition, species richness (number of taxa), diversity (Shannon-Wiener index, H'), and relative abundance should be similar among methods, since colonization appears to be directly related to density and taxa in surrounding substrate (Hare, 1995), and these parameters were used to compare samples.

Multivariate analysis techniques are better at detecting obscure relationships among variables (Maxon *et al.*, 1997), such as changes in invertebrate community composition, than standard invertebrate indices such as diversity, since they use each species as a variable (Cao *et al.*, 1996). Principal Component Analysis (PCA) was used to determine the relationship of macroinvertebrate communities in the study area. PCA is a type of ordination analysis, which compares samples based on similarity of taxa and has been successfully used in comparing invertebrate samples and relating species composition to environmental variables (e.g., Leland *et al.*, 1986; Delucchi, 1987; Knorr and Fairchild, 1987; Cao *et al.*, 1996; Yule, 1996). Since methods and sample sizes differed among study sites, analysis was based on relative abundance of taxa rather than density. Data were transformed (Log (x+1)) prior to analysis. Species occurring in less than 5% of the samples were excluded, as they may be transient rather than truly a part of the invertebrate community, and may skew results (Gauch, 1982). PCA factor scores were correlated with measured variables using Pearson Correlation. Variables used in the correlation matrix include substrate, river mile, structure (influenced or not influenced by training structure), position (within the weir or dike field, or in the surrounding area), and sampling season. Significance of correlation was determined using the sequential Bonferroni technique (Rice, 1989).

ANOVA (one and two way) followed by Tukey's multiple range tests and student's t-tests were used to detect differences in species richness and diversity.

RESULTS

The study area (MRM 289.5 to MRM 20) appears to support a species rich invertebrate community. A total of 238 taxa were collected in this study (Table II). The caddisflies, *Hydropsyche orris* (20%) and *Potamyia flava* (37%), were the dominant taxa. Chironomidae comprised 18% of the fauna, and *Rheotanytarsus sp.* (9%), *Glyptotendipes sp.* (3%), and *Polypedilum convictum* (2%) were the three most common chironomids. Other abundant taxa included *Dreissena polymorpha* (9%), the turbellarian *Dugesia tigrina* (5%), and the mayflies *Caenis sp.* (1%) and *Isonychia sp.* (1%).

Taxonomic composition appears to be related to substrate, structure, season, and river mile. PCA analysis resulted in a continuum of samples along both axis rather than distinct clusters (Figure 3). Factors 1 and 2 represented 19.3% and 10.9% of the variability in samples, respectively. Sample attributes that significantly correlated with Factor 1 included substrate, structure, position, and season. Factor 2 was significantly correlated with river mile (Table III).

Samples collected from river substrate and away from rock structures tended to cluster on the negative portion of Factor 1, while those associated with rock tended to plot toward the positive end. Samples from substrate near rock structure and rock baskets on the interior of chevron dikes tended to plot toward the center of the graph. A few of the rock basket samplers that filled with sand or silt plotted more toward the negative end of Factor 1 and substrate samples that contained gravel and larger substrate tended to plot toward the positive side of Factor 1. Lower (free flowing) river sites tended to plot toward the negative end of Factor 2 and upper river (pooled) sites tended to cluster more toward the positive portion of Factor 2. However, samples collected on the exterior and interior of dikes at MRM 289.5 plotted toward the negative and positive end of Factor 2, respectively. This suggests that current velocity may also influence sample distribution, however current velocity was not measured at sample sites and could not be incorporated in the model.

This pattern is more obvious when each sample site is considered separately. MRM 289.5 samples tended to scatter across the PCA more so than other sites, as samples were collected from three seasons and over three years, and species relative abundance varied with time as well as substrate and flow. In general, rock basket samples plotted on the positive side and substrate samples on the negative side of Factor 1 (Figure 4). Samples (both rock basket and substrate) collected on the inner face of the dike (slower flow) plotted in the upper half of the graph, while samples collected from exterior dike faces and exterior substrate (swifter flow) plotted toward the middle and lower portion of the graph.

The caddis flies, *P. flava* and *H. orris*, and the chironomid *Rheotanytarsus sp.* tended to be the dominant taxa in samples collected on the exterior rock of chevron dikes, with *D. polymorpha* abundance increasing over time (Table IV). Rock dwelling caddisflies and chironomids were replaced by the enchytraeid *Barbidrilus paucisetus* and the chironomids *Robackia sp.* and *Chernovskiia sp.*, which prefer sandy substrates, in the predominantly sand substrates surrounding the dikes. However, *D. polymorpha* was also dominant in the river substrates in 1996.

The substrate and rock baskets, which were within dikes and protected from the current, tended to be dominated by oligochaetes and chironomids. However, Naididae and Tubificidae were more abundant on rocks and in substrate, respectively. Chironomid species also varied with substrate, and *Glyptotendipes sp.* was the dominant chironomid on rocks, while *Chironomus sp.*, *Cladotanytarsus sp.*, and *Polypedilum sp.* were more abundant in the substrate. *Dugesia tigrina* was also abundant on interior rock basket samples and *Caenis sp.* (mayfly) was particularly abundant in the summer 1995 samples.

Sampling method, season, position with respect to the dike, and substrate, also influenced species richness and diversity near MRM 289.5. Rock basket samples had significantly greater species richness and diversity than ponar samples (t=-17.033, df=146, P<0.01; t=-5.477, df=146, P<0.01; respectively). Fall samples had significantly greater species richness (t=2.975, df=146, P<0.01) and diversity (t=4.653, df=146, P<0.01) than samples collected in the summer. Rock baskets collected on both the interior and exterior face of dikes had significantly greater species richness (F=100.594, df=144, P<0.01) than ponar samples on dike interiors and ponar samples collected in river substrate. However, diversity was similar between rock baskets on the interior and exterior dike faces and ponar samples on the interior of dikes, but differed from river substrate samples (F=15.375, df=144, P<0.01). Substrate also significantly affected richness, as species richness was significantly higher in rock baskets than in other substrates (F=75.246, df=143, P<0.01). Diversity was also affected by substrate. While diversity was similar in rock, sand/gravel, silt/sand, and silt substrate, it was significantly lower in sand substrate (F=9.787, df=143, P<0.01).

In contrast to the high variability in chevron dike samples, bendway weir samples at MRM 30 and substrate samples from MRM 20 formed fairly tight clusters (Figure 5). Dominant taxa at MRM 20 and 30 were similar to substrate and rock at MRM 289.5, however, species richness was much lower and a few taxa overwhelmingly dominated samples in both substrate (MRM 20) and weir rock samples (MRM 30). *Barbidrilus paucisetus* (89%) dominated substrate samples, and *H. orris* (67%) and *P. flava* (11%) dominated weir rock scrape samples (Table V). Species richness was significantly less at MRM 20 and 30 than at RM 289.5 and 203 (F=15.551, df=271, P<0.01) and diversity at MRM 20 and 30 was less than at all other sites except MRM 265.7 (F=25.587, df=271, P<0.01). As at MRM 289.5, species richness and diversity were significantly less in substrate samples than in samples associated with the rock structure (t=6.666, df=36, P<0.01; t=2.418, df=36, P<0.05).

Samples collected within and upstream of the weir field at MRM 164 formed one cluster (Figure 6). *Hydropsyche orris* and *P. flava* dominated all samples within and upstream of the weir field. *Rheotanytarsus sp.* was also abundant on the buoy anchors placed upstream of the weir field. Richness and diversity were also similar between weir and upstream samples (t=1.133, df=31, P=0.266; t=-0.674, df=31, P=0.506; respectively). Three methods were used to collect samples within the weir (rock baskets, weir rock scrapes, buoy anchor scrapes) and samples were collected from buoy anchors upstream of the weir field. Method did not appear to affect diversity (F=1.43, df=30, P=0.255). However, method did have a significant effect on species richness (F=4.813, df=30, P<0.05); with rock basket samples having the highest average richness, and buoy anchors and weir rocks yielding similar richness. The lack of difference within and upstream of weir samples in taxonomic composition, richness, and diversity is probably due to both areas being sampled with the same method, buoy anchors. Thus it appears that weir field rocks and isolated rocks placed upstream of the weir were similarly colonized.

Samples collected within rubble and riverward of rubble at MRM 203 tended to form a continuum (Figure 7) similar to MRM 289.5 samples in the PCA (Figure 4). Rock basket samples plotted toward the positive end of the Factor 1 axis, and ponar samples collected riverward of the rubble plotted toward the center of Factor 1, similar to the interior chevron dike samples. Substrate riverward of the rubble varied with year, consisting of a mixture of gravel, sand, silt and zebra mussel shells in 1997, and primarily sand or silt in 1998. This change in substrate most likely was due to the high river discharge experienced prior to sampling in 1998, and affected species composition, richness, and diversity. *Hydropsyche orris* and *P. flava* dominated rock basket samples, as they did at other sites (Table VI). However, *P. flava* was also dominant in riverward substrate in 1997, probably due to the gravel substrate and abundance of *D. polymorpha* riverward of the rubble, as *D. polymorpha* shells provide hard substrate for invertebrate colonization and tend to change the species composition of the community (Stewart *et al.*, 1998). Both richness and diversity were significantly greater in rock basket samples collected within the rubble than in substrate riverward of the rubble (t=9.326, df=36, P<0.01, F=3.017, df=36, P<0.01, respectively). Diversity in sand, silt, gravel substrate was similar to rock basket diversity, but differed from diversity in sand and in silt (F=8.153, df=34, P<0.01). Species richness was also affected by substrate (F=30.934, df=34, P<0.01), however only rock basket diversity was significantly higher than other substrate types.

Substrate samples collected near MRM 250.2 and 265.7 clustered toward the negative end of PCA Factor 1 (Figure 8), similar to substrate samples collected downstream of weirs at MRM 20 and substrate surrounding dikes at MRM 289.5 (Figures 4 and 5). As with most other substrate samples, *B. paucisetus* dominated samples (Table VII). Macrostomidae were also abundant at MRM 265.7 and Nematoda were also abundant at MRM 250.2. Substrate was somewhat more heterogeneous at MRM 250.2, consisting of some gravel, silt, and clay in addition to sand. Whereas, substrate was homogenous sand in MRM 265.7 samples. Although dominant species were similar at both sites, this substrate difference appeared to affect both richness and diversity. Species diversity ($t=3.936$, $df=18$, $P<0.01$) and richness ($t=2.169$, $df=18$, $P<0.05$) were significantly different between MRM 250.2 and 265.7. Richness at both sites was similar to MRM 164 and MRM 20 and 30, whereas, diversity at MRM 265.7 was similar to MRM 20 and 30 and MRM 164, and diversity at MRM 250.2 was similar to MRM 203 and 289.5.

DISCUSSION

The upper Mississippi River historically and currently supports a variety of habitats (Theiling, 1999), and biodiversity in rivers is attributable to heterogeneity on the habitat scale (Wise and Molles, 1979; Bourassa and Morin, 1995; Death and Winterbourn, 1995; Ward, 1998). Current habitat conditions vary from those historically found in the river due to wing dams, closing dams, dredging, dredge disposal, and navigation dams, as well as, clearing of woody debris (Theiling, 1999). Upper river locks and dams have inundated some of the floodplain, creating numerous backwaters. Hard substrate in the now pooled portion of the upper river was at one time available as gravel and cobble substrates and in unionid beds (Beckett *et al.*, 1996). However, sedimentation has filled many of the backwater areas in the past few decades and shallow rocky areas have been covered with sand (Bertrand, 1997). Flow has been directed toward the thalweg and away from side channels and backwater areas by dikes, and floodplain erosion and subsequent dredging to maintain a navigable channel have resulted in loose sandy substrate in much of the channel border. Habitats currently existing within the study area, based on differences in substrate and hydrology, include main channel, channel border (inside bend, outside bend, straight reach), dike field (stone and pile dike), side channel, slough, river lake, natural littoral zone, revetted littoral zone, navigation pool, tailwater, mouth of tributary, and downstream end of island (ESE, 1982).

Shifting sand is often the dominant substrate type in lowland rivers (Soluk, 1985) and the

Mississippi River is no exception to this (Sauer and Lubinski, 1999); as loose sand was the major river substrate in all areas sampled in this study. This substrate type generally supports a low density of macroinvertebrates due to the dynamic nature of the substrate and low retention of organic matter (Sauer and Lubinski, 1999). High levels of disturbance tend to result in low density and diversity (Sanders and Baker, 1984; Death and Winterbourn, 1995; Lancaster *et al.*, 1996; Casey and Kendall, 1997), and low organic matter availability tends to limit biomass (Soluk, 1985). Although density is apparently fairly bigh >5cm deep within sand where disturbance tends to be less (Soluk, 1985), sand is typically dominated by a few interstitial and burrowing invertebrates adapted to this particular type of substrate (Soluk, 1985), resulting in low density and species richness. For example, *B. paucisetus* apparently burrows into the sand (Seagle and Wetzel, 1982), and *Robackia sp.* and *Rheosmittia sp.* use silk to maintain a hold in sand substrate (Soluk, 1985).

Species richness and diversity tend to increase with substrate heterogeneity and stability, apparently due to interaction of disturbance and habitat patchiness (Death and Winterbourn, 1995; Townsend *et al.*, 1997), as well as, interspecific competition (Death and Winterbourn, 1995). Substrate surrounding chevron dikes at MRM 289.5, riverward of rubble at MRM 203, and at MRM 250.2 and MRM 265.7 was primarily sand. However, some substrate heterogeneity still exists and the pooled portion of the river still supports a more diverse benthic fauna than the lower river (ESE, 1982); as gravel, silt, and clay were found in the channel border at MRM 289.5, MRM 250.2, and MRM 203 and at sites sampled by ESE (1982). Sauer (1999), on the other hand, found most upper Mississippi River substrates were dominated by silt and clay.

Dominant species at MRM 289.5, 264.7, 250.2, and 203 were similar and tended to be those typical of sand substrate in swift current (*B. paucisetus*, Macrostomidae, Nematoda). However, taxa tended to vary on a local scale within the study. This is expected, as invertebrate communities do not tend to respond to natural or human activities as a single unit, even within a single pool (Sauer and Lubinski, 1999). Oligochaetes and chironomids were the most abundant groups collected by ESE (1982). *Barbidrilus paucisetus* was also one of the dominant taxa in Pool 26 channel border samples (Seagle and Wetzel, 1982). Soft substrates in Pool 19 of the upper Mississippi River were dominated by high densities of the fingernail clams *Musculium transversum* (Carlson, 1967; Anderson and Day, 1986) and *Sphaerium striatinum* (Anderson and Day, 1986), and the burrowing mayfly *Hexagenia sp.* (Carlson, 1967; Anderson and Day, 1986). Soft substrates in Pool 26 of the upper Mississippi River had high densities of the oligochaete worm *L. hoffmeisteri*, and the mayfly *Hexagenia bilineata* (Anderson and Day, 1986).

Richness and diversity were significantly affected by substrate in this study (excluding rock samples- F=8.171, df=122, P<0.01; F=6.571, df=122, P<0.01, respectively). Richness and diversity tended to be less in sand (6.8 and 1.7, respectively), than in silty sand (12.4 and 2.5, respectively) and sandy gravel (10.8 and 2.8, respectively). This pattern was significant with respect to diversity, but richness was only significantly different between silty sand and sand in this study. Thorp (1992) found highest invertebrate diversity in substrates with gravel and silt/gravel, and lowest diversity in sand.

The river downstream of St. Louis was historically more dynamic than the upper reaches, with increased flow, higher sediment load, and a more meandering channel, but is now primarily contained by dikes, which direct flow into the thalweg (Theiling, 1999). Habitat types currently include main channel, channel border (inside bend, outside bend, straight reach), side channel, natural and revetted littoral areas, and pile and stone dikes (ESE, 1982). Many of the dike fields have filled with sediment, narrowing the river and creating a deeper, swifter channel (Bertrand, 1977). Physical heterogeneity in stream channels imparts resilience and resistance to indigenous communities, and simplifying river channels alters hydraulic transport properties and influences river ecosystems (Lancaster *et al.*, 1996).

Substrate outside the weir fields is primarily sand (ESE, 1982; Sauer, 1999). This was the case at MRM 164 and 20 in this study. *Barbidrilus paucisetus* was the dominant species at MRM 20 and oligochaetes and chironomids dominated in ESE (1982) studies, whereas Beckett *et al.* (1983) found lower Mississippi River sand substrates were dominated by chironomids. Species richness (1.5) and diversity (0.68) were lowest at MRM 20. Species richness and diversity in the primarily sandy substrate at MRM 20 (1.5, 0.6, respectively) were significantly lower than in the sand with some gravel, silt, and clay at MRM 289.5 (8.4, 2.0, respectively), 250.2 (7.9, 2.3, respectively), and 203 (9.9, 1.9, respectively) ($F=9.09$, $df=121$, $P<0.01$; $F=11.806$, $df=121$, $P<0.01$, respectively). This could be due to the higher disturbance rate of substrate in the lower river, as highest taxa richness should occur in communities subject to intermediate disturbance (Townsend *et al.*, 1997). Sauer and Lubinski (1999) also noted substrate preferences in the upper river, with higher densities in silt and clay than in sand or silt.

Increasing substrate diversity by adding rock to the river should change species composition, and increase richness and diversity, since minor substrate heterogeneity seems to increase species richness and diversity, particle size is important in determining species composition (Smock, 1996), and taxonomic composition varies with substrate (Bourassa and Morin, 1995 and references therein). Currently rip rap, articulated concrete, lock and dam structures, and huoys provide hard substrate previously supplied by gravel and unionids (Beckett *et al.*, 1996). Indeed, samples collected on rock structures tended to plot near the positive portion of PCA Factor 1 and were dominated by *P. flava* and *H. orris* (although this varied with season and flow). *Hydropsyche orris* is often common in large rivers with fast current (Fremling, 1960) and tends to he more abundant in late summer and early fall than in winter and early spring (Beckett, 1982). Hydropsychid caddisflies appear to dominate the macroinvertebrate community at most Mississippi River structures (e.g. stone dikes [Hall,1982; Mathis *et al.*, 1982; Payne *et al.*, 1989 in Way *et al.*, 1995; Payne and Miller, 1996]; hard substrates in pools [Anderson and Day, 1986]; or articulated concrete mattress blocks [Way *et al.*, 1995]).

Rock apparently does not need to be associated with river training structures to increase habitat heterogeneity and produce a different invertebrate assemblage. Simply adding rock to the existing substrate seems to increase habitat heterogeneity. Species richness was significantly greater in rock substrate (19.3) than in other substrates ($F=34.253$, $df=272$, $P<0.01$). Diversity in rock substrate (2.1) was similar to heterogeneous substrates (silt/sand,2.5; sand/gravel, 2.8) but significantly greater than diversity in sand substrate (1.7) ($F=6.4$, $df=272$, $P<0.01$). In this study, results from buoy anchors placed in a bend without weirs (MRM 164) did not differ substantially from samples collected within the weir (Table V). Both positions (within and upstream of weir field samples) plotted in the same cluster (Figure 6) and were dominated by *H. orris* and *P. flava*. Additionally, richness and diversity did not differ significantly within and upstream of the weir field at MRM 164 ($t=1.133$, $df=31$, $P=0.266$; $t=-0.674$, $df=31$, $P=0.506$, respectively).

Species composition, richness, and diversity were also similar among weir field samples at MRM 164 and MRM 30, and samples upstream of the weir field at MRM 164. However, the invertebrate assemblage collected from substrate samples downstream of the weir field at MRM 20 differed (Table V). *Barbidrilus paucisetus* overwhelming dominated the samples, and species richness and diversity were significantly lower than in the weirs and on buoy anchors upstream of weirs ($F=8.058$, $df=1$, $P<0.01$; $F=4.328$, $df=1$, $P<0.05$) (Table V). Thus, similar invertebrate assemblages were found in both weir fields as well as on buoy anchors placed in a bend without weirs, and this assemblage differed from substrate samples in a bend without weirs. However, substrate was not collected in the bend without weirs at MRM 164, where samples were collected from buoy anchors.

Placement of rock in the river creates complex and variable flow patterns (Way *et al.*, 1995; Hart *et al.*, 1996), and alters the rate and length of particle and invertebrate retention and drift in tbe surrounding area (Lancaster *et al.*, 1996). Substrate within dike fields in the pooled and open reaches of the river harbor the highest diversity of any of the habitats samples by ESE (1982), presumably due to variability in depth, substrate, and flow (ESE, 1982; Miller, 1988; Payne and Miller, 1996). Leaving the I-wall rubble in the river at MRM 203, placing chevron dikes at MRM 289.5, and building weirs in bendways appears to have increased habitat heterogeneity. In this study, samples from within the I-wall rubble, dikes, and bendways tended to plot toward the positive end of PCA Factor 1 and were dominated by *P. flava* and *H. orris*.

The placement of rock in the river, whether or not it is associated with river training structures may influence the invertebrate assemblage in the nearby substrate. Rubble is providing greater habitat heterogeneity than nearby substrate. Additionally, invertebrate assemblages in nearby substrate seem to be influenced by assemblages in the rubble, as species richness and diversity in substrate near the rubble were significantly greater than in substrate at MRM 20 and MRM 265.7, which was primarily sand (F=9.090, df=121, P<0.01; F=11.806, df=121, P<0.01). River bottom fauna appears to be highly influenced by density and taxonomic composition in nearby substrate (Sheldon, 1977; Kirk and Perry, 1992; Smock, 1996). Substrate samples collected near rock structures (interior dike substrate at 289.5, substrate riverward of I-wall rubble at 203) tended to plot near the center of Factor 1 and were generally dominated by a combination of burrowing and clinging taxa. In contrast, substrate not associated with rock structure tended to plot toward the negative end of Factor 1 and tended to be dominated by *B. paucisetus*, Nematoda, and Macrostomidae (see Figure 3, and Tables IV, V, VI, and VII). ESE (1982) also found substrate, which provided or was close to hard or stable substrate was more productive and diverse than other substrates.

Alternatively, habitat and invertebrate community heterogeneity in this substrate near I-wall rubble may have been present before I-wall demolition, as substrate and invertebrate community characteristics previous to the I-wall demolition are not known. Pre-construction substrate samples were collected at MRM 250.2 and MRM 265.7, and post construction substrate sampling in these areas could yield insight into this hypothesis.

Rock structures such as bank revetment and wing dikes do provide some solid substrate for invertebrate colonization in both the pooled and free flowing upper river (ESE, 1982; Sanders and Baker, 1984; Sauer and Lubinski, 1999). However, most of the current river training structures divert flow from side channels, channel borders, and back channels and reduce habitat heterogeneity in these habitats (Theiling, 1999).

Chevron dikes, bendway weirs and other river training structures may improve habitat heterogeneity in the surrounding substrate, as well as within the training structures. The structures sampled in this study divert water toward the thalweg, however, they also assist with maintaining or perhaps increasing rather than reducing habitat heterogeneity in surrounding habitats. The shape of both chevron dikes and bendway weirs provide a variety of hard substrate microhabitats for invertebrate colonization by altering flow, and creating turbulent and quiet water areas. Chevron dikes divert water toward the thalweg, reducing the need for dredging in the channel and dredge placement in the channel border. Dredge material from dredging that is needed is placed behind the dikes rather than in the channel border, eventually creating islands that will provide habitat for terrestrial animals, wading birds, reptiles, and amphibians, and that will serve as a breaker for boat wakes, protecting the shoreline. Additionally, flow is maintained between the dikes and in backwater areas, reducing backwater sedimentation that typically results within backwater areas near standard dike fields (USACE, 1992).

Bendway weirs are in a much harsher environment, but should provide refugia and habitat heterogeneity for invertebrates. Indeed more taxa were found and diversity was higher on samples collected within both weirs than in the substrate at MRM 20. However, the buoy anchor placed within the bend without weirs near MRM 164 was colonized by a similar number of species (22) and diversity was similar (2.15), as the buoy anchor samples collected from within the weir field; 22 taxa and diversity of 2.17. This suggests that any rock placed in the open river will provide substrate for invertebrate colonization and that the weir field does not appear to provide additional habitat heterogeneity over rock simply placed on the substrate. However, the weir fields were designed to modify and stabilize substrate across the channel and weir fields should reduce the frequency of substrate disturbance within the weir substrate, and frequency of disturbance could be the major cause of low invertebrate diversity in the free flowing river. This process will take time and habitat heterogeneity not only within the weir field, but also across the channel may increase with time.

CONCLUSIONS

Dams and river training structures have depleted habitat heterogeneity in the study area. Invertebrate species richness and diversity is dependent on habitat heterogeneity. Shifting sand substrates support few species, and diversity and richness of the invertebrate assemblage appears to increase with only a slight increase in substrate heterogeneity, such as found in substrates around dikes (MRM 289.5), at MRM 250.2, and riverward of the I-wall rubble (MRM 203). Rock placed in the river appears to increase species richness and diversity, regardless of whether it is in the form of chevron dikes (MRM 289.5), bendway weirs (MRM 164 and MRM 30), rubble pile (MRM 203), or placed singly (MRM 164). River training structures, at least in the case of chevron dikes, not only provide rock habitat, but also increase habitat heterogeneity in substrate within the structure, such as in dike interiors. Species composition in dike interiors, both in the substrate and on rocks, differed from the assemblages on dike exteriors, resulting in a much higher species richness at MRM 289.5 than at other sites. Substrate within weir fields was not sampled, and species richness within weir fields may or may not be higher than indicated by simply sampling rocks.

Channel maintenance will be necessary as long the commercial shipping continues on the Mississippi River. However, channel maintenance does not necessarily need to decrease habitat heterogeneity. Both chevron dikes and bendway weirs should not only provide rock structure for colonization, but should provide variable current conditions within and around the structures and should stabilize habitat in the surrounding area. This study demonstrates that rock increases invertebrate assemblage richness over nearby river substrate. With time, substrates riverward of the bendways and around chevron dikes should become more heterogeneous. Existing dredge material near the chevron dikes should be gradually flushed out of the area and variable flow patterns around dikes should result in variable substrate mixtures. Similarly, weirs in bendways should gradually cause a wider, shallower channel and provide greater substrate stability for aquatic organisms (USACE, 1992; Stucky and Farabee, 1992). Eventually flow will be spread more evenly across the channel, resulting in less channel and outside bend degradation and less channel border aggregation (USACE, 1992; Stucky and Farabee, 1992).

Rock, whether alone or associated with a training structure, increases habitat and invertebrate assemblage heterogeneity. Species richness in substrate within dikes and near rubble tends to be higher than in areas without these structures. Training structures should also increase substrate and therefore invertebrate assemblage heterogeneity within the river cross section containing the training structure. However, further study is needed to demonstrate this benefit.

ACKNOWLEDGEMENTS

Funds for this study were provided by Parsons Harland Bartholomew & Associates under contract with the U.S. Army Corps of Engineers (USACE), St. Louis District as part of the Avoid and Minimize Program. The authors would like to thank Mr. Charles Theiling, Mr. Eric Nelson, Ms. Mary Furman, and Ms. Melissa Moore for providing valuable assistance with field work, sample processing, and data analysis, and Mr. Bernard Sietman and Mr. Paul Marangalo for assistance with data analysis. We would also like to thank Dr. Barry Poulton for kindly reviewing the manuscript.

LITERATURE CITED

Anderson, J. B. and Mason, W. T. Jr. 1968. 'A comparison of benthic macroinvertebrates collected by dredge and basket sampler', *Journal of Water Pollution Control Federation,* **40**, 252-259.

Anderson, R. V. and Day, D. M. 1986. 'Predictive quality of macroinvertebrate - habitat associations in lower navigation pools of the Mississippi River', *Hydrobiologia,* **136**, 101-112.

Beckett, D. C. 1982. 'Phenology of *Hydropsyche orris* (Trichoptera: Hydropsychidae) in the Ohio River: changes in larval age structure and substrate colonization rates', *Environmental Entomology,* **11**, 1154-1158.

Beckett, D. C., Bingham, C. R., and Sanders, L. G. 1983. 'Benthic macroinvertebrates of selected habitats of the lower Mississippi River', *Journal of Freshwater Ecology,* **2**, 247-261.

Beckett, C. C., Green, B. W., Thomas, S. A., and Miller, A. C. 1996. 'Epizoic invertebrate communities on upper Mississippi River unionid bivalves', *American Midland Naturalist,* **135**, 102-114.

Bertrand, B. A. 1997. 'Changes in the Mississippi River fishery along Illinois, 1976-1996', *Journal of Freshwater Ecology,* **12**, 585-597.

Bourassa, N. and Morin, A. 1995. 'Relationships between size structure of invertebrate assemblages and trophy and substrate composition in streams', *Journal of North American Benthological Society,* **14**, 393-403.

Carlson, C. A. 1967. 'Summer bottom fauna of the Mississippi River, above dam 19, Keokuk, Iowa', *Ecology,* **49**, 162-169.

Cao, Y., Bark, A. W., and Williams, W. P. 1996. 'Measuring the responses of macroinvertebrate communities to water pollution: a comparison of multivariate approaches, biotic and diversity indices', *Hydrobiologia,* 341, 1-19.

Casey, R. J., and Kendall, S. A. 1997. 'Sample number and colonization patterns of benthic macroinvertebrates and organic material on artificial and natural substrata', *Journal of Freshwater Ecology,* **12**, 577-584.

Ciborowski, J. J. J., and Clifford, H. F.. 1984. 'Short-term colonization patterns of lotic macroinvertebrates', *Canadian Journal of Fisheries and Aquatic Sciences,* **41**, 1626-1633.

Clifford, H. F., Casey, R. J., and Saffran, K. A. 1992. 'Short-term colonization of rough and smooth tiles by benthic macroinvertebrates and algae (chlorophyll *a*) in two streams', *Journal of the North American Benthological Society,* **11**, 304-315.

Culp, J. M., Walde, S. J., and Davies, R. W. 1983. 'Relative importance of substrate particle size and detritus to stream benthic macroinvertebrate microdistribution', *Canadian Journal of Fisheries and Aquatic Sciences,* **40**, 1568-1574.

Death, R. G., and Winterbourn, M. J. 1995. 'Diversity patterns in stream benthic invertebrate communities: the influence of habitat stability', *Ecology,* **76**, 1446-1460.

Delucchi, C. M. 1987. 'Comparison of community structure among streams with different temporal flow regimes', *Canadian Journal of Zoology,* **66**, 579-568.

Dickson, K. L., Cairns, J. Jr., and Arnold, J. C. 1971. 'An evaluation of the use of a basket-type artificial substrate for sampling macroinvertebrate organisms', *Transactions of the American Fisheries Society,* **3**, 553-559.

Environmental Science and Engineering, Inc. (ESE). 1982. *Final report, GREAT III ecological and habitat characterization*, submitted to St. Louis District, Army Corps of Engineers and Fish and Wildlife Work Group, Contract No. DACW43-81-C-0065.

Fremling, C. O. 1960. 'Biology and possible control of nuisance caddisflies of the upper Mississippi River', *Agriculture, Home, Economic Experiment Station Iowa State University Resource Bulletin* **483**, 856-879. *cited from* Beckett, D. C. 1982. 'Phenology of *Hydropsyche orris* (Trichoptera: Hydropsychidae) in the Ohio River: changes in larval age structure and substrate colonization rates', *Environmental Entomology,* **11**, 1154-1158.

Gauch, H. G., Jr. 1982. *Multivariate analysis in community ecology*, Cambridge Univ. Press, Cambridge, England.

Hall, T. J. 1982. 'Colonizing macroinvertebrates in the upper Mississippi River with a comparison of basket and multiplate samplers', *Freshwater Biology,* **12**, 211-215.

Hare, L. 1995. 'Sediment colonization by littoral and profundal insects', *Journal of the North American Benthological Society,* **14**, 315-323.

Hart, D. D., Clark, B. D., and Jasentuliyana, A. 1996. 'Fine-scale field measurement of benthic flow environments inhabited by stream invertebrates', *Limnology and Oceanography,* **41**, 297-308.

Kirk, E. J., and Perry, S. A. 1992. 'Differences in macroinvertebrate taxa richness and density between samplers located along the shoreline and inside the navigation channel of the Kanawha River, West Virginia', *Journal of Freshwater Ecology,* 8, 77-80.

Knorr, D. F., and Fairchild, G. W. 1987. 'Periphyton, benthic invertebrates and fishes as biological indicators of water quality in the East Branch Brandywine Creek', *Proceedings of the Pennsylvania Academy of Science,* **61**, 61-66.

Lancaster, J., Hildrew, A. G., and Gjerlov, C. 1996. 'Invertebrate drift and longitudinal transport processes in streams', *Canadian Journal of Fisheries and Aquatic Sciences,* **53**, 572-582.

Leland, H. V., Carter, J. L., and Fend, S. V. 1986. 'Use of detrended correspondence analysis to evaluate factors controlling spatial distribution of benthic insects', *Hydrobiologia,* **132**, 113-123.

Mathis, D. B., Bingham, C. R., and Sanders, L. G. 1982. *Assessment of implanted substrate samplers for macroinvertebrates inhabiting stone dikes of the lower Mississippi River*, Miscellaneous Paper E-82-1. U.S. Waterways Experimental Station, Vicksburg, Mississippi.

Maxon, C. L., Barnett, A. M., and Diener, D. R. 1997. 'Sediment contaminants and biological effects in southern California: use of a multivariate statistical approach to assess biological impact', *Environmental Toxicology and Chemistry,* **16**, 775-784.

Merritt, R. W. and Cummins, K. W. 1996. Trophic relations of macroinvertebrates, Pages 453-474 *in* Hauer, F. R., and Lamberti, G. A. (eds). *Methods in stream ecology*, Academic Press, Inc.

Miller, A. C. 1988. 'Mussel fauna associated with wing dams in pool 7 of the Mississippi River', *Journal of Freshwater Ecology,* 4, 299-302.

Payne, B. S., Bingham,. R. B., and Miller, A. C. 1989. *Life history and production of dominant larval insects on stone dikes in the Lower Mississippi River*. Lower Mississippi River Environmental Program, Report 18, Mississippi River Commission, Vicksburg, Mississippi. *cited from* Way, C. M., Burky, A. J., Bingham, C. R., and Miller, A. C. 1995. 'Substrate roughness, velocity refuges, and macroinvertebrate abundance on artificial substrates in the lower Mississippi River', *Journal of the North American Benthological Society* **14**, 510-518.

Payne, B. S. and Miller, A. C. 1996. 'Life history and production of filter-feeding insects on stone dikes in the lower Mississippi River', *Hydrobiologia,* **319**, 93-102.

Peckarsky, B. L. 1986. 'Colonization of natural substrates by stream benthos'. *Canadian Journal of Fisheries and Aquatic Sciences,* **43**, 700-709.

Rabeni, C. F., and Minshall, G. W. 1977. 'Factors affecting microdistribution of stream benthic insects', *Oikos,* **29**, 33-43.

Rice, W. R. 1989. 'Analyzing tables of statistical tests', *Evolution,* **43**, 223-225.

Sanders, L. G., and Baker, J. A. 1984. *Influence of dikes and revetments on biota of the Arkansas River*, U.S. Army Corps of Engineers Waterways Experiment Station. EWQOS Information Exchange Bulletin Vol E-84-2.

Sauer, J. S. 1999. *Annual status report, 1998: Macroinvertebrate sampling*, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI. LTRMP 99-002.

Sauer, J. S. and Lubinski, K. 1999. 'Macroinvertebrates', Pages 10-1 to 10-11 *in* U.S. Geological Survey. *Ecological status and trends of the upper Mississippi River system 1998: A report of the Long Term Resource Monitoring Program*, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI. LTRMP 99-T001.

Seagle, H. H., and Wetzel, M. S. 1982. 'Range extension of *Barbidrilus paucisetus* Loden and Locy (Oligochaeta; Enchytraeidae)', *Freshwater Invertebrate Biology,* **1**, 52-53.

Sheldon, A. L. 1977. 'Colonization curves: application to stream insects on semi-natural substrates', *Oikos,* 28, 256-261.

Smock, L. A. 1996. 'Macroinvertebrate movements: drift, colonization, and emergence', Pages 371-390 *in* Hauer, F. R., and Lamberti, G. A. (eds). *Methods in stream ecology*, Academic Press, Inc.

Soluk, D. A. 1985. 'Macroinvertebrate abundance and production of psammophilous Chironomidae in shifting sand areas of a lowland river', *Canadian Journal of Fisheries and Aquatic Science,* **42**, 1296-1302.

Stewart, T. W., Miner, J. G., and Lowe, R. L. 1998. Macroinvertebrate communities on hard substrates in western Lake Erie: structuring effects of *Dreissena*, *Journal Great Lakes Research,* 24, 868-879.

Stucky, N., and Farabee, G. 1992. 'An evaluation of designated lock approach waiting areas and bendway weirs', Appendix B *in* USACE. *Melvin Price Locks and Dam, Upper Mississippi River basin Mississippi River - Missouri and Illinois. Design memorandum no. 24, avoid and minimize measures*, St. Louis District, U.S. Army Corps of Engineers, St. Louis, Missouri.

Theiling, C. 1999. 'River geomorphology and floodplain habitats', Pages 4-1 to 4-21 *in* U.S. Geological Survey. *Ecological status and trends of the upper Mississippi River system 1998: A report of the Long Term Resource Monitoring Program*, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI. LTRMP 99-T001.

Thorp, J. H. 1992. 'Linkage between islands and benthos in the Ohio river, with implications for riverine management', *Canadian Journal of Fisheries and Aquatic Sciences*, **9**, 1873-1882.

Townsend, C. R. and Hildrew, A. G. 1976. 'Field experiments on the drifting, colonization and continuous redistribution of stream benthos', *Journal of Animal Ecology*, **45**, 759-772.

Townsend, C. R., Scarsbrook, M. R., and Doledec, S. 1997. 'Quantifying disturbance in streams: alternative measures of disturbance in relation to macroinvertebrate species traits and species richness', *Journal of the North American Benthological Society*, **16**, 531-544.

U.S. Army Corps of Engineer (USACE). 1992. *Melvin Price Locks and Dam, Upper Mississippi River basin Mississippi River - Missouri and Illinois. Design memorandum no. 24, avoid and minimize measures*, St. Louis District, U.S. Army Corps of Engineers. St. Louis, Missouri.

U.S. Fish and Wildlife Service (USFWS). 1992. 'An evaluation of natural resource benefits likely to occur from the implementation of measures to avoid and minimize navigation impacts', *in* U.S. Army Corps of Engineer (USACE). 1992. *Melvin Price Locks and Dam, Upper Mississippi River basin Mississippi River - Missouri and Illinois. Design memorandum no. 24, avoid and minimize measures*, St. Louis District, U.S. Army Corps of Engineers, St. Louis, Missouri.

Ward, J. V. 1998. 'Riverine landscapes: biodiversity patterns, disturbance regimes, and aquatic conservation', *Biological Conservation*, **83**, 269-278.

Waters, T. F. 1964. 'Recolonization of denuded stream bottom areas by drift', *Transactions of the American Fisheries Society*, **93**, 311-315.

Way, C. M., Burky, A. J., Bingham, C. R., and Miller, A. C. 1995. 'Substrate roughness, velocity refuges, and macroinvertebrate abundance on artificial substrates in the lower Mississippi

River', *Journal of the North American Benthological Society,* **14**, 510-518.

Wise, D. H. and Molles, M. C. Jr. 1979. 'Colonization of artificial substrates by stream insects: influence of substrate size and diversity', *Hydrobiologia,* **65**, 69-74.

Yule, C. M. 1996. 'Spatial distribution of the invertebrate fauna of an aseasonal tropical stream on Bougainville Island, Papua New Guinea', *Archives Hydrobiologia*, **137**, 227-249.

Table I. Summary of samples collected in the upper Mississippi River for the A & M Program, 1994 to 1998.

MRM	Structure	Constructed	Sampled	Sample type	Sample size
289.5	Chevron dikes	1992	Nov/Dec-94	Rock basket	20
			Nov-94	Standard ponar	3
			May/June-95	Rock basket	10
			June-95	Standard ponar	5
			Sept/Oct-95	Rock basket	18
			Sept-95	Standard ponar	5
			Aug/Sept-96	Rock basket	20
			Sept-96	Standard ponar	3
289.5	None	NA	Nov-94	Standard ponar	17
			June-95	Standard ponar	10
			Sept-95	Standard ponar	10
			Sept-96	Standard ponar	17
265.7	None	NA	Apr-96	Standard ponar	10
250.2	None	NA	Apr-96	Standard ponar	10
203	I-wall rubble	1995	July/Aug-96	Rock basket	10
			June/July-97	Rock basket	8
			June/Juy-98	Rock basket	4
203	None	NA	July-97	Standard ponar	4
			July-98	Standard ponar	12
164	Bendway weirs	1996	July/Aug-96	Buoy anchor	6
			July/Aug-96	Rock basket	3
			Sept-96	Weir rock	15
164	None	NA	Sep-96	Buoy anchor	9
30	Bendway weirs	1991	Aug-96	Weir rock	27
20	None	NA	Aug-96	Petite ponar	11

Table II. Relative abundance (%) of macroinvertebrates collected at upper Mississippi River sample sites[1], 1994 to 1998.

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	MRM 164	MRM 203	MRM 250.2	MRM 265.7	MRM 289.5	Total
Cnidaria	Hydrozoa	Hydroida	Hydridae		*Hydra sp.*						0.09	0.05
Platyhelminthes	Turbellaria					0.23	0.01	0.09			0.26	0.19
		Macrostomida	Macrostomidae					0.21	4.16	38.61	0.20	0.30
		Tricladida	Dendrocoelidae		*Procotyla fluviatilis*						0.00	0.00
			Planariidae		*Cura foremanii*			0.01				0.00
					Dugesia tigrina	4.00	0.47	6.30			4.76	4.73
Nematoda						2.02	1.00	0.22	31.29	2.21	0.20	0.38
Nematomorpha							0.00	0.01			0.29	0.19
Mollusca	Gastropoda	Lymnophila	Lymnaeidae		*Pseudosuccinea sp.*						0.00	0.00
			Physidae		*Physa sp.*			0.01			0.00	0.01
					Physella sp.						0.01	0.01
			Planorbidae		*Menetus sampsoni*	0.06						0.00
	Bivalvia	Veneroida	Corbiculidae		*Corbicula fluminea*			0.00			0.00	0.00
			Dreissenidae		*Dreissena polymorpha*	7.47	0.11	7.63			10.30	8.68
			Sphaeriidae					0.02			0.00	0.01
					Musculium sp.						0.00	0.00
					Sphaerium sp.			0.01			0.00	0.01
			Unionidae			0.01						0.00
				Ambleminae	*Megalonaias nervosa*			0.00				0.00
				Anodontinae	*Pyganodon grandis*			0.00				0.00
				Lampsilinae	*Leptodea fragilis*			0.02				0.00
					Potamilus ohiensis			0.00				0.00
Annelida	Aphanoneura	Aeolosomatida	Aeolosomatidae								0.00	0.00
	Oligochaeta	Haplotaxida	Enchytraeidae					0.00			0.00	0.00
					Barbidrilus paucisetus	2.69	0.02		34.41	52.09	0.84	0.80
			Naididae		*Amphichaeta leydigi*					0.08		0.00
					Chaetogaster diaphanus			0.03			0.04	0.03
					Chaetogaster diastrophus						0.01	0.00
					Dero digitata		0.00	0.08			0.18	0.13
					Dero nivea			0.05			0.00	0.01
					Nais behningi	0.13	0.07	0.02			0.12	0.09
					Nais bretscheri						0.01	0.01
					Nais communis			0.00			0.00	0.00
					Nais elinguis						0.00	0.00
					Nais pardalis			0.03			0.20	0.13
					Nais pseudobtusa						0.01	0.00

Table II. (continued).

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	MRM 164	MRM 203	MRM 250.2	MRM 265.7	MRM 289.5	Total
Annelida	Oligochaeta	Haplotaxida	Naididae		*Nais simplex*						0.04	0.02
					Nais variabilis		0.02	0.01			0.10	0.07
					Ophidonais serpentina						0.00	0.00
					Paranais frici						0.00	0.00
					Piguetiella michiganensis			0.01			0.01	0.01
					Pristina aequiseta						0.00	0.00
					Pristina breviseta						0.00	0.00
					Pristina leidyi			0.00			0.02	0.01
					Pristinella jenkinae			0.00				0.00
					Pristinella longisoma			0.00				0.00
					Pristinella osborni						0.00	0.00
					Pristinella sima						0.00	0.00
					Slavina appendiculata		0.00	0.39			0.01	0.11
					Stephensoniana trivandrana						0.00	0.00
					Stylaria lacustris			0.11			0.01	0.03
			Tubificidae		*immature w/ cap. setae*				0.92		0.00	0.00
					immature w/o cap. setae			0.27	4.39		0.16	0.18
					Aulodrilus limnobius				0.12		0.01	0.01
					Aulodrilus pigueti			0.05			0.05	0.05
					Branchiura sowerbyi			0.00	0.12		0.02	0.01
					Ilyodrilus templetoni						0.00	0.00
					Limnodrilus cervix			0.03	0.12		0.00	0.01
					Limnodrilus claparedianus						0.00	0.00
					Limnodrilus hoffmeisteri			0.07	0.69		0.02	0.03
					Limnodrilus maumeensis						0.00	0.00
					Limnodrilus udekemianus			0.00	0.46		0.00	0.00
	Branchiobdellida							0.00				0.00
	Hirudinea							0.00		0.08		0.00
		Pharyngobdellida	Erpobdellidae		*Mooreobdella fervida*						0.01	0.00
		Rhynchobdellida	Glossiphoniidae								0.00	0.00
					Alboglossiphoniaheteroclita						0.00	0.00
					Helobdella stagnalis						0.00	0.00
					Placobdella ornata			0.00				0.00
					Placobdella parasitica						0.00	0.00
Arthropoda	Arachnoidea	Hydrachnellae									0.02	0.01
			Oribatei				0.00					0.00
	Insecta	Collembola									0.00	0.00
			Entomobryidae			0.01						0.00
			Isotomidae								0.00	0.00
					Semicerura sp.						0.01	0.01

Table II. (continued).

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	164	203	250.2	265.7	289.6	Total
Arthropoda	Insecta	Ephemeroptera									0.03	0.02
			Ameletidae		*Ameletus sp.*		0.00					0.00
			Baetidae					0.00			0.01	0.00
					Baetis sp.	1.36	1.63	1.34			0.11	0.59
					Labiobaetis sp.						0.28	0.18
			Caenidae		*Amercaenis sp.*	0.23		0.06				0.02
					Brachyserus sp.						0.00	0.00
					Caenis sp.		0.39	0.67		0.08	1.97	1.44
			Ephemeridae								0.00	0.00
					Hexagenia sp.						0.01	0.01
					Hexagenia limbata			0.01	2.42		0.01	0.01
					Pentagenia sp.			0.00	1.27		0.02	0.01
			Heptageniidae			0.10	0.06				0.13	0.09
					Heptagenia sp.		0.00	0.00				0.00
					Stenacron sp.		0.00	0.02			0.00	0.01
					Stenonema sp.	0.01	0.07	0.01			0.00	0.01
					Stenonema femoratum	0.04					0.00	0.00
					Stenonema integrum	0.12		0.64			0.46	0.43
					Stenonema modestum						0.01	0.00
			Isonychiidae		*Isonychia sp.*	0.05		1.58			1.64	1.44
			Polymitarcyidae		*Ephoron sp.*			0.00				0.00
			Potamanthidae		*Anthopotamus sp.*						0.00	0.00
			Tricorythidae		*Tricorythodes sp.*			0.01			0.23	0.15
		Odonata (Anisoptera)	Corduliidae		*Neurocordulia sp.*						0.00	0.00
					Neurocordulia molesta			0.02			0.01	0.01
					Neurocordulia virginiensis			0.00				0.00
			Gomphidae						0.12		0.00	0.00
					Arigomphus sp.						0.01	0.00
					Dromogomphus sp.			0.00			0.00	0.00
					Gomphurus crassus						0.00	0.00
					Gomphurus hybridus						0.00	0.00
					Gomphus sp.			0.01			0.00	0.00
					Gomphus consanguis			0.00				0.00
					Gomphus spicatus			0.01				0.00
					Stylurus sp.						0.00	0.00
					Stylurus plagiatus						0.00	0.00
			Libellulidae		*Ladona sp.*						0.00	0.00
			Macromiidae		*Macromia sp.*						0.00	0.00
		Odonata (Zygoptera)	Coenagrionidae					0.01			0.01	0.01
					Argia sp.			0.09			0.14	0.11
					Enallagma sp.						0.03	0.02

Table II. (continued).

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	164	203	250.2	265.7	289.5	Total
Arthropoda	Insecta	Plecoptera					0.00				0.10	0.06
			Chloroperlidae								0.00	0.00
					Haploperla brevis						0.03	0.02
			Perlidae								0.00	0.00
					Acroneuria sp.						0.00	0.00
					Neoperla sp.						0.03	0.02
					Perlesta sp.			0.00				0.00
					Perlesta placida						0.02	0.01
			Perlodidae								0.02	0.01
					Isoperla sp.				0.12		0.21	0.13
			Taeniopterygidae		*Taeniopteryx sp.*						0.08	0.05
		Hemiptera	Corixidae					0.00				0.00
					Trichocorixa sp.						0.07	0.05
			Saldidae								0.00	0.00
		Coleoptera	Carabidae								0.00	0.00
			Chrysomelidae		*Disonycha sp.*						0.00	0.00
			Dryopidae		*Helichus basalis*						0.00	0.00
			Elmidae		*Stenelmis sp.*		0.01	0.03			0.04	0.03
					Dubiraphia sp.						0.00	0.00
			Heteroceridae (larvae)								0.00	0.00
			Hydrophilidae		*Berosus sp.*						0.00	0.00
			Lampyridae								0.00	0.00
			Tenebrionidae (larvae)				0.01				0.00	0.00
		Megaloptera	Corydalidae		*Corydalus sp.*						0.01	0.00
		Diptera			(pupa)		0.05		2.31		0.41	0.27
			Ceratopogonidae						0.12		0.01	0.01
					Bezzia sp.				0.46		0.04	0.03
					Culicoides sp.						0.00	0.00
					Nilobezzia sp.						0.00	0.00
					Probezzia sp.				0.46	0.23	0.01	0.01
					Sphaeromias sp.						0.00	0.00
			Chaoboridae		*Chaoborus sp.*						0.00	0.00
			Chironomidae			0.01	0.01	0.32	0.12	0.63	1.69	1.14
				Chironominae		0.01		0.00				0.00
					Axarus sp.				0.12		0.01	0.00
					Chernovskiia sp.			0.26	2.08	1.07	0.26	0.24
					Chironomini						0.01	0.00
					Chironomus sp.			0.01			0.20	0.13

Table II. (continued).

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	164	203	250.2	265.7	289.5	Total
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	*Cladotanytarsus sp.*						0.13	0.08
					Cryptochironomus sp.	0.01		0.05	1.73		0.03	0.04
					Dicrotendipes sp.		0.00	0.04	0.12		0.22	0.15
					Glyptotendipes sp.	0.02		0.10			4.32	2.73
					Harnischia sp.			0.01			0.00	0.00
					Lipiniella sp.						0.10	0.06
					Micropsectra sp.						0.00	0.00
					Parachironomus sp.			0.00			0.13	0.08
					Paracladopelma sp.						0.00	0.00
					Paralauterborniella sp.						0.00	0.00
					Paratanytarsus sp.						0.00	0.00
					Paratendipes sp.	0.02		0.01	2.19	0.69	0.09	0.07
					Polypedilum sp.				0.12		0.04	0.02
					Polypedilum convictum	2.97	6.02	1.87			1.81	2.22
					Polypedilum fallax group			0.00				0.00
					Polypedilum illinoense		0.05	0.05			0.06	0.06
					Polypedilum scalaenum	0.02		0.29			0.09	0.13
					Rheotanytarsus sp.	0.82	3.48	2.45		0.08	13.56	9.45
					Robackia sp.	0.07	0.01	0.00	0.35	2.36	0.22	0.16
					Saetheria sp.						0.02	0.01
					Stictochironomus sp.						0.00	0.00
					Tanytarsus sp.	0.01		0.00			0.12	0.08
				Orthocladiinae			0.04	0.00		0.30	0.00	0.01
					Corynoneura sp.						0.01	0.01
					Cricotopus sp.				0.12		0.00	0.00
					Cricotopus bicinctus group						0.14	0.09
					Cricotopus sylvestris group						0.14	0.09
					Cricotopus tremulus group						0.01	0.01
					Eukiefferiella claripennis group		0.00					0.00
					Hydrobaenus sp.						0.01	0.00
					Lopescladius sp.						0.02	0.01
					Nanocladius sp.	0.02	0.03	0.34			0.21	0.22
					Parakiefferiella sp.				6.00	1.07	0.00	0.02
					Procladius sp.						0.00	0.00
					Pseudosmittia sp.						0.00	0.00
					Rheosmittia sp.		0.07		0.36	0.08	0.00	0.01
					Thienemanniella sp.	0.01					0.01	0.01
				Tanypodinae							0.01	0.00
					Ablabesmyia sp.			0.55	0.12		0.08	0.20
					Coelotanypus sp.				0.12		0.01	0.01
					Corynoneura sp.			0.00				0.00
					Labrundinia sp.						0.01	0.00
					Larsia sp.			0.00				0.00
					Paramerina sp.			0.00				0.00
					Thienemannimyia sp. group	0.16	0.07	1.27			0.67	0.76

Table II. (continued).

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	MRM 164	MRM 203	MRM 260.2	MRM 265.7	MRM 289.6	Total
Arthropoda	Insecta	Diptera	Empididae								0.14	0.09
					Hemerodromia sp.	0.01	0.03				0.22	0.14
			Simuliidae		*Simulium sp.*			0.00			0.01	0.01
			Tanyderidae		*Tanyderidae*				1.15	0.38		0.00
			Tipulidae								0.00	0.00
		Trichoptera			(pupa)	0.61	1.42	3.94			0.26	1.33
			Hydropsychidae			0.07		0.00			0.08	0.05
					Cheumatopsyche sp.			0.03	1.27	0.08	0.33	0.22
					Hydropsyche sp.	0.04			0.12		0.00	0.00
					Hydropsyche bidens			0.01				0.00
					Hydropsyche orris	64.56	33.41	29.11			13.14	20.02
					Hydropsyche simulans	0.02	0.04	0.10			0.11	0.10
					Potamyia flava	10.86	61.36	37.65			35.68	36.95
			Hydroptilidae					0.00			0.13	0.08
					Hydroptila sp.						0.55	0.34
					Mayatrichia sp.			0.04				0.01
					Neotrichia sp.	1.19						0.02
			Leptoceridae		*Nectopsyche sp.*			0.14			0.31	0.23
					Oecetis sp.						0.03	0.02
					Triaenodes sp.						0.00	0.00
			Philopotamidae		*Dolophilides sp.*						0.01	0.01
			Polycentropodidae					0.00			0.00	0.00
					Cyrnellus fraternus			1.21			0.16	0.41
					Neureclipsis sp.		0.00	0.04			0.01	0.02
					Polycentropus sp.						0.05	0.03
	Crustacea	Amphipoda	Crangonyctidae								0.01	0.01
			Gammaridae		*Gammarus fasciatus*						0.01	0.00
					Gammarus lacustris						0.00	0.00
					Gammarus minus	0.01					0.00	0.00
					Gammarus troglophilus						0.00	0.00
			Talitridae		*Hyalella azteca*						0.00	0.00
		Isopoda	Asellidae								0.00	0.00
					Asellus intermedius						0.00	0.00
					Caecidotea sp.						0.03	0.02
					Lirceus fontinalis		0.00	0.00				0.00
		Decapoda	Cambaridae					0.00			0.00	0.00
					Orconectes luteus			0.01			0.01	0.01
					Orconectes virilis			0.00			0.00	0.00

Table II. (continued).

Phylum	Class	Order	Family	Subfamily	Species	MRM 20-30	164	203	250.2	265.7	289.5	Total
					Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
					No. taxa (total)	38	40	104	34	17	203	238
					No. taxa (mean±2SE)	6.3±1.3	8.9±1.4	20.0±3.4	7.9±2.0	5.0±1.7	16.5±1.8	
					SW Index (total)	2.04	1.84	2.85	2.95	1.62	3.46	3.33
					SW Index (mean±2SE)	0.95±0.19	1.50±0.21	2.23±0.19	2.26±0.43	1.18±0.39	2.4±0.14	
					No. samples	38	33	38	10	10	148	

[1]Sites correspond to Figure 1-1

Table III. Pearson correlation matrix of PCA factor scores and sample attributes.

	Factor 1	Factor 2
Factor 1	1.000	
Factor 2	<0.001	1.000
Substrate	**0.779**	-0.124
Structure	**0.697**	0.142
Position	**-0.347**	0.113
Season	**0.270**	0.128
River mile	-0.155	**0.603**

Significant correlations (<0.001) are bolded

Table IV. Invertebrate community parameters associated with upper Mississippi River chevron dikes, MRM 289.5, 1994 to 1996.

Date	Nov./Dec. 1994				May/June 1995			
Structure	None	Chevron dikes			None	Chevron dikes		
Substrate[1]	Sd/St/Cl/minor Gr	Rock	Sd/St	Rock	Sd/minor Gr	Rock	Sd/St/Cl/Det	Rock
Sample location	River substrate	Interior rock	Int. substrate	Exterior rock	River substrate	Interior rock	Int. substrate	Exterior rock
Sample type	Ponar	Rock basket	Ponar	Rock basket	Ponar	Rock basket	Ponar	Rock basket
Sample size (n)	17	4	3	16	10	3	5	7
Taxonomic richness (total)	31	60	22	93	19	53	20	54
Taxonomic richness (mean±2SE)	7.3±1.5	28.3±10.2	11.3±4.1	28.1±4.6	6.2±1.8	29.7±8.2	7.4±2.1	21.1±7.7
Diversity (SW-total)	2.57	4.34	3.24	4.32	2.17	2.50	3.60	2.08
Diversity (SW-mean±2SE)	1.94±0.29	3.31±0.73	2.50±0.30	3.50±0.21	1.09±0.48	2.57±0.63	2.24±0.40	1.84±0.70
Dominant taxa (%)	*B. paucisetus* (43) Macrostomidae (16) *Dugesia tigrina* (16) *Chernovskiia sp.* (15) *Robackia sp.* (11)	*Nais variabilis* (14) *Dero digitata* (14) *Cladotanytarsus* (13)	Tubificidae (60) *Dero digitata* (18)	*Rheotanytarsus sp.* (15) *Hydroptila sp.* (16) *Isoperla sp.* (12) *Potamyia flava* (10)	Nematoda (46) *B. paucisetus* (28) *Paratendipes sp.* (11)	*Caenis sp.* (01) *Dugesia tigrina* (11)	Tubificidae (21) *B. paucisetus* (19) Nematoda (17)	*Potamyia flava* (63) *Hydropsyche orris* (12)

Date	Sept./Oct. 1995				Aug./Sept. 1996			
Structure	None	Chevron dikes			None	Chevron dikes		
Substrate[1]	Sd/minor Gr	Rock	Gr/Sd/St	Rock	Sd/minor Gr	Rock	Sd/St/Det	
Sample location	River substrate	Interior rock	Int. substrate	Exterior rock	River substrate	Interior rock	Int. substrate	Exterior rock
Sample type	Ponar	Rock basket	Ponar	Rock basket	Ponar	Rock basket	Ponar	Rock basket
Sample size (n)	10	6	5	13	20	6	10	14
Taxonomic richness (total)	18	43	31	59	42	62	37	88
Taxonomic richness (mean±2SE)	5.6±2.2	22.8±3.1	13.0±4.1	23.7±4.9	9.4±2.2	26.0±5.8	11.4±2.6	28.0±2.1
Diversity (SW-total)	1.38	3.09	3.63	2.26	3.47	1.94	3.07	3.07
Diversity (SW-mean±2SE)	1.49±0.45	2.83±0.55	3.04±0.46	2.66±0.50	2.20±0.36	1.85±0.30	2.34±0.26	2.59±0.17
Dominant taxa (%)	*B. pauciseltus* (80)	*Dugesia tigrina* (28) *Glyptotendipes sp.* (28) *Dicrotendipes sp.* (17)	Tubificidae (26) *Polypedilum sp.* (25) *Cladotanytarsus sp.* (16)	*Potamyia flava* (50) *Hydropsyche orris* (27) *Rheotanytarsus sp.* (10)	*Chernovskiia sp.* (23) *Robackia sp.* (22) *D. polymorpha* (17)	*Glyptotendipes sp.* (64) *Dugesia tigrina* (21)	*Chironomus sp.* (31) *Lipiniella sp.* (20)	*Potamyia flava* (27) *Rheotanytarsus sp.* (22) *D. polymorpha* (19) *Hydropsyche orris* (12)

[1]Gr=gravel, Sd=sand, St=silt, Cl=clay, Det=detritus

Table V. Invertebrate community parameters associated with upper Mississippi River bendways, MRM 20, 30, and 164, 1996.

Date	Aug. 1996		Aug/Sept-96			
Structure	None	Bendway weir	None	Bendway weirs		
Substrate	Sand	Rock	Rock/sand	Rock	Rock	Rock
Sample location	Bend w/o weirs	On weirs	Bend w/o weirs	On weirs	On weirs	On weirs
MRM	20	30	164	164	164	164
Sample type	Clam shell/ponar	Weir rock	Buoy anchor	Rock basket	Buoy anchor	Weir rock
Sample size (n)	11	27	9	3	6	15
Taxonomic richness (total)	7	34	22	25	22	22
Taxonomic richness (mean±2SE)	1.5±0.7	8.3±1.2	7.7±2.2	15.0±5.0	9.8±2.9	8.1±1.8
Diversity (SW-total)	0.68	1.88	2.15	1.49	1.88	2.18
Diversity (SW-mean±2SE)	0.59±0.40	1.09±0.19	1.70±0.24	1.09±0.52	1.40±0.31	1.70±0.39
Dominant taxa (%)	*Barbidrilus paucisetus* (89)	*Hydropsyche orris* (67)	*Potamyia flava* (38)	*Potamyia flava* (63)	*Hydropsyche orris* (44)	*Hydropsyche orris* (60)
		Potamyia flava (11)	*Rheotanytarsus* sp. (26)	*Hydropsyche orris* (27)	*Potamyia flava* (39)	*Potamyia flava* (26)
			Hydropsyche orris (26)			

Table VI. Invertebrate community parameters associated with upper Mississippi River I-wall rubble, MRM 203, 1996 to 1998.

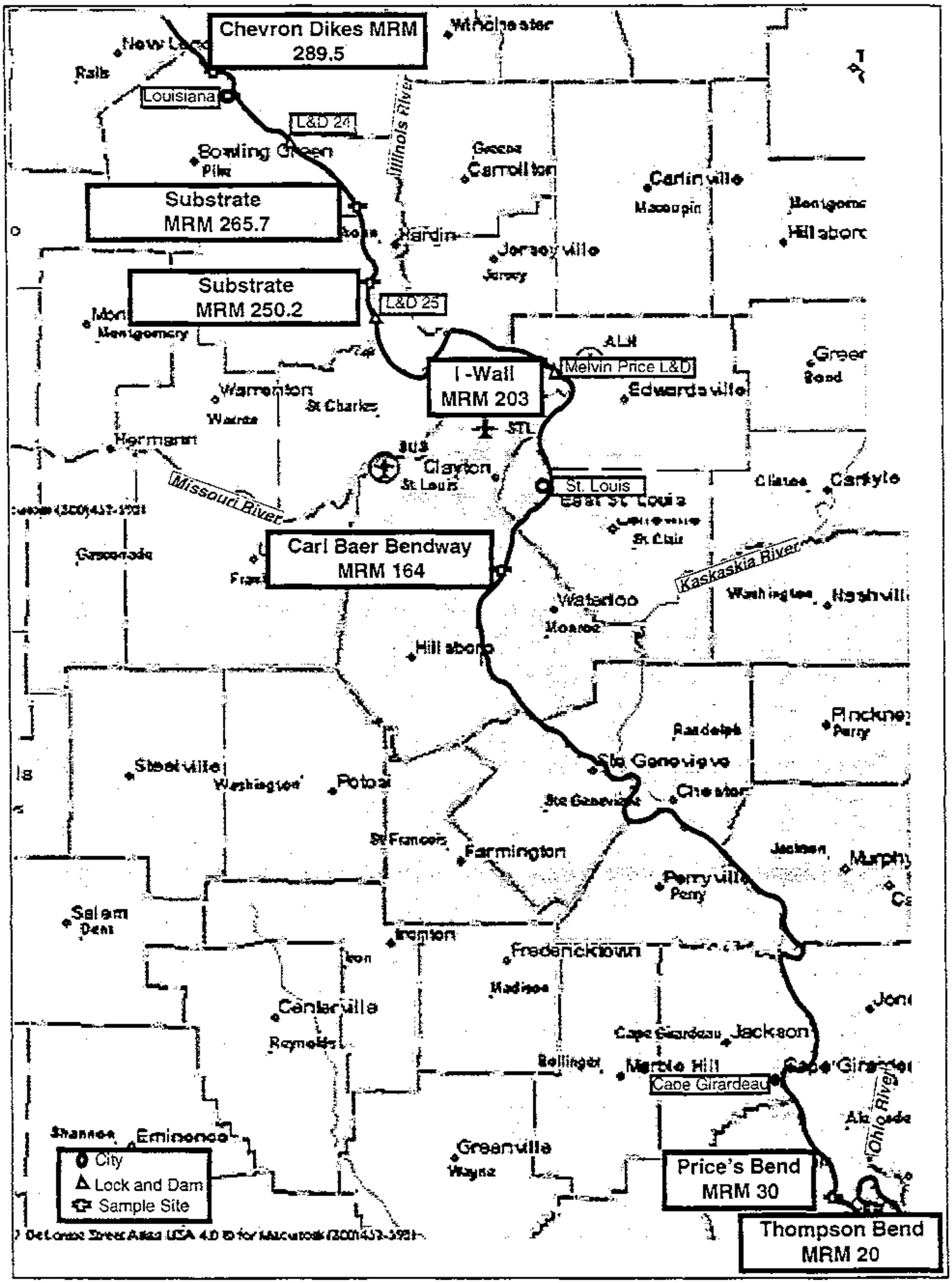
Date	July/Aug. 1996	June/July. 1997	June/July 1998	July 1997	July 1998
Structure	I-wall rubble	I-wall rubble	I-wall rubble	None	None
Substrate[1]	Rock	Rock	Rock	Gr/Sd/St/zebs	Sd/Cl
Sample location	On rubble	On rubble	On rubble	Riverward of rubble	Riverward of rubble
Sample type	Rock basket	Rock basket	Rock basket	Ponar	Ponar
Sample size (n)	10	8	4	4	12
Taxonomic richness (total)	57	62	43	34	31
Taxonomic richness (mean±2SE)	26.4±2.5	31.3±3.9	21.8±7.9	16.5±4.5	7.7±1.5
Diversity (SW-total)	2.49	2.86	1.61	2.65	2.55
Diversity (SW-mean±2SE)	2.47±0.24	2.71±0.26	1.88±0.53	2.60±0.47	1.75±0.28
Dominant taxa (%)	*Potamyia flava* (40)	*Potamyia flava* (31)	*Potamyia flava* (78)	*Potamyia flava* (50)	*Chernovskiia sp.* (39)
	Hydropsyche orris (36)	*Hydropsyche orris* (24)		*Dreissena polymorpha* (19)	Macrostomidae (31)
		Dreissena polymorpha (17)			Nematoda (12)
		Dugesia tigrina (13)			

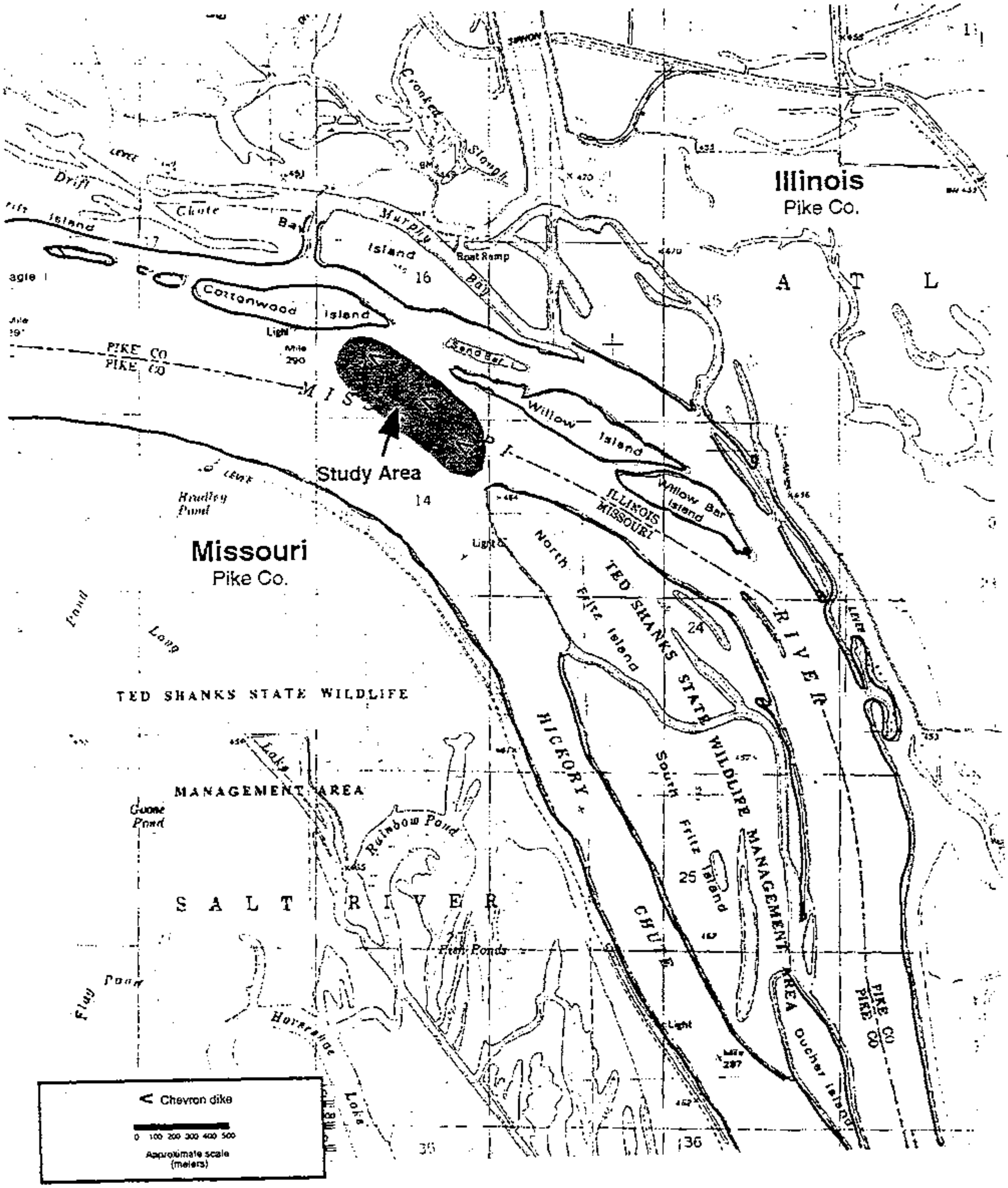
[1]Gr=gravel, Sd=sand, St=silt, Cl=clay, Det=detritus

Table VII. Invertebrate community parameters associated with upper Mississippi River substrate, MRM 250.2 and 265.7, 1996.

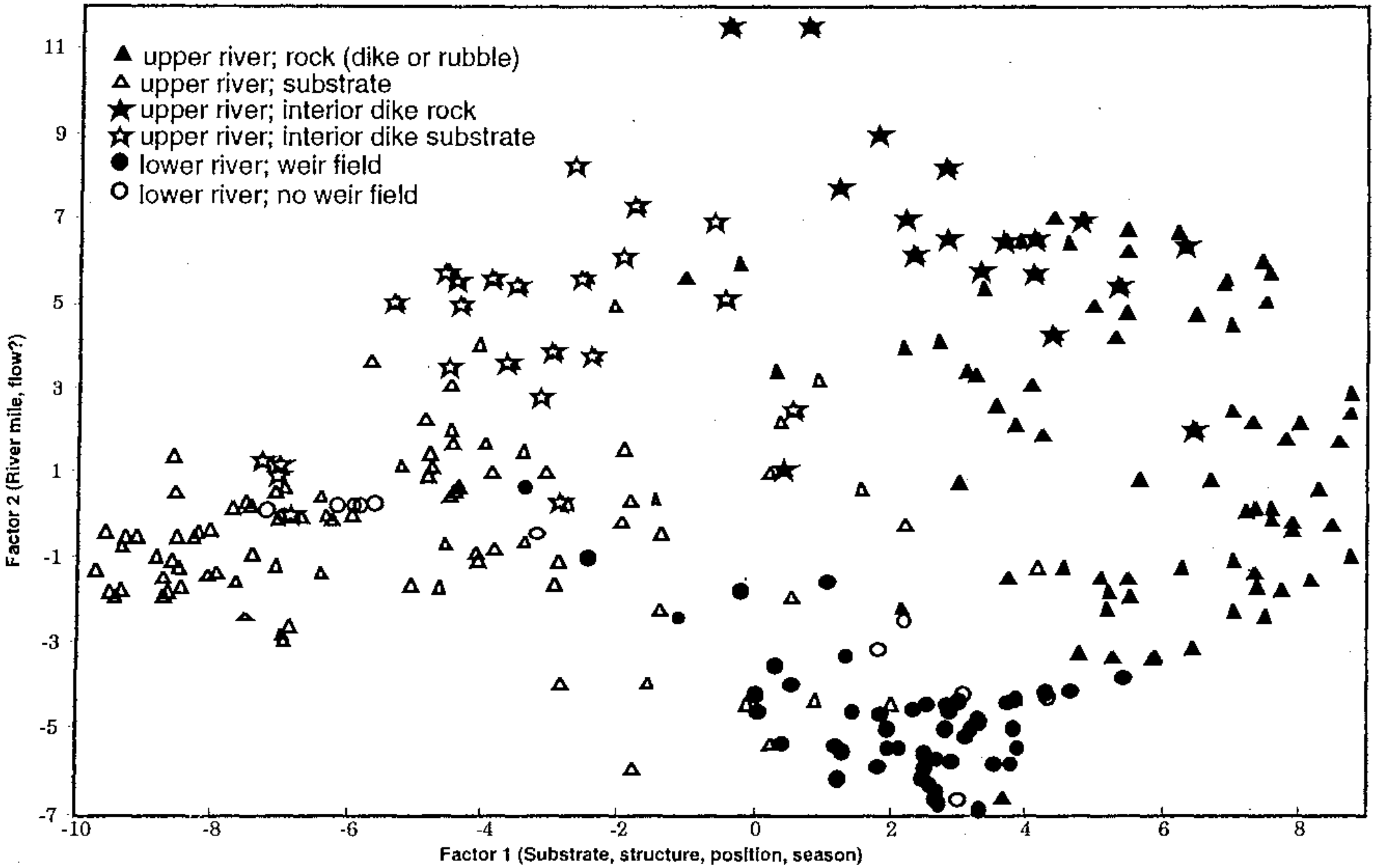
Date	Apr-96	Apr-96
Structure	None	None
Substrate	Sd/Gr/St/Cl	Sand
Sample location (MRM)	250.2	265.7
Sample type	Ponar	Ponar
Sample size (n)	10	10
Taxonomic richness (total)	34	17
Taxonomic richness (mean±2SE)	7.9±2.0	5.0±1.7
Diversity (SW-total)	2.95	1.62
Diversity (SW-mean±2SE)	2.26±0.43	1.07±0.42
Dominant taxa (%)	*Barbidrilus paucisetus* (34)	*Barbidrilus paucisetus* (52)
	Nematoda (31)	Macrostomidae (39)

Sd=sand, Gr=gravel, St=silt, Cl=clay

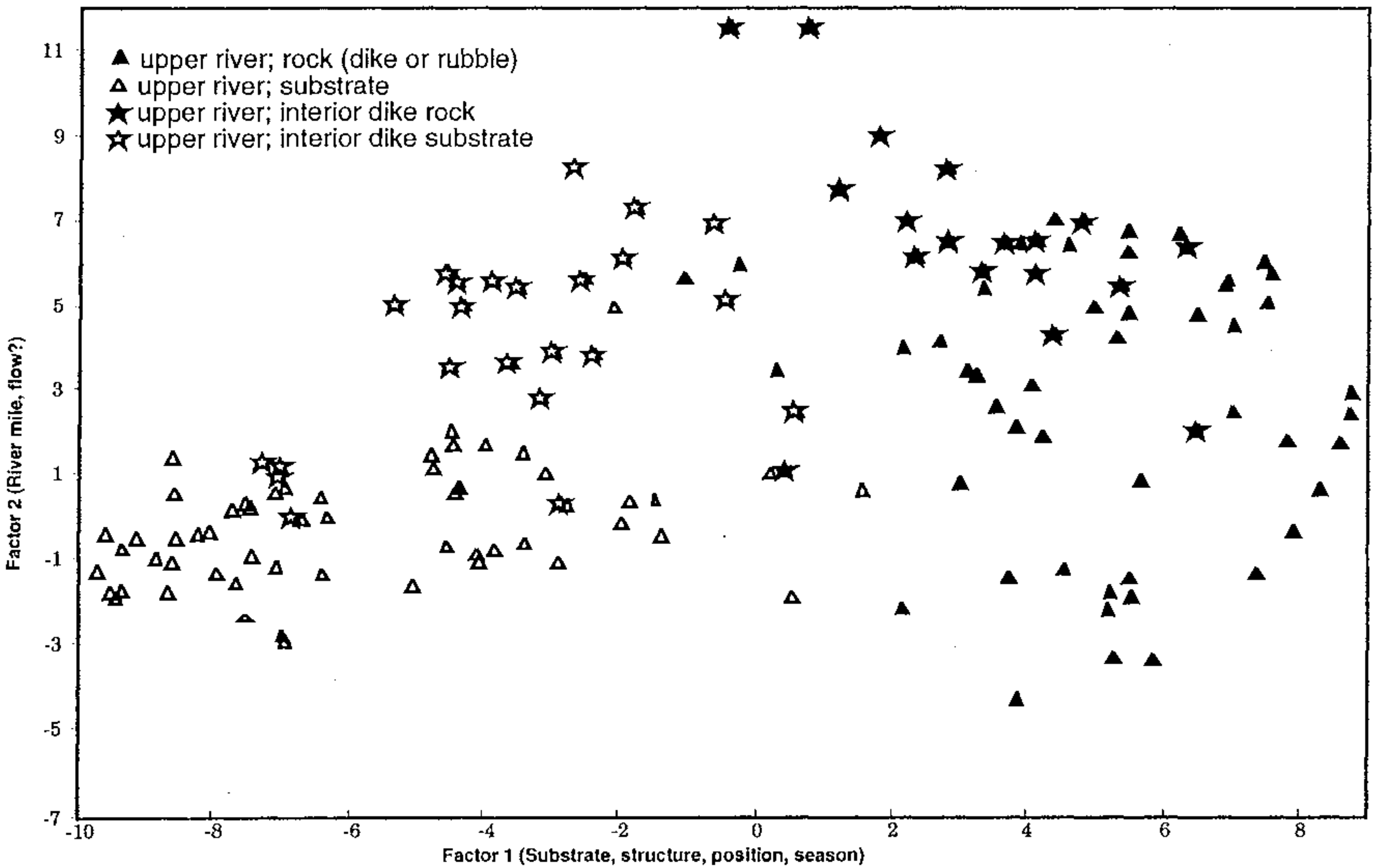

Chevron Dikes MRM 289.5
Louisiana
L&D 24
Illinois River
Substrate MRM 265.7
Substrate MRM 250.2
L&D 25
I-Wall MRM 203
Melvin Price L&D
St. Louis
Missouri River
Carl Baer Bendway MRM 164
Kaskaskia River
Cape Girardeau
Ohio River
Price's Bend MRM 30
Thompson Bend MRM 20
City
Lock and Dam
Sample Site



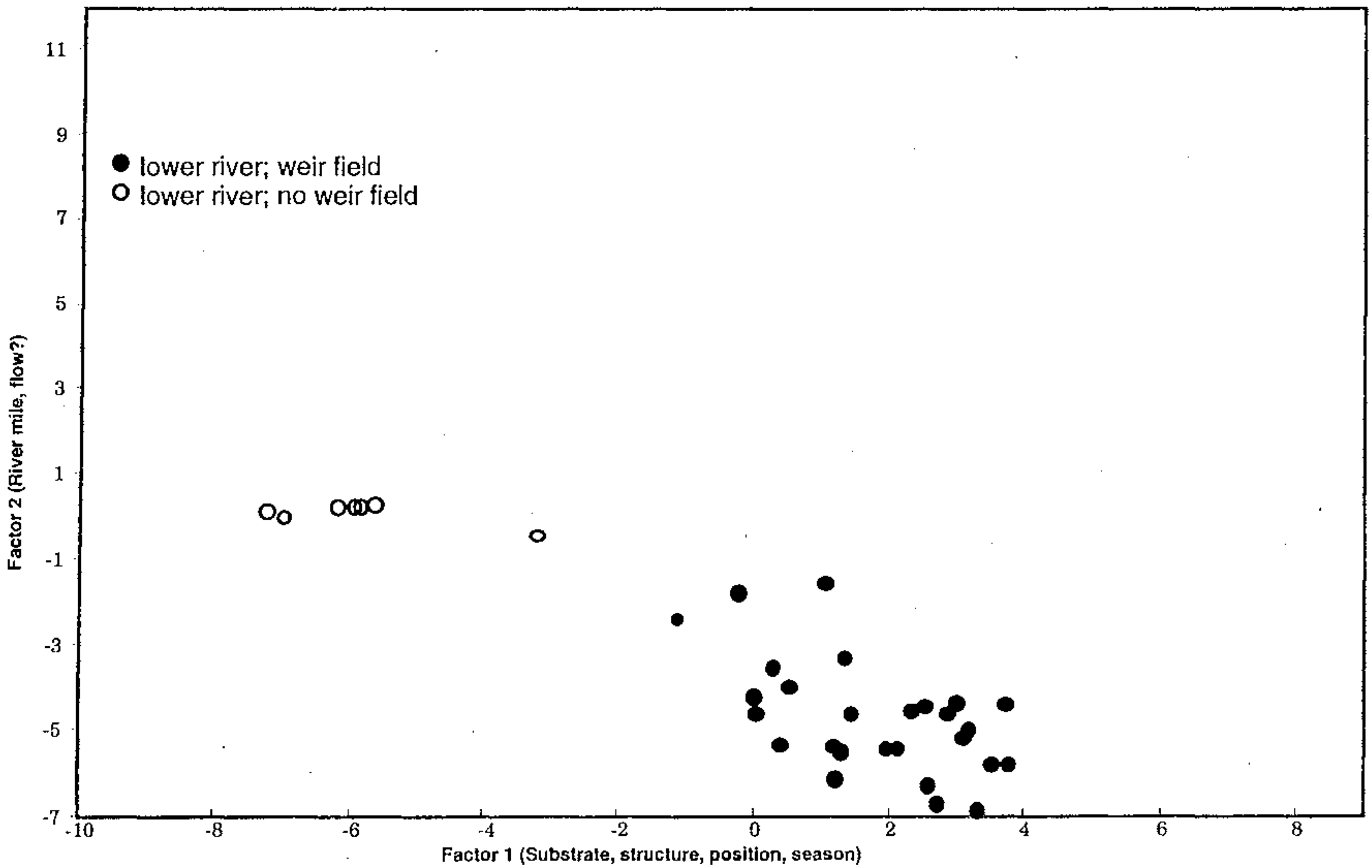
Illinois
Pike Co.
Missouri
Pike Co.
Study Area
Cottonwood Island
Willow Island
Willow Bar Island
Murphy Bay
Crooked Slough
Boat Ramp
Sand Bar
North Fritz Island
South Fritz Island
Ouchor Island
TED SHANKS STATE WILDLIFE MANAGEMENT AREA
SALT RIVER
HICKORY CHUTE
ILLINOIS
MISSOURI
PIKE CO
Rainbow Pond
Fish Ponds
Horseshoe Lake
Chevron dike
0 100 200 300 400 500
Approximate scale (meters)



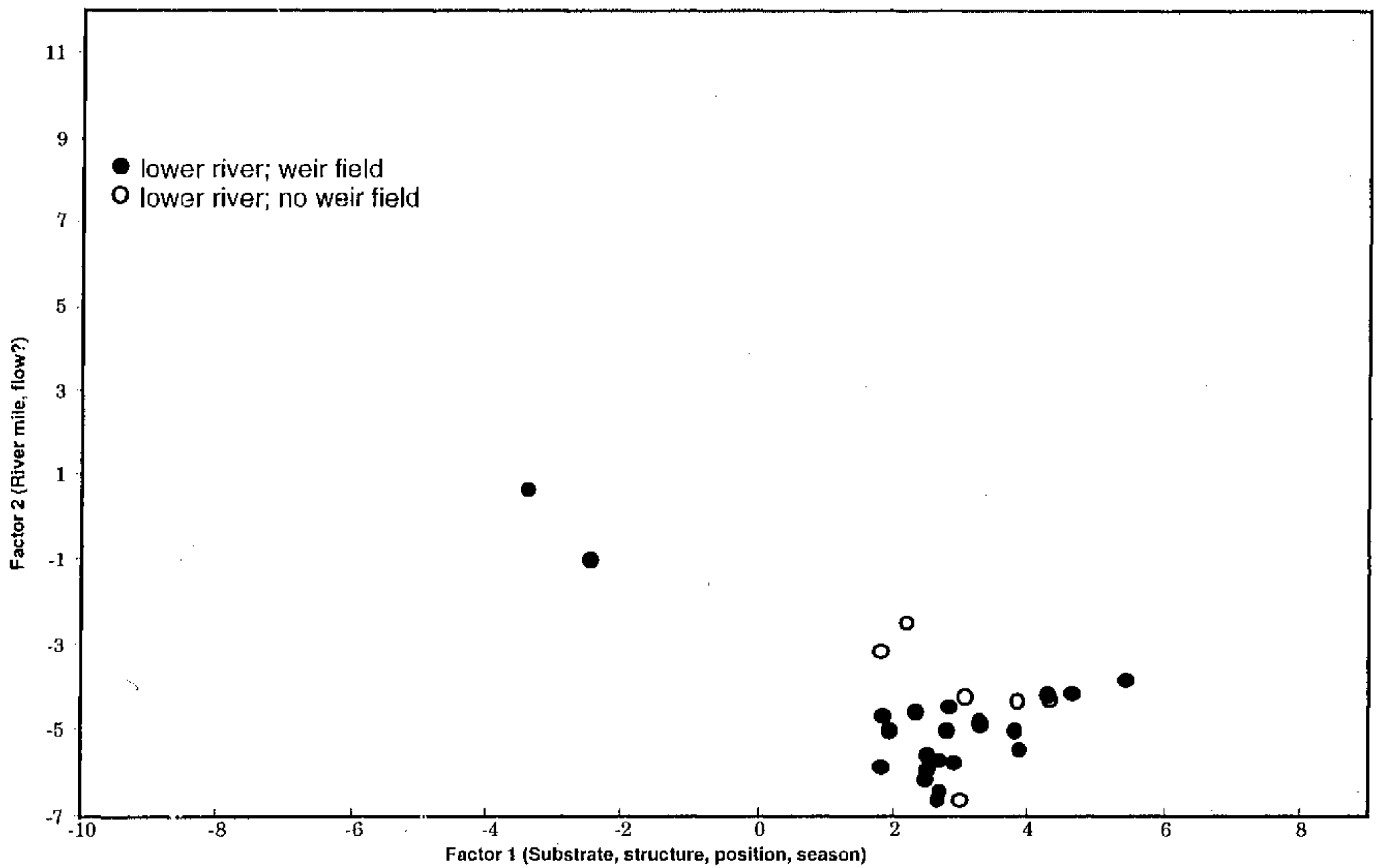
upper river; rock (dike or rubble)
upper river; substrate
upper river; interior dike rock
upper river; interior dike substrate
lower river; weir field
lower river; no weir field
Factor 2 (River mile, flow?)
Factor 1 (Substrate, structure, position, season)
11
9
7
5
3
1
-1
-3
-5
-7
-10
-8
-6
-4
-2
0
2
4
6
8

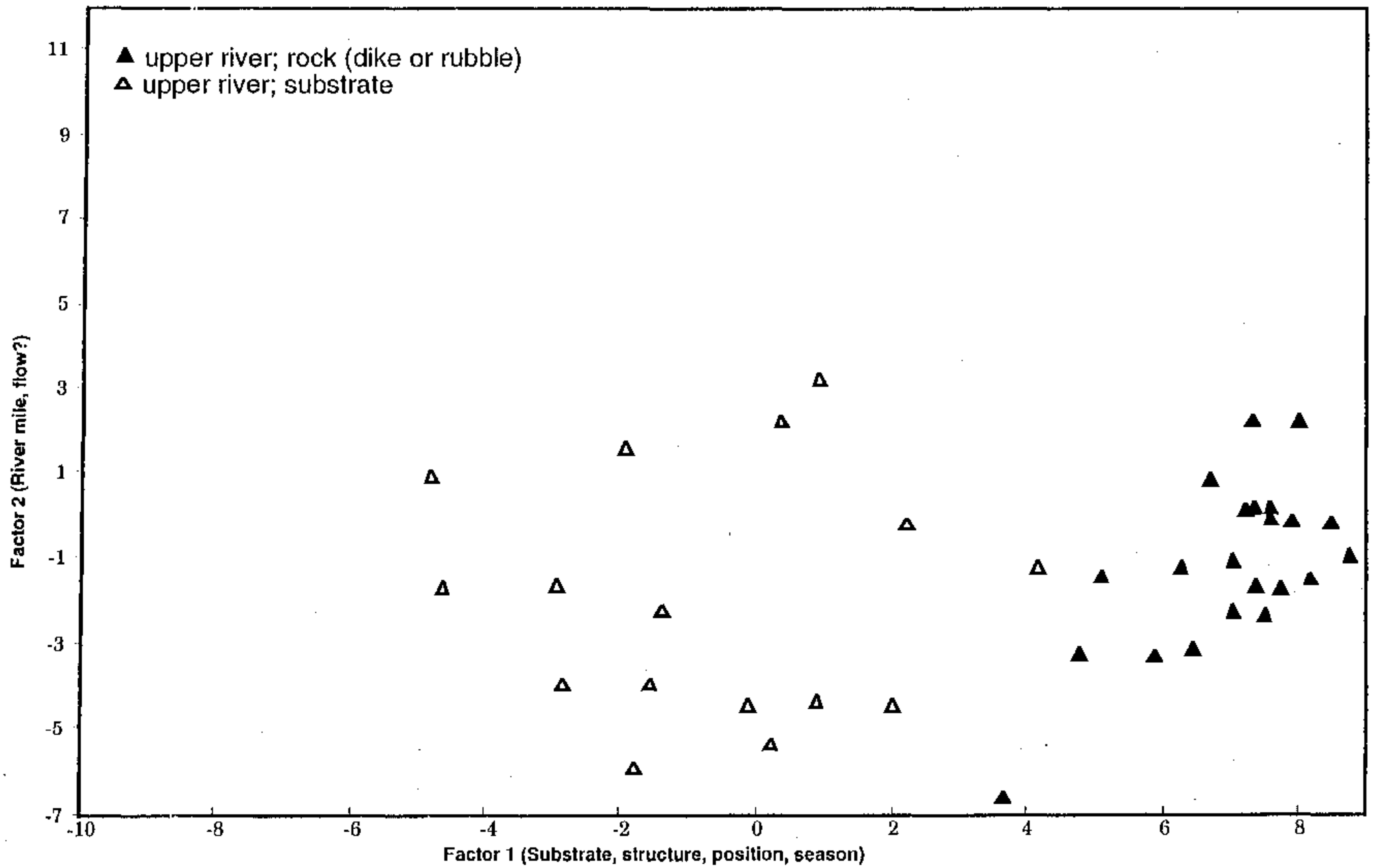


upper river; rock (dike or rubble)
upper river; substrate
upper river; interior dike rock
upper river; interior dike substrate
Factor 2 (River mile, flow?)
Factor 1 (Substrate, structure, position, season)
11
9
7
5
3
1
-1
-3
-5
-7
-10
-8
-6
-4
-2
0
2
4
6
8

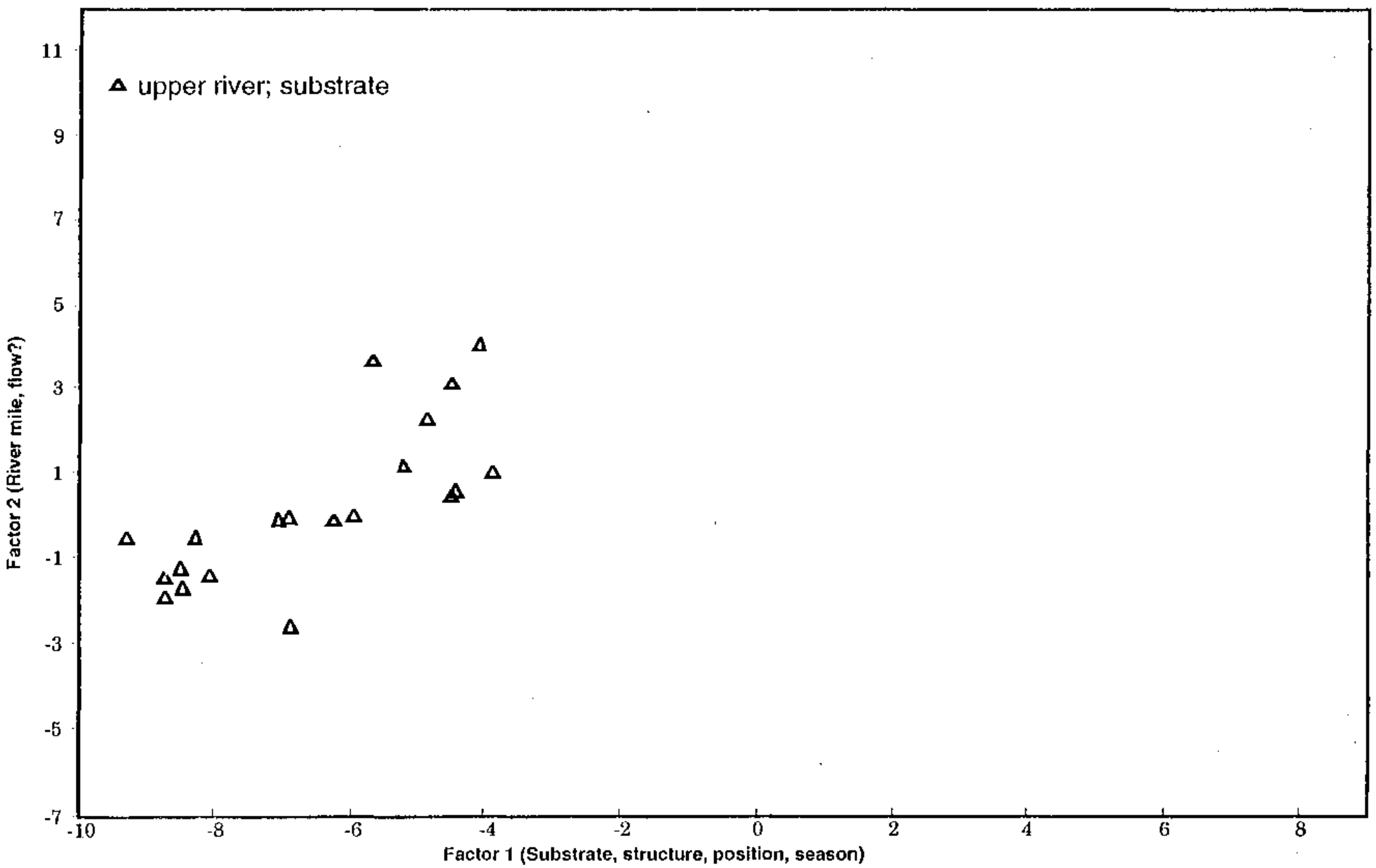


lower river; weir field
lower river; no weir field
Factor 2 (River mile, flow?)
11
9
7
5
3
1
-1
-3
-5
-7
-10
-8
-6
-4
-2
0
2
4
6
8
Factor 1 (Substrate, structure, position, season)


lower river; weir field
lower river; no weir field
Factor 2 (River mile, flow?)
Factor 1 (Substrate, structure, position, season)
11
9
7
5
3
1
-1
-3
-5
-7
-10
-8
-6
-4
-2
0
2
4
6
8



upper river; rock (dike or rubble)
upper river; substrate
11
9
7
5
3
1
-1
-3
-5
-7
-10
-8
-6
-4
-2
0
2
4
6
8
Factor 2 (River mile, flow?)
Factor 1 (Substrate, structure, position, season)


upper river; substrate
Factor 2 (River mile, flow?)
Factor 1 (Substrate, structure, position, season)
11
9
7
5
3
1
-1
-3
-5
-7
-10
-8
-6
-4
-2
0
2
4
6
8

APPENDIX F.

Draft Report - The Freshwater Mussel Fauna of the Middle Mississippi River, U.S. Army Corps of Engineers, St. Louis District.

The Freshwater Mussel Fauna of the Middle Mississippi River

Thomas M. Keevin
Environmental Analysis Section
U.S. Army Corps of Engineers
St. Louis District
1222 Spruce Street
St. Louis, MO 63103-2833

and

Kevin S. Cummings
Illinois Natural History Survey
Natural Resources Building
607 East Peabody Drive
Champaign, Illinois 61820

DRAFT

ABSTRACT

A total of 2,536 specimens of 19 native unionid species was collected during the survey. Eighteen species were collected from 24 sidechannels sampled, while 12 species were found in four borrow pit sites surveyed. The three numerically most abundant species collected (Anadonta grandis, Leptodea fragilis, and Potamilus ohiensis) made up 87.5% of the total number of specimens collected. With the addition of species previously reported in the literature (Oesch 1984), 24 native species are known to occur in the Middle Mississippi River. This represents approximately 73% of the 33 native species known to occur in the Upper Mississippi River reported by Hornbach et al. (1992).

INTRODUCTION

The Middle Mississippi River is the reach of the Mississippi River between its' confluence with the Ohio River (River Mile 0) and the Missouri River (River Mile 195.25). This section of the Mississippi River has been highly modified for navigation and much of the floodplain has been isolated from the river by agricultural levees (Stevens et al. 1975, Strauser and Long 1976). With the exception of mussel collections made at three sites by Oesch (1984), the Middle Mississippi River has been poorly studied. Perry (1979) summarized data from a number of collectors for 18 sites (data for three of the sites were provided by Oesch) on the Middle Mississippi River. However, two of the three data sheets provided by Oesch were improperly transcribed by Perry (1979, Table 20), which calls into the question the remainder of the data summary. Van der Schalie and Van der Schalie (1950) noted that "Below the mouth of the Missouri River, the Mississippi River has been poor in mussel producton [sic] because of the tremendous loads of erosion silt carried into it from the extensive treeless plains drained by the Missouri River. Collecting in this heavily silted lower portion of the Mississippi is usually possible only in sloughs along shore."

MATERIALS AND METHODS

Field collections were made during the period December 19, 1988, through April 7, 1989. The majority of collections were made on January 11 and 19, 1989, when collectors were ferried to sidechannel, backwater, and borrow pit sites along the Middle Mississippi River by helicopter. The collection period followed the drought of 1988 when large areas of sidechannels and backwaters dried, either killing the mussel fauna by desiccation or making them extremely vulnerable to predation. Two collectors walked as much of the collection area as possible in a 3-4 hour period making surface collections of mussels that had died during the drought of 1988. The low water conditions provided a unique opportunity to make surface collections of recently dead mussels. Collectors were instructed to collect all surface shells encountered while walking the dewatered areas.

Taxonomic names follow Cummings and Mayer (1992) which updated the nomenclature used by Turgeon et al. (1988) based on taxonomic revisions since the publication of the 1988 list. Subspecies are not recognized in this publication. Voucher specimens are housed in the Illinois Natural History Survey (INHS).

The following information is provided for each collection site description: river mile, right or left bank, name of the side channel or chute, general location information, county, state, and collection date. Site locations are referenced by river miles, as this is the standard unit of measure used by the U.S. Army Corps of Engineers (COE 1978). Right and left refer to right and left descending banks.

COLLECTION SITES

Site 1. River Mile 194.1-195.0 R; Duck Island Side Channel, 2 ,o S Hartford, IL. St. Louis Co., MO. 1/11/89.

Site 2. River Mile 185.0-188.5 L; Mosenthein Chute, at Granite City, IL. Madison Co., IL. 1/11/89.

Site 3. River Mile 166.4-168.8 L; Jefferson Barracks Chute, opposite South St. Louis, MO. Monroe County, IL. 3/24/89.

Site 4. River Mile 144.6-146.5 L; Osborne Chute, 3 mi S Crystal City, MO. Monroe Co., IL. 12/19/88.

Site 5. River Mile 139.5-140.5 L; Durfee Bar backwater/slough. Monroe Co., IL. 1/6/89.

Site 6. River Mile 132.3-134.4 L; Fort Chartres Chute, 3 mi W Prairie du Rocher. Randolph Co., IL. 1/5/89.

Site 7. River Mile 130.0-132.3 R; Establishment Chute, 3 mi SSW Prairie Du Rocher, IL St. Genevieve Co., MO. 1/11/89.

Site 8. River Mile 120.0-122.3 L; Moro Chute, 2 miles S St. Genevieve, MO. Randolph Co., IL. 1/11/89.

Site 9. River Mile 110.5-116.5 R; Old channel around Kaskaskia Island. Randolph Co., IL. 1/11/89

Site 10. River Mile 116.4-118.5 R; Kaskaskia Chute; Randolph Co., IL. 1/11/89.

Site 11. River Mile 109.5-110.8 R; Chester Bridge Side Channel at Horse Island; Perry Co., MO. 3/17/89.

Site 12. River Mile 109.7-110.2 R; Side Channel just below Chester Bridge, opposite Chester, Illinois, Perry Co., MO. 3/17/89.

Site 13. River Mile 104.2-105.6 R; Crains Chute, 3 miles SE Chester, Randolph County, IL. 1/19/88.

Site 14. River Mile 99.9-102.8 L; Liberty Chute, 1 mi W Rockwood, IL. Randolph Co. IL. 1/11/89.

Site 15. River Mile 95.1-98.3 R; Jones Chute. Perry Co., MO. 1/19/89.

Site 16. River Mile 76.4-78.8 L; Tower Island Chute, 1.5 mi S Grand Tower, IL. Perry Co., MO. 1/19/89.

Site 17. River Mile 71.6-73.7 L; Crawford Chute, 3.5 mi NW Wolf Lake. Union Co., IL. 1/19/89.

Site 18. River Mile 67.0-69.1 L; Vancill Towhead dike field, across from Trail of Tears State Park, MO. Union Co., IL. 1/19/89.

Site 19. River Mile 57.0-62.8 R; Schenimann Chute, 2 mi W Reynoldsville, IL. Cape Giradeau Co., MO. 1/19/89.

Site 20. River Mile 54.6-60.8 L; Picayune Chute, 2 mi N Cape Girardeau, MO. Union/Alexander Co., IL. 1/19/89.

Site 21. River Mile 50.8-51.3 L; Cape Bend Chute, near Cape Girardeau, MO. Alexander Co., IL. 1/19/89.

Site 22. River Mile 47.8-50.5 L; Cape Bend Chute, 2 miles SE of Cape Girardeau, MO. Alexander Co., IL. 1/19/89.

Site 23. River Mile 38.9-39.5 R; Commerce dike field. Scott Co., MO. 1/19/89.

Site 24. River Mile 35.5-37.6 L; Chute between Burnham and Goose Island (Santa Fe Chute Interior). Alexander Co., IL. 1/19/89.

Site 25. River Mile 147.3; Borrow pit near Mitchie, 110E Levee Road and 900N Mitchie Road. Monroe Co., IL. 3/22/89.

Site 26. River Mile 117; Kaskaskia Island borrow pits. Randolph Co., IL. 1/11/89.

Site27. River Mile 110.5 R; Borrow pits along old main channel, just west of Horse Island, Perry Co., MO. 4/7/89.

Site 28. River Mile 110.0 R; Borrow pit on Horse Island, opposite Chester, IL. Perry Co., MO. 3/17/89.

RESULTS

A total of 2,536 specimens of 19 native unionid species was collected during the survey. Eighteen species were collected from 24 sidechannels sampled (Table 1), while 12 species were found in four borrow pit sites surveyed (Table 2).

The Asian clam, Corbicula fluminea, an exotic species, was the most abundant species collected (1,123 specimens). The species was widespread, occurring in 20 sidechannels and two borrow pit lakes. Weathered dead shells of the brackish water, mactrid clam, Rangia cuneata, were found in Horse Island Side Channel (Site 11, 61 specimens) and Liberty Chute (Site 14, 1 specimen).

The giant floater, Anadonta grandis, was numerically the most abundant native species (902 specimens) collected during the survey. It was the second most abundant species collected from sidechannel habitat (644 specimens) and the most abundant species in the borrow pit lakes (258 specimens).

The fragile papershell, Leptodea fragilis, was the second most abundant native species (800 specimens). It was the most abundant species in sidechannel habitat (715 specimens) and the second most abundant species in borrow pits (85 specimens).

The pink papershell, Potamilus ohiensis, was the third most abundant native species collected (518 specimens). It was the third most abundant species in sidechannels and the fourth most abundant species in borrow pits.

The flat floater, Anodonta suborbiculata, a species classified as rare in Missouri, was the fourth most abundant native species (94 specimens). It was found in ten sidechannels and in two borrow pit lakes.

The three numerically most abundant native species (Anadonta grandis, Leptodea fragilis, and Potamilus ohiensis) made up 87.5% of the total number of specimens collected. Each of the species was found in eighteen sidechannels. Anadonta grandis and Potamilus ohiensis occurred in all four borrow pit lakes, while Leptodea fragilis was found in three.

DISCUSSION

Oesch (1984) reported six species, Ellipsaria lineolata, Lampsilis cardium [ventricosa per Oesch], Megalonaias nervosa, Obliquaria reflexa, Quadrula pustulosa, and Truncilla donaciformis, from the Middle Mississippi River that were not collected during this survey. Although Lampsilis cardium appears on Oesch's distribution map (page 222), the species was not on his field notes and apparently was in error (Oesch, personal communication). Perry (1979) also reported both Truncilla donaciformis and Megalonaia nervosa from the Middle Mississippi River. With the addition of the five additional species collected by Oesch (1984), 24 native species are known to occur in the Middle Mississippi River. This represents approximately 73% of the 33 native species known to occur in the Upper Mississippi River reported by Hornbach et al. (1992). Hornback et al. (1992) did not collect either Potamilus purpuratus which is a southern species rarely found above the confluence of the Mississippi and Ohio rivers (Cummings and Mayer 1992) or Uniomerus tetralasmus which most frequently inhabits ponds, sloughs, lakes, and quiet stretches of rivers where it is generally uncommon and only very locally does it become numerous (Parmalee 1967).

Perry (1979) incorrectly transcribed data for Table 20 (Site 153 and 159) from two of the three data sheets provided to him by Oesch. For example, Perry (1979) indicated that no mussels were present at site 159, where Oesch had collected 9 species. He further indicated on Table 20 that the specimens collected from site 159 were dead. Oesch collected 9 species from site 153, and Perry transcribed 10 species, incorrectly adding Truncilla truncata. These transcription errors call into question the reliability of Perry's data summary for the remainder of the Middle Mississippi River.

Eight species, Anadonta grandis, Anodonta imbecillis, Anodonta suborbiculata, Quadrula metanevra, Quadrula nodulata, Toxolasma parvus, Truncilla truncata, and Uniomerus tetralasmus, collected during this survey were not previously reported by Oesch (1984) from the Middle Mississippi River. The difference in species composition between the two studies reflects the habitat types sampled and individual species' habitat preference. The present survey concentrated on lentic habitat (side channels with little flow, sloughs, and borrow pit lakes) while Oesch's collections were made in lotic habitat along the main channel border (Oesch, personal communication).

The three numerically most abundant native species (Anadonta grandis, Leptodea fragilis, and Potamilus ohiensis) are all common wide-spread species that are either habitat generalists or show a preference for sluggish water found in floodplain lakes, sloughs, and oxbows (Parmalee 1967, Oesch 1984, and Cummings and Mayer 1992).

The flat floater, Anodonta suborbiculata, was the fourth most abundant species collected during our survey. Oesch (1984) noted that the flat floater was one of the rarest naiades in Missouri, having been found in only two locations during his State survey. The species was wide-spread in the study area, occurring at twelve sites. It was most abundant at Site 26, a borrow pit lake, where 57 specimens were collected. The senior author has previously observed large numbers of the species on mud flats in the lower reaches of Pool 26, when the pool was drawn down. Parmalee (1967) indicated that the species was "locally abundant in the floodplain lakes, sloughs, and oxbows of the Mississippi" River which agrees with our findings.

The weathered dead shells of Rangia cuneata, found in Horse Island Side Channel (Site 11, 61 specimens) and Liberty Chute (Site 14, 1 specimen) were probably transported to the site by humans, either by Native Americans (Parmalee 1958) or in historic times. Oesch's (1984) data sheets contain a record of an oyster shell collected at Brickeys, River Mile 135.9 in St. Genevieve Co., MO (Site 15, Perry 1979).

Sidechannel habitat supported 18 native mussel species. Only four of the species collected from this habitat type are typically associated with flowing water conditions. The ebony shell (Fusconaia ebena - 8 specimens, 1 site), hickorynut (Obovaria olivaria - 10 specimens, 3 sites), monkey face (Quadrula metanevra - 1 specimen, 1 site) and deertoe (Truncilla truncata - 2 specimens, 1 site) generally show a habitat preference for water with current(Parmalee 1967, Oesch 1984). The remaining fourteen species are common wide-spread species that are either habitat generalists or show a preference for sluggish water found in floodplain lakes, sloughs, and oxbows (Parmalee 1967, Oesch 1984, and Cummings and Mayer 1992). The mussel fauna reflects the modified hydraulic conditions of the sidechannels in the Middle Mississippi River. Many of the sidechannels surveyed have closing structures restricting flow, thus diverting water to the mainchannel to support a 9-foot navigation channel.

Although the diversity of mussels is high in side channels and chutes of the Middle Mississippi River, the density is extremely low. For example, during this survey, Osborne Chute (Site 4) was dry with the exception of plunge pools behind closing structures. This presented ideal conditions to collect all of the recently dead mussels in the side channel. However, only 66 specimens of five native species were collected. The bottom substrate in Osborne Chute was entirely sand which provides little habitat for mussels during flowing water conditions. Van der Schalie and van der Schalie (1950) indicated that Mississippi River, below the mouth of the Missouri River, was "poor in mussel production because of the tremendous loads of erosion silt carried into it from the extensive treeless plains drained by the Missouri River. They indicated that "Collecting in this heavily silted lower portion of the Mississippi is usually possible only in sloughs along shore." The bottom substrate of the Mississippi River below the confluence of the Missouri River is predominantly sand. The Middle Mississippi River main channel has large sand waves that move downstream (Claude Strauser, U.S. Army Corps of Engineers, personal communication) which would cover and kill mussels. The three channel border sites surveyed by Oesch (1984) were all rock outcrops with crevices that supported mussel populations.

The four borrow pit lakes surveyed supported 12 species of native unionids. Natural, floodplain lakes have been drained and filled for agriculture and the natural regime of regular, moderate flooding of the floodplain has been disrupted by construction of agricultural levees along the Middle Mississippi River. Flooding as an integral, beneficial part of natural river ecosystems, best expressed by the flood-pulse concept, has been eliminated. The predictable advance and retraction of water on the floodplain which is the principal agent controlling the adaptations of the biota, in particular fish populations (Junk et al. 1989; Bayley 1991 1995) and glochidia dispersal, has been eliminated except on the river-side of agricultural levees. Borrow pit lakes, on the river-side of agricultural levees, provide habitat for lucustrine mussel species similar to natural floodplain and oxbow lakes that have been eliminated from the floodplain.

ACKNOWLEDGMENTS

Personnel from the U.S. Army Corps of Engineers (T. Furdek, D. Gates, T. George, B. Groth, S. Harris, K. McMullen, G. Molchan, R. Myhre, L. Nico, F. Niermann, F. T. Norris, K. Porter, D. Ragland, J. Remley, D. Stephens, and M. Trimble), Illinois Department of Natural Resources (B. Atwood, D. Carney, B. Fritz, R. Sauer, B. Schanzle) and the U.S. Fish and Wildlife Service (B. Stebbings) provided field assistance. We thank all of these people for the tireless hours spent in the field. The St. Louis District, U.S. Army Corps of Engineers provided funding for helicopter transportation for this study. We thank Dr. Stansbery for his confirmation of the Uniomerus tetralasmus identification and Ron Oesch for providing his data sheets and and discussing his collections.

LITERATURE CITED

Bayley, P. B. 1991. The flood pulse advantage and the restoration of river-flooplain ecosystems. Regulated Rivers 6:75-86.

Bayley, P. B. 1995. Understanding large river-floodplain ecosystems. BioScience 45:153-158.

Cummings, K. S. and C. A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey Manaual 5. 194 pp.

Hornbach, D. J., A. C. Miller, and B. S. Payne. 1992. Species composition of the mussel assemblages in the upper Mississippi River. Malacological Review 25:119-128.

Ellis, M. M. 1931. A survey of conditions affecting fisheries in the Upper Mississippi. Bureau of Fisheries Circular v. 5, no. 1-18.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain ecosystems. Canadian Special Publication of Fisheries and Aquatic Sciences 106:110-127.

Oesch, R. D. 1984. Missouri naiades. A guide to the mussels of Missouri. Missouri Department of Conservation. Jefferson City, Missouri. vii + 270 pp.

Parmalee, P. W. 1958. Marine shells of Illinois Indian sites. Nautilus 71:131-139.

Parmalee, P. W. 1967. The fresh-water mussels of Illinois. Illinois State Museum, Popular Science Series 8. 108 pp.

Perry, E. W. 1979. A survey of Upper Mississippi River mussels. Pp. 118-139. In: A compendium of fishery information on the Upper Mississippi River (J. L. Rasmussen ed.). Upper Mississippi Conservation Committee. Rock Island, Illinois.

Stevens, M. A., D. B. Simons, and S. A. Schumm. 1975. Man-induced changes of Middle Mississippi River. Journal of the Waterways Harbors and Coastal Engineering Division, American Society of Civil Engineers

Strauser, C. N. and N. C. Long. 1976. Discussion by Claude N. Strauser, A.M. ASCE and Norbert C. Long. Journal of the Waterways Harbors and Coastal Engineering Division, American Society of Civil Engineers 102:281-282.

Turgeon, D. D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. E. Roper, A. Scheltema, F. G. Thompson, and J. D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: Mollusks. American Fisheries Society Special Publication 16. 277 pp.

U.S. Army Corps of Engineers (COE). 1978. Upper Mississippi River Navigation Charts. U.S. Army Engineer Division, North Central. Chicago, Illinois.

Van der Schalie, H. and A. Van der Schalie. 1950. The mussels of the Mississippi River. American Midland Naturalist 44:448-466.

Table 1. Mussels species collected from Middle Mississippi sidechannels and chutes.

Species	Collection Sites												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Amblema plicata	--	--	--	--	--	--	--	--	--	--	--	--	11
Anadonta grandis	1	--	46	4	2	6	1	--	17	9	137	--	184
Anodonta imbecillis	--	2	10	1	2	1	--	--	--	--	5	--	7
Anodonta suborbiculata	--	--	1	--	--	--	--	--	1	--	1	--	1
Arcidens confragosus	--	--	--	--	--	--	--	--	--	1	1	--	4
Fusconaia ebena	8	--	--	--	--	--	--	--	--	--	--	--	--
Lampsilis teres	--	--	--	--	--	--	--	--	--	--	--	--	6
Lasmigona complanta	--	--	--	--	--	1	--	--	3	2	4	--	2
Leptodea fragilis	13	2	--	35	93	--	8	13	1	141	9	4	205
Obovaria olivaria	--	--	--	--	--	--	--	--	--	1	--	3	--
Potamilus alatus	1	--	1	--	--	--	--	--	--	3	--	2	18
Potamilus ohiensis	30	3	14	25	86	10	26	19	--	23	19	--	23
Potamilus purpurata	--	--	--	--	--	--	--	--	--	--	--	--	1
Quadrula metanevra	1	--	--	--	--	--	--	--	--	--	--	--	--
Quadrula nodulata	1	--	--	--	--	--	--	--	--	--	--	--	--
Quadrula quadrula	1	--	--	1	--	1	--	--	1	1	--	--	1

Toxolasma parvus	--	--	22	--	--	--	--	--	--	--	1	--	--
Truncilla truncata	--	--	--	--	--	--	--	--	--	--	--	--	--
Uniomerus tetralasmus	--	--	--	--	--	--	--	--	--	--	--	--	--
EXOTICS													
Corbicula fluminea	19	273	90	19	25	11	53	23	2	23	--	2	252
Rangia cuneata	--	--	--	--	--	--	--	--	--	--	61	--	--
# Species	6	4	7	6	5	6	4	3	5	9	9	4	13

Table 1 (Continued).

Species	Collection Sites 14	15	16	17	18	19	20	21	22	23	24	Total
Amblema plicata	--	1	--	--	--	5	--	--	--	--	--	17
Anadonta grandis	1	57	--	63	30	16	2	--	--	39	29	644
Anodonta imbecillis	--	--	--	--	--	--	--	--	--	--	--	28
Anodonta suborbiculata	--	1	--	1	1	1	--	--	--	7	21	36
Arcidens confragosus	--	--	--	--	--	1	--	--	--	--	--	7
Fusconaia ebena	--	--	--	--	--	--	--	--	--	--	--	8
Lampsilis teres	--	--	1	--	--	1	--	--	--	--	--	8
Lasmigona complanta	--	3	--	3	--	16	--	--	--	--	--	34
Leptodea fragilis	27	54	8	6	1	49	46	--	--	--	--	715
Obovaria olivaria	--	--	7	--	--	--	--	--	--	--	--	11
Potamilus alatus	1	--	2	--	--	3	2	--	--	--	--	33
Potamilus ohiensis	16	124	2	20	3	20	13	--	--	--	--	476
Potamilus purpurata	--	--	--	--	--	--	--	--	--	--	--	1
Quadrula metanevra	--	--	--	--	--	--	--	--	--	--	--	1
Quadrula nodulata	--	--	--	--	--	--	--	--	--	--	--	1
Quadrula quadrula	--	2	--	3	--	3	--	--	--	--	--	14

Toxolasma parvus	--	3	--	--	--	--	--	--	--	1	1	28
Truncilla truncata	--	--	2	--	--	--	--	--	--	--	--	2
Uniomerus tetralasmus	--	--	--	--	--	--	--	--	--	--	--	0
EXOTICS												
Corbicula fluminea	31	190	--	14	--	31	39	1	6	--	1	1,105
Rangia cuneata	1	--	--	--	--	--	--	--	--	--	--	62
# Species	6	9	6	7	4	11	5	1	1	3	4	

Table 2. Mussel species collected from borrow pit lakes along the Middle Mississippi River.

Species	Collection Sites				
	25	26	27	28	Total
Anadonta grandis	52	143	10	53	258
Anodonta imbecillis	--	4	--	--	4
Anodonta suborbiculata	--	57	1	--	58
Arcidens confragosus	--	1	--	--	1
Lampsilis teres	1	--	3	--	4
Lasmigona complanta	--	2	1	--	3
Leptodea fragilis	3	81	--	1	85
Potamilus alatus	--	3	--	--	3
Potamilus ohiensis	5	34	1	2	42
Quadrula quadrula	--	1	--	--	1
Toxolasma parvus	--	--	4	--	4
Uniomerus tetralasmus	--	--	9	--	9
EXOTICS					
Corbicula fluminea	--	13	5	--	18
# Species	3	10	8	3	

APPENDIX G.

Status Report – Bolters Bar Micro Model Study
U.S. Army Corps of Engineers, St. Louis District.

U.S Army Corps of Engineers, St. Louis District
Avoid & Minimize Environmental Program

Bolters Bar Micro Model Study
Status Report, June 24, 1999
Applied River Engineering Center

The Bolters Bar reach of the Upper Mississippi River is located in Pool 26 approximately 25 miles northwest of Downtown St. Louis. A Micro Model study was initiated to address the repetitive maintenance dredging that occurs in the reach. The Micro Model covered Mississippi River Miles 232 to 222 and the study specifically addressed the sedimentation problems between River Miles 227.5 and 224.5.

Of the three pools in the St. Louis District, the Bolters Bar reach is one of the most troublesome, in terms of dredging frequency and groundings. During an 18 year time period, between 1979 and 1996, over 3.9 million cubic yards of material was dredged in the reach at a cost of over $5.1 million. The average per year equals nearly 220,000 cubic yards and $290,000. This reach consists of two main areas of repetitive dredging. The most troublesome reach has been between miles 226.0 and 224.8, just upstream of Iowa Island. This reach has also been the most repetitive. It is has been dredged at least once a year in 16 of the past 18 years. Of the dredging volume and costs previously stated, 77% is attributed to this area or 170,000 cubic yards and $220,000 per year.

The Micro Model of this reach was calibrated and verified using current and historical hydrographic survey information. After the model was calibrated, nine design alternatives were studied in an attempt to reduce or eliminate dredging. The designs tested included several structural configurations, consisting of chevrons and dikes, that would transfer flow from the side channels to the main channel and realign areas of the main channel. The desired effect was to increase depths in the main channel without decreasing depths in the side channel complex.

The most effective and economical alternative included the following structural modifications:

- A 1200 foot longitudinal/deflector dike near river mile 226.2R*
- Four chevron structures; each with a length of 270 feet and a width of 200 feet near miles 225.7R, 225.5R, 225.3R, and 225.1R*
- Removal of the remnants of dikes 226.0R, 225.8R, 225.6R, and 225.4R
- Raise and notch closure structure 226.3R

*All structures will be built to an elevation of +2 feet referenced to normal pool.

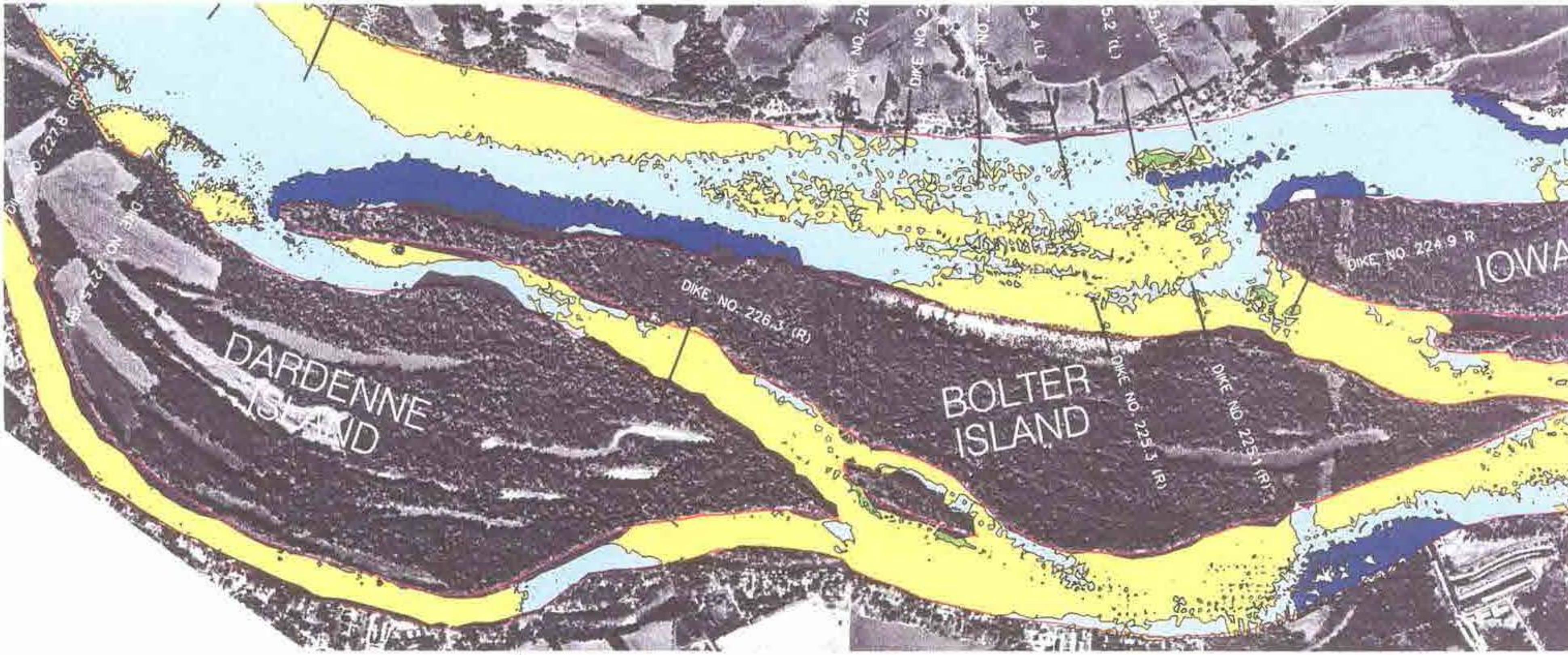
Figures 1 and 2 show the bathymetry of the base test and the chosen design, Alternative I. This design significantly reduced the shoaling in the main channel, which is shown in the base test. It also showed that a better alignment is achieved for downbound navigation approaching the head of Iowa Island. Figure 3 is a comparative elevation difference map of the same area. This diagram shows where both deposition and degradation occurred in the micro model as a result of the design alternative as compared to the Base Test. The survey shows that some deposition occurred along the right descending bankline while degradation occurred throughout the middle of the navigation channel. It also showed that the chute between Iowa and Bolter Islands remained relatively unchanged.

Although traditional dike structures produced favorable results in the micro model, chevrons were the chosen structure for this design. Chevrons act as detached dikes that not only provide a protected area for dredge disposal, they also have immense environmental benefits. Each chevron provides aquatic habitat at variable depths, natural sandbars isolated from the mainland, plunge pools, and increased wetted perimeter. Studies on existing chevrons in Pool 24 have found an abundance of fish species and macro invertebrates as well as very favorable water quality conditions. In addition to these environmental benefits, recreationists thoroughly enjoy the sandbars each chevron provides.

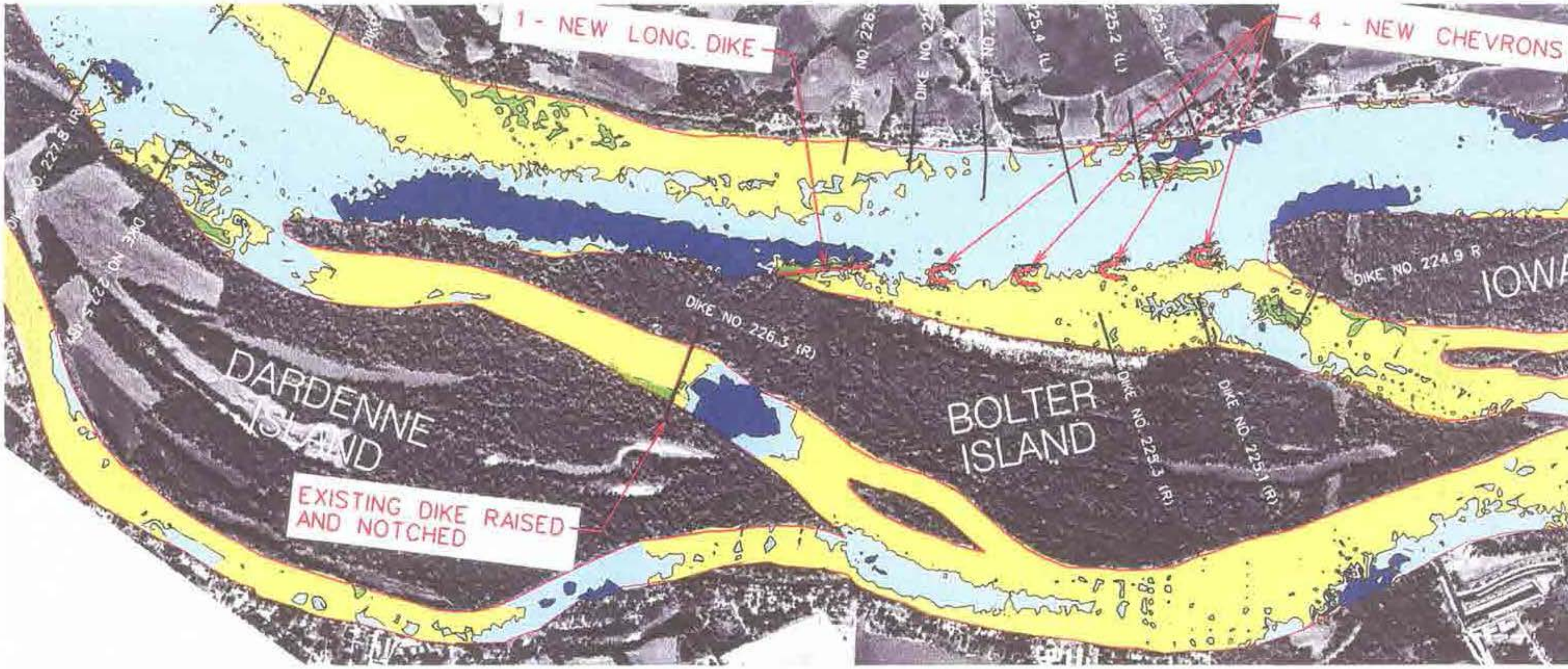
The estimated cost of constructing the longitudinal dike and the 4 chevrons is approximately $700,000. Funding for this work will be secured in the future. The work on closure structure 226.3R has been designed and bid and is scheduled to be completed in 2000. The removal of the four dikes recommended might be completed at a later date after the longitudinal dike and chevrons are constructed and evaluated.

The final Micro Model Technical Report detailing the study is currently underway.

Dave Gordon
Hydraulic Engineer

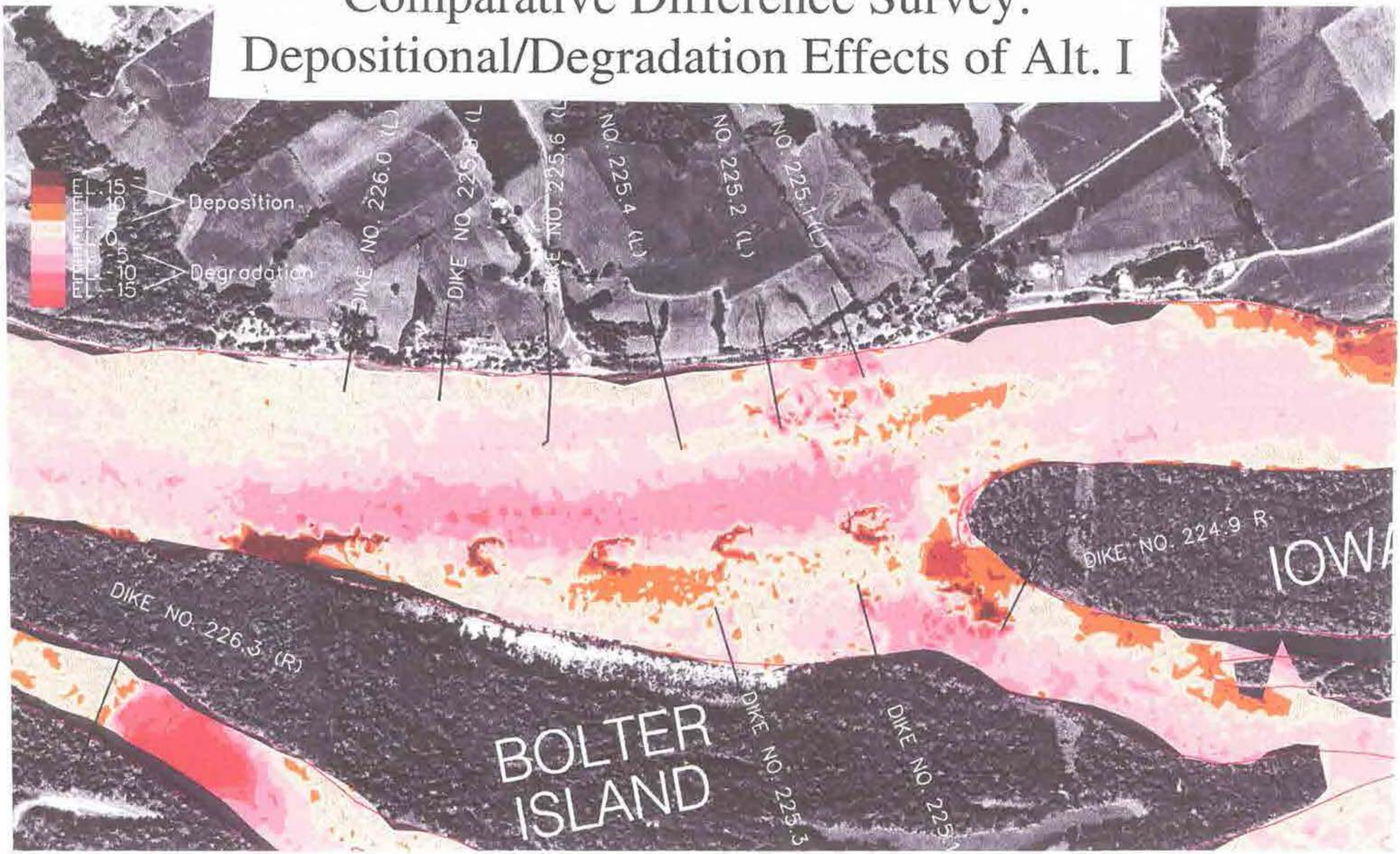


Micro Model Base Test



Alternative I

Comparative Difference Survey: Depositional/Degradation Effects of Alt. I



APPENDIX I.

Trip Reports
Ohio Mouth and Greenfield Bend Sampling - U.S. Army Corps of Engineers, St. Louis District.

Ohio Mouth Sampling Trip Report

Date: 04 October 1999

Purpose: To collect fish habitat use data prior to installation of new 500 foot long dikes along the right bank at MRM .6 and MRM .3 that will alter sandbar habitat.

Participants: Eric Laux, Brian Johnson, and T. Miller

Summary:

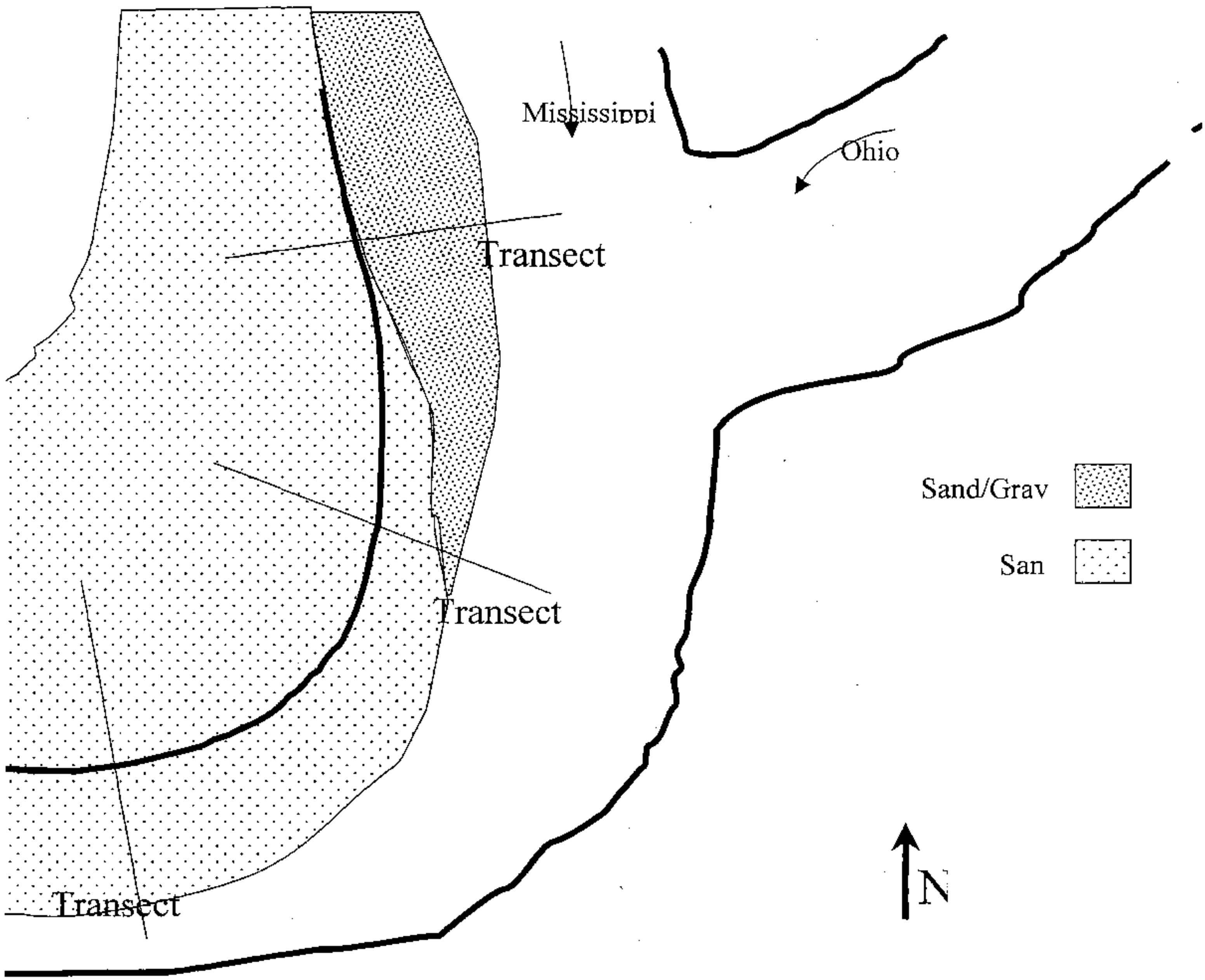
Sampling was performed at the confluence of the Ohio River and the Mississippi River (approx. MRM0) on September 13 and 14, 1999. Method used for collection was a 16 foot Otter Trawl modified with 1/8th inch mesh to enhance collection of smaller species. Sampling is typically conducted along three transects beginning near shore and extending out from the upper, lower and middle portions of a sandbar. Along each transect, four trawl hauls are completed when possible at each 5 foot deep contour interval up to 20 feet. At this site, conditions allowed for all 12 trawling attempts to be taken. No large snags were encountered at the site, however a tear in the net had to be repaired after taking the 5 foot trawl on the middle transect. The tear did not appear to impact gear effectiveness.

Numbers and species collected included the following: 601 Channel Catfish *(Ictalurus punctatus),* 182 Speckled Chub *(Macrohybopsis aestivalis),* 79 Blue Catfish *(Ictalurus furcatus),* 84 Freshwater Drum *(Aplodinotus grunniens),* 17 Shovelnose Sturgeon *(Scaphirhynchus platorynchu),* eight Gizzard Shad *(Dorosoma cepedianum),* three White Bass *(Morone chrysops),* two Silverband Shiners *(Notropis shumardi),* one Emerald Shiner *(Notropis atherinoides),* one Striped Bass *(Morone saxatilis),* one Goldeye *(Hiodon alosoides)* one Sauger *(Stizostedion canadense),* and one Sicklefin Chub *(Macrohybopsis meeki).*

The sandbar sampled was extremely large (approximately one mile long). Substrate consisted predominantly of sand but some gravel and organics were picked up in the trawl on transect 1 and 2. Bathymetry of the area appeared to be fairly shallow until nearing the main channel markers on the lower part of the sandbar, however near transect 2 the slope of the bottom was steeper extending out from the bank. The bottom was fairly uniform with no obvious deep scour holes or drop off areas. The site is summarized in the attached figure.

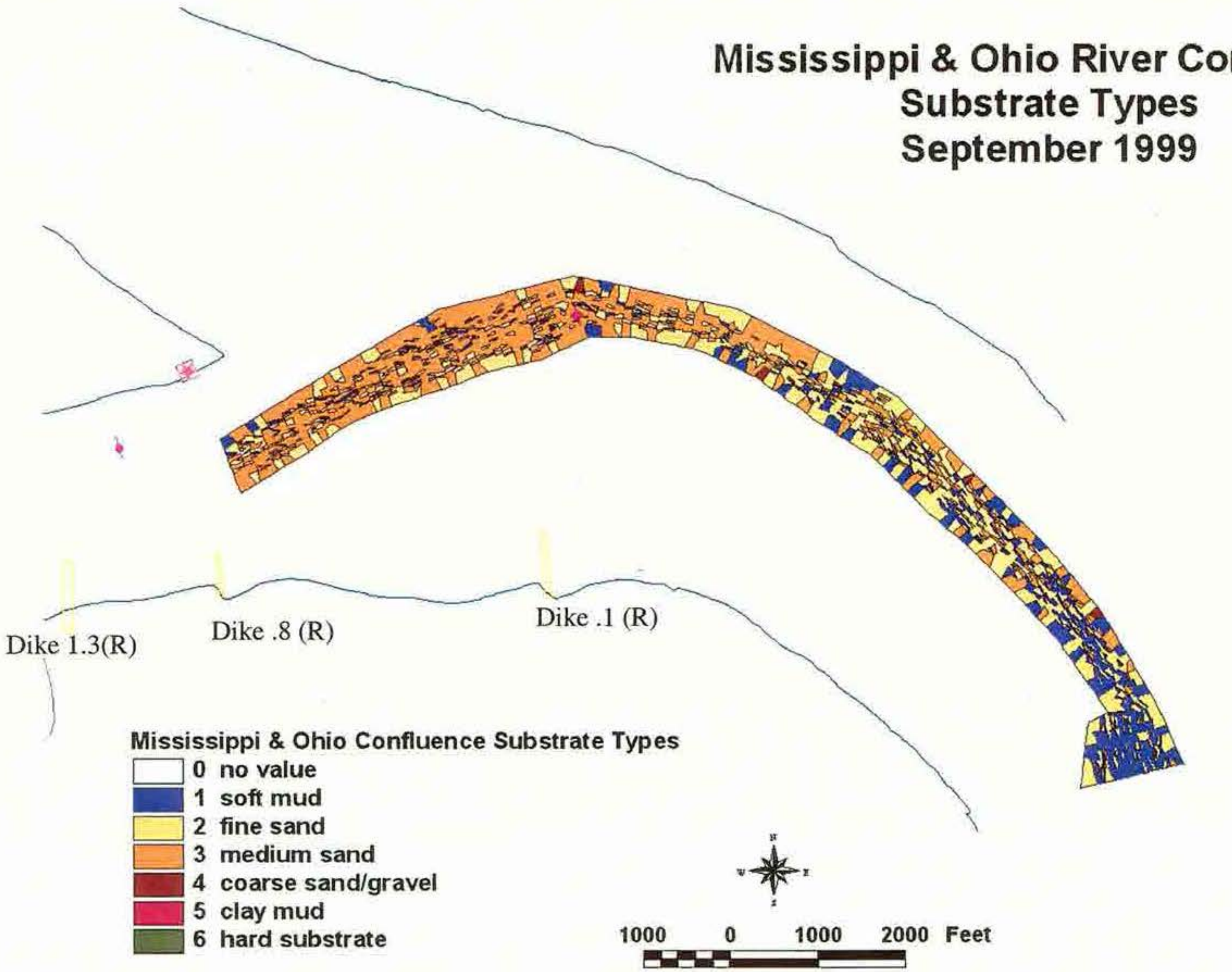
On September 22nd and 23rd the area was surveyed by the M.V. Boyer. Bathymetry, velocity, substrate, and hydroacoustic fisheries information was collected at that time.

Eric Laux
Fisheries Biologist
Planning, Programs, and Project
Management Division
Environmental and Economics Branch
Environmental Section



Mississippi
Ohio
Transect
Transect
Transect
Sand/Grav
San
N

Mississippi & Ohio River Confluence
Substrate Types
September 1999



Greenfield Bend Sampling Trip Report

Date: 04 October 1999
Purpose: To collect fish habitat use data prior to modification of the bendway weir field (additional weirs extending from right bank MRM 4.2 and MRM 4.0).
Participants: Eric Laux, Brian Johnson, and T. Miller

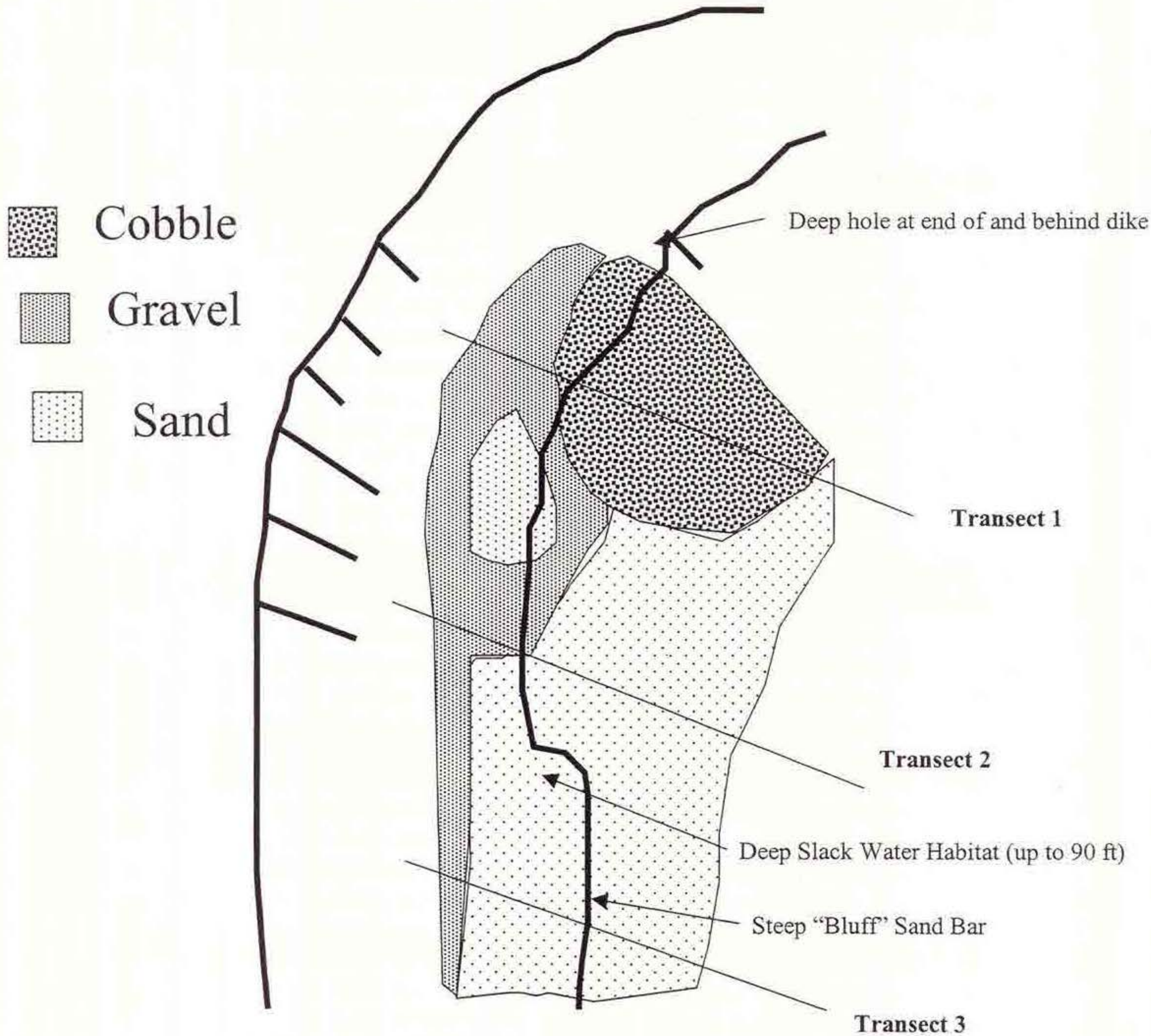
Summary:
Sampling was performed at Greenfield Bend (approx. MRM4) on September 27 and 28, 1999. Method used for collection was a 16 foot Otter Trawl modified with 1/8th inch mesh to enhance collection of smaller species. Sampling is typically conducted along three transects beginning near shore and extending out from the upper, lower and middle portions of a sandbar. Along each transect, four trawl hauls are usually completed at each 5 foot deep contour interval up to 20 feet. At this site, the middle transect was deleted because thalweg conditions existed directly at the edge of the shoreline, so sampling this area with a trawl was impractical. Because of river substrate conditions, including snags and substrate type, only three successful trawl hauls were completed on the upper transect at 10, 15, and 20 feet. One unsuccessful trawl (snag) was attempted at the five foot interval of the upper transect, and one other unsuccessful trawl (snag) was completed at the 10 foot interval of the lower transect. No other sampling was completed on this trip.

Fish species collected included speckled chub, shovelnose sturgeon, channel catfish and a blue catfish and one stonecat. The stonecat was collected in the unsuccessful trawl over the cobble substrate on the upper transect. Stonecats are not widely distributed throughout the river, occurring primarily in areas with both flow and rocky crevices. Its capture points to the uniqueness of this site.

Contrary to the poor sampling results, the site appeared to have diverse habitat, and a change to sampling methods more appropriate for the site (i.e. seines and trammel nets) could reveal a more diverse group of fishes. Habitat able to be sampled included mostly sand substrate. Other habitats that were unable to be sampled included gravel and cobble substrates, as well as a large deep, scour hole off the end of the last weir. The site is summarized in the attached figure.

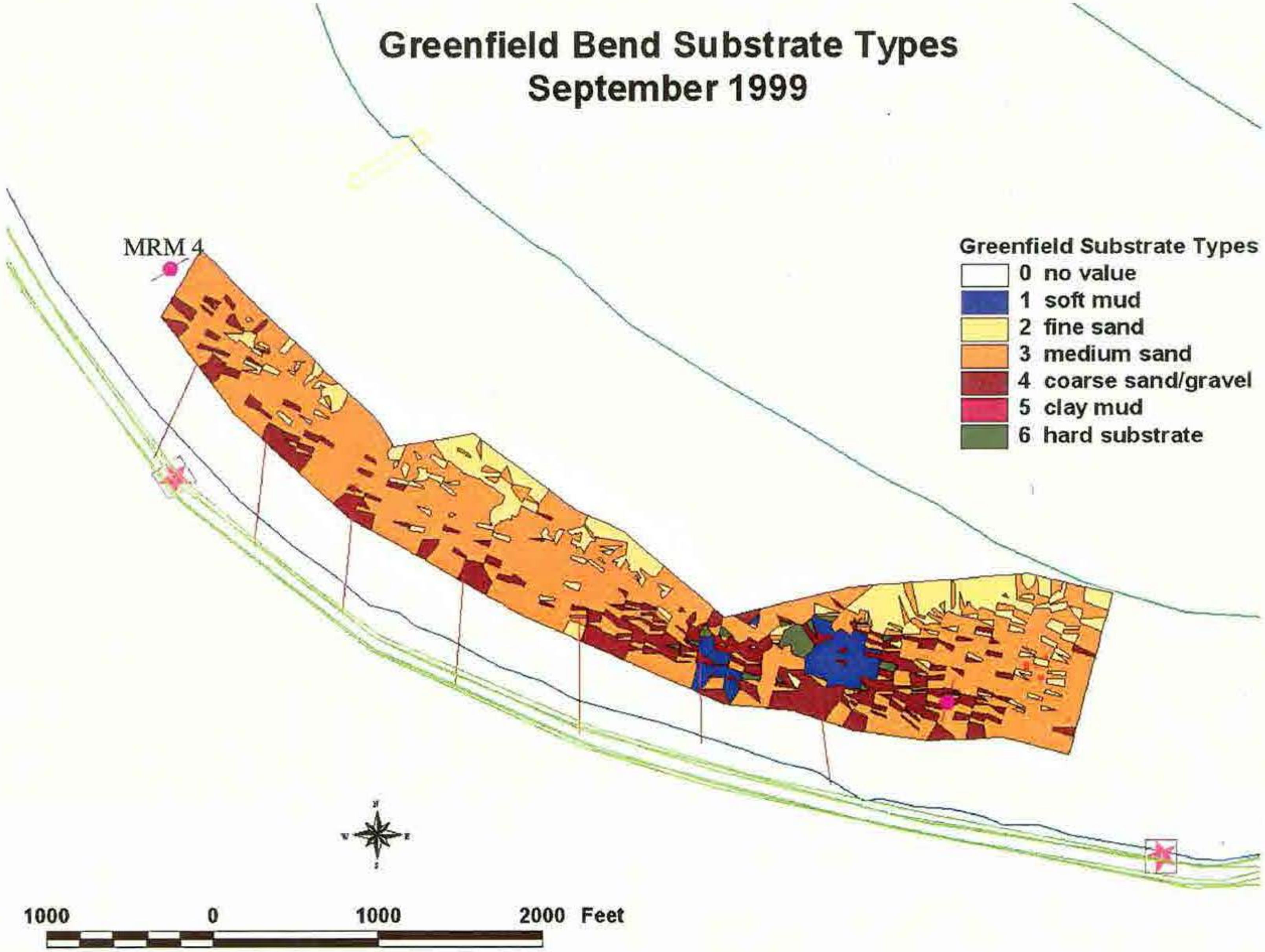
On September 22nd and 23rd the area was surveyed by the M.V. Boyer. Bathemetry, velocity, substrate, and hydroacoustic fisheries information was collected at that time. Based on field observations it appears that a large continuous area of gravel substrate exists off the ends of the weirs. The hydroacoustic equipment indicated that there was a substantial number of fish using the deep hole of the end off the last weir. Based on the present configuration of the sandbar, it appears that this hole is largely sheltered from channel flows.

Eric Laux
Fisheries Biologist
Planning, Programs, and Project
Management Division
Environmental and Economics Branch
Environmental Section



Cobble
Gravel
Sand
Deep hole at end of and behind dike
Transect 1
Transect 2
Deep Slack Water Habitat (up to 90 ft)
Steep "Bluff" Sand Bar
Transect 3

Greenfield Bend Substrate Types
September 1999



APPENDIX H.

Final Report – Evaluation of fish assemblages near the Ste. Genevieve Bend, Mississippi River, Illinois Natural History Survey, Center for Aquatic Ecology

Illinois Natural History Survey

EVALUATION OF FISH ASSEMBLAGES NEAR THE STE.GENEVIEVE BEND, MISSISSIPPI

John M. Dettmers, David H. Wahl, and Daniel A. Soluk
Center for Aquatic Ecology, Illinois Natural History Survey

Submitted to:

U.S. Army Corps of Engineers

FINAL REPORT

July 1999

Aquatic Ecology Technical Report 99/9

Evaluation of the Fish Assemblage near the Ste. Genevieve Bend, Mississippi River, Before Construction of Bendway Weirs

John M. Dettmers, David H. Wahl, and Daniel A. Soluk

Center for Aquatic Ecology, Illinois Natural History Survey
607 E. Peabody Drive
Champaign, Illinois 61820

FINAL REPORT

Submitted to the U. S. Army Corps of Engineers

David H. Wahl
Co-Principal Investigator
Center for Aquatic Ecology

Daniel A. Soluk
Co-Principal Investigator
Center for Aquatic Ecology

Daniel A. Soluk, Director
Center for Aquatic Ecology

July 1999

This study was conducted through a cooperative agreement between the U.S. Geological Survey and the Board of Trustees of the University of Illinois. The actual research was a collaborative effort by the Illinois Natural History Survey and the Upper Mississippi Science Center under the auspices of the Long-term Resource Monitoring Program. The project was supported primarily by the U. S. Army Corps of Engineers, with additional support from the U. S. Geological Survey, and the Illinois Natural History Survey. The form, content, and data interpretation are the responsibility of the U. S. Geological Survey, University of Illinois, and the Illinois Natural History Survey, not the Illinois Department of Natural Resources.

Abstract

Bottom trawling was conducted in and near the main channel of the Ste. Genevieve Bend of the Mississippi River to determine what fish might be present in this area before channel modification using bendway weirs and to evaluate the potential of using bottom trawling in the unimpounded reach of the river. Blue catfish and shovelnose sturgeon dominated the trawl catch. One sicklefin chub, a species of special concern in this part of the Mississippi River, also was collected. Fish do appear to use the Ste Genevieve Bend area. However, our equipment was not powerful or large enough to conduct efficient trawling operations in the heart of the main channel to determine the exact usage of this habitat. This trawling gear would be better suited for work in channel border and side channel areas of the unimpounded river where surface flow rates are less than 1.2 m/s.

Introduction

At the request of the U.S. Army Corps of Engineers (USACE) and the U.S. Fish and Wildlife Service, the Illinois Natural History Survey (INHS) was invited to evaluate the fish community near the Ste. Genevieve Bend of the Mississippi River (River Miles 118-120) before construction of bendway weirs. INHS operated a 24-foot research trawling vessel (*R/V Quillback*) in conjunction with the USACE and the U.S. Geological Survey to conduct evaluations of the main channel fish community.

Methods

We used a rockhopper trawl to sample for fish in the main channel and main channel borders of the Ste. Genevieve Bend of the Mississippi River (River Miles 118-120 above its confluence with the Ohio River). The trawl dimensions included a footrope length of 10.2 m and a headrope length of 8.0 m. Mesh of the trawl mouth and cod end consisted of #21 nylon twine with a bar-measure mesh size of 2.54 cm. The length of the cod end was approximately 2.4 m, and the total length from the wings to the cod end was approximately 10.7 m. Sampling occurred during August 12-13, 1997. All fishes collected were immediately removed from the net, measured (nearest mm TL; FL for sturgeons), weighed (nearest g) if conditions were appropriate (e.g., low wind and waves), and then released. Each run lasted 20 minutes unless the trawl snagged an object.

Results

Water temperatures ranged from 24.5 to 27.6 C, with Secchi disk readings about 45 cm. In the navigation channel, surface flow rates always exceeded 1.5 m/s, with a reading near the outside bend of 1.75 m/s. Outside the navigation channel on the inside bend, flow rates were about 1.35 m/s.

We attempted to use a 3.6-m frame midwater trawl to sample any pelagic fishes present in the water column. However, this net was ineffective in preliminary sampling on August 11 and was not used as part of the evaluation of the Ste. Genevieve Bend fish assemblage. The current was sufficiently strong to prevent this midwater trawl from fishing without twisting and tangling.

We collected 35 fish of six species during 8 rockhopper trawl runs at the Ste. Genevieve Bend during August 12-13, 1997 (Table 1). Two trawls taken in the navigation channel toward the outside bend of the river yielded no fish; all other trawls collected at least one fish. We collected one adult sicklefin chub *Macrhybopsis meeki* (92 mm TL) in the heart of the navigation channel; all other fish were collected either toward the inside bend of the navigation channel or outside of the navigation channel on the inside bend side of the river. In fact, 80% of all fish collected at the bend were collected outside the navigation channel toward the inside bend. In addition to sicklefin chub, we collected common carp *Cyprinus carpio*, channel catfish *Ictalurus punctatus*, blue catfish *Ictalurus furcatus*, mooneye *Hiodon tergisus*, and shovelnose sturgeon *Scaphirhynchus platorynchus*. Blue catfish (14) and shovelnose sturgeon (16) comprised over 85% of the total catch. Both blue catfish and shovelnose sturgeon likely spawn in or near the Ste. Genevieve Bend because we found small individuals of each species present during our sampling (Table 1). We collected no species of special concern other than sicklefin chub.

Discussion

The vessel and gear worked acceptably in parts of the open river. We do not believe that the vessel is sufficiently large or has sufficient power to employ it regularly in the heart of the navigation channel of the open river. When trawling at the inside bend of the river, we could maintain forward speeds similar to those we typically can generate in the pooled portion of the river only by using maximum throttle. With the vessel at maximum throttle in the navigation channel, our forward speed was much reduced and we believe that our capture efficiency suffered accordingly. Given the gear limitations, we cannot provide a complete assessment of how diverse or abundant the fish community may be in the main channel of the Ste. Genevieve Bend.

Despite these shortcomings, we did document the presence of adult sicklefin chub in the navigation channel at Ste. Genevieve Bend. We also collected several shovelnose sturgeon on the inside of the bend outside of the navigation channel. At the very least, these sturgeon are using habitat very close to the navigation channel. Because of our inability to collect many fish within the navigation channel boundaries, we do not know whether sturgeon are also present in the navigation channel. Given the relatively large number of shovelnose sturgeon collected, the inside of river bends near the tail of islands may be suitable habitat for both shovelnose and pallid sturgeon.

Blue catfish and shovelnose sturgeon both may spawn in or near the Ste. Genevieve Bend. The size structure of both these fish reveals both young-of-year and adult sizes present in the area during our sampling. Because most of these fish were collected in the inside bend channel border or on the inside margin of the navigation channel, we believe that the inside bend channel border could be a major source of habitat for both juveniles and adults of these two species. It also could be an important habitat for other fish species, but our sampling did not allow us to make conclusions about other fishes.

One potential way to effectively estimate fish biomass in the main channel in the open river would be to use hydroacoustic gear. This gear has the advantage of not deploying large nets into the current that generate tremendous drag for the vessel to overcome. However, hydroacoustic gear will provide only estimates of total fish biomass and size structure, not species composition. We believe that this option has strong potential for estimating fish biomass, and could be combined with other methods to estimate the species composition of fish present.

We believe that if trawling equipment is used in the open river that it must be used only under the proper circumstances and with extreme caution. In particular, we believe the equipment should not be used unless surface current velocities are less than 1.2 m/s and preferably less than 1.0 m/s. Under no circumstance should this equipment be used when surface current velocities exceed 1.4 m/s because 1) the trawl will be ineffective and 2) the strong risk of gear loss and/or loss of life if a boat positioning mistake is made and/or the trawl is snagged. Likely, then, the areas of greatest potential utility for trawling in the open river would include side channels, inside bends, and selected main channel sites with low surface current velocities.

Acknowledgments

We thank Randy Claramunt, Chad Dolan, and John Rader for their help in the field. Special thanks go to Steve Gutreuter, U. S. Geological Survey, for his administrative support and coordination efforts. We also appreciate the coordination efforts of Bob Clevenstine, U.S. Fish and Wildlife Service, and T Miller, U.S. Army Corps of Engineers.

Table 1. Length (mm), measured as per LTRMP procedures (Gutreuter et al. 1995) and weight (g) of all fish of each species collected at the Ste. Genevieve Bend during August 12-13, 1997.

Species	Scientific name	Length (mm)	Weight (g)
Blue catfish	*Ictalurus furcatus*	42	2
		53	NA
		58	NA
		68	4
		72	NA
		72	4
		80	5
		88	8
		90	5
		96	7
		166	38
		167	36
		230	101
		427	667
Channel catfish	*Ictalurus punctatus*	437	662
Common carp	*Cyprinus carpio*	360	615
		552	NA
Mooneye	*Hiodon tergisus*	107	7
Sicklefin chub	*Macrhybopsis meeki*	92	7
Shovelnose sturgeon	*Scaphirhynchus platorhynchus*	110	5
		195	26

Species	Scientific name	Length (mm)	Weight (g)
Table 1, Continued			
Shovelnose sturgeon		446	304
		447	273
		457	273
		482	394
		484	370
		502	430
		529	526
		532	645
		546	609
		578	671
		591	985
		622	990
		637	1016
		674	1290

END OF DOCUMENT