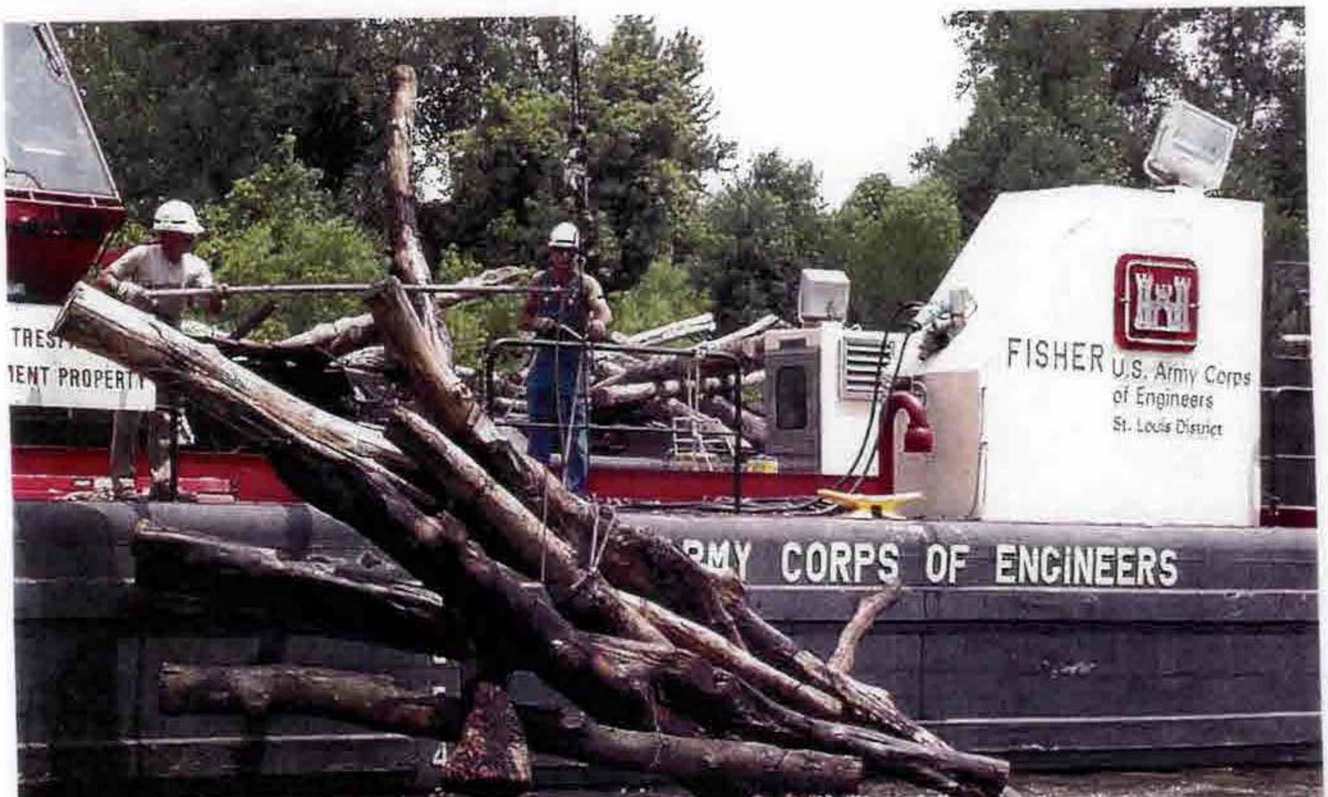
MELVIN PRICE LOCKS AND DAM

UPPER MISSISSIPPI RIVER BASIN
MISSISSIPPI RIVER MISSOURI AND ILLINOIS

PROGRESS REPORT 2001



DESIGN MEMORANDUM NO. 24
AVOID AND MINIMIZE MEASURES

"Good engineering enhances the environment"

US Army Corps of Engineers
St. Louis District

AUGUST 2002

Cover photo

Woody structure placement in Calico Chute (river mile 148.3 – 147.3). State and Federal natural resource agencies partners in the Avoid and Minimize program have long requested that the Corps of Engineers consider ways to incorporate woody structure into our dike and revetment program. These requests were based on concerns within the natural resource community about a perceived lack of large woody debris present in the present day Mississippi River. As a result, during 2001 and early 2002 the Corps created three log pile structures and placed a total of 62 wood bundles at seven locations on the middle Mississippi River. Logs for the project were donated by the Westvaco Corp., Wyckliffe, Ky. Post construction monitoring is a critical tool in assessing the value and impact of these structures as both river training structures and as aquatic habitat. Both biological and physical studies will conducted. Post-construction monitoring is scheduled to begin in 2003. The results of this work to date, are in Appendix G.

DESIGN MEMORANDUM NO. 24

AVOID AND MINIMIZE MEASURES

2001 PROGRESS REPORT

MELVIN PRICE LOCKS AND DAM
MISSISSIPPI RIVER - MISSOURI AND ILLINOIS

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Executive Summary

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

Construction efforts in 2000 were focused on Pool 24. In 1993 the A&M program constructed three chevron dikes at river mile 289. The original design called for the placement of five chevron dikes at the site. In 2000 the A&M Program issued a contract for the construction of the final two chevrons and a closure structure. Due to conflicting construction activities the contractor was unable to initiate the work in 2000. In 2001, the contractor indicated the velocities were too high to maintain alignment when the flows were high enough to provide enough depth for access. Based upon later site inspections, it was determined that flow and depth were insufficient to allow construction of more than one chevron.

Biological monitoring work continued on the chevron dike fields in Pools 24 and 25. Those results are showing that fish are using the structures as over-wintering and nursery habitat. Fifty-one species have been collected while sampling in conjunction with these structures since monitoring was initiated. One new species was documented in association with the Pool 25 multiple roundpoint structures (MRS) in 2001, bringing the total number of fish species collected during the sampling to 24. Prior years collections have included the blue sucker, an uncommon species in the Mississippi River.

Work to assess and improve fish passage at Lock and Dam 25 continued in 2001. Results from 1999 showed that fish movement through the dam gates occurs almost exclusively during open river conditions. Monitoring efforts in 2000 focused on creating hydraulic conditions to extend or create open river conditions outside of the natural period of open river. Gate manipulation work during the summer found that extending the period of open river is possible, but that velocities increased in gate bay 17. Fish movement data was inconclusive. Efforts in 2001 focused on the collection of additional data, while trying to determine if attempts by fish to pass through the gate were greater during a rise or fall in water levels and velocities. Data was collected for only a short time due to river flows. A complete analysis of all data collected to date is in process.

A post-construction survey and fish sampling of a dike modification site in the middle river (river mile 53.0(L)) was completed. The dike, which extended into the navigation channel, was modified by lowering 300 ft. of the river end of the dike to -15 ft. below the LWRP, which

coincides with the top elevation of weirs. Prior to construction the site was considered an excellent over-wintering location for fishes. Fish sampling resulted in the collection of 123 fish behind the dike, which is comparable to the 126 fish captured in 2000. The collection was dominated by shovelnose sturgeon but also included paddlefish, blue catfish, flathead catfish, and a gizzard shad. Post-modification monitoring at this site is scheduled for 2002.

A report on the monitoring of effects of Environmental Pool Management (EPM) in Pool 25 was completed in 2001. Fieldwork to assess the impacts of EPM will be completed in 2002 with a final report expected in early 2003. The data collected over the course of the monitoring has covered two extreme years (one high flow and one low flow) and one year that was considered "average". The final report will provide several water management regimes that can be implemented depending upon the spring and early summer hydrograph for a given year.

2001 field surveys recorded fourteen species of wetland plants with sedges being most common, followed by pigweed and millet. Conversion of seed biomass to potential waterfowl use days revealed an abundance of available forage. Preliminary data for 2001 suggests that EPM continues to produce a plant community comprised mainly of moist-soil species that generate abundant seed for waterfowl. Waterbird surveys were initiated in 2001 with seven species recorded. Killdeer were the most abundant species, followed by Great-blue Heron, Pectoral Sandpiper and Canada Goose. Waterfowl use surveys were difficult in 2001 due to variable river levels and dangerous ice conditions. Results indicated lower use by waterfowl than in 2000.

The report on fish use of vegetation produced by EPM found that fish numbers in late fall of 2000 were lower than in previous years due to the decreased amount of vegetation. Vegetation was ample enough in 2001 to repeat the technique used in 1999, though fish samples from 2001 had not been processed in order to be included in this report. Data on invertebrate use, and benthic core samples were also collected in 2001 but were not yet analyzed. Observations on water quality and zooplankton use were also collected and will be reported in 2002.

2001 was the sixth year of the Middle Mississippi River pallid sturgeon habitat use study. Tracking success was very limited in 2001 due to high river levels and the unavailability of fish suitable for implanting transmitters. Only two fish large enough for transmitter implants were received in 2001. Pallid sturgeon have shown a positive selection for areas in the main channel border, downstream of island tips, between wing dams, and the tips of wing dams. Pallid sturgeon show a negative selection of areas in the main channel, downstream of wing dams and upstream of wing dams. No selection, negative or positive, for bendway weirs has been demonstrated. Based on this information, future St. Louis District projects in the open river will give consideration to the creation or protection of preferred habitats and the importance they may play in the recovery of the species.

In November 2000, a meeting was held to coordinate the placement of wood structures in the Mississippi River. This meeting was in response to requests from our A&M partner agencies that the St. Louis District explore ways to incorporate woody structure into our Operation and Maintenance Program on the Mississippi River. The District placed wood structures at three locations in the middle Mississippi River in July and August 2001. Twelve log bundles were placed in Calico chute (R.M. 148.3 (L) – 147.3 (L)). These bundles, comprised of 80 – 100 logs total, were placed at four locations within the chute. Fifteen log bundles (over 100 logs) were placed at two locations along the main channel border between R.M. 165.5 (R) and 165.0 (R). Over 50 logs were driven into the substrate to create modified pile dikes at two sites between R.M. 165.0 (R) and 163.5 (R). All three sites are being monitored to assess both the biological benefits of the wood placement and the potential of using woody structures for river training. The wood structures area expected to increase habitat diversity by providing attachment sites for aquatic invertebrates in areas of otherwise unstable substrates. The structures are also expected to benefit fish species directly through the creation of cover, reproduction and forage sites, and through an increase in diversity of localized habitat types created by changes in the river bottom and flow patterns. The collection and deposition of organic debris, like leaves and drifting wood, in and around the structures will be utilized by both aquatic invertebrates and young fishes.

A presentation entitled "River Training Structures: New Ways of Doing Old Business" was prepared and presented at the Illinois River Conference. The A & M program has pioneered the use of some structures that may have applicability at some locations on the Illinois River. The presentation was included in the conference proceedings for future reference. (Appendix I)

Avoid and Minimize
Environmental Impacts Program
St. Louis District - Mississippi Valley Division
2001 Progress Report

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

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

2001 A&M Program Activities

A&M 1. 2001 Construction. Construction efforts in 2001 were focused on Pool 24. In 1993 the A&M program constructed three chevron dikes at RM 289.0. These chevrons were placed to hold dredge material, control main channel and side channel deposition, and improve habitat diversity. These structures have proven to be excellent habitat for both fish and macroinvertebrates. The original design called for the placement of five chevron dikes at the site. In 2000 the A&M program issued a contract for the construction of the final two chevrons, which were to be placed between the existing structures, and the construction of a closing structure adjacent to North Fritz Island, just below the chevrons. However, due to conflicting construction activities the contractor was unable to initiate the work in 2000. In 2001 the contractor said the velocities were too high to maintain alignment when the flows were high enough to provide enough depth for access. The money for the contract was subsequently moved to another O & M contract not associated with the A & M program.

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

Pool 24, River Mile 289 Biological Monitoring. The Illinois Department of Natural Resources (IDNR) has sampled the set of three chevron dikes located in Pool 24, near Cottonwood Island (river mile 289), since they were constructed in 1993. The site was sampled four times in 2001. Analysis of the entire data set shows that fish are using the chevron dikes and that catch rates inside the chevron dikes are more than double catch rates outside of the dikes. Catch rates inside of the chevron dikes were higher than those in nearby Drift Slough. Over 48 species have been found in association with the chevron dikes. The lentic environment inside of the chevron dikes appears to be providing favorable nursery habitat to young-of-the-year and juvenile fishes, including white bass, smallmouth buffalo, largemouth bass, and bluegill. The outside of the chevron dikes are providing excellent habitat for a variety of fishes including channel catfish, flathead catfish, common carp, minnows, and shiners. A detailed summary of the IDNR fish sampling efforts is available in Appendix A.

Pool 25, River Mile 266 Biological Monitoring. The A&M program has constructed three chevron dikes in Pool 25 of the Mississippi River (river mile 266). One complete and one partial dike were constructed in June 1998. In March 1999 the partial dike was completed and one additional chevron dike was constructed. The three chevron dikes at river mile 266 were surveyed in August 1999, December 1999, September 2000 and December 2001 During each trip bathymetry, velocity, and hydroacoustic fisheries data was collected.

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

Monitoring at the site will continue in 2002. Presently a summer and a winter sample are scheduled. In addition to hydroacoustic monitoring, gill nets will be set to determine species composition behind the dikes. Gill nets were employed in 2001 for the December sample, but results of the sets were very poor. A different deployment technique will be used in 2002 since it was felt that the 2001 technique did not sample at the depths where fish were present. Driving and pounding were also attempted in 2001 with equally poor results.

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

The multiple round point structure has been monitored since construction for both fish use and bathymetric changes. Electro-fish sampling has been conducted by the Illinois Department of Natural Resources at the site since 1998. The structure was sampled four times in 2001. Three new species were collected in 2001, bringing the number of species collected to 23. New species collected in 2001 were the silverband shiner, spotfin and the river darter. Gizzard shad, emerald shiners, carp, freshwater drum, and flathead catfish continue to make up the majority of the collected fish. On every sampling occasion prior to 2000, blue sucker were collected. Collection of the blue suckers is of interest because the species is uncommon in the Mississippi River and is a species of concern with resource agencies. No blue suckers were collected in 2000 or 2001. The Illinois report concluded that the structure was providing useful and valuable habitat (Appendix B). Bathymetric surveys have shown that the MRS have increased diversity at the site through a series of individual scour holes that have been created directly below and downstream of the MRS. The area was all shallow sand wave habitat prior to construction.

Future A & M construction plans call for an additional row of round point structures to be constructed, off-set from the existing row. The second row will have the round points constructed in the gaps left between the structures in the first row. The addition of the second row of structures should increase the effectiveness of the round points as a river training structure while increasing overall habitat diversity. Monitoring at the site will continue.

A&M 4. Off-bankline Revetment Monitoring.

No off-bankline revetment monitoring occurred in 2001. Monitoring may occur in future years due to plans to place new off-bankline revetment adjacent to the Batchtown Refuge. Construction is scheduled for 2002 or 2003 depending upon water conditions.

A&M 5. The Use of High Explosives to Conduct a Fisheries Study at a Bendway Weir Field. The District, in conjunction with our partners conducted a fisheries survey of the Prices Bend bendway weir field in 1993. A & M funds were used to complete a final report on this activity as a reference for future aquatic surveys conducted with high explosives. Appendix C contains the final report.

A&M 6. Effects of Environmental Pool Management on Fish and Wildlife. The St. Louis District has employed Environmental Pool Management (EPM) since 1994. EPM resulted from operational changes in the way the navigation pools are regulated after high water events. What results is a large crop of vegetation in the lower ends of Pools 24, 25,and 26. This vegetation becomes available to fish, aquatic insects, and migratory birds as water levels rise. The District is exploring ways to further enhance EPM but lacks basic information on fish and migratory bird use of the EPM created vegetation. In 2001, Southern Illinois University-Carbondale completed two studies to determine the response of waterfowl, aquatic invertebrates, fish and water quality to wetland vegetation produced by EPM (Appendix D).

The hydraulic regimes that have resulted from EPM have been monitored as in the past. Data has been collected for three years with a different regime each year. Results will be compared on high flow, low flow and moderate flow years in order to predict results of each and recommend changes in EPM implementation with each flow level. The final report will be prepared in early 2003.

6A. Response of Fish, Invertebrates, Vegetation, Waterbirds, and Water Quality to Environmental Pool Management: Mississippi River Pool 25. The objectives of this study were to characterize the plant community associated with water level management and estimate seed biomass production, quantify the aquatic invertebrate population response to increased vegetation production, and characterize the spring migratory waterfowl use of habitats produced by water level management.

Fourteen species of plants were documented during the study in 2001, with sedges, pigweed and millet, occurring most frequently. Seed production levels produced by EPM were substantially higher than those documented in 2000. Sedges and millets dominated seed production in 2001, although it was felt that the estimate for Red-root nutsedge might be over inflated due to the large size of the plants. Cottonwood, maple, and willow trees have also started to occur at many of the sampling locations. The presence of these species may be an unwanted consequence of EPM, yet they provide protection for the shoreline and cover for fish and invertebrates since they are frequently inundated. By varying the way EPM is implemented every year, minimization of tree species establishment may be possible. Preliminary results indicate that EPM continues to produce a plant community comprised primarily of moist-soil plants that produce abundant seeds for migratory birds, especially waterfowl. Annual differences in the plant community likely reflect the variations in the timing of the pool drawdowns.

Invertebrate samples collected in 2000 have been processed but not quantified, and samples collected in 2001 are being processed to remove and sort invertebrates and organic material. No significant increase in density was apparent between plots and years, though more study is needed to fully understand the invertebrate dynamics in Pool 25.

Waterfowl surveys and behavioral observations were conducted during February and March 2001. However, variable water levels and dangerous ice conditions made survey efforts difficult. Little residual vegetation was available to waterfowl in 2001 due to the hydroperiod in 2000, and bird abundance was lower. Mallards were again the most abundant species.

A shorebird count was conducted following the drawdown in late July, 2001 to assess the use of exposed mudflats by shorebird species. Seven species were found and overall abundance was low, likely due to the timing of the drawdown. The most common species was the killdeer, followed by the Great-blue Heron, both resident nesting species. Shorebird use was not expected to be a great benefit of EPM due to the drawdown timing not coinciding with either spring or fall shorebird migrations. Earlier or later dewatering may provide substantial benefits for shorebirds.

The results of this study have shown that EPM is producing a community of annual moist soil plants that in turn are producing a large quantity of seeds known to be important to waterfowl and other migratory birds. The organic matter produced by EPM contributes to the overall energy budget of the river, provides a food source and cover for invertebrates and is having benefits both inside and outside of the project area. Additional research needs to be conducted on the relationship of macroinvertebrate densities and

EPM and how varying the EPM regime affects plant growth and organism usage. Evidence suggests that varying the way EPM is implemented between pools and between years may provide the greatest spectrum of benefits to organisms.

6B. Fish and Water Quality Responses to Vegetation Produced via Environmental Pool Management Pool 25, Mississippi River. The objectives of this portion of the study were to examine fish use of EPM created vegetated areas versus similar non-vegetated areas, determine the benefit of residual vegetation to young fishes, and monitor the effect of vegetation on water quality and zooplankton.

Four sites in Pool 25 were sampled after the 1999 summer pool drawdown (29 June to 12 August). Vegetated and non-vegetated areas were sampled at each site from late August to middle October. Substantial numbers of fish were found in the vegetated areas but fish abundance and diversity were not statically significantly higher in the vegetated plots. These sites were again sampled in 2000, though devegetation was not necessary due to the drawdown timing. Experimental plots at most sites were shallow, open water habitats with some sparse vegetation at one site. The other four sites had an approximately 1-meter band of inundated vegetation. A total of 15,703 fish representing 17 taxa were collected during the seining effort, with approximately 70 percent associated with the narrow band of vegetation. Emerald shiners numerically dominated the samples, whereas mosquitofish were numerically dominant in 1999. The greatest diversity of species occurred in samples from the vegetation band, emphasizing the value of cover for a variety of species. The difference in vegetation production between 1999 and 2000 influenced fish communities in habitats sampled, but the effect of the hydrologic regime was also evident. Backwater isolation was not a problem in 2000, and likely was responsible for the larger numbers of centrachides in the samples. Orangespotted sunfish and bluegill were the most abundant species. Sunfish, particularly bluegill, benefited form the drawdown cycle of 2000 compared to the drawdown of 1999. Samples were collected in 2001 similar to the methodology used in 1999 due to the increase in vegetation resulting from the drawdown regime. Fish samples taken in the fall of 2001 have not been processed at this time.

The results of water quality measurements in 2000 were significantly better than 1999 for dissolved oxygen. DO levels in 1999 were as low as 1.4 mg/L, while the lowest DO at any location in 2000 was 7.8 mg/L. The vegetative response in 2000 was not nearly as dense as the 1999 response. Zooplankton samples were collected in 2000, but analysis has not been completed.

The hydraulic regime in 1999 was extreme compared to EPM in past years. High water during much of the drawdown kept water levels about two feet lower than the target EPM elevation and for much longer than what had been experienced in other years. This resulted in a greater vegetative response than in other years and the extended dewatering of areas that typically would not have been exposed for such a long time. The

2000 hydrologic regime was purposely held higher than normal during late June and early July in hopes of facilitating the spawning success of some species and was viewed as somewhat successful in that regard, pending review of fisheries survey data collected following the higher hydrologic regime. The hydrologic regime in 2001 was more moderate than the 1999 drawdown in terms of duration and no attempt was made to facilitate spawning as in 2000. Pool 25 was held at 432 beginning in late June and remained at or slightly below that level (except for a spike down for several days in mid-July) until early August. Consequently, this study will document differences from three drawdown cycles that can be characterized according to vegetation production as exceptional (1999), minimal (2000), and moderate (2001)

Data from 2001, during which water levels manipulations were viewed as moderate are presently being analyzed. Future work will focus on the analysis of the 2001 data and further evaluation of the timing, duration and depth of EPM drawdowns, and how annual hydrologic regimes can be better managed for the benefit of fish and wildlife.

A&M 7. Middle Mississippi River Pallid Sturgeon Habitat Use Project. The A&M program continued for the sixth year to fund Southern Illinois University-Carbondale, Cooperative Fisheries Research Laboratory to monitor the relationship between river training structures and the federally listed endangered pallid sturgeon, and to collect life history information. Efforts in 2001 focused on attempting to track sturgeon implanted with transmitters, publications and an examination of gastric lavage techniques to determine their suitability for studying diets of pallid sturgeion.

Unfortunately, only four specimens were collected during the year that showed pallid sturgeon characteristics. Only two showed strong pallid sturgeon characteristics and were implanted with sonic transmitters. No pallid sturgeon were located by sonic tracking during the year due to decreased tracking efforts. Factors causing the decreased effort were long periods of ice flow, high water and low numbers of fish with active transmitters. A summary of all sonic telemetry work to date is included in the annual report.

Two publications were produced, one was a further exploration of the Character Index (published in the Transactions of the American Fisheries Society, the other reported development of a substantial set of genetic markers that should ultimately facilitate sturgeon conservation in general (published in the American Fisheries Society Sturgeon Symposium Proceedings).

Gastric lavage techniques were examined to determine their suitability for studying diets of the pallid sturgeon. Results indicated that gastric lavage should not lead to any substantial additional stress or mortality in captured sturgeon, although it was felt that there is room for improvement in the technique.

The annual report is included in Appendix E.

A&M 8. Fish Passage Improvement at Lock and Dam 25. Work in 2001 involved manipulating gates as Lock and Dam 25 headed towards the spring open river event. Testing at that time better coincided with spring fish movement and should give a better indication of the true effects of gate manipulation on fish movement than the work done in 2000. Fish and velocity data were to be analyzed in 2002, but the analysis was deferred due to decreased funding for the A&M program in 2002. The data is now scheduled for analysis in 2003. A preliminary look at the data suggests that altering gate patterns can improve fish passage prior to the lock and dam going to open river.

A summary letter report is in Appendix F.

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

The St. Louis District placed wood structures at three locations in the middle Mississippi River during July and August, 2001. Log bundles were placed in Calico Chute R.M. 148.3L – 147.3L at four different locations. Log bundles were placed at two locations along the main channel border between R.M. 165.5R and 165.0R. Individual logs were driven into the substrate to create modified pile dikes at two sites between R.M. 165.0R and 163.5R. All three sites are being monitored to assess both the biological benefits of the wood placement and the potential for using woody structure as river training structures.

Reports on this work are in Appendix G.

A&M 10. Wing Dike Modification Post-project monitoring, Dike 53.0L. This work was completed under Avoid and Minimize measure A-16, dike configuration studies. Pre-construction monitoring occurred in January 2000. Multi-beam bathymetry, velocity, hydroacoustic and gill net fisheries data were collected in early February, 2001, at modified dike 53.0L. The last 300 feet of the dike (riverward) has been lowered to –15 feet below the LWRP, with the remaining 300 feet (landward) left intact.

Bathymetric survey data showed a distinct difference between pre and post-construction. Pre-construction data showed the presence of two holes below the dike, while post-construction data showed only one hole directly below the weir. Field observations of the hydroacoustic data showed fish using the entire area behind the dike, but densities did not appear as high as in pre-construction monitoring. Gill net catch numbers were similar in both pre and post-construction sampling, but species composition and numbers were different.

Results of this work are in Appendix H.

FY 2002 A&M Program

The FY 2002 A&M budget was expected to be $1 million. This figure would have been in line with previous years' budgets but is less than the $1.5 million per year outlined in Design Memorandum No. 24. However, the program is expected to be extended until 2008 to offset the annual differences in funding. Proposed A&M activities for 2002 will be greatly curtailed due to a lack of funding for the program. Available program dollars in 2002 will likely be less than $100,000.

Avoid & Minimize Team

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Appendices

Appendix A.

2001 Summary Report on Pool 26 Chevron Dike Hydroacoustic Fisheries Sampling – U.S. Army Corps of Engineers, St. Louis District.

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

Appendix B.

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

Appendix C.

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

Appendix D.

Response of Fish, Invertebrates, Vegetation, Waterbirds, and Water Quality to Environmental Pool Management: Mississippi River Pool 25. Southern Illinois University.

Appendix E.

2001 Progress Report – Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University – Carbondale, Fisheries Research Laboratory and Department of Zoology.

Appendix F.

2001 Summary Letter Report – Lock and Dam 25 Fish Passage Project. U.S. Army Corps of Engineers, St. Louis District.

Appendix G.

2001 Progress Reports – Wood Structure Construction and Placement. U.S. Army Corps of Engineers, St. Louis District.

Appendix H.

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

Appendix I.

Papers Presented – River Training Structures: New Ways of Doing Old Business. U.S. Army Corps of Engineers, St. Louis District.

Appendix A.

2001 Summary Report on Pool 26 Chevron Dike Hydroacoustic Fisheries Sampling – U.S. Army Corps of Engineers, St. Louis District

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

Cottonwood Island Chevron Dike Fisheries Evaluation Update

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

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Boundary River Program

May 2002

Introduction

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

Methods

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

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

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

Results and Discussion

A total of 10499 fishes representing 58 species have been collected during 1444 minutes of electrofishing (109.06 fish/15 ef min). When these data are summarized by habitat type (inside, outside, Drift Island Slough and Head of Bay Island) over all sampling periods (Table 2), the highest catch rate was observed inside the chevrons (143.31 fish/15 min EF), followed by Drift Island Slough (112.57 fish/15 min EF), outside the chevrons (91.96 fish/15 min EF) and Head of Bay Island (67.26 fish/15 min EF). The number of species collected was also highest inside the chevrons (44 species), followed by Drift Island Slough (40 species), outside the chevrons (32 species) and Head of Bay Island (31 species) [Table 2]. Fifty one of the 58 species collected have been collected at the chevrons (inside and outside combined).

When the total number of species collected at each station over all years are compared (Table 3), the highest species richness was observed inside the upper chevron (41 species) followed by Drift Island Slough (40 species), upper outside and Head of Bay Island (31 species), lower inside (28 species), and lower outside (19 species). When total catch rates for each site (over all sampling periods) are compared, the upper inside chevron is higher than all other sites with 146.66 fish/15 min EF, followed by lower inside (130.94 fish/15 min) and Drift Island Slough (112.57 fish/15 min) [Table 3]. Although some of the difference in catch rates and species richness can be explained by variable sampling effort among stations, and differences in electrofishing efficiency among stations, these data suggest that the habitat types created inside the chevron dikes are holding more individual fishes and more fish species than either the habitat immediately outside of the chevrons or nearby side channel and backwater habitats.

The total catch rate for bigmouth buffalo, smallmouth buffalo, black crappie, white crappie, bluegill and orangespotted sunfish was highest in the slough. The total catch rates for spotfin shiner, emerald shiner, sand shiner, channel catfish, flathead catfish and smallmouth bass were highest on the outside of the chevrons (Table 3). The total catch rates for shortnose gar, gizzard shad, river shiner, channel shiner, bullhead minnow, quillback, river carpsucker, white bass, largemouth bass, green sunfish, sauger and freshwater drum (Table 3) were higher inside chevrons than elsewhere. As these data suggest, the fish communities described by the compostion of fishes collected in this study indicate that the habitat inside the chevrons is ecologically intermediate between main channel border and backwater habitats. This is logical, as the backwater type habitat inside the chevrons is nested within main channel border habitat. A look at the annual catch rates of selected numerically dominant fishes which prefer either flowing water or quiet water help illustrate the point. Plots of the annual catch rates for the current loving emerald shiner and spotfin shiner for three habitat types indicate that densities of these fishes inside the chevrons are generally lower that rate outside and higher than those at Drift Slough (Figures 1 & 2). Conversely, the catch rates for smallmouth buffalo and bluegill, fishes which generally prefer quiet water habitats, indicate the opposite trend, the estimated density of these fishes inside the chevrons is lower than at Drifts Island Slough and higher than outside the chevrons (Figures 3 & 4).

An examination of the length frequencies of selected fishes collected from the vicinity of the chevrons and Drift Island Slough helps illustrate the similarities and differences in the fish populations inhabitating these habitat types. For instance, although smallmouth buffalo densities associated with the chevrons appear to be considerably less than those in Drift Island Slough, the size range observed for this species is slightly greater in the vicinity of the chevrons than in the slough. This may indicate the nursery habitat provided by the chevron and slough habitats are similar in quality for this species (Atwood, 2001).

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

Unlike the channel catfish, the catch rate for white bass on the inside was almost 2 times that on the outside and the observed size distribution of these fishes between these habitats is markedly different. The majority of white bass found inside were young of the year fishes, while most of those fish collected on the outside of the chevrons were one year or older, suggesting the interior habitat is providing valuable nursery habitat for young white bass.

Largemouth bass and bluegill densities also appear to be higher in Drift Island Slough than inside chevrons and the size structure in these habitats is similar, probably indicating the chevrons are providing favorable juvenile and adult habitat conditions (Atwood 2001).

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.

Literature Cited

Atwood, E.R. 2001. Cottonwood Island Chevron Dike Fisheries Evaluation Update. Design Memorandum No. 24 Avoid and Minimize Measures 2000 Progress Report. U.S. Army Engineering District - St. Louis, June 2001.

Ecological Specialists, Inc. 1997. Macroinvertebrates Associated with Habitats of Chevron Dikes in Pool 24 of the Mississippi River. Design Memorandum No. 24 Avoid and Minimize Measures 2000 Progress Report. U.S. Army Engineering District - St. Louis, December 1997.

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
12-Sep-95	Lower Chevron Inside	16
14-Aug-96	Lower Chevron Inside	15
16-Jul-97	Lower Chevron Inside	15
12-Jun-98	Lower Chevron Inside	15
17-Aug-98	Lower Chevron Inside	15
14-Oct-93	Lower Chevron Outside	9
12-Sep-95	Lower Chevron Outside	16
14-Aug-96	Lower Chevron Outside	15
09-Sep-96	Lower Chevron Outside	15
08-Oct-96	Lower Chevron Outside	15
16-Jul-97	Lower Chevron Outside	15
17-Aug-98	Lower Chevron Outside	15
14-Oct-93	Upper Chevron Inside	9
02-Aug-95	Upper Chevron Inside	14
12-Sep-95	Upper Chevron Inside	16
11-Oct-95	Upper Chevron Inside	14
14-Aug-96	Upper Chevron Inside	15
09-Sep-96	Upper Chevron Inside	15
08-Oct-96	Upper Chevron Inside	15
16-Jul-97	Upper Chevron Inside	10
26-Sep-97	Upper Chevron Inside	15
12-Jun-98	Upper Chevron Inside	15
17-Aug-98	Upper Chevron Inside	15
14-Oct-98	Upper Chevron Inside	15
26-Aug-99	Upper Chevron Inside	15
23-Sep-99	Upper Chevron Inside	12
22-May-00	Upper Chevron Inside	12
29-Aug-00	Upper Chevron Inside	15
29-Sep-00	Upper Chevron Inside	15
18-Oct-00	Upper Chevron Inside	15
27-Jul-01	Upper Chevron Inside	15
21-Aug-01	Upper Chevron Inside	17
20-Sep-01	Upper Chevron Inside	15
17-Oct-01	Upper Chevron Inside	15
14-Oct-93	Upper Chevron Outside	9
02-Aug-95	Upper Chevron Outside	14
12-Sep-95	Upper Chevron Outside	16
11-Oct-95	Upper Chevron Outside	14

Sampling date	Station name	Electrofishing effort(min)
14-Aug-96	Upper Chevron Outside	15
09-Sep-96	Upper Chevron Outside	15
08-Oct-96	Upper Chevron Outside	15
16-Jul-97	Upper Chevron Outside	10
26-Sep-97	Upper Chevron Outside	15
12-Jun-98	Upper Chevron Outside	20
17-Aug-98	Upper Chevron Outside	15
14-Oct-98	Upper Chevron Outside	15
26-Aug-99	Upper Chevron Outside	15
23-Sep-99	Upper Chevron Outside	12
22-May-00	Upper Chevron Outside	12
29-Aug-00	Upper Chevron Outside	15
29-Sep-00	Upper Chevron Outside	15
18-Oct-00	Upper Chevron Outside	15
27-Jul-01	Upper Chevron Outside	15
21-Aug-01	Upper Chevron Outside	18
20-Sep-01	Upper Chevron Outside	15
17-Oct-01	Upper Chevron Outside	15
14-Oct-98	Head of Bay Island	20
26-Aug-99	Head of Bay Island	15
23-Sep-99	Head of Bay Island	20
22-May-00	Head of Bay Island	20
29-Sep-00	Head of Bay Island	15
18-Oct-00	Head of Bay Island	15
21-Aug-01	Head of Bay Island	20
20-Sep-01	Head of Bay Island	15
17-Oct-01	Head of Bay Island	15
12-Jun-98	Cottonwood MCB	20
21-Jul-95	Drift Island Slough	60
12-Aug-96	Drift Island Slough	60
09-Sep-96	Drift Island Slough	15
08-Oct-96	Drift Island Slough	15
04-Aug-97	Drift Island Slough	60
06-Aug-98	Drift Island Slough	60
25-Aug-99	Drift Island Slough	60
29-Aug-00	Drift Island Slough	60
21-Aug-01	Drift Island Slough	60
	Total effort to date	1444

Table 2. Compostition of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes study area, 1993 - 2001.

	Chevron Inside		Chevron Outside		Chevron total		Head of Bay Is.		Drift Is. Slough		All Stations	
sampling effort (min)	399		420		819		155		450		1424	
Species	N	N/15min	N	N/15min	N	N/15min	N	N/15min	N	N/15min	N	N/15min
Shortnose gar	5	0.19			5	0.09	2	0.19	3	0.10	**10**	0.11
Longnose gar									6	0.20	**6**	0.06
Bowfin									29	0.97	**29**	0.31
American eel			2	0.07	2	0.04					**2**	0.02
Skipjack herring	1	0.04			1	0.02	1	0.10			**2**	0.02
Gizzard shad	861	32.37	241	8.61	1102	20.18	21	2.03	309	10.30	**1432**	15.08
Threadfin shad	2	0.08			2	0.04					**2**	0.02
Mooneye			3	0.11	3	0.05					**3**	0.03
Silver carp									1	0.03	**1**	0.01
Bighead carp	1	0.04			1	0.02			1	0.03	**2**	0.02
Goldfish	4	0.15			4	0.07			2	0.07	**6**	0.06
Carp	54	2.03	119	4.25	173	3.17	64	6.19	145	4.83	**382**	4.02
Carp x Goldfish hybrid									1	0.03	**1**	0.01
Central stoneroller			2	0.07	2	0.04	1	0.10			**3**	0.03
Suckermouth minnow	5	0.19			5	0.09					**5**	0.05
Silver chub	7	0.26	11	0.39	18	0.33			13	0.43	**31**	0.33
Silvery minnow							1	0.10			**1**	0.01
Spotfin shiner	139	5.23	339	12.11	478	8.75	73	7.06	4	0.13	**555**	5.85
Red shiner	14	0.53	46	1.64	60	1.10	34	3.29			**94**	0.99
Bluntnose minnow	6	0.23	7	0.25	13	0.24			1	0.03	**14**	0.15
Bullhead minnow	535	20.11	74	2.64	609	11.15	21	2.03	66	2.20	**696**	7.33
Emerald shiner	694	26.09	1091	38.96	1785	32.69	195	18.87	4	0.13	**1984**	20.90
Silverband shiner	1	0.04			1	0.02					**1**	0.01
River shiner	56	2.11	35	1.25	91	1.67					**91**	0.96
Bigmouth shiner			1	0.04	1	0.02					**1**	0.01
Sand shiner	8	0.30	17	0.61	25	0.46					**25**	0.26
Channel shiner	87	3.27	63	2.25	150	2.75	12	1.16	1	0.03	**163**	1.72
Spottail shiner	4	0.15			4	0.07					**4**	0.04
Shiner spp.	13	0.49			13	0.24					**13**	0.14
Bigmouth buffalo	19	0.71			19	0.35	14	1.35	125	4.17	**158**	1.66
Smallmouth buffalo	62	2.33	25	0.89	87	1.59	4	0.39	297	9.90	**388**	4.09
Black buffalo	1	0.04			1	0.02	2	0.19	11	0.37	**14**	0.15
Carpsucker spp.	14	0.53			14	0.26					**14**	0.15
Quillback	15	0.56	1	0.04	16	0.29			1	0.03	**17**	0.18
River carpsucker	115	4.32	1	0.04	116	2.12	1	0.10	19	0.63	**136**	1.43
Highfin carpsucker	1	0.04			1	0.02					**1**	0.01
Spotted sucker									4	0.13	**4**	0.04
Shorthead redhorse	4	0.15	11	0.39	15	0.27	5	0.48	8	0.27	**28**	0.29
Golden redhorse	3	0.11			3	0.05	1	0.10			**4**	0.04
Channel catfish	37	1.39	115	4.11	152	2.78	19	1.84	49	1.63	**220**	2.32
Flathead catfish	6	0.23	109	3.89	115	2.11	10	0.97	41	1.37	**166**	1.75
Freckled madtom			1	0.04	1	0.02	1	0.10	1	0.03	**3**	0.03
Mosquitofish	23	0.86			23	0.42	1	0.10	45	1.50	**69**	0.73
Brook silverside	3	0.11			3	0.05			1	0.03	**4**	0.04
White bass	34	1.28	20	0.71	54	0.99	6	0.58	4	0.13	**64**	0.67
Yellow bass	4	0.15	1	0.04	5	0.09					**5**	0.05
Black crappie	9	0.34			9	0.16	21	2.03	145	4.83	**175**	1.84
White crappie	2	0.08			2	0.04	1	0.10	57	1.90	**60**	0.63
Largemouth bass	125	4.70	68	2.43	193	3.53	25	2.42	156	5.20	**374**	3.94
Smallmouth bass			7	0.25	7	0.13	1	0.10			**8**	0.08
Warmouth	8	0.30			8	0.15			14	0.47	**22**	0.23
Green sunfish	141	5.30	38	1.36	179	3.28	5	0.48	7	0.23	**191**	2.01
Bluegill x Green sunfish	1	0.04			1	0.02					**1**	0.01
Bluegill	360	13.53	62	2.21	422	7.73	120	11.61	1250	41.67	**1792**	18.88
Redear sunfish	1	0.04			1	0.02			2	0.07	**3**	0.03
Orangespotted sunfish	135	5.08	3	0.11	138	2.53	6	0.58	444	14.80	**588**	6.19
Walleye									1	0.03	**1**	0.01
Sauger	3	0.11			3	0.05			2	0.07	**5**	0.05
Slenderhead darter			1	0.04	1	0.02	1	0.10			**2**	0.02
Logperch	1	0.04	2	0.07	3	0.05			2	0.07	**5**	0.05
Mud darter									2	0.07	**2**	0.02
Freshwater drum	188	7.07	59	2.11	247	4.52	26	2.52	103	3.43	**376**	3.96
Total number fish collected	3812	143.31	2575	91.96	6387	116.98	695	67.26	3377	112.57	**10459**	110.17
Number of species collected	44		32		51		31		40		58	

Table 3. Summary of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes study area, 1993 - 2001.

	Chevrons				Control sites			
	Lower Inside	Upper inside	Lower outside	Upper outside	Head of Bay Is.	MCB	Drift Is. Slough	All Stations
sampling effort (min)	85	314	100	320	155	20	450	1444
Species								
Shortnose gar		5			2		3	10
Longnose gar							6	6
Bowfin							29	29
American eel				2				2
Skipjack herring		1			1			2
Gizzard shad	215	646	41	200	21	5	309	1437
Threadfin shad	1	1						2
Mooneye				3				3
Silver carp							1	1
Bighead carp	1						1	2
Goldfish		4					2	6
Carp	7	47	27	92	64	4	145	386
Carp x Goldfish hybrid							1	1
Central stoneroller				2	1			3
Suckermouth minnow	3	2						5
Silver chub		7	2	9			13	31
Silvery minnow					1			1
Spotfin shiner	52	87	57	282	73	3	4	558
Red shiner	1	13	5	41	34			94
Bluntnose minnow	1	5		7			1	14
Bullhead minnow	114	421	7	67	21	1	66	697
Emerald shiner	119	575	194	897	195	3	4	1987
Silverband shiner	1							1
River shiner	20	36	13	22		2		93
Bigmouth shiner				1				1
Sand shiner		8	1	16				25
Channel shiner	5	82	8	55	12	2	1	165
Spottail shiner		4						4
Shiner spp.		13						13
Bigmouth buffalo	10	9			14		125	158
Smallmouth buffalo	27	35	8	17	4	2	297	390
Black buffalo	1				2		11	14
Carpsucker spp.		14						14
Quillback	5	10		1		1	1	18
River carpsucker	30	85		1	1	3	19	139
Highfin carpsucker		1						1
Spotted sucker							4	4
Shorthead redhorse		4	4	7	5	5	8	33
Golden redhorse	1	2			1	1		5
Channel catfish	8	29	56	59	19	2	49	222
Flathead catfish	3	3	27	82	10		41	166
Freckled madtom				1	1		1	3
Mosquitofish		23			1		45	69
Brook silverside		3					1	4
White bass	14	20	5	15	6	1	4	65
Yellow bass		4	1					5
Black crappie	3	6			21		145	175
White crappie		2			1		57	60
Largemouth bass	11	114		68	25		156	374
Smallmouth bass			1	6	1			8
Warmouth		8					14	22
Green sunfish	4	137		38	5		7	191
Bluegill x Green sunfish		1						1
Bluegill	23	337	4	58	120	1	1250	1793
Redear sunfish		1					2	3
Orangespotted sunfish	23	112		3	6		444	588
Walleye							1	1
Sauger		3					2	5
Slenderhead darter				1	1			2
Logperch		1		2			2	5
Mud darter							2	2
Freshwater drum	39	149	18	41	26	4	103	380
Total number fish collected	742	3070	479	2096	695	40	3377	10499
Number of species collected	28	41	19	31	31	16	40	58

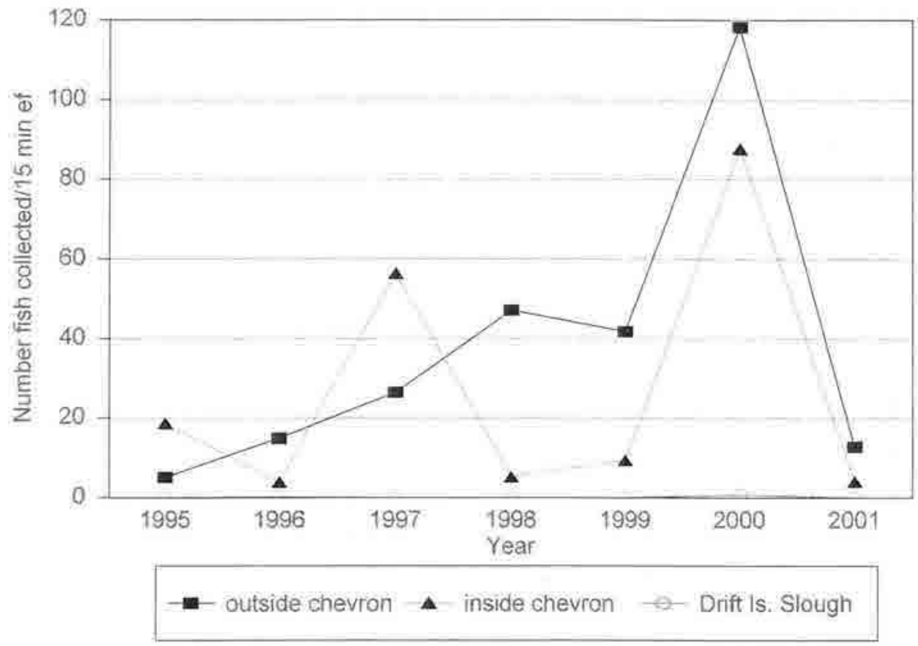


Figure 1. Annual catch rates of emerald shiner at three chevron dike study sites.

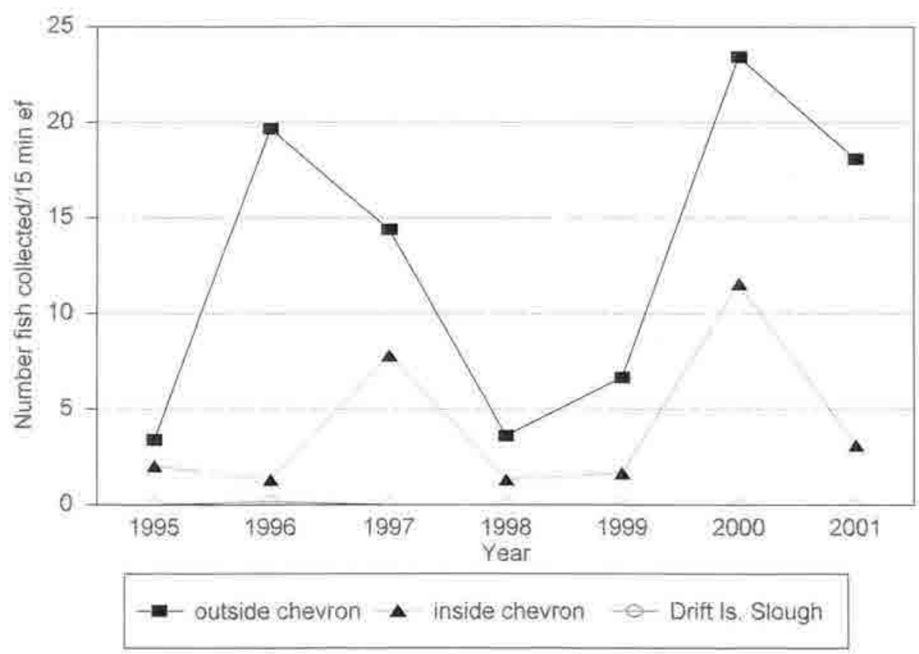


Figure 2. Annual catch rates of spotfin shiner at three chevron dike study sites.

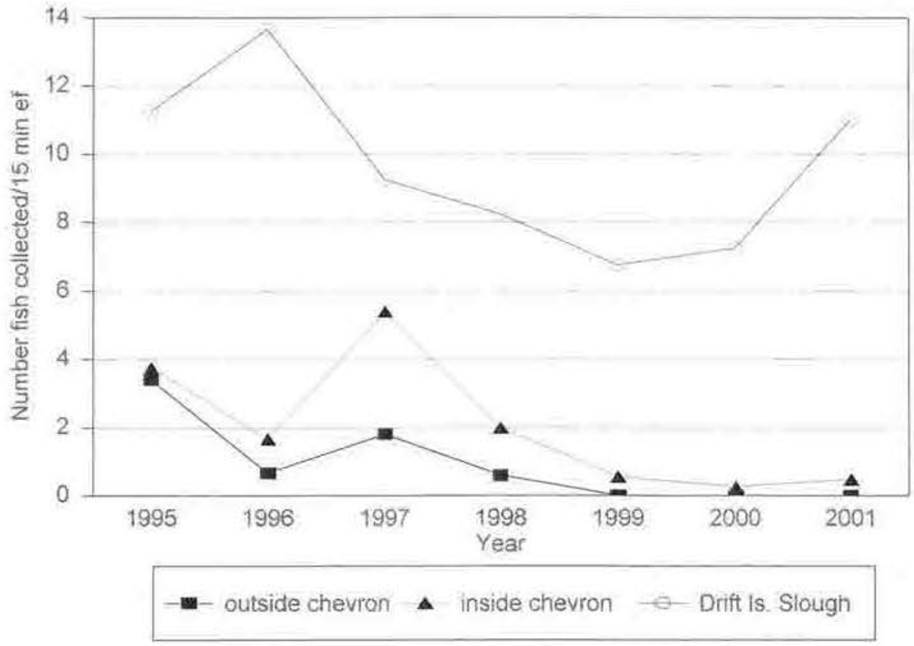


Figure 3. Annual catch rates of smallmouth buffalo at three chevron dike study sites.

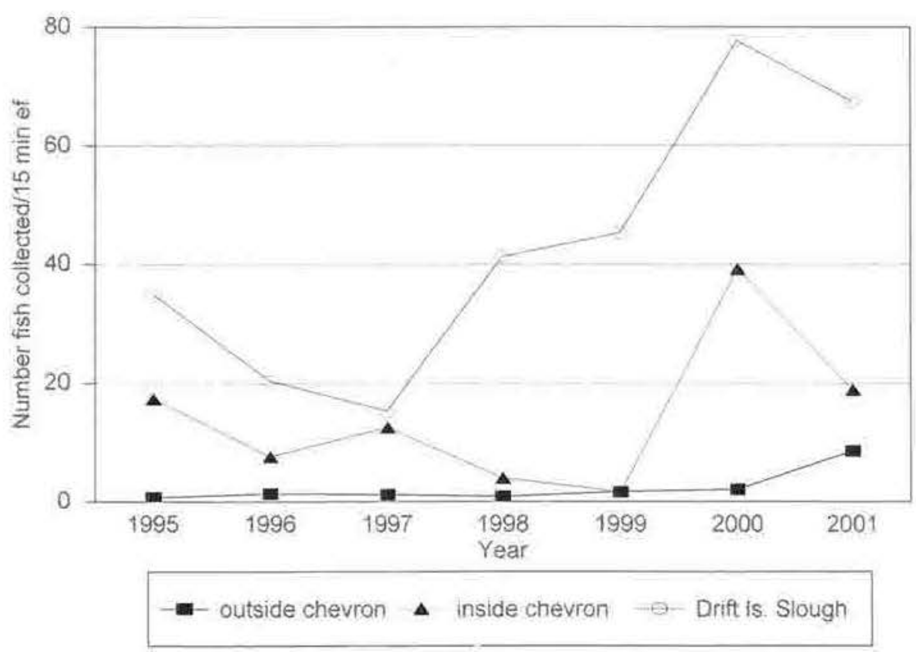
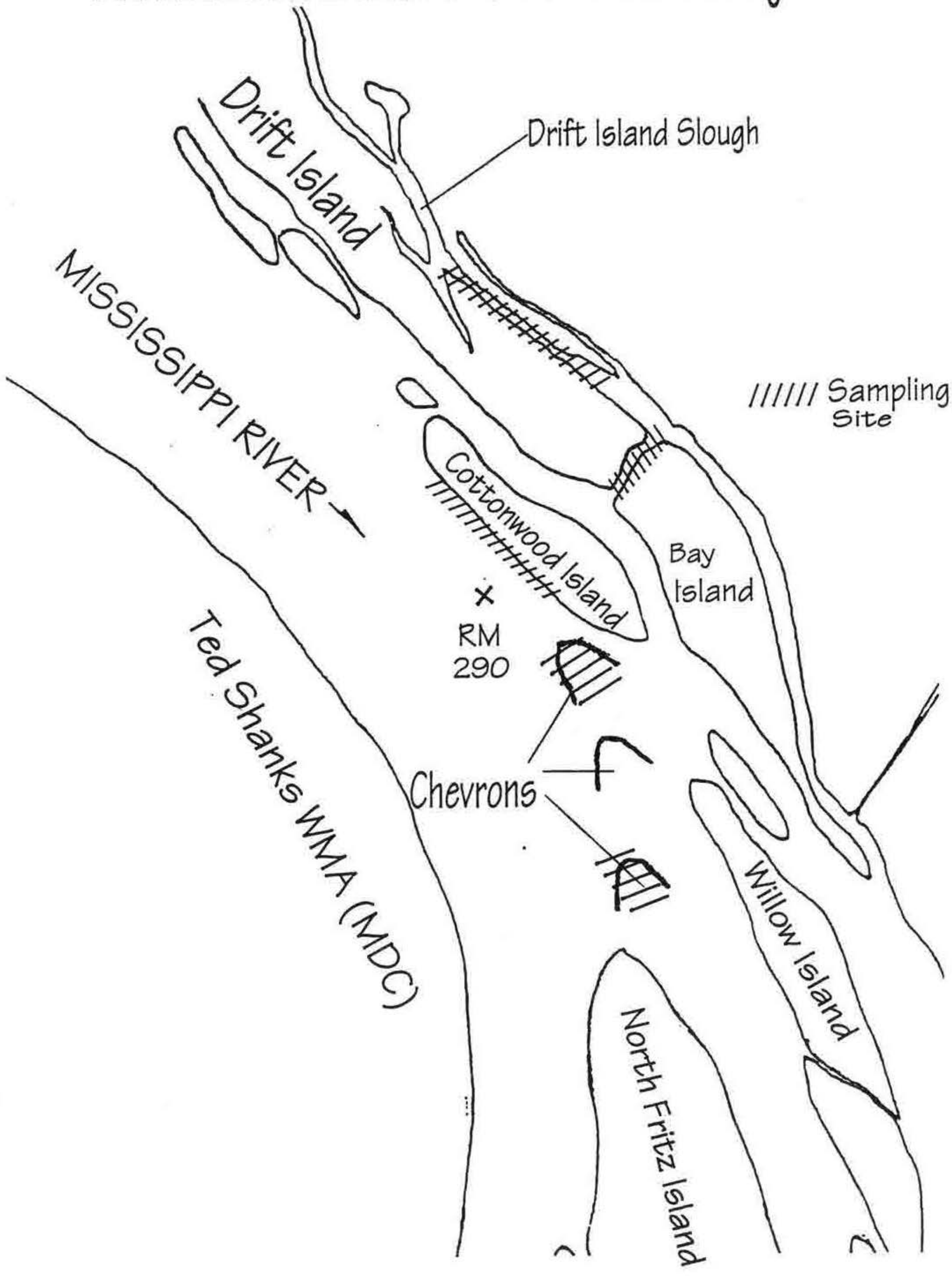
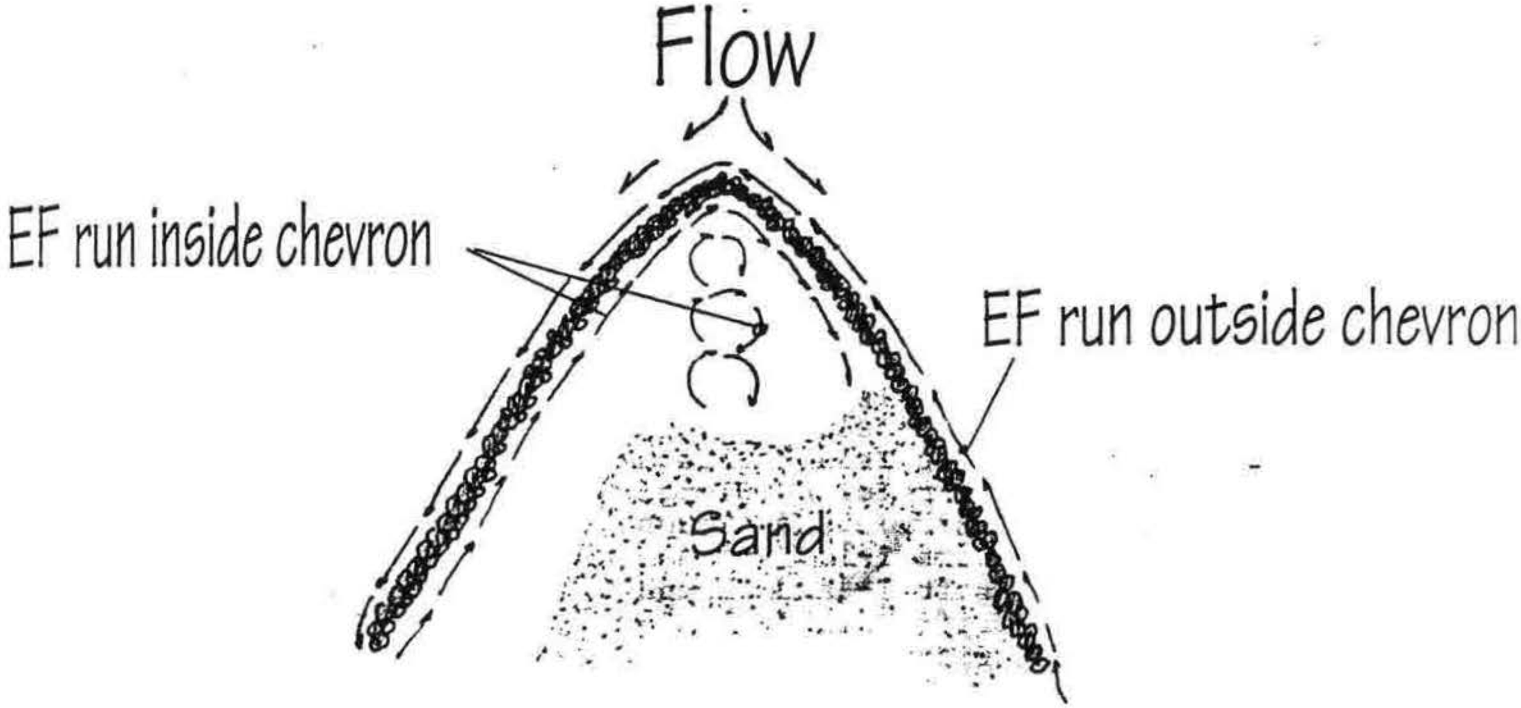


Figure 4. Annual catch rates of bluegill at three chevron dike study sites.

Cottonwood Island Chevron Dike Study Area



Typical Chevron Electrofishing Runs



2001 Summary Report
Chevron Dike Hydroacoustic Fisheries Sampling

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

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

Sampling to Date: The three chevron dikes at 266.0 were sampled on 24 July and 11 December 2001. The chevrons were previously sampled in August 1999, December 1999, and September 2000. Information on the 2001 sampling trips follows. Information about previous sampling trips is found at the end of the report

24 July 2001

All three chevron dikes were sampled. Water temperature was 29°C. Pool 25 was at normal pool conditions. Velocity and hydroacoustic fisheries data were collected. Transects were run upstream from the bottom of the chevron dike to the apex. Four transects were run inside of each the three dikes. Depths behind the top and middle chevron dikes exceeded 11 meters. Depths behind the lower chevron dike were near 7 meters. Analysis of the hydroacoustic data found similar fish densities behind all three dikes. Densities during this sample were slightly higher than those collected during the August 1999 sample, but like the 1999 sample, were relatively evenly distributed between the three dikes. Equipment malfunction caused the data to be collected without GPS coordinates for all transects on the upper dike and two of the transects of the middle dike. Transects lengths for those samples were estimated based on past transect lengths, to derive densities.

11 December 2001

All three chevron dikes were sampled. Water temperature was 6.4°C. Pool 25 was at normal pool conditions. The MV Boyer collected 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 6 meters. Fish densities between the three dikes varied greatly but were all higher than previously collected samples. Experimental gill net sampling on 12 December inside the top and middle dike collected very few fish, mostly small Drum. A fair amount of leaf litter was collected in the nets. The effect of the leaf litter on hydroacoustic fish density estimates was examined and believed to be minimal.

Table 1. Chevron sampling data.

	Sample date	Max. depth meters	Fish density #/acre	Water temp. °C	Pool conditions
Upper Chevron inside	8-4-99	11	325	27.2	Open river
Upper Chevron inside	12-13-99	9	1823	5	Normal pool (winter)
Upper Chevron inside	9-7-00	9	490	24.8	Normal pool
Upper Chevron inside	7-24-01	12	679*	29	Normal pool
Upper Chevron inside	12-11-01	12	3222	6.4	Normal pool
Middle Chevron inside	8-4-99	11	402	27.2	Open river
Middle Chevron inside	12-13-99	9	2590	5	Normal pool (winter)
Middle Chevron inside	9-7-00	8	317	24.8	Normal pool
Middle Chevron inside	7-24-01	11	1000*	29	Normal pool
Middle Chevron inside	12-11-01	11	8445	6.4	Normal pool
Lower Chevron inside	8-4-99	7	406	27.2	Open river
Lower Chevron inside	12-13-99	4	0	5	Normal pool (winter)
Lower Chevron inside	9-7-00	5	52	24.8	Normal pool
Lower Chevron inside	7-24-01	7	757	29	Normal pool
Lower Chevron inside	12-11-01	6	2063	6.4	Normal pool

* some transects lengths were estimated, due to GPS failure

Conclusions: Fish were using the chevron dikes during all sampling trips. Consistent with past findings, fish appear to be using the upper and middle dikes more than the lower dike. Both winter samples show a marked increase in density over the summer samples. 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 in 1999 and had lower numbers than the upper and middle dikes in 2001. 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. Depths behind the lower chevron dike are shallower than behind either of the upper two chevron dikes. This difference is likely a result of a decrease in available energy (to scour) caused by flow disruption from the upper two dikes.

Monitoring at this site was set to conclude in 2001. Given the discrepancy between the high December 2001 hydroacoustic estimates and the low gill netting success, we have determined that another winter sample is necessary. That sample will take place in the late 2002 and will include hydroacoustics, deep water electro-fishing, and/or use of a purse seine. That information should provide more insight into species use of the chevron dikes, while at the same time allowing us to assess the validity of the hydroacoustic estimates.

References:

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

Previous sampling trips:

4 August 1999

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

13 December 1999

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

7 September 2000

All three chevron dikes were sampled. Water temperature was 24.8°C. Pool 25 was at normal pool conditions. The MV Boyer was used to collect bathymetry, velocity, and hydroacoustic fisheries data. Transects were run upstream from the bottom of the chevron dike to the apex. Four transects were run inside of each the three dikes. Depths behind the top and middle chevron dikes exceeded 8 meters. Depths behind the lower chevron dike did not exceed 5 meters. Analysis of the hydroacoustic data found similar fish densities behind the upper and middle dikes

(490 and 317 fish per acre). Fish density behind the lower chevron was very low (52 fish per acre). Densities during this sample were similar to those collected during the August 1999 sample.

Submitted: 10 September 2002

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

Appendix B.

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

Multiple Round Point Structures
Preliminary Fisheries Evaluation

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

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

May 2002

Introduction

Since August 1998, the Illinois Department of Natural Resources, Division of Fisheries, Boundary Rivers Program has collected twelve fish samples (245 min) with A.C. electrofishing (EF) at the Multiple Round Point Structures constructed by the St. Louis District, Corps of Engineers at Mississippi River mile 256.6L. The sampling was conducted to obtain information on the composition of fishes utilizing these structures.

Methods

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

Results and Discussion

A total of 993 fish (60.80 fish/15min ef), representing 24 species were collected on the twelve sampling runs (245 minutes total) [Table 1 and Table 2]. Emerald shiner, gizzard shad and flathead catfish exhibited the highest overall catch rates, followed by carp, freshwater drum, spotfin shiner and channel catfish (Table 2). Emerald shiner and freshwater drum were collected on each sampling trip, carp, channel catfish, flathead catfish and shorthead redhorse were collected on at least 10 of 12 trips (Table 2).

A notable species collected in this effort is the blue sucker. This big river species is uncommonly collected in the Mississippi River and is considered a species of special concern by state and federal natural resources agencies. The collection of a blue sucker on 4 of 12 sampling runs may indicate that these fishes are seeking the habitat conditions provided by these structures. Other species of interest include the stonecat, river darter and slenderhead darter. These riffle loving species are also infrequently collected with boat electrofishing and their presence in these collections may indicate quality habitat conditions are present for these fishes.

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

Conclusion

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

Table 1. Sampling dates and electrofishing effort for Pool 25 Multiple Round Point Structures, 1998-2001.

Sampling date	Electrofishing effort (min)
18-Aug-98	22
15-Oct-98	15
07-Sep-99	20
22-Sep-99	30
23-May-2000	15
28-Aug-2000	20
26-Sep-2000	20
17-Oct-2000	22
24-Jul-2001	25
20-Aug-2001	21
17-Sep-2001	20
16-Oct-2001	15
Total min.	245

Table 2. Composition of fishes collected with A.C. electrofishing at Pool 25 Multiple Round Point Structures, 1998-2001 (245 total minutes ef).

Species	Number	% of total	No./15min	Frequency of occurence
Gizzard shad	91	9.16	5.57	7
Mooneye	1	0.10	0.06	1
Carp	59	5.94	3.61	11
Silvery minnow	4	0.40	0.24	1
Spotfin shiner	33	3.32	2.02	7
Red shiner	13	1.31	0.80	6
Bullhead minnow	4	0.40	0.24	4
Emerald shiner	546	54.98	33.43	12
Silverband shiner	1	0.10	0.06	1
River shiner	5	0.50	0.31	3
Sand shiner	2	0.20	0.12	2
Mimic shiner	23	2.32	1.41	8
Smallmouth buffalo	9	0.91	0.55	6
Blue sucker	9	0.91	0.55	4
Shorthead redhorse	24	2.42	1.47	10
Channel catfish	31	3.12	1.90	11
Flathead catfish	71	7.15	4.35	11
Stonecat	2	0.20	0.12	2
White bass	3	0.30	0.18	2
Green sunfish	12	1.21	0.73	6
Bluegill	2	0.20	0.12	2
River darter	2	0.20	0.12	1
Slenderhead darter	1	0.10	0.06	1
Freshwater drum	45	4.53	2.76	12
Totals	993	100.00	60.80	
Total no. spp.	24			

Table 3. Composition of fishes collected with A.C. electrofishing at Pool 25 Multiple Round Point Structures, 1998 - 2001.

sampling month	8/98	10/98	9/99	10/99	5/00	8/00	9/00	10/00	7/01	8/01	9/01	10/01	Totals
sampling effort (min)	22	15	20	30	15	20	20	22	25	21	20	15	245
Species													
Gizzard shad	22	30	1	5	17			13	3				91
Mooneye						1							1
Carp	3		5	12	3	6	1	2	5	5	6	11	59
Silvery minnow										4			4
Spotfin shiner					1	5	3		10	8	4	2	33
Red shiner			1			1		1	4	3	3		13
Bullhead minnow							1	1	1	1			4
Emerald shiner	41	8	31	1	1	87	55	164	24	51	52	31	546
Silverband shiner												1	1
River shiner								2	1	2			5
Sand shiner						1		1					2
Mimic shiner				4	1	1	2	5	2	4	4		23
Smallmouth buffalo	2	2	2						1	1	1		9
Blue sucker	1	1	6	1									9
Shorthead redhorse	2	3	2	3		3	1	1	1	2	6		24
Channel catfish	5	3	3	3	4	3	1	1	6	1	1		31
Flathead catfish	14	5	13	5	2	11	4	3	1	10	3		71
Stonecat			1			1							2
White bass				1						2			3
Green sunfish			2			3		2		2	1	2	12
Bluegill			1							1			2
River darter									2				2
Slenderhead darter			1										1
Freshwater drum	2	3	4	1	1	3	12	2	2	5	9	1	45
Totals	92	55	73	36	30	126	80	198	63	102	90	48	993
Total no. spp.	9	8	14	10	8	13	9	13	14	16	11	6	24

MRPS length and weight data for selected fishes, 1998-2001

Channel catfish

N	TL(mm)	WT(g)
1	64	
1	67	
1	81	
1	83	
1	87	
1	90	
1	98	10
1	99	
1	101	20
1	103	
1	110	15
1	142	20
1	300	195
1	317	305
1	333	300
1	356	360
1	364	400
1	375	385
1	385	460
1	388	455
1	400	510
1	421	600
1	426	575
1	447	865
1	494	1240
1	500	1325
1	536	1735
1	539	1225
1	555	1660
1	678	3200

Flathead catfish

N	TL(mm)	WT(g)
1	43	
1	54	
1	60	
1	75	
1	77	
1	85	
1	88	
1	90	
1	92	
1	96	10
1	96	
1	107	10
1	110	20
1	113	20
1	115	20
1	125	30
1	125	20
1	160	50
1	165	50
1	175	55
1	178	55
1	178	50
1	181	60
1	182	70
1	182	60
1	183	65
1	186	70
1	190	90
1	191	50
1	193	70
1	196	85
1	200	100
1	201	90
1	201	75
1	202	80
1	204	95
1	206	65
1	210	120
1	214	100
1	216	95
1	217	115
1	219	140
1	220	105
1	222	130
1	224	125
1	227	125
1	230	155
1	231	125
1	231	105
1	259	170
1	264	190
1	266	220
1	266	180
1	282	250
1	285	240
1	297	255
1	308	270
1	310	300
1	312	290
1	315	330
1	315	325
1	316	320
1	335	350
1	352	440
1	353	525
1	362	500
1	398	640
1	399	675
1	420	775

Blue sucker

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

Appendix C.

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

PROCEEDINGS
OF THE
TWENTY-EIGHTH ANNUAL CONFERENCE ON EXPLOSIVES AND BLASTING TECHNIQUE

FEBRUARY 10-13, 2002
LAS VEGAS, NEVADA USA

Volume I

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INTERNATIONAL SOCIETY OF EXPLOSIVES ENGINEERS

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

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ABSTRACT

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

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

A 152-m section over a bendway weir field was blasted using a series of 3.4 kilograms (kg) charges of T-100 binary explosive. Preparation for the blast (placing charges and catch nets), took approximately 6 hours. A total of 217 fish was captured, representing 12 species. Freshwater drum (*Aplodinotus grunniens*) dominated the catch comprising 35.5% of the total catch, followed by gizzard shad (*Dorosoma cepedianum*) (27.2%), and blue catfish (*Ictalurus furcatus)* (16.6%). Conventional fish collection techniques (e.g., trotlines, trammel nets, and hoop nets) captured 12 fish specimens representing 7 species. One new species, the paddlefish (*Polyodon spathula*) was added to the species list by the conventional sampling. The most numerically abundant species taken by explosives (freshwater drum, 35.5%) was not taken by conventional sampling techniques.

INTRODUCTION

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

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

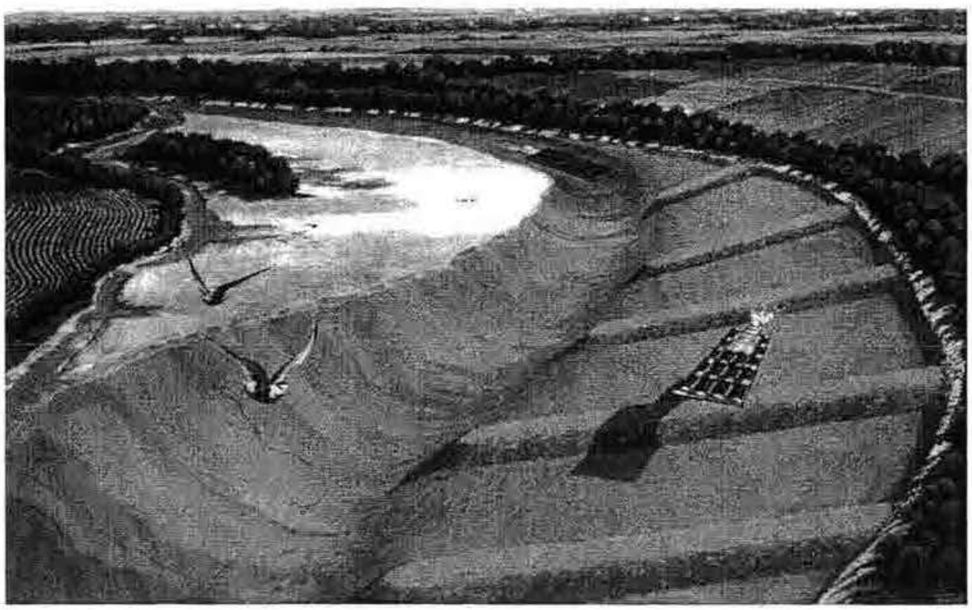

Figure 1.-Illustration of a towboat passing over a bendway weir field.

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

Table 3.-Fish species collected using conventional (trotlines, trammel nets, and hoop nets) during sampling of the Price Towhead bendway weir.

Species	Number	Total Length (cm)
Trotlines		
Blue catfish (*Ictalurus furcatus*)	1	58.2
Trammel Nets		
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	1	79.2
Paddlefish (*Polyodon spathula*)	1	23.3
Gizzard shad (*Dorosoma cepedianum*)	1	19.0
Carp (*Cyprinus carpio*)	1	65.3
Hoop Nets		
Flathead catfish (*Pylodictis olivaris*)	4	24.2, 24.8, 36.6, 40.8
Channel catfish (*Ictalurus punctatus*)	1	68.8
Blue catfish (*Ictalurus furcatus*)	2	38.1, 44.0

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

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

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

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

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

The goal of our study was to sample a single weir at Price Towhead weir field, a bendway weir field on the Middle Mississippi River, to determine the species composition at the bendway weir using both hydroacoustics and blast fishing. A hydroacoustic survey was conducted by Kasual and Baker (1996) to provide quantitative information on fish numbers, location, and size; however, hydroacoustics does not provide information on the species being observed. The blast survey was conducted to identify the fish species present at the bendway weir, thus complimenting the hydroacoustic survey.

MATERIALS AND METHODS

On 20 September 1995, a 152-m section over a bendway weir (Mississippi River Mile 30.3) at Price Towhead weir field was surveyed with explosives to document fish use.

Explosive. IBLAST (Coastline Environmental Services Ltd 1986), a fish mortality model, was used to determine the explosive charge size required to kill fish within 30 m of the blast. The calculated charge weight was then increased by 1/3 to ensure mortality. Fish sampling blasts utilized 3.4 kg charges of T-100 Two Component (green stick) explosive and initiated by two Atlas #8 instantaneous electric blasting caps. Slurry Explosive Corporation's T-100 Two component is a water-resistant, Class A, high explosive with a 1.6 relative bulk strength equivalency to ammonium nitrate and fuel oil (ANFO). It has a detonation velocity of 14,000 mps and a density of 1.22 grams per cubic centimeter (Slurry Explosive Corporation 1991).

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

Fish Recovery. Six chase boats and sixty-three catch nets were used to capture fish. Each chase boat had a minimum crew of three, a boat operator and two dip netters. The catch nets each had a 1.2 m diameter opening and either 4.8 mm or 19.05 mm mesh. The catch nets had a bridle with a swivel clip to keep the net from fouling in the current. Catch nets were fastened to a 12.5 mm steel cable that was attached to a 680 kg anchor and a buoy on the other end of the cable to keep the line taut. Twenty-one lines, each with three catch nets, were set. Catch nets were attached at 3 m below the buoy (surface), 3 m above the anchor (bottom), and at the mid-point between the two (middle) based on depth.

Conventional Fishery Survey Methods. Two 91.5 m trotlines, each with 50-hooks bated with cut shad were set on September 26, 1995, parallel to the shoreline at River Mile (R.M.) 29.8 and R. M. 29.6.

Two 45.7 m trammel nets (outer panel 25.4 cm, inner panel 5.08 cm bar mesh) were set on September 26th. The first was set below the weir, parallel to the shoreline at R.M. 30.1 and the second was set at R.M. 29.8, parallel and downstream of the weir. Three hoop net sets, each with 4 hoop nets, were set on September 25th at R. M. 30.5,5, 30.5 and 30.3, parallel to and downstream of a weir in the field. Each hoop net had a 1.2 m diameter mouth, two had 38.1 mm mesh and two had 19.05 mm mesh. All gear was retrieved on September 27th (trotlines, 24 hr. set, trammel nets, 24 hr. set, hoop nets 48 hr. set).

RESULTS

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

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

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

Conventional fish collection techniques (e.g., trotlines, trammel nets, and hoop nets) captured twelve fish specimens representing seven species (Table 3). One blue catfish was caught on the two trotlines. Four specimens of four species (1 gizzard shad, 1 carp, 1 paddlefish (*Polyodon spathula)*, 1 sturgeon) were caught in gill nets. Three species (4 flathead catfish, 2 blue catfish and 1 channel catfish) were captured in hoop nets.

DISCUSSION

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

Fish detected in the pre-blast hydroacoustic survey of Price Towhead (Kasual and Baker 1996) varied in size from approximately 3 to 96 cm. The mean fish size was approximately 9 cm. Approximately 80% of the fish were ≤ 5 cm. Based on the abundance and size distribution of fish collected during the blast survey, it would appear that many of these fish were gizzard shad. Eight echoes of fish that were approximately 50 cm or larger were all found on the downstream side or downstream base of the weir. Blast fishing produced four species: blue catfish, channel catfish, drum, and buffalo that exceed 50 cm total length.

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

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

Conventional fish collection techniques (e.g., trotlines, trammel nets, and hoop nets) were ineffective capture methods in the bendway weir field when compared with the blast fishing. Twelve fish specimens were collected using conventional collection methods compared with 217 by blast fishing. There were only two species (blue catfish, 3 specimens and flathead catfish, 4 specimens) with more than one specimen collected by conventional methods. The larger number of fish collected using blast fishing produced a better size distribution of specimens to compare with the hydroacoustic survey data. Only seven species were collected using conventional techniques compared with 12 species taken by explosives. One new species, the paddlefish (*Polyodon spathula*) was added to the species list by the conventional sampling. The most numerically abundant species taken by explosives (freshwater drum, 35.5%) was not taken by conventional sampling techniques. The gill net set parallel to the revetted shoreline became twisted in the high water currents and no fish were collected in this net.

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

In August of 1994, an attempt was made to sample the same bendway weir field using explosives. Capture boats and a 91.4 m long experimental gillnet were deployed to capture fish. The net was deployed downstream of the blast. After the blast the net was gone. The ropes attaching the net to the anchor buoys had snapped in the high currents. The 1.2 m mouth opening catch nets used during 1995 sampled only a small fraction of the water column below the bendway weir. Deployment of large gill nets would have sampled a much larger portion of the water column than possible with the catch nets. It may be possible to design gillnets to withstand the high currents and increase catch efficiency. Because of the high current, small mesh sizes may be impractical. Although more fish may be captured, they may be larger specimens. Another potential sampling method would be to drift experimental gill nets between two boats that are moving downstream slower than the currents. Should additional bendway weir blast sampling be conducted, it is recommended that the drift net capture method be tested and nets should be specially designed to withstand the high water velocities, thus increasing catch efficiency.

The results of this study indicate that blast sampling provided an effective technique to sample the bendway weir field when combined with the hydroacoustic survey. Blast sampling provided species composition data and the hydroacoustic survey provided fish location, density, and size data. Fish species composition and density data would have been extremely difficult, if not impossible, to obtain using conventional fishery techniques.

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Appendix D.

Response of Fish, Invertebrates, Vegetation, Waterbirds, and Water Quality to Environmental Pool Management: Mississippi River Pool 25. Southern Illinois University

Response of Fish, Invertebrates, Vegetation, Waterbirds, and Water Quality to Environmental Pool Management: Mississippi River Pool 25

Annual Progress Report

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Response of Fish, Invertebrates, Vegetation, Waterbirds, and Water Quality to Environmental Pool Management: Mississippi River Pool 25*

Introduction

Water levels in Pool 25, Mississippi River, are currently managed at a midpool control point located near Mosier Landing at river mile 260.3 by the U.S. Army Corps of Engineers (USACE), St. Louis District. To maintain a 2.7-m navigation channel, water levels are managed between 434 - 437 ft at Mosier Landing and from 429.7 - 434 ft at Lock and Dam 25 over a specific range of discharges. During moderate flows, the pool becomes "tilted" when gates are lifted to maintain water levels at the midpool control point. 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 (L&D 25 Water Control Plan). If the discharge

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continues to fall, the pool is regained based on discharge rates. Typically, the Corps starts to regain pool when the discharge causes the water level at Mosier Landing to fall below 437.0 feet. Herein, "drawdown" is synonymous with the maximum drawdown which generally follows spring floods.

Resource agencies recognize the need to work in conjunction with the USACE to improve hydrologic conditions for biota within the constraints of a multi-use system (Woltemade 1997). Given the real estate constraints that the St. Louis District operates under, the L&D has limited control over the timing of the drawdown during open river conditions. However, there is some flexibility in how water levels are managed during the return of the river to the target pool elevation. From 1994 to 1999, the time period conducive to water-level management ranged from approximately 38 to 57 days.

The operational goal of Environmental Pool Management (EPM) is to maintain relatively low, stable water levels in the lower portion of the pool, following drawdown in the spring, in order to better simulate the natural hydrograph (Figure 1). Under some circumstances (e.g., high discharges), water levels in Pool 25 may descend to elevations greater than 2.0 feet below the target pool elevation due to management of the pool with a midpool control point. When implementing EPM, however, water levels are held 0.5 to 2.0 feet below the target pool elevation (434 ft in Pool 25) at the lock and dam for at least 30 days (Atwood et al. 1996). Environmental Pool Management prolongs the dry phase during the summer growing season for nonpersistent wetland vegetation. Vegetation produced by EPM is primarily found in backwaters located in the lower reach of the pool. The St. Louis District implemented EPM in 1994 on Pools 24, 25, and 26. Early investigations of mudflats exposed via EPM showed lush production of nonpersistent wetland vegetation consisting mainly of millet, chufa, and smartweeds (Atwood et al. 1996).

Recently, intensive evaluation of EPM in Pool 25 was initiated by personnel from the Southern Illinois University Cooperative Wildlife Research Lab, the Fisheries and Illinois Aquaculture Center, and the Southern Illinois University Department of Zoology. The goals of this research were to quantify plant responses, estimate above ground seed production, and measure invertebrate, waterfowl, fish, and water quality responses to EPM. During previous research, we documented substantial seed production by moist-soil plants and heavy use of vegetated areas by waterfowl during spring migration. Inundated emergent vegetation provided cover for juvenile cyprinids in late summer and early fall, and residual vegetation was used as nursery habitat by the young of many fish species in late winter and spring. However, given the high inter-annual variability in river hydroperiod, data associated with one drawdown cycle was not adequate to evaluate EPM. Furthermore, the data indicated a complex response by fish and aquatic macroinvertebrates that required additional sampling to understand.

In order to better manage water levels in Mississippi River pools to benefit fish, waterfowl, and other wetland organisms, it is imperative that data are collected during years with different drawdown regimes. A goal of the current research is to document responses to EPM over two additional drawdown cycles (Summer/Fall/Spring 2000-2001; Summer/Fall/Spring 2001-2002). Combined with data collected over the 1999-2000 drawdown cycle, these additional data will lead to a better understanding of how EPM can be refined to maximize ecological benefits to wetland dependent taxa.

Objectives

1. Quantify emergent vegetation response and estimate above ground seed biomass produced by EPM in the lower end of Pool 25, UMR.
2. Characterize waterbird use of EPM created habitat.
3. Quantify fish use of emergent vegetation created by EPM.
4. Quantify aquatic macroinvertebrate abundance, diversity, and biomass, and assess how they are related to available vegetation and EPM.
5. Determine effects of vegetation on water quality and zooplankton communities.
6. Characterize fish use of residual vegetation produced by EPM.
7. Evaluate the influences of timing, length, and severity of EPM drawdown on fish and invertebrates.

Current Progress

Water levels in 1999 remained 0.5 ft below an elevation of 434 ft (full pool) for 70 days over the period from mid June to mid August and were greater than 2.0 ft below full pool for 54 days, resulting in an exceptional vegetation response (Figure 2). Following a second maximum drawdown event in late June of 2000, water levels remained 0.5 ft below full pool for 30 days and below 432 ft for 22 days before returning to full pool in early August (Figure 2). Mud flats were not exposed for a long enough period in the summer of 2000 to allow plant germination and/or enough growth to withstand inundation except at the highest elevations. Water levels in summer of 2000 were purposely maintained as high as possible by the St. Louis District. Therefore, we had the opportunity to evaluate biotic and abiotic responses in a year where vegetation production and drawdown magnitude were great and in a year with very little vegetation production. During the EPM cycle of 2001, the drawdown resulted in a vegetation response different from what occurred in 1999 and 2000. Consequently, we will have studied three drawdown cycles that can be characterized according to vegetation production as exceptional (1999), minimal to none (2000), and moderate (2001) by the time the project is completed.

Objective 1. Plant response. The hydrograph during summer 2000 was variable (Figure 2). Although low water conditions did occur during the growing season, the rise in water levels during June prevented successful establishment of emergent macrophytes. We did not collect plant composition data along transects during summer 2000.

We collected vegetation composition data, beginning 3 weeks post-drawdown, during 1-3 August 2001. Data were collected for 11 transects in Batchtown. We used a GPS to relocate each transect origin that had been georeferenced in 1999. Transects were oriented perpendicular to the shoreline and followed the elevation gradient. A single 0.5-m^2 sample square 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). In each square, we recorded occurrence and percent cover for each plant species. We also collected plant composition data in three 0.5-m^2 sample squares for each vegetated study plot included in the paired-plot field experiment designed to measure responses to EPM (see Objectives 3, 4, and 5). Nomenclature follows Scott and Wasser (1980) and Mohlenbrock (1986).

Fourteen species of wetland plant were recorded during 2001. Species of sedge in the genus *Cyperus* were most common, occurring in 68.5% of samples, followed by pigweed (*Amaranthus sp.*) and millet (*Echinochloa crusgalli* and *E. muricata*; Table 1). Smartweeds (*Polygonum* sp.), the most common plant in 1999, were found in < 30% of plots in 2001. Similar to 1999, the abundance of each species varied little with elevation, the exception being river bulrush (*Scirpus fluviatilis*), which only occurred at the lowest elevations (Table 2).

We collected data on seed biomass on 19-20 September 2001 and estimated seed biomass using techniques developed by Laubahn and Fredrickson (1992). This technique uses a series of regression equations developed from seed bead and plant height dimensions for a single plant species or a group of 2 or 3 species (Laubahn and Fredrickson 1992). Including all species, our estimate for seed biomass was 3,336 $\pm$ 3,737 lbs/ac (Table 3). Excluding Red-root nutsedge, the estimate was 1,552 $\pm$ 1,739. Similar to 1999, the estimate for red-root seems overinflated. It is possible that morphological characteristics of the plant in Batchtown (plants were extremely large) fall outside the range of morphology measures used to develop the regression equations; thus biasing the estimate high. Estimates of sedge biomass were high in both 1999 and 2001; however, while *Polygonum* dominated in 1999, *Echinochloa* and *Leptochloa* dominated in 2001.

Preliminary results indicate EPM continues to produce a plant community comprised mainly of moist-soil species that generate abundant seeds used as food for waterfowl. Differences in plant species community between 1999 and 2001 likely reflect differences in the timing of the dewatering event between years. The relatively uniform plant community that develops along the elevation gradient likely reflects the relatively quick rate of dewatering that occurred in both years. This was the last year that plant data will be collected.

Objective 2. Waterbird response. Shortly after dewatering in 2001, we conducted a waterbird count including the Batchtown area and Turner Island. The goal of the survey was to evaluate the use of exposed mudflats, which can provide important habitat for species like shorebirds. Shoreline habitats were counted from a boat where possible; the interior horseshoe area of Batchtown was surveyed on foot. Using binoculars and a 20-60x spotting scope, we recorded all waterbirds seen along the survey route.

We found 7 species in the survey area, and overall abundance was low (138 total individuals). Killdeer (*Charadrius vociferus*) were most common (105 individuals) followed by Great-blue Heron (*Ardea herodias*, 14), Pectoral Sandpiper (*Calidris melanotos*, 7), Canada Goose (*Branta canadensis*, 7), Great Egret (*Ardea alba*, 3), Ring-billed Gull (*Larus delawarensis*, 2) and Spotted Sandpiper (*Actitis macularia*, 1).

Use of mudflat habitats by migratory shorebirds will depend, in part, on the timing of habitat availability relative to migration chronology of these species. Given mudflat availability was highest prior to the arrival of fall migrating shorebirds in August and September, low numbers are not unexpected. However, variability in the timing of dewatering (either earlier or later), may provide substantial habitat benefits for shorebirds. The final spring field season to quantify shorebird abundance and behavior will begin in early February 2002.

Winter/spring waterfowl surveys and behavioral observations were conducted during February and March 2001. Surveys were conducted from the bow of a boat in the 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 reservoir 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 (O ^{0}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.

Variable river levels and dangerous ice conditions made survey efforts difficult during 2001. As a result, we were unable to survey every week during the period of interest. Because of the hydroperiod during summer 2000, little residual vegetation was available to waterfowl during spring migration 2001. Not surprisingly, bird abundance was lower than in 2000, a year following extensive dewatering in 1999. Similar to 2000, mallards (*Anas platyrhynhcos*) were most abundant. Waterfowl survey and behavior data are currently being analyzed. We will begin collecting the final year of waterfowl data in early February 2002.

Objective 3. Fish use of emergent vegetation. In 1999, we sampled fish, macroinvertebrates, and water quality in two experimental plots established at each of four study sites (Jim Crow, Turner, Batchtown East, Batchtown West) (Figure 3 and Table 4). One experimental plot was devegetated with a herbicide, and the other plot was left vegetated at each study site in 1999. Due to the sparse amount of vegetation produced in the summer of 2000, we did not apply herbicide to any experimental plots located at sites in lower Pool 25, and plots generally did not contain any vegetation. Some sites did contain a narrow band (approximately 1 m) of vegetation along the shoreline, but vegetation at this elevation (water depth) was not sampled in 1999 and, therefore, not considered to be within the experimental plots. We sampled fish, invertebrates, and water quality in the fall of 2000 in the two previously established experimental plots at a given site in a manner similar to the methodology used in the fall of 1999. Herein, we refer to experimental plots in 2000 as "vegetated" and "devegetated" even though neither plot contained vegetation or received an herbicide application. Plots at a new site (Dixon Pond) were sampled in addition to plots at previously established sites (Jim Crow, Turner Island, Batchtown East, Batchtown West) (Figure 3 and Table 4).

In contrast to 1999, there was no structural habitat difference (cover vs. no cover) between vegetated and devegetated plots in 2000. This enabled us to sample fish from both plots with a similar method. Fish were collected from each 400-m^2 plot with a 3.7-m seine (1.6-mm mesh) on three sampling trips (15 September - 20 October 2000). Two seine hauls, each 10 m long, were made in both plots at all five sites during each sampling trip. Experimental plots at most sites were shallow, open water habitats, but plots at Jim Crow did contain sparse amounts of vegetation. An approximately 1-m band of inundated emergent vegetation existed along the shoreline at Turner Island, Batchtown East, Batchtown West, and Dixon Pond. Five kicksets were conducted in the shoreline vegetation at all four sites on at least one occasion (Turner Island - 3 samples; Dixon Pond - 2 samples; Batchtown East - 1 sample; Batchtown West - 1 sample). An intensive analysis of all of the data has not been conducted at this time, but we present some findings and discuss general trends below.

We collected 15,703 fish, including 17 taxa, by seining at the five sites located in lower Pool 25 in fall 2000 (Table 5). Despite a relatively modest amount of sampling effort (number of samples and total area) in the shoreline vegetation as compared to effort in the experimental plots, approximately 70% of all of the fish were captured in the narrow band of shoreline vegetation. Also, 9 fish taxa were collected in the shoreline vegetation that were not found in the experimental plots. Fish community structure, as described by number of individuals, number of taxa, and concordance of ranks, was very similar between experimental plots (Table 6). This is to be expected since no habitat difference existed between plot treatments.

With the exception of Jim Crow, habitat structure at sites in the fall of 2000 was very different from that available in 1999, and is reflected in the fish samples. Treatment plots in Jim Crow slough responded differently to EPM in 1999 and 2000 compared to plots at other sites; therefore, we do not include data from Jim Crow in the discussion that follows. In general, vegetated plots in 1999 were numerically dominated by western mosquitofish (*Gambusia affinis*) and YOY (young-of-year) spotfin shiners (*Cyprinella spiloptera*) and channel shiners (*Notropis wickliffi*), whereas emerald shiners (*Notropis atherinoides*) were most abundant in devegetated plots. In contrast, the so-called vegetated and devegetated plots in 2000 were both dominated numerically by emerald shiners and contained few species (Table 6). Devegetated plots in 1999 and 2000 were characterized by high numbers of emerald shiners, but devegetated plots in 1999 tended to have higher numbers of species (Tables 7, 8, 9, 10). This is an indication that, to a degree, devegetated plots in 1999 were influenced by the proximity of dense stands of vegetation. Vegetation present in 2000 was restricted to a narrow band along the shoreline, but this narrow band generally contained more fish species than vegetated plots in 1999. The vegetation in 2000 functioned as edge habitat, similar to the vegetated edge in 1999; however, direct comparisons are complicated by many variables (e.g., water depth). In addition to providing the opportunity to examine the littoral zone fish community without the presence of dense stands of emergent vegetation, fish sampling in 2000 gave us insight into the interpretation of our experimental approach (i.e., vegetated vs. devegetated plots).

The difference in vegetation production between 1999 and 2000 influenced fish communities in habitats sampled, but the effect of the hydrology underlying EPM was also evident. During the drawdown of 1999, we documented deteriorated conditions (e.g., low dissolved oxygen, high water temperatures, and lack of water) in backwater's of lower Pool 25 due to the length of time they were isolated from the main channel (54 consecutive days below 432 ft). In contrast, backwaters remained connected throughout most of the summer of 2000, and were isolated no more than 22 consecutive days. In 2000, mean number of centrarchids captured per trip at a given site (mean = 9.11) was higher than in 1999 (mean = 0.88). Dixon Pond was not sampled in 1999 and not included in this analysis. The centrarchid response was most evident at Jim Crow slough where no sunfish were collected in 1999 but 175 were captured in 2000 (Table 9). The centrarchids in 2000 were primarily comprised of orangespotted sunfish (*Lepomis humilis*) and bluegill (*Lepomis macrochirus*). In fall of 1999, only one bluegill (an adult) was collected, whereas, 86 bluegill (mostly YOY) were captured at 3 of the 4 same study sites (Tables 7, 8, 9, 10) in 2000. Both orangespotted sunfish and bluegill were relatively abundant at Dixon Pond in 2000 (Table 5). Sunfish, particularly bluegill, benefited from the drawdown cycle of 2000 compared to the drawdown of 1999.

Similar to 1998 and 1999, we collected fish by boat electrofishing (one pilot, one dip netter) within the large bay in Batchtown (near Batchtown West) on 25 October 2000 (Figure 3). Electrical current was supplied by a 3-phase 5 KW generator producing 240 volts AC. Electrofishing time was 1 hr, and fish were netted with a dipnet having a mesh size of 6.4 mm.

Vegetation was not present, but sampling was done along the shoreline perimeter of the bay similar to previous years. Gizzard shad (*Dorosoma cepedianum*) and freshwater drum (*Aplodinotus grunniens*) were the most abundant fish collected (Table 11). Fewer species were captured in 2000 compared with previous years; this may have been due to the lack of shoreline structure (Table 11).

Enough vegetation was produced in the summer of 2001 for us to repeat the experimental approach used in 1999. We applied a herbicide to the "devegetated" plot at all previously established sites (Turner, Jim Crow, Batchtown East, Batchtown West, and Dixon Pond) prior to reflood. An additional plot was treated with herbicide on Hausgen Island, bringing the total number of sites to six (Figure 3). Following reflood, fish were sampled in all plots on three occasions (8 Sep 01 to 6 Oct 01) and fixed in 10% formalin. An electrofishing sample was also taken in Batchtown on 4 Oct 01. Fish samples taken in the fall of 2001 have not been processed at this time.

Objective 4. Macroinvertebrate responses to emergent vegetation. Five sites in lower Pool 25 (Jim Crow, Turner, Batchtown West, Batchtown East, Dixon Pond) were chosen to study macroinvertebrate community responses to the presence or absence of vegetation (Figure 3). Within each site, a paired-plot consisting of a 400-m^2 vegetated and a 400-m^2 devegetated plot was designated (see Objective 3). In 2001, devegetated plots were made using the aquatic herbicide Rodeo® and a backpack sprayer during the summer drawdown period. Three 314-cm^2 stovepipe core samples were taken within each vegetated and devegetated site after late summer/fall reflood. Samples were taken from experimental plots in fall of 2000 and 2001.

In the laboratory, samples are processed to remove all macroinvertebrates by washing through nested sieves (1 mm and 250 um mesh sizes). Invertebrates in large fractions (>1 mm) are removed by hand, and fine fractions are processed under a dissecting microscope. Following removal from samples, invertebrates are identified to the lowest practical taxonomic level (usually genus) and length-mass regressions are used to convert densities into biomass. Final analyses will include diversity, density, and biomass of invertebrates in vegetated and devegetated plots.

Benthic core samples are also being analyzed to quantify benthic organic matter available to macroinvertebrates. Fine particulate organic matter (FPOM = < 1mm > 250 um) and coarse particulate organic matter (CPOM = > 1mm) can be important determinants of invertebrate diversity and productivity, and these analyses will shed light on factors influencing the observed patterns. After separation of organic matter size classes in sieves, organic matter resources are dried and ashed to estimate ash-free dry mass (AFDM) of organic matter resources available to benthic macroinvertebrates.

Currently, all benthic core samples collected during fall 2000 have been processed to remove and sort invertebrates and organic matter, and are currently being identified and weighed. The 2001 samples are being processed to remove macroinvertebrates and sort organic matter.

Objective 5. Water quality and zooplankton responses to emergent vegetation. Point-in-time measurements of major water quality variables (dissolved oxygen, temperature, pH, conductivity, and turbidity) and water depth were made in each plot on each sampling trip in

2000 between 1045 and 1600 hrs. Dissolved oxygen and temperature were measured with a Yellow Springs Instrument YSI Model 95 digital meter. Dissolved oxygen and temperature were measured at approximately 5 cm below the water's surface and 5 cm above the substrate if water depth exceeded 30 cm. A Hanna Instruments pHep®2 pocket-sized meter was used to measure pH. Dissolved ion concentration was measured with a YSI Model 33 conductivity meter. Conductivity and pH were measured at approximately 5 cm below the water's surface. Turbidity was measured in each plot with a LaMotte Model 2020 turbidimeter. A wooden meter stick was used to measure water depth. Habitat measurements in fall 2000 were generally similar to fall 1999 (Table 12). One exception was that we did not find dissolved oxygen lower than 7.8 mg/L in any location in 2000. In contrast, we found dissolved oxygen to be as low as 1.4 mg/L in the vegetation during fall 1999.

Vertically integrated zooplankton samples were taken in triplicate from each plot in fall 2000 with a modified littoral sampling tube (Pennak 1962). Samples were filtered through a Wisconsin-style plankton net that had a collection bucket lined with 80 µm Nitex® mesh. Samples were preserved in 5% buffered formalin. Laboratory analysis of these samples has not been completed.

Objective 6. Fish use of residual emergent vegetation. We sampled YOY fish and water quality at 14 sites in lower Pool 25 from 21 May to 24 June 2000. Young fish were sampled within a 30-m reach of shoreline with a 3.7-m seine (1.6 mm mesh). Residual smartweed stalks, remaining from the fall of 1999, were present at three of the sites. Fish were fixed in 10% formalin in the field. Laboratory analysis of these samples has not been completed, but it appears that many species of YOY fishes were captured in the residual, EPM-induced, vegetation.

Objective 7. Fish and invertebrate communities at midpool and lowerpool. Three sites at midpool and four sites in lower Pool 25 were chosen to study fish and macroinvertebrate communities under variable hydrologic regimes (Table 13; Figures 3 and 4). We attempted to select sites at midpool that were similar in morphology and other habitat variables to sites in the lower pool when Pool 25 is at full pool (434 ft at L&D 25). This will allow us to compare, within the same year, wetland communities in backwaters effected by EPM located in the lower pool to communities in similar habitats at midpool that are not influenced by EPM. Macroinvertebrates, fish, and zooplankton, were sampled in a 30-m study reach at each site in July (during drawdown) and September 2000 (following reflood). Samples were not taken in July at Turner and Serpent Slough due to the lack of water during this time.

Three benthic stovepipe cores ($314cm^2$ sampling area) were taken within each site to assess and compare macroinvertebrate communities. Fish were sampled in study reaches for three minutes with a 3.7-m seine (1.6 mm mesh). A fyke net was also set overnight at each site to target larger, adult fishes. Zooplankton were sampled with three 4-m hauls using a Wisconsin-style zooplankton net fitted with an 80um Nitex® mesh collection trap. Habitat measurements (wetted surface area, maximum depth, substrate, flow, and water quality) were also taken in association with all biological sampling. Fish, macroinvertebrate, and zooplankton samples are currently being processed in the laboratory.

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Table 1. Percent occurrence of plant taxa in sample plots located along an elevation gradient (cm) relative to full pool (132.3 m. NGVD, $n = 11$ transects). Data are for the Batchtown area of Pool 25, Mississippi River, during summer 2001.

	Elevation below full pool (cm)					
Taxa	5	20	35	50	75	Overall
Cyperus[c]	72.7	72.7	72.7	80.0	54.5	68.5
Amaranthus rudis	63.6	63.6	63.6	50.0	54.5	59.3
Echinochloa[b]	63.6	72.7	54.5	45.5	27.3	52.7
Polygonum[a]	27.3	18.2	36.4	20.0	36.4	27.8
Eragrostis hypnoides	19.2	19.2	19.2	10.0	36.4	20.4
Digitaria	27.3	27.3	9.1	9.1	0.0	14.5
Ipomea purpurea	18.2	9.1	18.2	9.1	9.1	12.7
Leptochloa panicoides	9.1	9.1	18.2	9.1	9.1	10.9

Table 1. Continued.

	Elevation below full pool					
Taxa	5	20	35	50	75	Overall
Ludwigia	--	--	19.2	9.0	18.2	9.1
Leersia oryzoides	9.1	9.1	9.1	9.1	9.1	9.1
Lindernia dubia	--	9.1	--	--	18.2	5.5
Scirpus	--	--	--	18.2	9.1	5.5
Xanthium strumarium	9.1	--	9.1	--	--	3.6

[a]Includes *Polygonum lapathifolium* and *P. pennsylvanicum*
[b]Includes *Echinochloa crusgalli* and *E. muricata*
[c]Includes *Cyperus esculentus* and *C. erythrorhizos*
[d]Includes *Populus* spp., *Acer* spp., and *Salix* spp.

Table 2. Mean percent cover (SE) of plants along an elevation gradient (cm) relative to full pool (132.3 m. NGVD) in Pool 25, Mississippi River, during summer 2001. Transects (n = 11) were oriented perpendicular to the shoreline.

	Elevation below full pool					
Taxa	5	20	35	50	75	Overall
Cyperus	12.5 (8.0)	9.0 (4.1)	13.4 (6.4)	8.1 (4.4)	13.7 (7.3)	11.3 (2.7)
Amaranthus	7.3 (5.8)	6.3 (3.1)	9.5 (3.9)	6.4 (4.2)	3.8 (2.6)	6.6 (1.8)
Echinochloa	24.3 (10.6)	13.9 (6.1)	6.2 (3.8)	4.4 (2.4)	5.2 (5.0)	10.8 (2.9)
Polygomum	1.5 (1.0)	2.1 (1.8)	3.9 (2.4)	2.4 (2.0)	4.0 (2.4)	2.8 (1.3)
Eragrostis hypnoides	tr[d]	7.3 (5.1)	2.5 (2.3)	tr	2.9 (2.2)	2.7 (1.2)
Digitaria	3.4 (3.2)	tr	tr	tr	--	tr
Ipomea purpurea	tr	tr	tr	tr	tr	tr
Leptochloa panicoides	tr	2.7 (2.7)	tr	tr	tr	tr
Ludwigia	--	--	tr	tr	tr	tr
Leersia oryzoides	tr	7.3 (7.3)	3.6 (3.6)	tr	1.4 (1.4)	2.6 (1.6)
Lindernia dubia	--	tr	--	--	tr	tr
Scirpus fluviatilis	--	--	--	12.3 (8.8)	7.3 (7.3)	3.9 (2.3)
Xanthium strumarium	tr	--	--	--	--	tr

[a]Includes *Polygonum lapathifolium* and *P. pennsylvanicum*
[b]Includes *Echinochloa crusgalli* and *E. muricata*
[c]Includes *Cyperus esculentus* and *C. erythrorhizos*
[d] tr = < 1.0%

Table 3. Estimated seed biomass (kg/ha) produced by moist-soil plants measured at Batchtown in Pool 25, Mississippi River, during summer 2001. Seed biomass estimates were calculated using regression equations developed by Laubahn and Fredrickson (1992).

Taxa	*n*	Mean	SD
Echinochloa	120	909	742
Leersia oryzoides	120	36	119
Cyperus erythrorhizos	120	1,783	2,868
Leptochloa panicoides	120	486	953
Polygonum lapathifolium	120	120	239
Total		3,336	

Table 4.

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

Site	Locality
Batchtown East	Pool 25, Mississippi River; approx. 0.5 mi North of boat ramp in Cockrell Hollow; Calhoun Co. Illinois; T12S, R2W, Sec 6; N39^{0}02.361 W90^{0}40.669; River Mile 244.5
Batchtown West	Pool 25, Mississippi River; in northend of large bay; Calhoun Co. Illinois; T12S, R2W, Sec 6; N39^{0}02.362 W90^{0}41.456; River Mile 244
Jim Crow	Pool 25, Mississippi River; slough on Jim Crow Island; Lincoln Co. Missouri; T50N, R3E, Sec 25; N39^{0}03.792 W90^{0}42.685; River Mile 246
Turner	Pool 25, Mississippi River; southern tip of Turner Island; Calhoun Co. Illinois; T12S, R2W, Sec 1; N39^{0}02.720 W90^{0}42.347; River Mile 244.5
Dixon Pond	Pool 25, Mississippi River; southern shoreline of Dixon Pond complex; Calhoun Co. Illinois; T12S, R2W, Sec 6; N39^{0}03.090 W90^{0}41.081; River Mile 245
Hausgen	Pool 25, Mississippi River; backwater shoreline of Hausgen Island; Lincoln Co. Missouri; T50N, R3E, Sec 24; River Mile 247

Table 5. Species abundance and richness in vegetated (Veg) and devegetated (∅) plots and in shoreline vegetation (Shore) at five sites in Pool 25, Mississippi River. Numbers represent pooled seine samples from three sampling trips during fall 2000. Vegetation produced via EPM was limited to a narrow band along the shoreline; therefore, experimental plots did not contain vegetation in fall 2000.

	Batchtown West			Batchtown East			Jim Crow	
Species	Veg	∅ Plot	Shore	Veg	∅ Plot	Shore	Veg	∅ Plot
Cyprinus carpio	0	0	1	0	0	1	11	11
Cyprinella lutrensis	0	0	0	0	0	0	0	0
Cyprinella spiloptera	0	1	89	0	0	279	291	689
Notropis atherinoides	7	29	4	3	1	23	72	75
Notropis blennius	0	0	1	0	0	0	7	2
Notropis ludibundus	0	0	0	0	0	0	7	3
Notropis wickliffi	2	0	4	0	1	135	212	402
Pimephales notatus	0	0	0	0	0	2	2	0
Pimephales vigilax	0	0	0	0	0	14	4	0
Carpiodes sp.	0	0	0	0	0	0	0	0
Ictalurus punctatus	0	0	0	0	0	0	1	0
Gambusia affinis	0	0	3036	0	0	2968	999	1279
Lepomis humilis	2	1	1	0	0	13	31	60
Lepomis macrochirus	0	0	0	0	0	4	30	49
Lepomis cyanellus	0	0	1	0	0	0	0	0
Lepomis sp.	0	0	0	0	0	0	0	4
Micropterus salmoides	0	0	0	0	0	0	0	1
Aplodinotus grunniens	0	0	0	0	0	0	0	2
Totals:								
Number of Taxa	3	3	8	1	2	9	12	11
Fish Abundance	11	31	3,137	3	2	3,439	1667	2577

Table 5. Continued

Species	Turner Island Veg	Turner Island Ø Plot	Turner Island Shore	Dixon Pond Veg	Dixon Pond Ø Plot	Dixon Pond Shore
Cyprinus carpio	0	0	4	0	0	0
Cyprinella lutrensis	0	0	1	0	0	0
Cyprinella spiloptera	0	1	335	0	0	18
Notropis atherinoides	22	171	54	137	5	3
Notropis blennius	0	0	38	0	0	0
Notropis ludibundus	0	0	0	0	0	0
Notropis wickliffi	7	68	89	0	0	1
Pimephales notatus	0	0	0	0	0	0
Pimephales vigilax	0	0	2	1	0	4
Carpiodes sp	0	0	5	0	0	0
Ictalurus punctatus	0	0	2	0	0	0
Gambusia affinis	0	0	1126	0	0	2333
Lepomis humilis	0	0	9	1	0	170
Lepomis macrochirus	2	0	1	7	2	215
Lepomis cyanellus	0	0	0	0	0	0
Lepomis sp.	0	0	0	0	0	0
Micropterus salmoides	0	0	0	0	0	0
Aplodinotus grunniens	0	0	1	0	0	1
Totals:						
Number of Taxa	3	3	13	4	2	8
Fish Abundance	31	240	1,667	146	7	2,745

Table 6.

Fish collected in three stations (Veg Plot, ∅ Plot, and Shoreline) at four sites in Pool 25 of the Mississippi River during Fall 2000. Numbers represent pooled seine samples with the omission of Jim Crow. Vegetation produced via EPM was limited to a narrow band along the shoreline; therefore, experimental plots did not contain vegetation in fall 2000.

Species	Veg Plot	∅ Plot	Shoreline
Cyprinus carpio	0	0	6
Cyprinella lutrensis	0	0	1
Cyprinella spiloptera	0	2	721
Notropis atherinoides	169	206	84
Notropis blennius	0	0	39
Notropis ludibundus	0	0	0
Notropis wickliffi	9	69	229
Pimephales notatus	0	0	2
Pimephales vigilax	1	0	20
Carpiodes sp.	0	0	5
Ictalurus punctatus	0	0	2
Gambusia affinis	0	0	9463
Lepomis humilis	3	1	193
Lepomis macrochirus	9	2	220
Lepomis cyanellus	0	0	1
Lepomis sp.	0	0	0
Micropterus salmoides	0	0	0
Aplodinotus grunniens	0	0	2
Totals:			
Number of Taxa	5	5	15
Fish Abundance	191	280	10,988

Table 7. Fish abundance in stations at Batchtown East, Pool 25, Mississippi River in Fall of 1999 and 2000. Numbers are expressed as fish/sampling trip. Fish were sampled at four stations in 1999: vegetated plot (VegPlot), vegetated edge (VegEdge), devegetated plot (∅Plot) and devegetated edge (∅Edge). Vegetation production in 2000 was limited to the shoreline (Shore); therefore, neither vegetated plots (VegPlot) or devegetated plots (∅Plot) contained vegetation.

	1999				2000		
Species	VegPlot	VegEdge	∅Plot	∅Edge	VegPlot	∅Plot	Shore
Dorosoma cepedianum	0	0	0	0	0	0	0
Cyprinus carpio	15.8	0	0	0	0	0	1
Cyprinella lutrensis	0	0	0	0	0	0	0
Cyprinella spiloptera	0.6	117.7	5.2	0	0	0	279
Notemigonus crysoleucas	0	0	0	0	0	0	0
Notropis atherinoides	0	133.3	69.8	1	1	0.3	23
Notropis blennius	0	1	0	0	0	0	0
Notropis ludibundus	0	0.3	0	0	0	0	0
Notropis shumardi	0	0	0.2	0	0	0	0
Notropis wickliffi	0	1.7	0.6	0.7	0	0.3	135
Pimephales notatus	0	0.3	0	0	0	0	2
Pimephales vigilax	0	0	0	0	0	0	14
Carpiodes carpio	0	0.3	0.2	0	0	0	0
Carpiodes sp.	0	0	0	0	0	0	0
Ictalurus punctatus	0	0	0	0	0	0	0
Gambusia affinis	26.2	1.3	0.2	0	0	0	2968
Labidesthes sicculus	0	0	1.2	0	0	0	0
Lepomis cyanellus	0	0	0	0	0	0	0
Lepomis humilis	0	0.7	0	0.3	0	0	13
Lepomis macrochirus	0	0	0	0	0	0	4
Aplodinotus grunniens	0	0	0	0	0	0	0
Totals:							
Number of Taxa	3	8	7	3	1	2	9
Fish Abundance	42.6	256.6	77.4	2	1	0.6	3,439

Table 8. Fish abundance in stations at Batchtown West, Pool 25, Mississippi River in Fall of 1999 and 2000. Numbers are expressed as fish/sampling trip. Fish were sampled at four stations in 1999: vegetated plot (VegPlot), vegetated edge (VegEdge), devegetated plot (∅Plot) and devegetated edge (∅Edge). Vegetation production in 2000 was limited to the shoreline (Shore); therefore, neither vegetated plots (VegPlot) or devegetated plots (∅Plot) contained vegetation.

	1999				2000		
Species	VegPlot	VegEdge	∅Plot	∅Edge	VegPlot	∅Plot	Shore
Dorosoma cepedianum	0	0.3	0	0	0	0	0
Cyprinus carpio	35.4	0.6	0	0	0	0	1
Cyprinella lutrensis	0	0	0	0	0	0	0
Cyprinella spiloptera	6.6	15.7	0.4	0	0	0.3	89
Notemigonus crysoleucas	0	0.3	0	0	0	0	0
Notropis atherinoides	3.2	31.7	7.4	6.3	2.3	9.7	4
Notropis blennius	0	0	0	0	0	0	1
Notropis ludibundus	0	0	0	0	0	0	0
Notropis shumardi	0	0	0	0	0	0	0
Notropis wickliffi	0	3.3	0.8	0	0.7	0	4
Pimephales notatus	0	0	0	0	0	0	0
Pimephales vigilax	0	0	0	0	0	0	0
Carpiodes carpio	0	0	0.2	0	0	0	0
Carpiodes sp.	0	0	0	0	0	0	0
Ictalurus punctatus	0	0	0	0	0	0	0
Gambusia affinis	37.6	4	0.2	0	0	0	3036
Labidesthes sicculus	0	0	0	0	0	0	0
Lepomis cyanellus	0.4	0	0	0	0	0	1
Lepomis humilis	0.2	7	0.6	0	0.7	0.3	1
Lepomis macrochirus	0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	0	0
Totals:							
Number of Taxa	6	8	6	1	3	3	8
Fish Abundance	83.4	62.9	9.6	6.3	3.7	10.3	3,137

Table 9. Fish abundance in stations at Jim Crow, Pool 25, Mississippi River in Fall of 1999 and 2000. Numbers are expressed as fish/sampling trip. In 1999, fish were sampled in a vegetated plot (VegPlot) and devegetated plot (∅Plot). Vegetation production was low in 2000; therefore, both experimental plots contained only sparse amounts of vegetation.

	1999		2000	
Species	VegPlot	∅Plot	VegPlot	∅Plot
Dorosoma cepedianum	0	0	0	0
Ctenopharyngodon idella	39.2	4.8	0	0
Cyprinus carpio	13.2	25.4	3.7	3.7
Cyprinella lutrensis	0	0	0	0
Cyprinella spiloptera	5.2	15.8	97	229.7
Notemigonus crysoleucas	0	0	0	0
Notropis atherinoides	1	10.4	24	25
Notropis blennius	0.2	0.6	2.3	0.7
Notropis ludibundus	0	0.2	2.3	1
Notropis shumardi	0	0	0	0
Notropis wickliffi	11.4	71.2	70.7	134
Pimephales notatus	0.2	0	0.7	0
Pimephales vigilax	0	0.2	1.3	0
Carpiodes carpio	0	0.2	0	0
Carpiodes sp.	0	0	0	0
Ictalurus punctatus	0	0	0.3	0
Gambusia affinis	367.2	90	333	426.3
Labidesthes sicculus	0	0	0	0
Lepomis cyanellus	0	0	0	0
Lepomis humilis	0	0	10.3	20
Lepomis macrochirus	0	0	10	16.3
Lepomis sp.	0	0	0	1.3
Micropterus salmoides	0	0	0	0.3
Aplodinotus grunniens	0	0	0	0.7
Totals:				
Number of Taxa	8	10	12	12
Fish Abundance	437.6	218.8	555.6	859

Table 10. Fish abundance in stations at Turner, Pool 25, Mississippi River in Fall of 1999 and 2000. Numbers are expressed as fish/sampling trip. Vegetation production in 2000 was limited to the shoreline (Shore); therefore, neither vegetated plots (VegPlot) or devegetated plots (∅Plot) contained vegetation.

	1999		2000		
Species	VegPlot	∅Plot	VegPlot	∅Plot	Shore
Dorosoma cepedianum	0.4	0.4	0	0	0
Cyprinus carpio	9.6	0	0	0	1.3
Cyprinella lutrensis	0	0	0	0	0.3
Cyprinella spiloptera	211.8	3.6	0	0.3	111.7
Notemigonus crysoleucas	0	0	0	0	0
Notropis atherinoides	12.6	52.4	7.3	57	18
Notropis blennius	10.2	0	0	0	12.7
Notropis ludibundus	0	0	0	0	0
Notropis shumardi	0	0	0	0	0
Notropis wickliffi	435.4	12	2.3	22.7	29.7
Pimephales notatus	0	0	0	0	0
Pimephales vigilax	0.4	0.4	0	0	0.7
Carpiodes carpio	0	0	0	0	0
Carpiodes sp.	0	0	0	0	1.7
Ictalurus punctatus	0	0	0	0	0.7
Gambusia affinis	17.4	0	0	0	375.3
Labidesthes sicculus	0	0	0	0	0
Lepomis cyanellus	0	0	0	0	0
Lepomis humilis	0.4	1.8	0	0	3
Lepomis macrochirus	0.2	0	0.7	0	0.3
Aplodinotus grunniens	0	0	0	0	0.3
Totals:					
Number of Taxa	10	6	3	3	13
Fish Abundance	698.4	70.6	10.3	80	555.7

Table 11. Fish collected by boat electrofishing from the Batchtown State Wildlife Management Area 1998-2000, Pool 25, Mississippi River. Numbers are based on 1.5 hrs of electrofishing in 1998 and 1 hr of effort in 1999 and 2000. Sampling was conducted at midday in October of all years. Vegetation production in 2000 was much less than in 1998 and 1999, and limited to a narrow band along the shoreline.

Common Name	Scientific Name	1998 (fish/hr)	1999 (fish/hr)	2000 (fish/hr)
Gizzard Shad	*Dorosoma cepedianum*	96	141	113
Common Carp	*Cyprinus carpio*	11.3	7	6
Emerald Shiner	*Notropis atherinoides*	3.3	0	6
River Carpsucker	*Carpiodes carpio*	8	14	0
Smallmouth Buffalo	*Ictiobus bubalus*	13.3	13	0
Bigmouth Buffalo	*Ictiobus cyprinellus*	0.7	1	0
Black Buffalo	*Ictiobus niger*	2.7	6	0
Redhorse	*Moxostoma* sp.	1.3	0	0
Channel Catfish	*Ictalurus punctatus*	1.3	1	0
White Bass	*Morone chrysops*	0.7	0	0
Bluegill	*Lepomis macrochirus*	2.7	0	0
Orangespotted Sunfish	*Lepomis humilis*	2.7	1	0
Warmouth	*Lepomis gulosus*	0.7	0	0
Freshwater Drum	*Aplodinotus grunniens*	1.3	0	66
Number of Taxa:		14	8	4

Table 12. Habitat measurements in devegetated (∅Plot) and vegetated (Veg) plots at five sites in Pool 25, Mississippi River. Means, with ranges in parentheses, are based on three sampling trips during fall 2000. Only ranges are provided for pH and conductivity. Vegetation production in 2000 was limited to the shoreline; therefore, neither vegetated plots (VegPlot) or devegetated plots (∅Plot) contained vegetation.

	Batchtown East		Batchtown West		Dixon Pond	
	∅Plot	Veg	∅Plot	Veg	∅Plot	Veg
Water Depth (cm)	56.6 (52.0-61.0)	53.7 (50.0-60.0)	42.3 (41.0-44.0)	46.3 (44.0-49.0)	43.7 (40.0-49.0)	45 (41.0-51.0)
Temperature (^{0}C)	20.4 (17.6-23.6)	20.5 (17.6-23.5)	20.8 (19.1-23.4)	20.7 (18.7-23.3)	21.7 (19.3-25.1)	21.8 (19.1-25.1)
Dissolved Oxygen (mg/L)	8.9 (8.5-9.5)	8.6 (7.9-9.2)	11.2 (9.9-12.4)	11.0 (9.8-12.3)	12.1 (10.6-14.0)	12.0 (10.0-13.6)
pH	7.9-8.8	8.0-8.8	8.3-9.0	8.4-9.0	8.5-9.0	8.5-9.0
Conductivity (μmhos/cm)	345-410	355-390	360-400	358-400	345-380	340-390
Turbidity (NTU)	22.7 (19.5-26.0)	25.8 (23.7-28.0)	26.5 (16.0-37.0)	20.8 (18.7-23.0)	23.5 (18.0-29.0)	29.2 (19.4-39.0)

Table 12. Continued

	Jim Crow		Turner	
	∅Plot	Veg	∅Plot	Veg
Water Depth (cm)	26.5 (25.0-28.0)	23.0 (22.0-24.0)	22.5 (18.0-27.0)	28.7 (26.0-33.0)
Temperature (^{0}C)	20.9 (16.7-24.1)	21.1 (16.3-25.0)	21.7 (16.2-27.2)	21.8 (16.2-27.3)
Dissolved Oxygen (mg/L)	11.3 (9.7-13.4)	10.9 (8.3-15.1)	11.0 (8.9-13.2)	10.3 (7.8-14.9)
pH	8.1-8.9	8.0-9.0	8.0-9.0	7.8-9.0
Conductivity (μmhos/cm)	340-410	340-420	350-410	350-400
Turbidity (NTU)	15.4 (14.0-16.9)	14.3 (13.6-15.0)	20.1 (17.3-23.0)	28.3 (23.5-33.0)

Table 13. Seven sites established in Pool 25, Mississippi River to study the effects of variable hydrology on the biota of backwaters located at midpool and lowerpool.

SITE NAME	LOCALITY
TURNER	Pool 25, Mississippi River; southern tip of Turner Island; Calhoun Co. Illinois; T12S, R2w, Sec 1; N39°03.7920 W90°42.347, River Mile 244.
SERPENT SLOUGH	Pool 25, Mississippi River, slough on Turner Island; Calhoun Co. Illinois; N39°23'00" W90°43'00", River Mile 245.
JIM CROW	Pool 25, Mississippi River; slough on Jim Crow Island; Lincoln Co. Missouri; N39°03.792 W90°42.685; River Mile 246.
STAG ISLAND	Pool 25, Mississippi River, slough on Stag Island, Lincoln Co. Missouri; N39°05'529" W90°41'388"; River Mile 248.5.
GYRINID POINT	Pool 25, Mississippi River, on cut between Missouri shore and Howard Island, Pike Co. Missouri; N39°15'505" W90°45'102"; River Mile 261.3.
COON SLOUGH	Pool 25, Mississippi River, slough on Coon Island, Calhoun Co. Illinois; N39°19'472" W90°48'818"; River Mile 267.5.
MCCOY SLOUGH	Pool 25, Mississippi River, slough on backwater side of McCoy Island, Calhoun Co. Illinois; N39°17'001" W090°46'121"; River Mile 263.5.

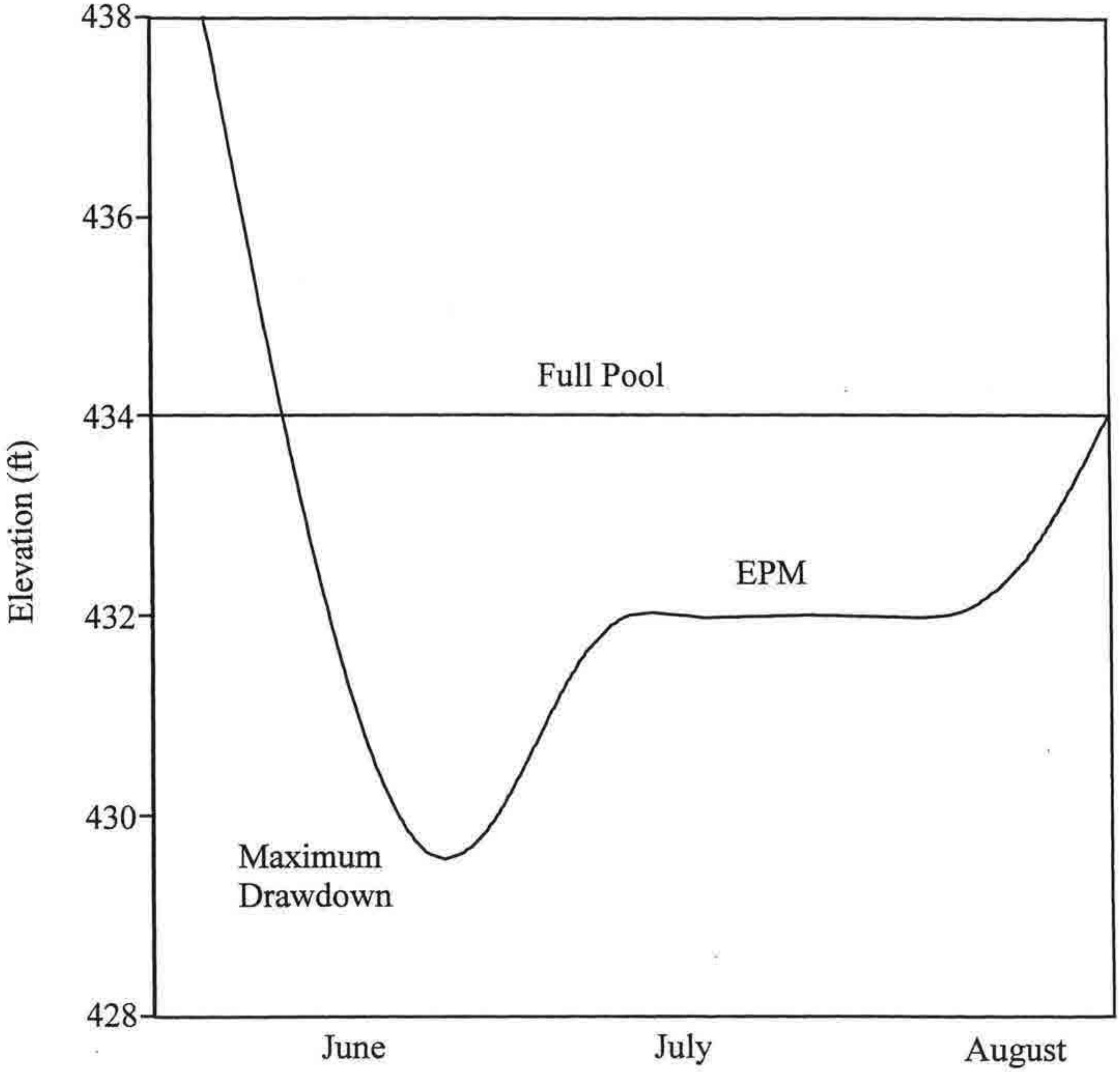

Figure 1. A theoretical depiction of Environmental Pool Management (EPM) in Pool 25, Mississippi River.

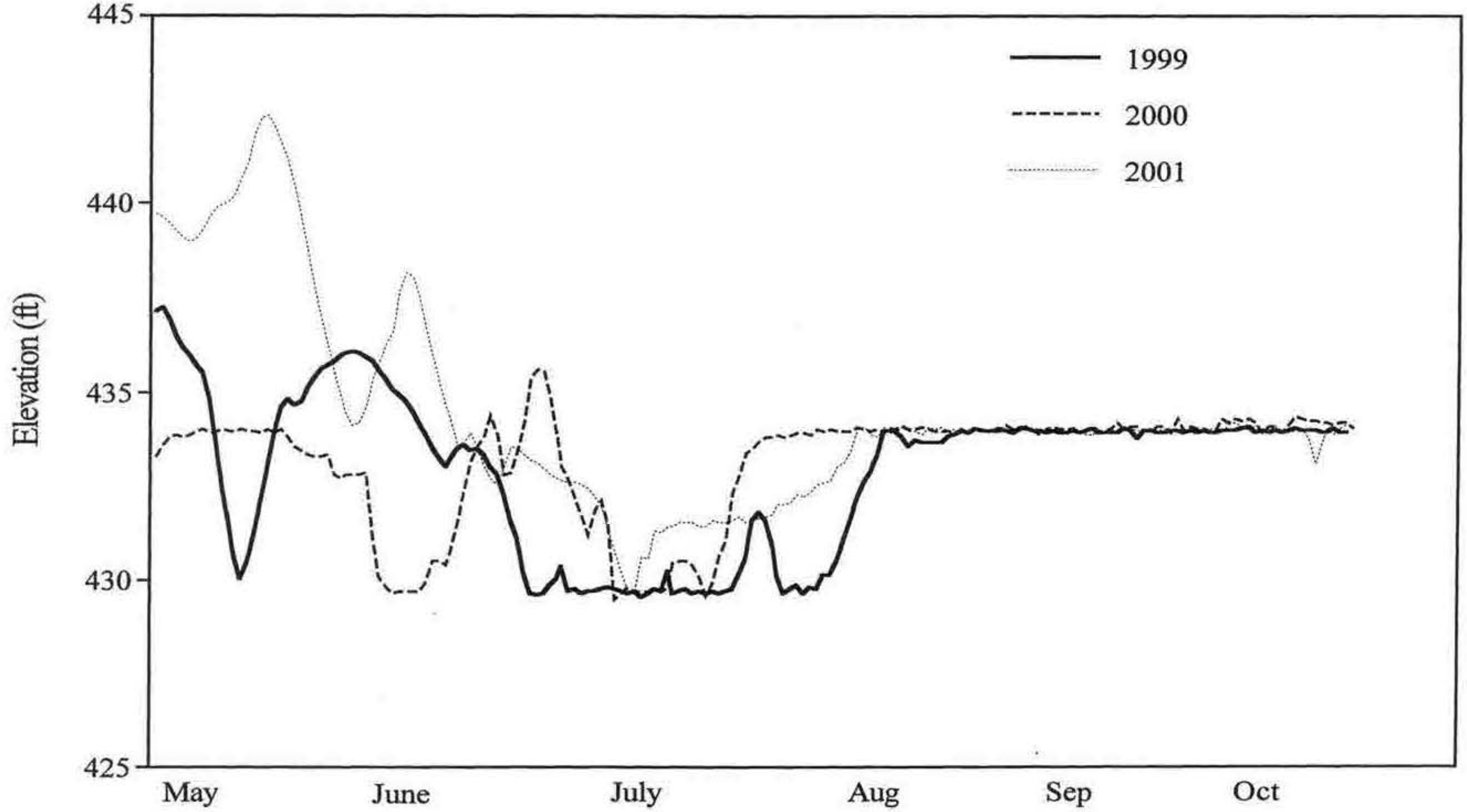

Figure 2. Hydrograph for lower Pool 25, Mississippi River from 1999 to 2001. Daily stages were obtained from Lock and Dam 25 (Upper) Winfield, MO.

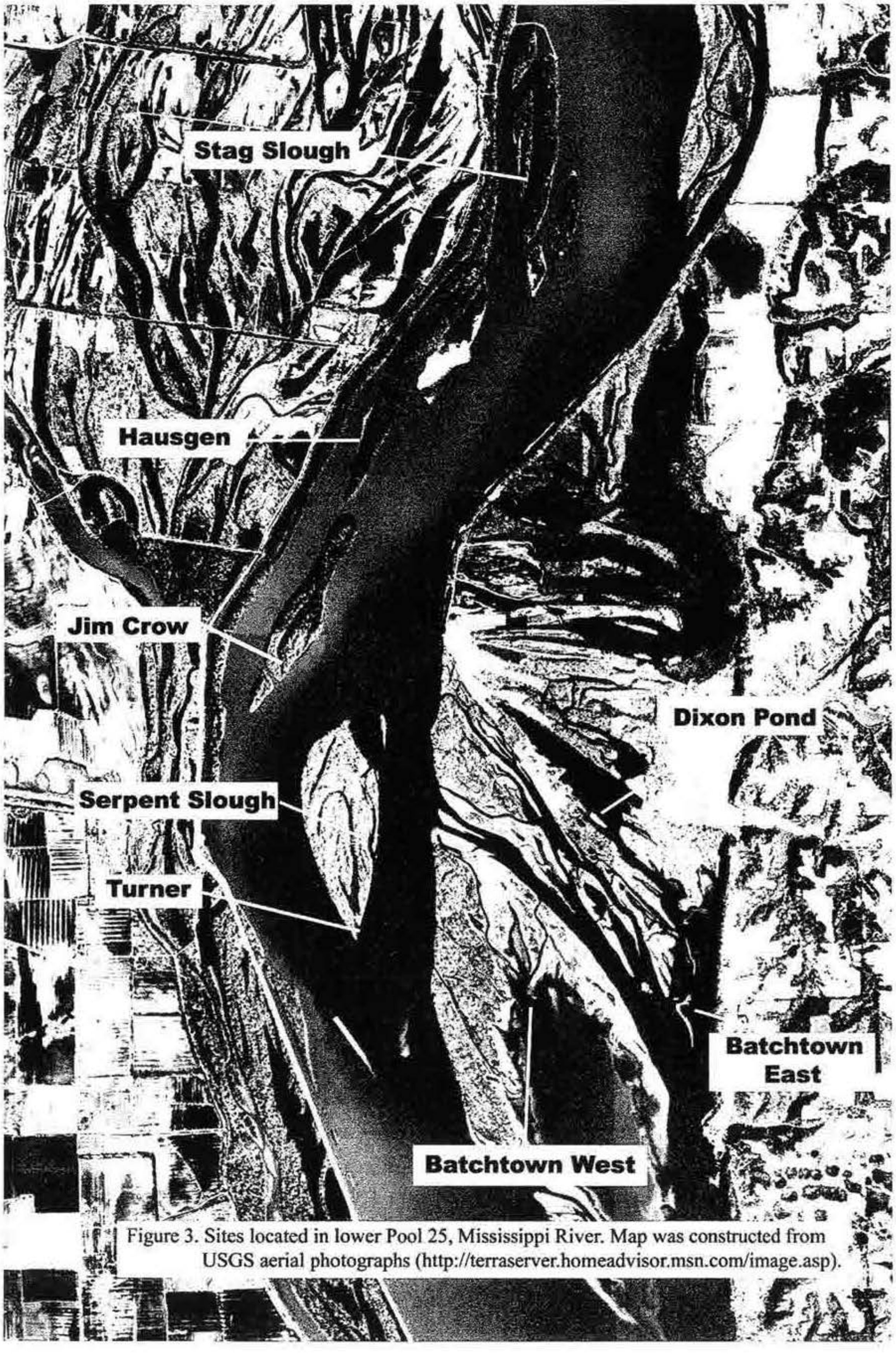

Figure 3. Sites located in lower Pool 25, Mississippi River. Map was constructed from USGS aerial photographs (http://terraserver.homeadvisor.msn.com/image.asp).

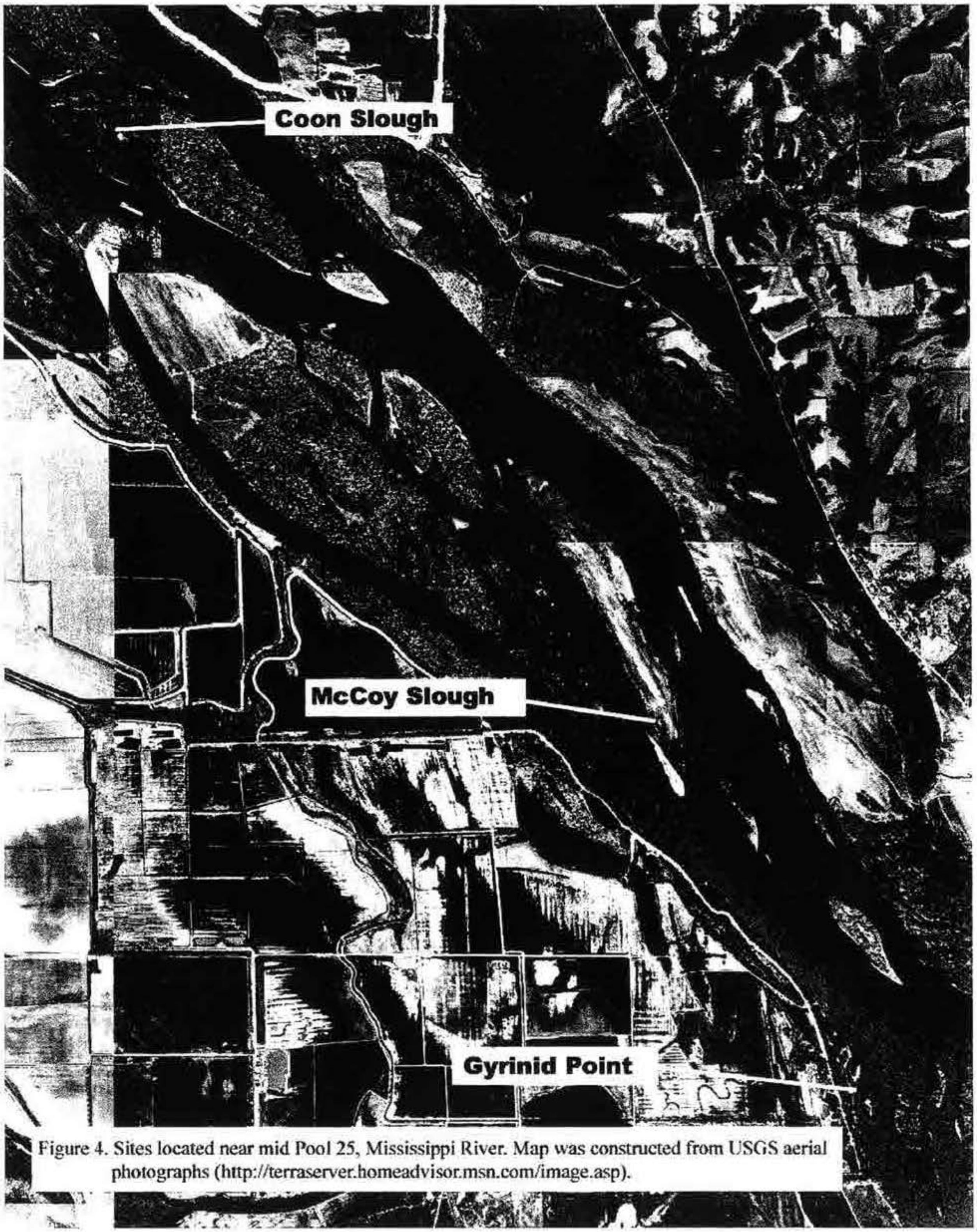

Figure 4. Sites located near mid Pool 25, Mississippi River. Map was constructed from USGS aerial photographs (http://terraserver.homeadvisor.msn.com/image.asp).

Appendix E.

2001 Progress Report – Middle Mississippi River Pallid Sturgeon Habitat Use Project. Southern Illinois University – Carbondale, Fisheries Research Laboratory and Department of Zoology.

Middle Mississippi River Pallid Sturgeon Habitat Use Project

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Year 6

Annual Progress Report

January 2002

EXECUTIVE SUMMARY

Four specimens were collected that showed pallid sturgeon characteristics during this year of work. Two we believed to be hybrids. The other two showed strong pallid sturgeon characteristics and were given sonic transmitters. No pallid sturgeon were located via sonic tracking during year six. Factors contributing to the lack of contacts were decreased tracking effort due to long periods of ice flow and high water levels as well as low numbers of tagged fish (the maximum number of fish with live tags at any point during the year was two). Analyses relating to sonic telemetry work to date (i.e., all years of the project) have been compiled herein.

Despite the limited success in this year's telemetry work, there have been significant accomplishments since the last annual report. We produced two publications (Transactions of the American Fisheries Society and the AFS Sturgeon Symposium Proceedings). One is a further exploration of the Character Index developed by us, and the other reports our development of a substantial set of genetic (microsatellite) markers that should ultimately greatly facilitate sturgeon conservation in general, and *Scaphirhynchus* conservation in particular.

We also examined gastric lavage techniques to determine their suitability for studying diets of the pallid sturgeon.

Our results indicate that gastric lavage should not lead to any substantial additional stress or mortality in captured sturgeon. We do, however, feel there is room to improve gastric lavage techniques currently being used for other sturgeon species.

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 sixth year of the study (January 1, 2001 through December 31, 2001). Goal 1 during year 6 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 seasonally 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.

Towards the end of the 5th year of the study, we did not attempt to collect more pallid sturgeon for transmitter implantation, because there was uncertainty regarding whether the study would be continued into a 6th year. Also, we only obtained 2 pallid sturgeon large enough to give transmitter implants during year 6. Although we tracked whenever river conditions allowed, we unable to relocate these fish—we cannot readily explain this, but one contributing factor was that river stages during much of the year limited detection ranges, essentially making it difficult to effectively track fish. Because we no longer were in contact with pallid sturgeon given transmitters in the previous year, it appeared that tracking was not going to be as fruitful as in previous years.

An additional goal, Goal 2, was undertaken in year 6. Work on Goal 2 was not in the contract, but it was done to make more effective use of project personnel, to offset the lack of success during year 6 regarding Goal 1, and to facilitate further pallid sturgeon research.

Goal 2 sought to assess the effects of gastric lavage on *Scaphirhynchus* spp. Specific objectives for this ongoing Goal 2 are as follows. Objective A was determination of whether or not anesthesia is necessary for removal of stomach contents by gastric lavage. Objective B was assessment of the physiological response to gastric lavage, as measured by weight gain, blood osmolality and blood cell counts.

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 of the length of the outer barbels (OB) to the inner barbels (IB)) from five pallid sturgeon collected near the Fort Peck Dam were far greater than the range for this character reported by Bailey and Cross (1954). This was not the case for values for this character calculated from data reported by Carlson and Pflieger (1981).

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

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

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

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

Techniques for Characterizing Diets of Pallid Sturgeon

In order to better characterize the life history and preferred habitat of pallid sturgeon, it is important to investigate their food habits. This requires the collection of stomach contents, which often requires sacrificing fish. However, when working with endangered species, it is imperative that steps be taken to prevent any harm to the fish. Thus, alternative methods have been developed to avoid mortality including: insertion of tubes, use of emetics, stomach suction, gastroscopes, stomach flushing (gastric lavage), forceps, and intestinal flushing have been developed to avoid mortality (Hartleb and Moring 1995). Of these methods, gastric lavage has been considered the most applicable (Hyslop 1980). Furthermore, gastric lavage has been used on many species of fish including sturgeon and appears to be an effective method for removing stomach contents (Haley 1998, Hartleb and Moring 1995).

Although gastric lavage has been used successfully for sampling sturgeon gut contents, it is important to determine whether or not this method is best for removing gut contents of pallid sturgeon. While a technique using polyethylene tubing and a 60cc syringe has been successful for Atlantic and shortnose sturgeon (Haley 1998), Sprague et al. (1993) showed 33% mortality in juvenile white sturgeon using a syringe and aquarium tubing. Hartleb and Moring (1995) had success on various fish species with a compression sprayer attached to a polypropylene pipette and polyethylene tubing. However, the testing of these methods on *Scaphirhynchus* spp. has not been reported. Furthermore, the necessity of using anesthesia before removing gut contents is unclear. Thus, we attempted to find a method for sampling stomach contents from pallid sturgeon that would not result in mortalities. We used shovelnose sturgeon as a surrogate species for this work.

While gastric lavage has been successful in removing the stomach contents of sturgeon, no one has reported the physiological effects of this procedure on sturgeon.

Gastric lavage requires handling of fish. To address the stress response due to handling, numerous studies have looked at changes in blood plasma osmolality (Lewis 1971, Hattingh and Van Pletzen 1974, Davin et al. 1992). Additionally, decreases in hemoglobin and red and white blood cell counts have been shown in response to capture and transport (Hattingh and Van Pletzen 1974, Davin et al. 1992). In order to assess the stress response of shovelnose sturgeon to this procedure, we measured blood osmolality, hematocrit and leucocrit.

Water is introduced into the gut of the fish during gastric lavage. Freshwater fish are hypertonic and hyperosmotic to the surrounding water. Because of this, they are constantly working to limit the amount of excess water taken into the body. If water remains in the stomach after gastric lavage, fish must rid themselves of this water. Water could be removed from the gut in two ways. It could be removed before absorption by coughing, or water could be absorbed into the bloodstream and removed via the kidney. If water is absorbed into the bloodstream, then the blood may become more dilute, resulting in lowered hematocrit and/or blood osmolality.

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 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. After recovery, wild fish 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-rivermile 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 they 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, and to quantify observed home ranges and movement patterns.

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 is more appropriate 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 represent positive selection, or selection for, the given habitat while negative numbers represent 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 - Techniques for Characterizing Diets of Pallid Sturgeon

In October, 2001, 45 shovelnose sturgeon were captured in a 24-hour trammel-net set in the middle Mississippi river, near Thebes IL. The fish were placed in a tank of oxygenated river water upon capture, transported to an indoor holding facility and acclimated from 13°C to 15°C water.

Upon acclimation, 27 fish were placed randomly in three 2,000L circular tanks—these would be used in a subsequent study (see below). The remaining 18 fish were immediately subjected to 1 of 6 treatments and held for four weeks to assess mortality associated with the gastric lavage procedure. The treatments were as follows: 1) control (handled and released, procedures common to all of the other treatments); 2) lavage; 3) anesthetized with CO_2 and lavaged; 4) anesthetized with tricane methanesulfonate (MS-222) and lavaged; 5) anesthetized with CO_2 no lavage; 6) anesthetized with MS-222 no lavage. Prior to each treatment, fish were weighed to the nearest gram, fork length was measured to the nearest millimeter and a pit tag was implanted at the base of the dorsal fin.

Fish were anesthetized with CO_2 using the previously described technique. Fish anesthetized with MS-222 were placed in a holding tank filled with a 100 mg/L solution

(Haley, 98). Fish were considered sedated when ventilation ceased.

We used the lavage method described for Atlantic sturgeon by Haley (1998). A 60 cc syringe was used with a Sovereign® 4 mm X 410 mm feeding tube and Urethral Catheter. The lavage tube and syringe was filled six times for each fish flushing approximately 360 cm^3 of system water into the gut of the fish. The fish were palpated during flushing to aid in the removal of the gut contents. Gut contents were collected in a 0.5-mm sieve, transferred to 250-ml plastic jars and fixed with 10% buffered formalin.

On November 19, 2001 28 fish were subjected to the aforementioned treatments to assess physiological responses to the gastric lavage procedure. Each fish was weighed to the nearest gram after the treatment and again 1 hour post treatment to assess weight changes that may have occurred due to the addition of water to the gut and retention of water by fish after lavage. Twenty-four hours after the initial workup, blood samples were taken from the caudal insertion of the anal fin using a 1 cc syringe and 25 gauge needle. Blood was transferred to a series of heparinized hematocrit tubes and sealed using critoseal®. The samples were then centrifuged for 1 minute and hematocrit and leucocrit were read using a micro-hematocrit tube reader.

Plasma was transferred into a microcentrifuge tube and put on ice for determination of blood osmolality.

Analysis

Differences in weight, hematocrit, leucocrit, and blood osmolality were determined using a one-way ANOVA. Pairwise comparisons were made to detect differences between treatments using Tukey-Kramer HSD. All statistical analyses were performed using JMP® IN 4.0.2 (SAS Institute Inc. 2001).

Results

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

Two additional pallid sturgeon were obtained from commercial fishers and implanted with sonic transmitters during Year 6. Both fish had high character index (CI) values (Sheehan et al. 1997a); both values were in the pallid sturgeon range (Tables 2 and 3). One of the 2 fish implanted with a transmitter (455) was confirmed to be a female with eggs during the implantation surgery.

Two other putative pallid sturgeon were examined but not implanted with sonic transmitters. One fish was deemed a hybrid based on its low CI value. The other was deemed a hybrid despite its high CI value because it had many prominent ventral scutes (Table 4).

No pallid sturgeon were located via sonic tracking during year six. Factors contributing to the lack of contacts were decreased tracking effort due to long periods of ice flow and high water levels as well as low numbers of tagged fish (the maximum number of fish with live tags at any point during the year was two). The following analysis is a synopsis of all relocation data gathered throughout the six years of this project.

Habitat Associations

A total of 195 relocations of the study fish were made from November 13, 1995 to December 31, 2001. These 195 contacts were all made during daylight hours. Approximately 4250 miles of tracking effort were exerted during the six years of this study to accumulate these relocations. Most tracking effort was expended between river miles 81 and 151 (Figure 2). This was the portion of the study area that was occupied by the sturgeon for the majority of the study and effort was focused in this stretch in order to maintain contact with the study fish and maximize relocations.

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

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

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

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

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

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

During the summer (surface water temperatures over 20 °C), habitat associations were diverse and resembled the overall habitat associations. The WDT macrohabitat saw its heaviest use during the summer months at 14%. The major habitats of use during the summer were the MCL (26%), MCB (34%), ITD (9%), and the WDB areas (15%) (Figure 8).

Maximum water depths at the point of relocations could be important as pallid sturgeon are generally considered to be a benthic species. The study sturgeon were found in locations with water depths ranging from 1.82 to 19.17 m. They were found most often (88.8% of all relocations; n=187) in water with maximum depths from 3 to 12 m (Table 4). Sturgeon were most commonly found (37.4% of relocations) at depths ranging between 6 and 9 meters (table 4). The study sturgeon were primarily found in the MCL and MCB habitats, where depths in these ranges are common.

Fifty-five substrate samples were taken at points where pallid sturgeon were relocated. Study fish were found over sand substrates 81.8% of the time (n = 45) (Table 6). Sturgeon were found over sand/gravel substrates 9.1% of the time (n=5). Fish were located over mud/silt substrates 5.5% of the time (n = 3). The mean surface velocity measurement taken at points where pallid sturgeon were relocated was 0.55 m/s (SD=0.27; n=28).

Habitat Selection

Habitat availability analysis indicates that the study area was approximately 64.85% MCL and 11.05% MCB. The ITD habitat comprises the smallest amount of the study area at

0.67%. The other macrohabitat types, WDD, WDB, WDU and WDD, comprise 8.73%, 7.82%, 3.71%, 3.04% and 8.73% respectively (Figure 9).

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

Effects of Temperature and Discharge

A Chi-square goodness-of-fit test indicated that the distribution of habitat use was significantly different from the habitat availability at each temperature regime (Table 7). However, only three habitats showed a change in selection. WDT habitats were positively selected for during each temperature regime except at 4-10° C. Selection of WDD habitat was not significantly different from zero during the 0-4° C temperature range (t-test; alpha=0.05), and L_i for the WDB was not significantly different from zero at the 4-10° C temperature range (t-test; alpha=0.05)(Figure 11).

A Chi-square goodness-of-fit test indicated that the distribution of habitat use was significantly different from the habitat availability at the low, medium, and high discharge regimes (Table 8). Selection direction did not change for any habitat during the three discharge regimes (Figure 12). L_i values for each habitat type at all three discharge regimes were significantly different from zero (t-test; alpha=0.05).

Observed Home Ranges and Movements

Observed home ranges for the study sturgeon varied greatly. Pallid sturgeon 7-8 and 2273 (with 1 post-release contact each) were each located along a 0.1-mi stretch of river. In contrast, pallid sturgeon 384 was located along a 72.2-mi stretch of river in 6 contacts (Table 9). The mean observed home range was 18.0 mi (SD=18.4). These observed home ranges represent the minimum range occupied by the study fish since they may have moved in and out of the observed range between consecutive tracking trips. In addition, six study fish were never relocated and seven other study fish were relocated fewer than two times. These fish may have died, moved outside the study area, or remained in inaccessible areas and should be considered with care when examining the observed home range data.

Twenty-one of the 29 fish implanted with a transmitter were relocated at least one time during the five years of this study. The longest period of contact on a fish to date was fish 2237 at approximately 19 months (Figure 13). The observed movements of each of these fish are depicted in Figures 14-34. Figure 35 provides daily discharges from 1 January 1996 through 31 December 2000 of the study period.

Identification of Pallid Sturgeon

As indicated in previous reports, the Pallid Sturgeon Recovery Team has recommended our Pallid Sturgeon Character Index for identifying sturgeon specimens. Although we had limited success adding to the habitat use data set, we have produced two important publications regarding pallid sturgeon identification since the last annual report. We added substantially to the data set and used a new statistical approach to determine the effectiveness of the index. The new analysis gave strong indications that the Character Index developed by us works well. This work (submitted and approved for publication) will appear in the upcoming American Fisheries Society's Sturgeon Symposium Proceedings (Wills et al., *in press*).

We also published the initial and highly successful findings regarding the identification of genetic markers that in all probability will be the much-needed genetic tools to address sturgeon conservation issues (McQuown et al. 2000).

Goal 2 - Techniques for Characterizing Diets of Pallid Sturgeon

Overall, identifiable food items were successfully removed from 96.3% of the study fish (n = 27). Fork lengths of the study fish ranged from 436 to 703mm (Mean = 560 ± 74mm). No mortality occurred during any part of the study.

Differences in weight gain as measured before lavage and immediately after the procedure were significant between fish anesthetized with CO^2 and lavaged and the control (ANOVA, p = 0.0374)(Figure 36). However, no differences in weight were seen between treatments 1hr post procedure (Figure 37). In addition, no differences were determined in hematocrit (Figure 38), leucocrit (Figure 39), or blood osmolality (Figure 40).

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 egg type that fishes typically release over a flat firm substrate such as rock or gravel. WDB habitats, by contrast, typically have sandy unstable substrates. The increased use of WDB habitats during the spring does not appear to be consistent with inferred spawning migrations.

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

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

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

Habitat Selection

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

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

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

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

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

Effects of Temperature and Discharge

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

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

Observed Home Ranges and Movements

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

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

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

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

MMR pallid sturgeon movements during the spring and summer months of March through July were variable. These were periods of high daily mean discharge in the MMR (Figure 35). Pallid sturgeon movement rates in Lake Sharpe, SD were highest during the months of June through August (Erickson 1992).

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

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

Goal 2 - Techniques for Characterizing Diets of Pallid Sturgeon

None of the treatments resulted in shovelnose sturgeon mortalities. Fish anesthetized using CO_2 and lavaged showed a significant gain in water weight. No treatment, however, showed significant weight change after one hour of recovery. This suggests that shovelnose sturgeon are readily capable of ridding their guts of excess water introduced during lavage.

There were no differences in hematocrit, leucocrit, or blood osmolality among treatments. Thus, we were unable to detect any differences in stress indicators between any of the treatments and the positive control. In essence, sturgeon subjected to gastric lavage, with or without anesthesia, did not give any indication that they had been affected in any adverse way over and above effects related to handling alone.

While our results indicate that gastric lavage is an effective non-lethal method for removing the stomach contents of shovelnose sturgeon, a few difficulties should be addressed. First, most fish required more than one syringe full of water to remove all of the gut contents. Removing the catheter from the esophagus, filling it with water, and inserting it again into the esophagus increased handling time and increased the chance of injuring a fish. Thus, the use of a pressure sprayer such as that used by Hartleb and Moring (1995) for continuous water flow and pressure should be tested. Secondly, difficulties also arose during handling of fish that were not sedated. Fish were often uncontrollable. As a result, they were dropped, which increased the difficulty of taking measurements. Furthermore, insertion of the catheter tube into the esophagus was more difficult. The fish's movement often caused the catheter tube to slide away from the esophageal opening, past the gills, and out the buccal cavity. The propensity for damaging the gills with the catheter seemed to increase with fish that were not sedated. Thus, it would seem that sedation would provide some advantages and result in less risk when working with endangered fishes such as the pallid sturgeon.

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, 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 wing dam 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.

Information on the preferred diet of pallid sturgeon will lead to a better understanding of their life history and habitat use. We found that gastric lavage is a safe and effective method for removing stomach contents from shovelnose sturgeon. Given the similarities between shovelnose and pallid sturgeon, we believe that this method is appropriate for use on pallid sturgeon as well. However, it is important to the health of the fish that the fish be sedated prior to lavage. In addition, further work should focus on quantifying the differences in handling time between sedated and non-sedated fish, as well as the efficiency of stomach content removal under different treatments.

The genetic markers, microsatellites, they we developed will be very useful regarding sturgeon conservation issues in general, in that they are effective in both *Scaphirhynchus* as well as *Acipenser*. This work essentially means that more genetic tools are now available for *Scaphirhynchus* than for any other fish group, with the exception of salmonids. This work was funded through activities on this project, the U.S. Fish & Wildlife Service, SIUC, and by colleagues at the University of California-Davis. We are seeking funding to expand on this work at the present time.

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

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

Table 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 6.

Transmitter			Length (mm)			Character	
Number	Date	Weight (g)	Total	Standard	Fork	Index Value	Source
329	4/11/01	1986	831	709	754	-0.5781	Jim Eskar
455	4/24/01	-	895	770	810	-1.6268	Jim Eskar

Table 3. Meristic and Morphometric measurements, and Character index (CI) values for pallid sturgeon captured in the Middle Mississippi River during Year 6 and 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.

Transmitter							Fin Ray Counts		Ventral
Number	CI	OB/IB	HL/IB	HL/MIB	IL/IB	IL/MIB	Anal	Dorsal	Scutes
329	-0.5781	2.1408	5.6056	4.8537	2.2535	1.9512	23	39	Few
455	-1.6268	1.6827	4.2692	6.1667	1.7500	2.5278	33	19	Many

Table 4. Meristic and Morphometric measurements, and Character index (CI) values for pallid sturgeon and putative hybrids captured in the Middle Mississippi River during Year 6 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	Weight							Fin Ray Counts		Ventral
Length(mm)	(g)	CI	OB/IB	HL/IB	HL/MIB	IL/IB	IL/MIB	Anal	Dorsal	Scutes
721	1908	-0.18	1.83	4.94	5.13	2.02	2.10	23	38	Few
737	2156	-0.48	1.74	4.41	4.84	1.74	1.91	26	38	Many

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

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

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

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

Table 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	190.4	6	12.59
4-10	90.3	6	12.59
10-20	114.9	6	12.59
20+	234.5	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	87.4	6	12.59
Medium	124.3	6	12.59
High	399.1	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]	118	118	1	0.1
2273	106	106	1	0.1
5--10[3]	103	104	2	0.7
338	131	132	1	1.4
239	118	120	1	2
456	104	106	2	2.2
267	114	118	15	4.3
366	108	117	19	9.7
2363	126	136	3	9.9
2237	115	126	9	11.4
249	109	121	21	11.9
276	130	142	1	11.9
294	124	143	18	18.7
2264	98.4	120	8	21.5
357	95.5	118	23	22.9
3334	80.2	110	7	30.1
2588	109	142	17	32.6
465	107	142	11	35.2
339	106	142	5	35.4
375	98.2	142	12	44.1
384	32.3	105	6	72.2

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

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.

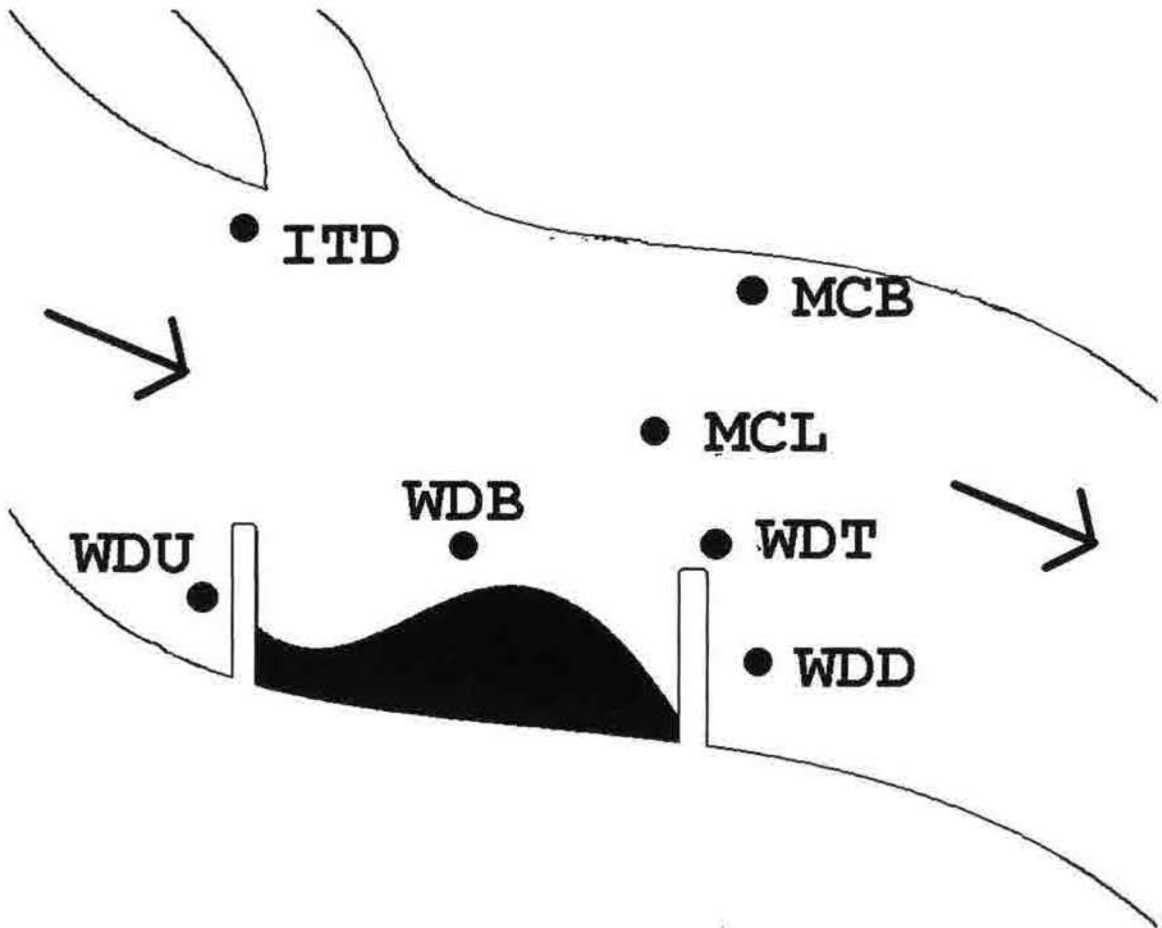


Figure 2. Tracking effort expressed as the frequency that each river mile in the study area was tracked from November 1995 through December 2001.

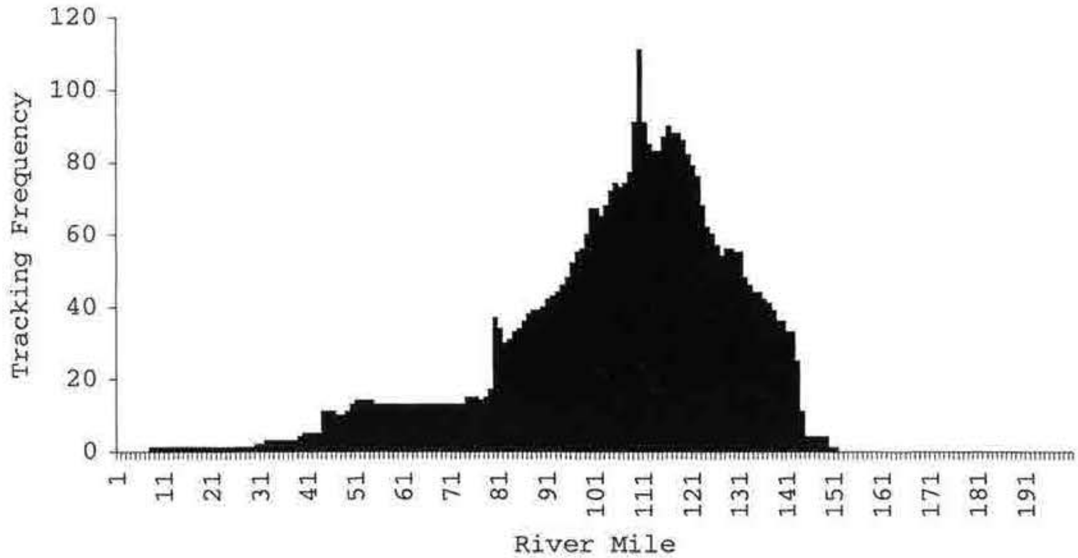


Figure 3. Pallid sturgeon habitat associations in the middle Mississippi River from November 1995 through December 2001. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 195.

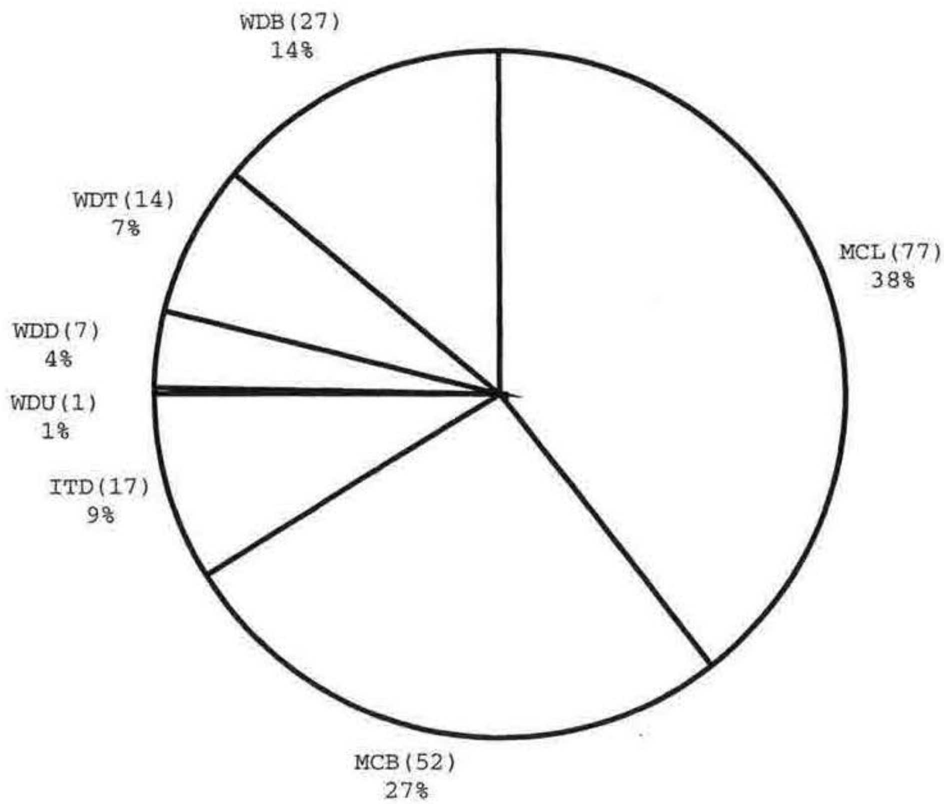


Figure 4. Pallid sturgeon habitat associations at surface water temperatures at or below 4° C in the middle Mississippi River from November 1995 through December 2001. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N =43.

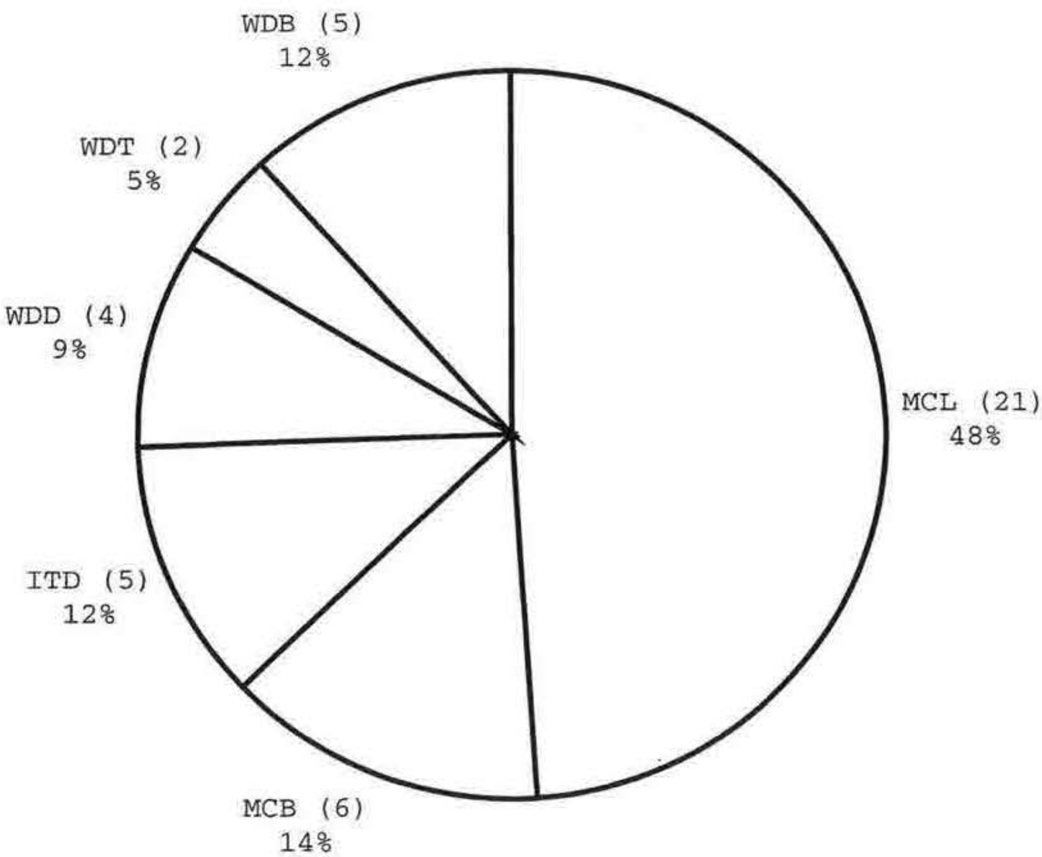


Figure 5. Pallid sturgeon habitat associations at surface water temperatures at or above 4° C and below 10° C in the middle Mississippi River from November 1995 through December 2001. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 33.

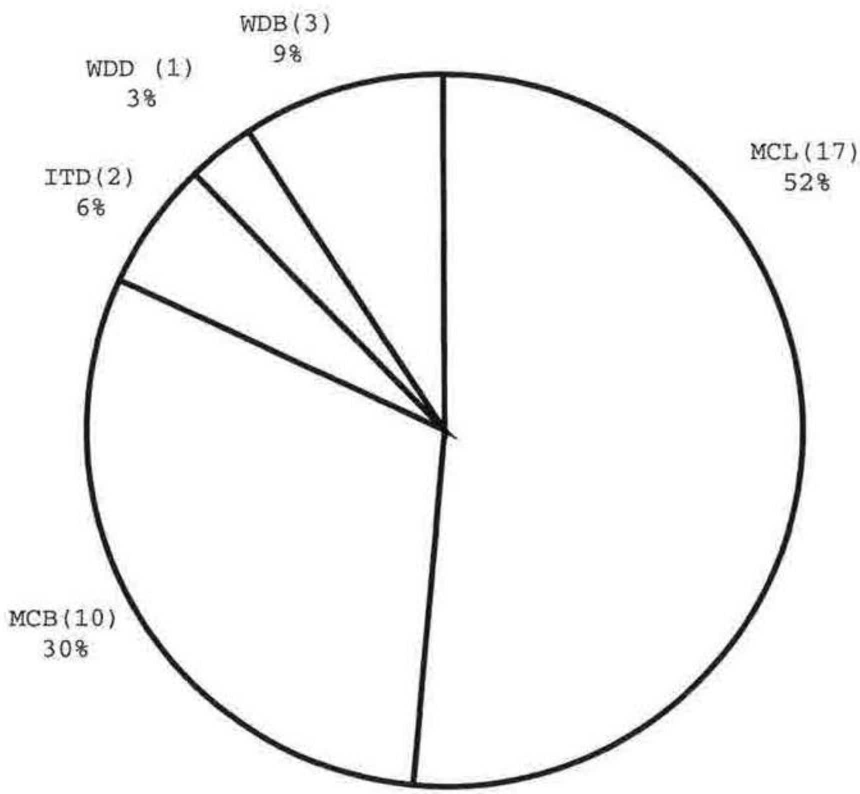


Figure 6. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River during spring months during 1996-2001. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 24.

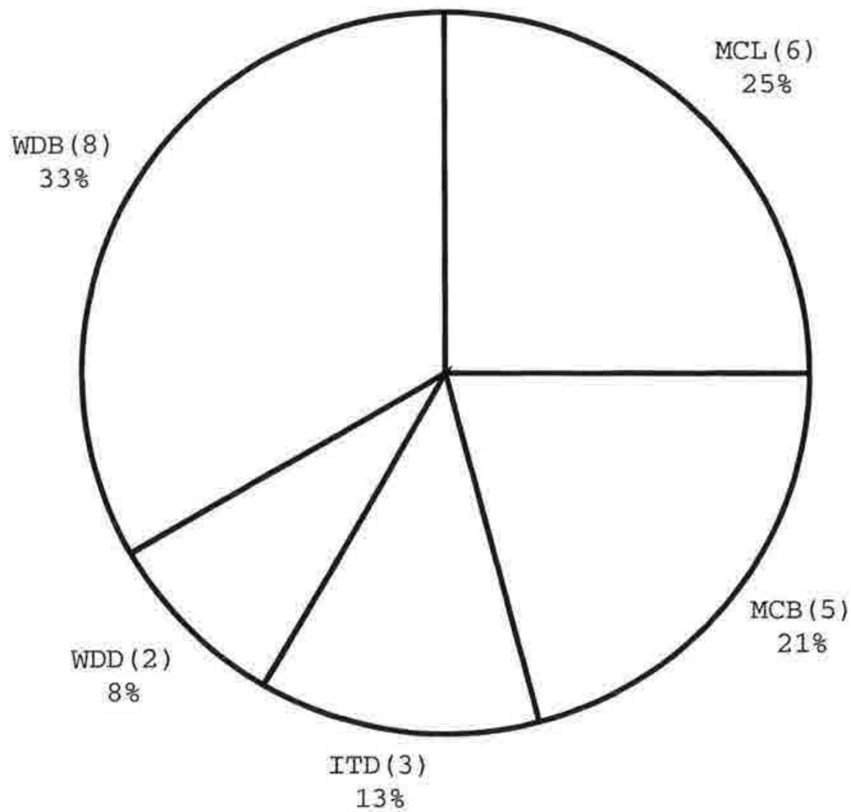


Figure 7. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River during fall months of 1995-2001. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 29.

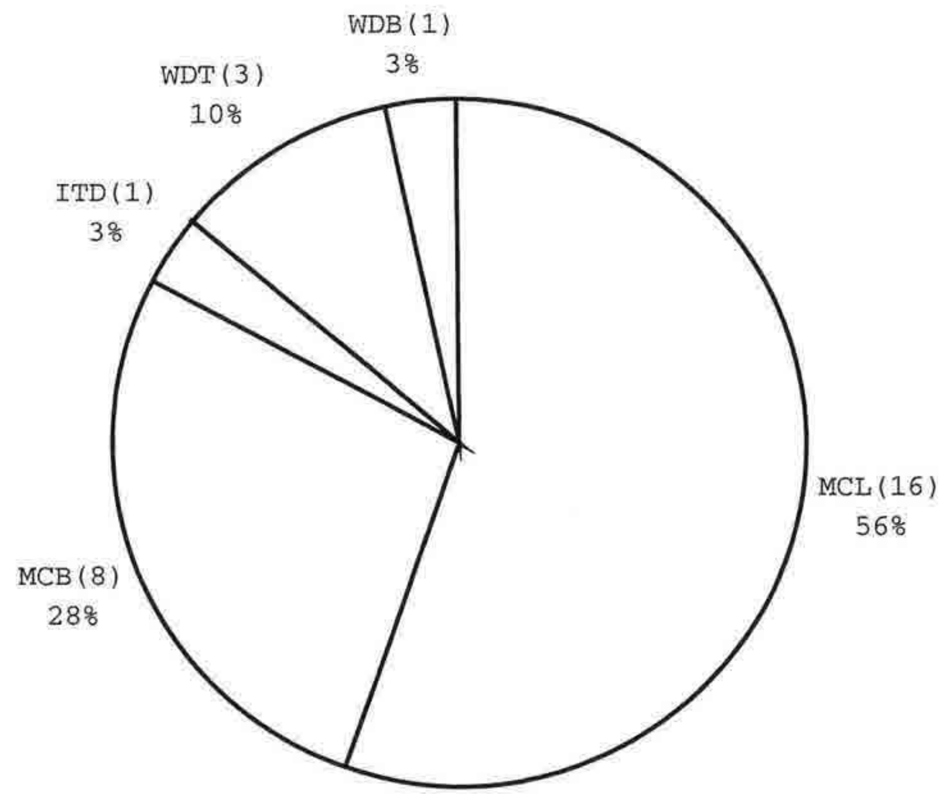


Figure 8. Pallid sturgeon habitat associations at surface water temperatures at or above 20° C in the middle Mississippi River from November 1995 through December 2001. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 66.

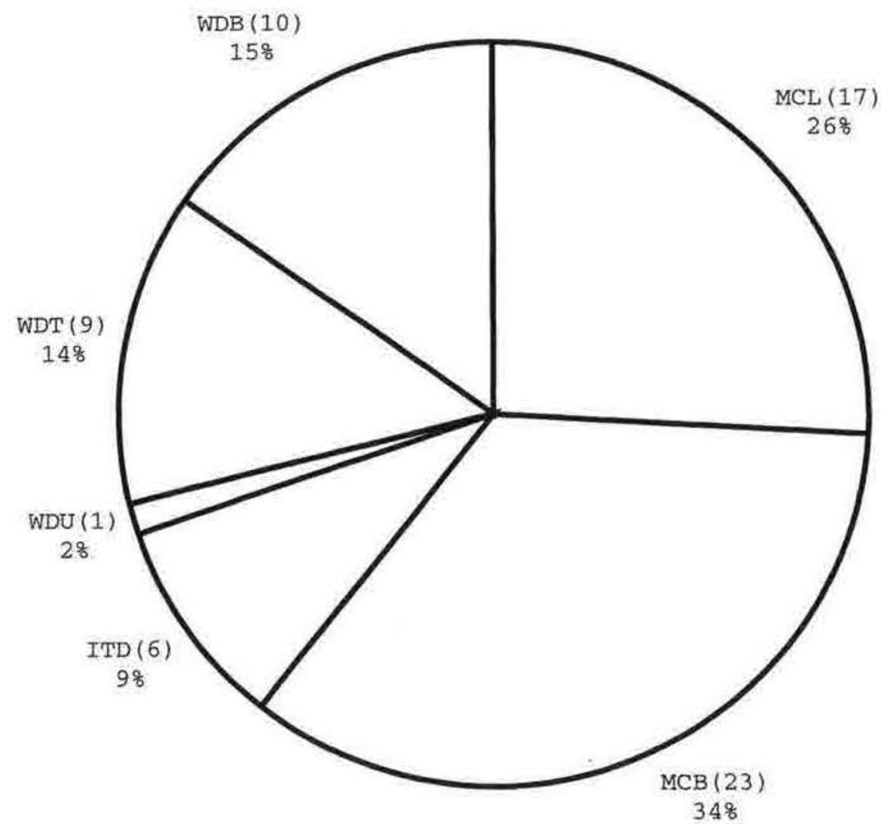


Figure 9. Habitat availability in the Middle Mississippi River expressed as a percentage. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip.

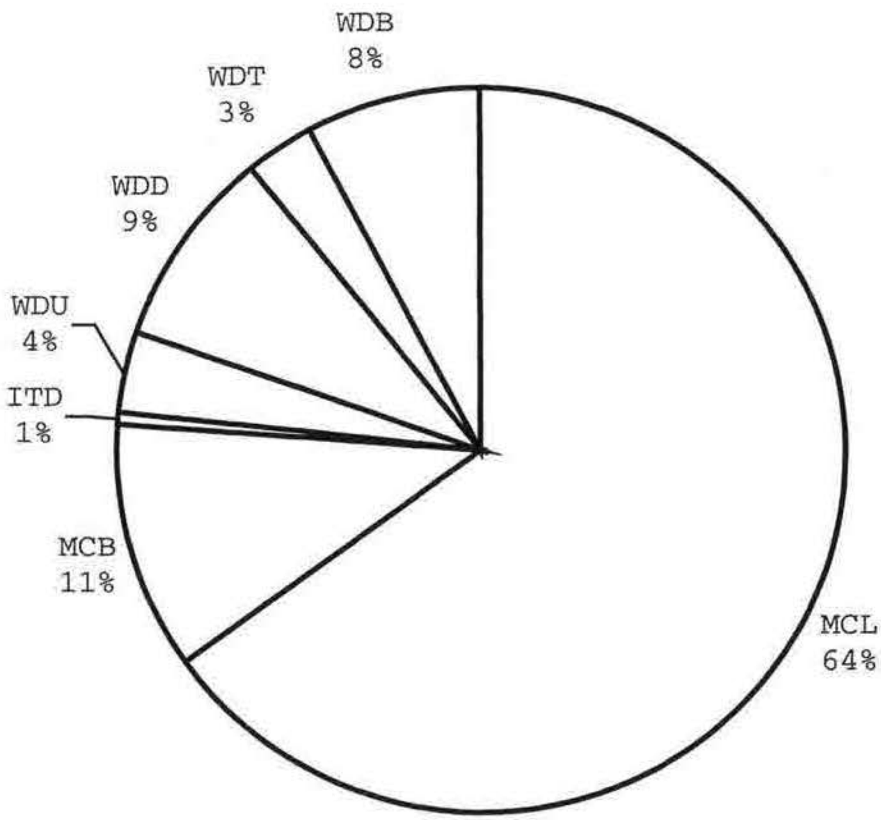


Figure 10. Strauss's linear selectivity index (L_i) values for each macrohabitat in the middle Mississippi River from November 1995 through December 2001. Positive values represent selection for a habitat while negative values represent selection against a habitat. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. Values indicated by an "*" are not significantly different from zero (t-test; alpha=0.05).

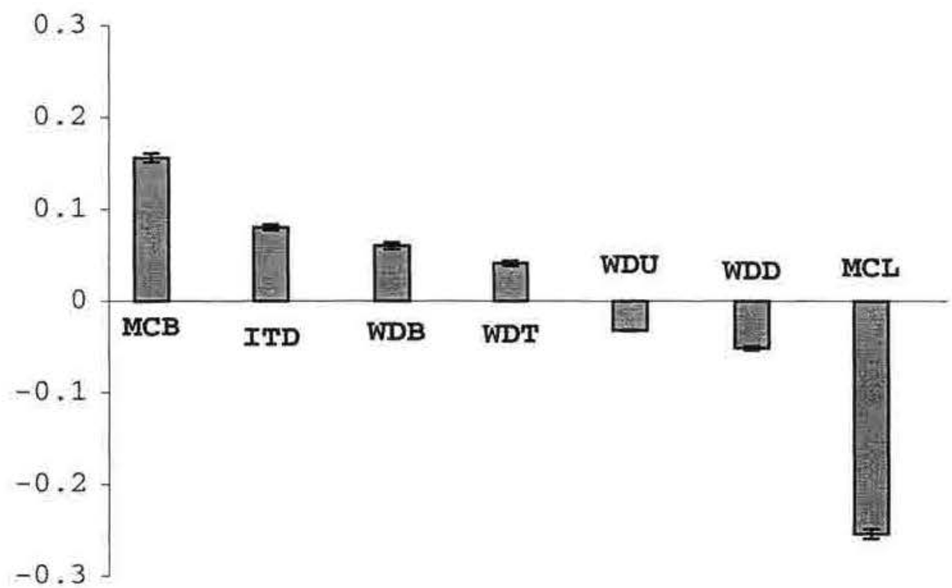


Figure 11. Strauss's linear selectivity index (L_i) values for each macrohabitat by temperature regimes (°C) in the middle Mississippi River from November 1995 through December 2001. Positive values represent selection for a habitat while negative values represent selection against a habitat. Error bars 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).

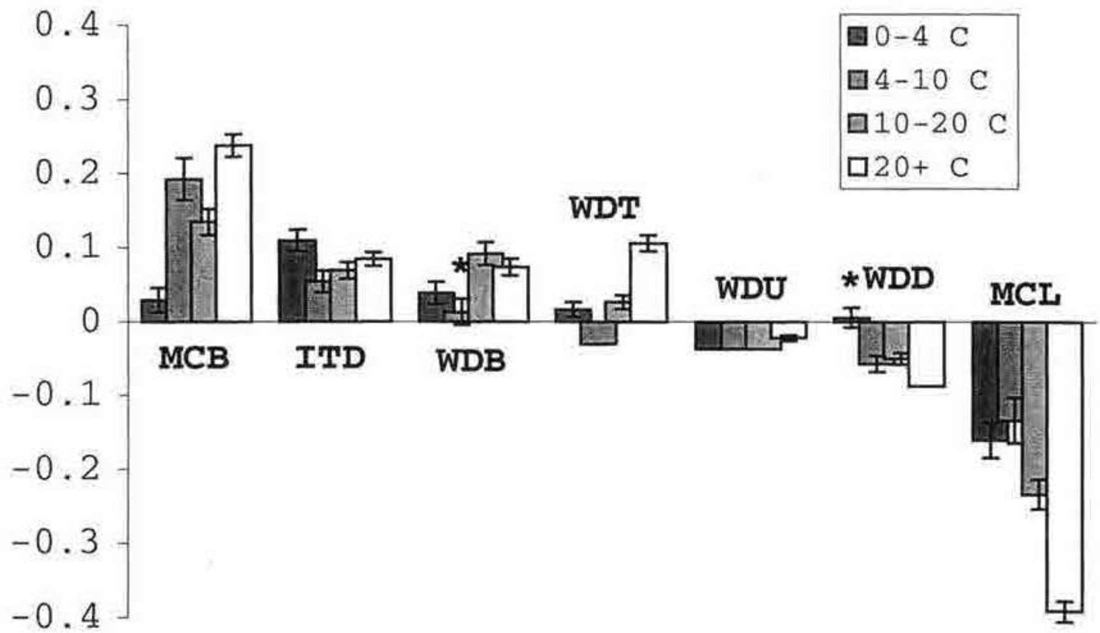


Figure 12. Strauss's linear selectivity index (L_i) values for each macrohabitat by discharge regimes. Positive values represent selection for a habitat while negative values represent selection against a habitat. Error bars represent 95% confidence interval. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. Values indicated by an "*" are not significantly different from zero (t-test; alpha=0.05).

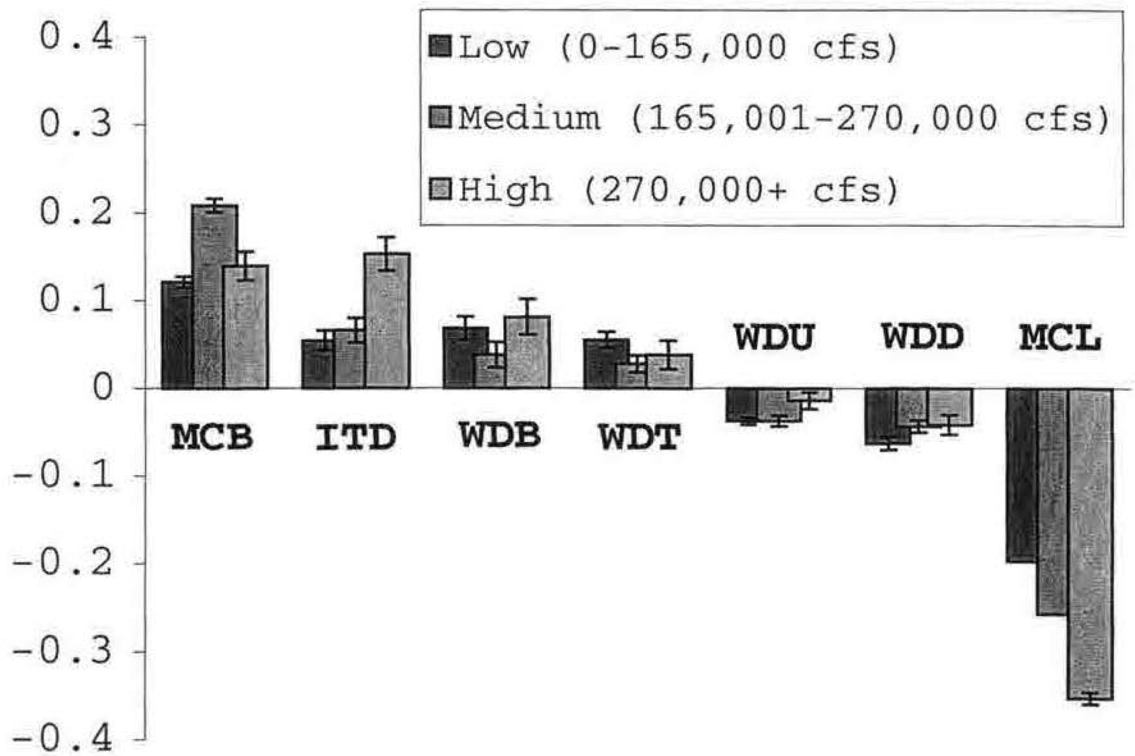


Figure 13. Contact period (date of release to last contact date) for each fish with at least one post-release contact from October 1995 through December 2001.

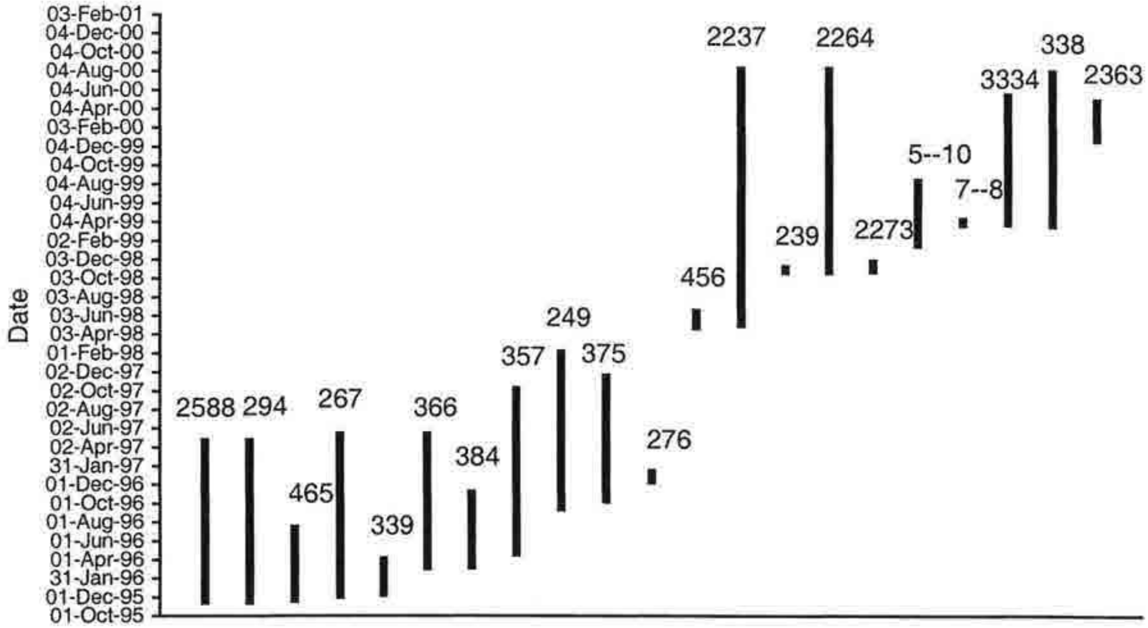


Figure 14. Observed movements of pallid sturgeon 2588 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

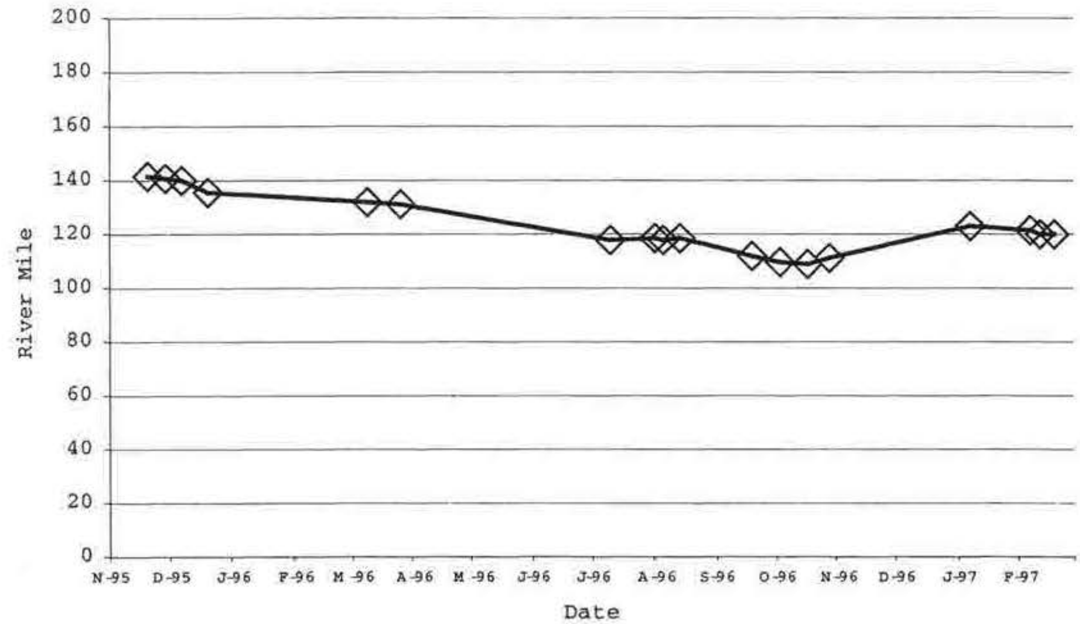


Figure 15. Observed movements of pallid sturgeon 294 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

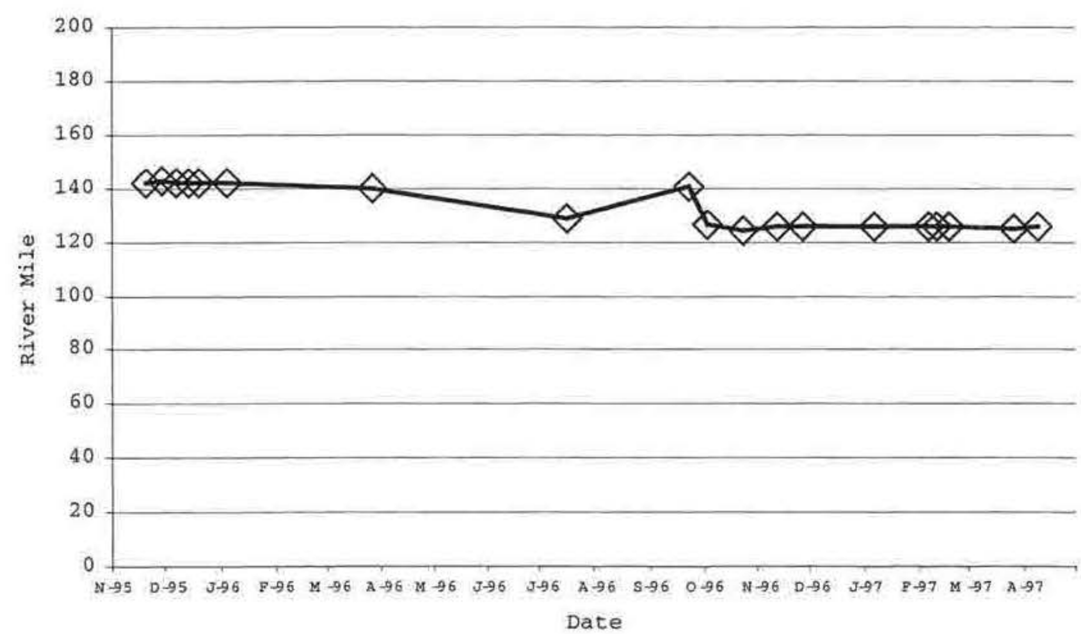


Figure 16. Observed movements of pallid sturgeon 465 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

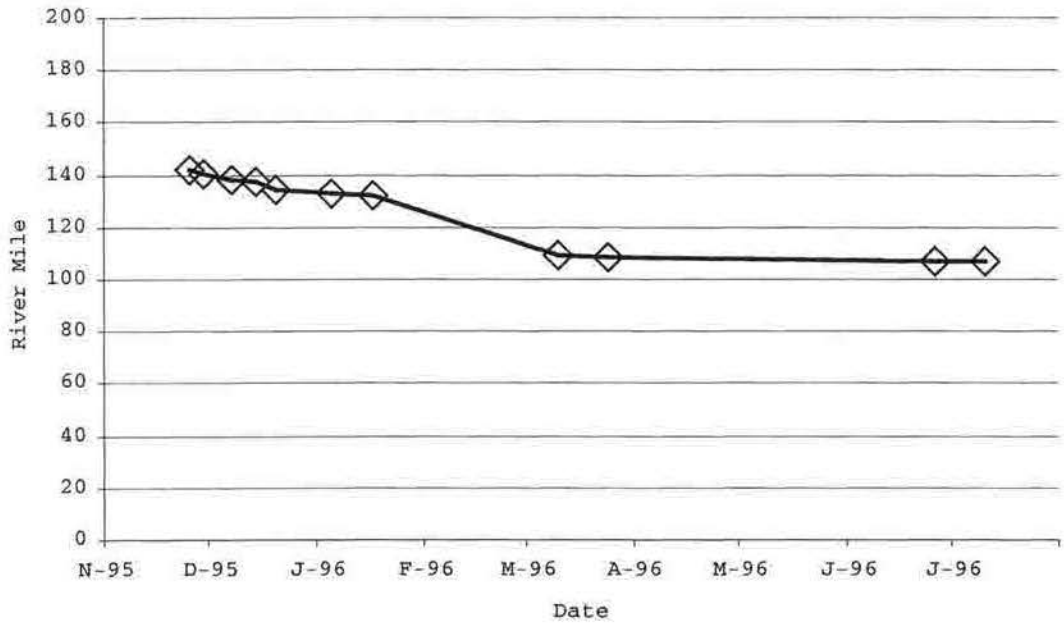


Figure 17. Observed movements of pallid sturgeon 267 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

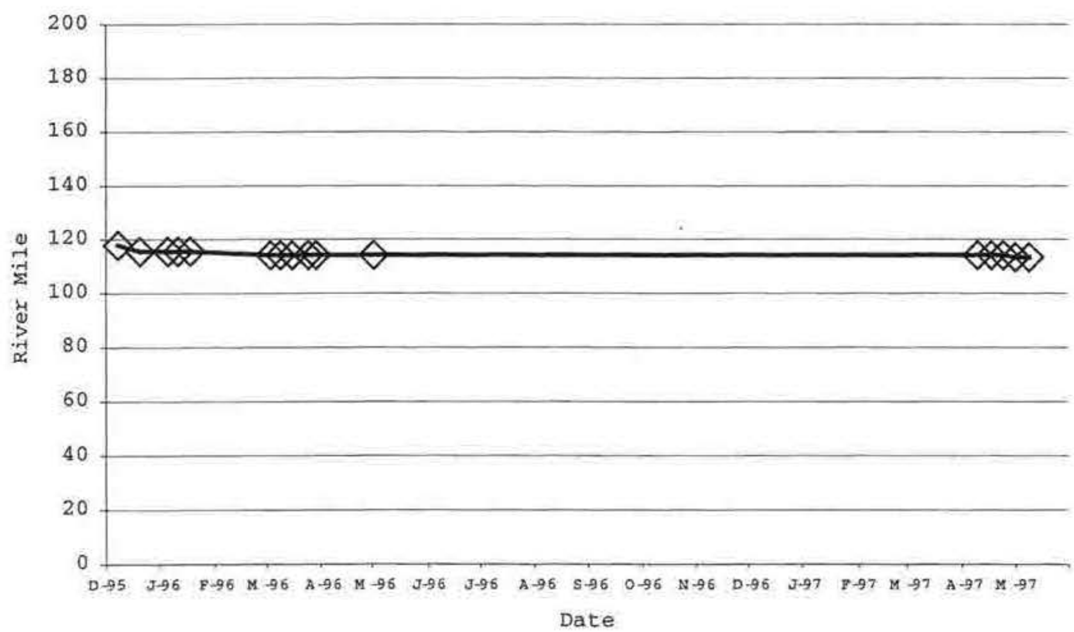


Figure 18. Observed movements of pallid sturgeon 339 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

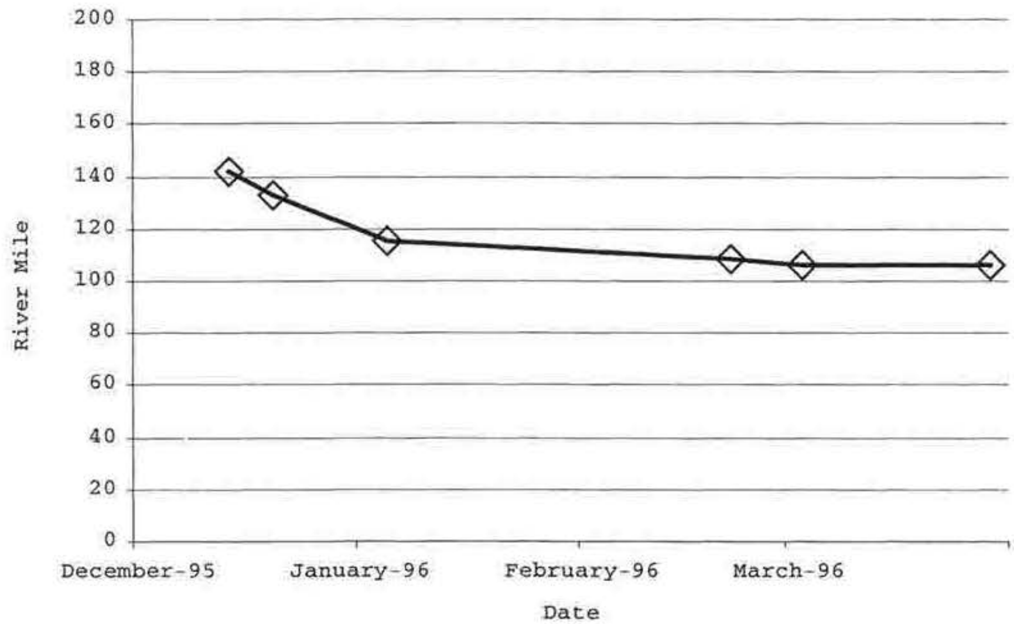


Figure 19. Observed movements of pallid sturgeon 366 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

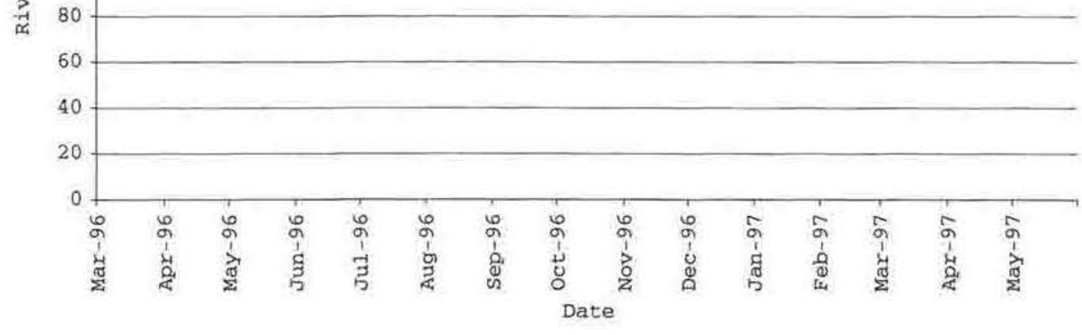


Figure 20. Observed movements of pallid sturgeon 384 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

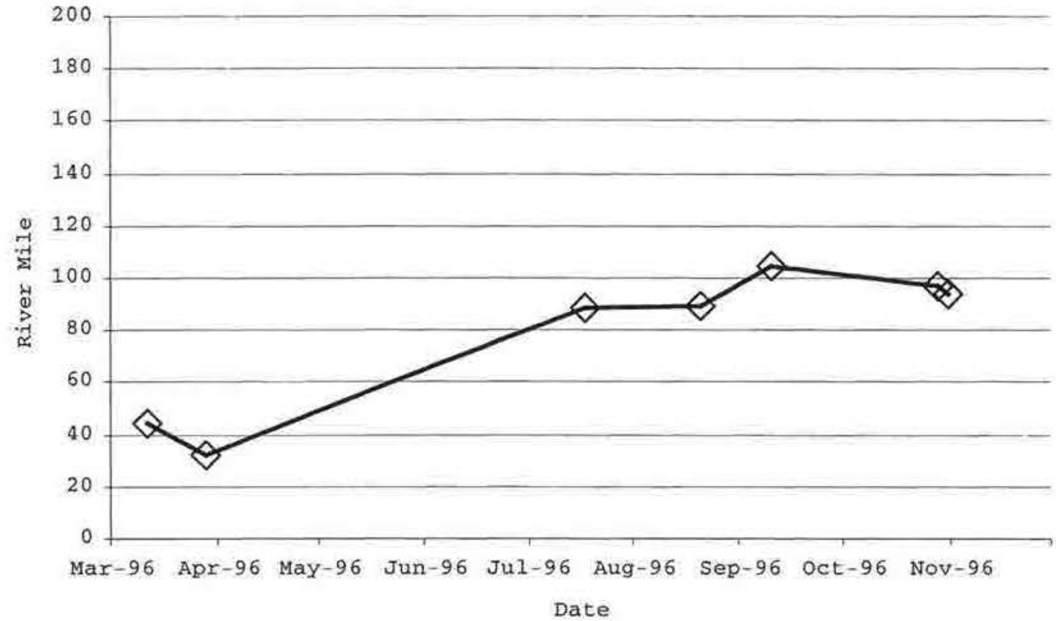


Figure 21. Observed movements of pallid sturgeon 357 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

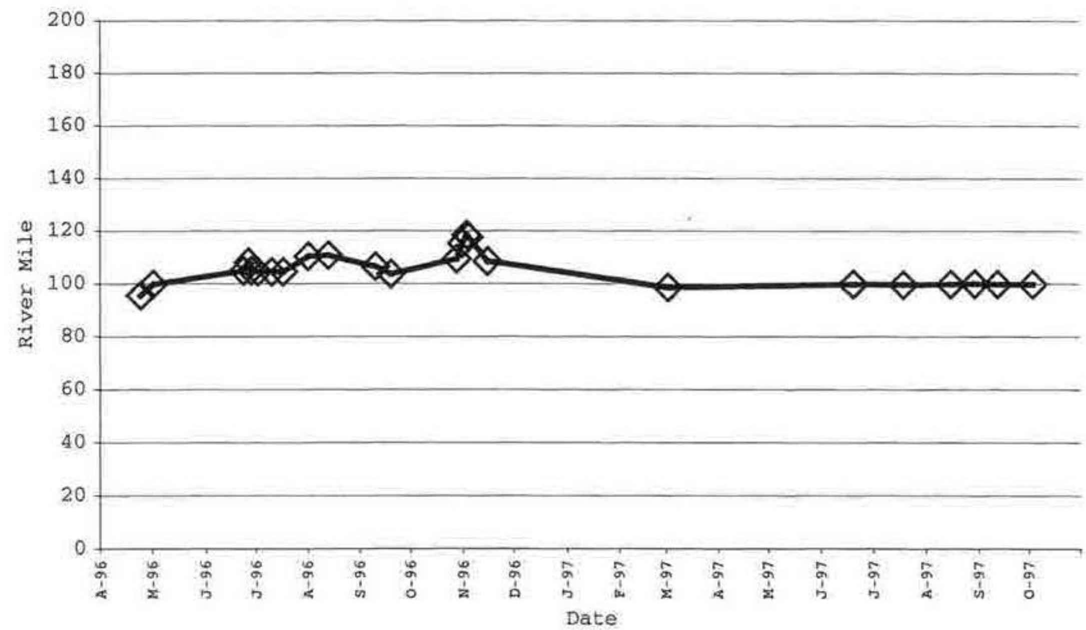


Figure 22. Observed movements of pallid sturgeon 249 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

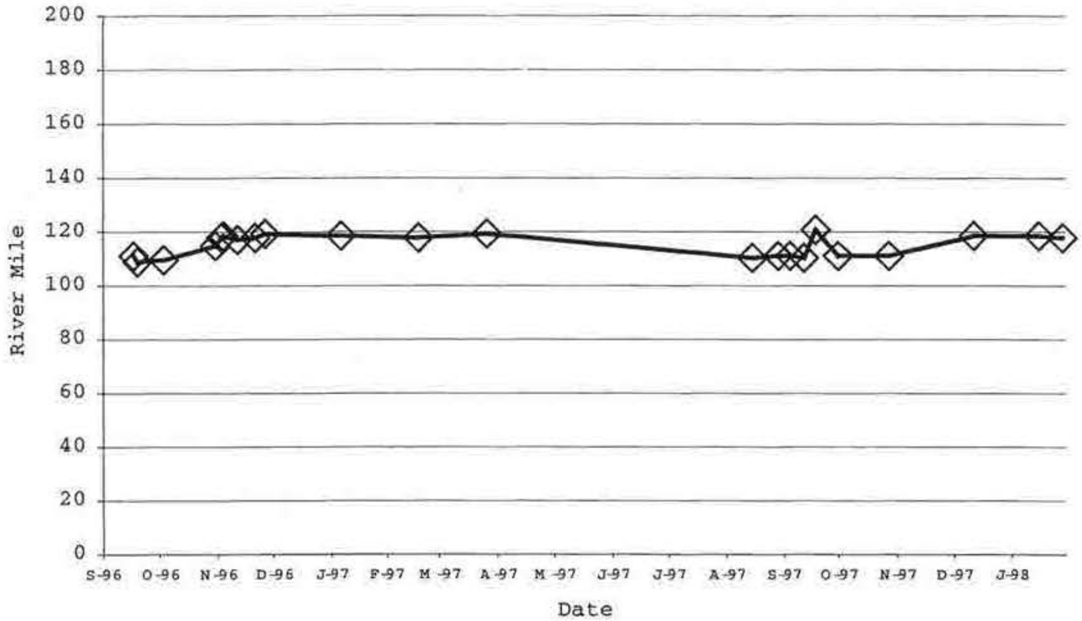


Figure 23. Observed movements of pallid sturgeon 375 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

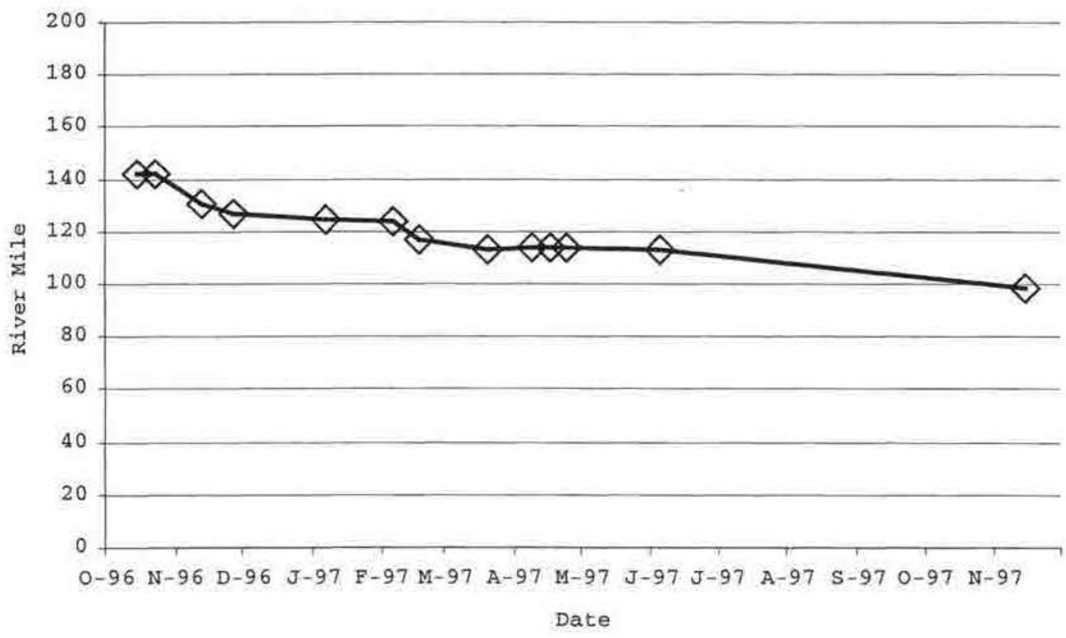


Figure 24. Observed movements of pallid sturgeon 276 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

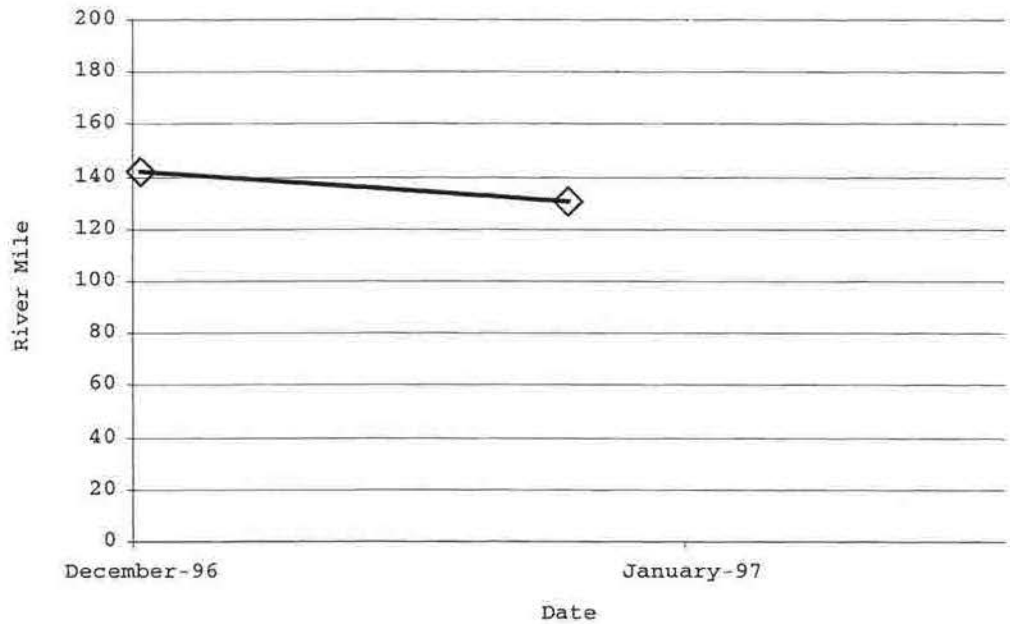


Figure 25. Observed movements of pallid sturgeon 456 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

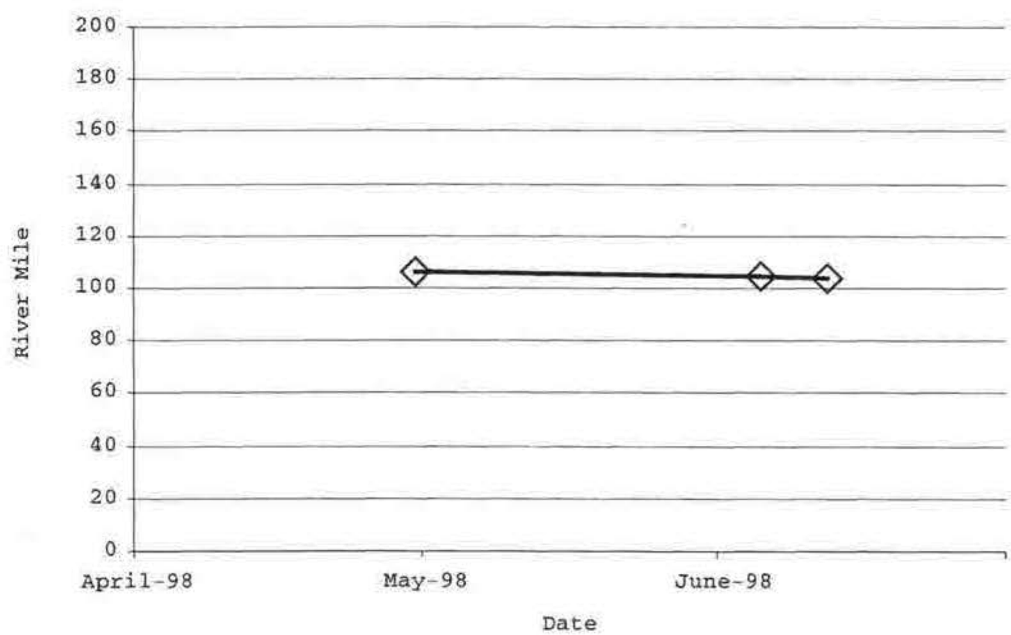


Figure 26. Observed movements of pallid sturgeon 2237 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

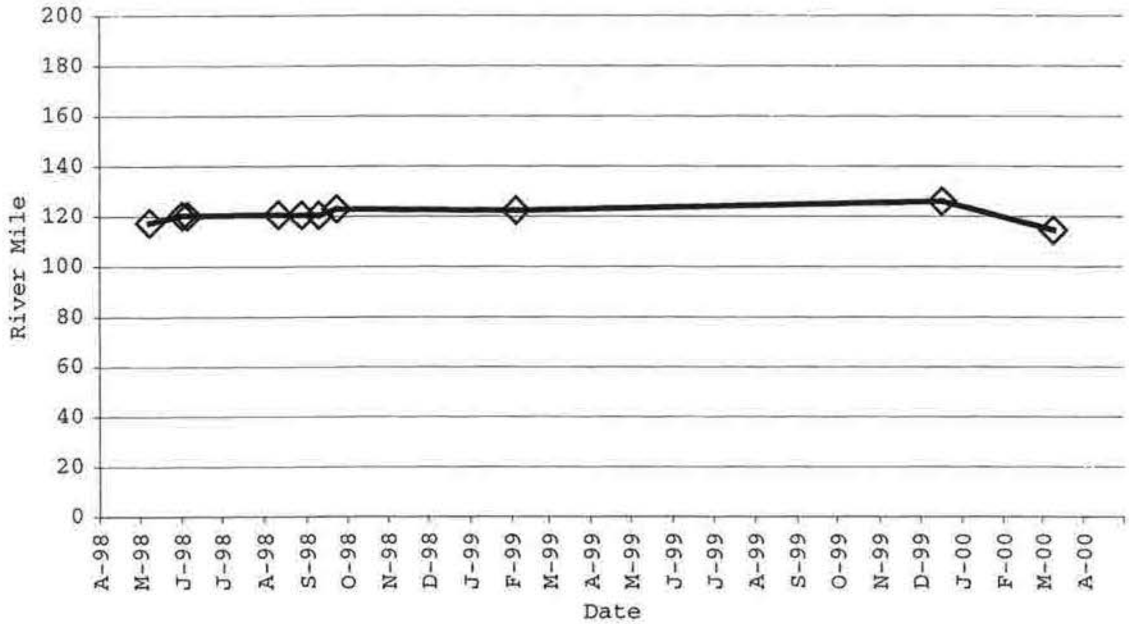


Figure 27. Observed movements of pallid sturgeon 239 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

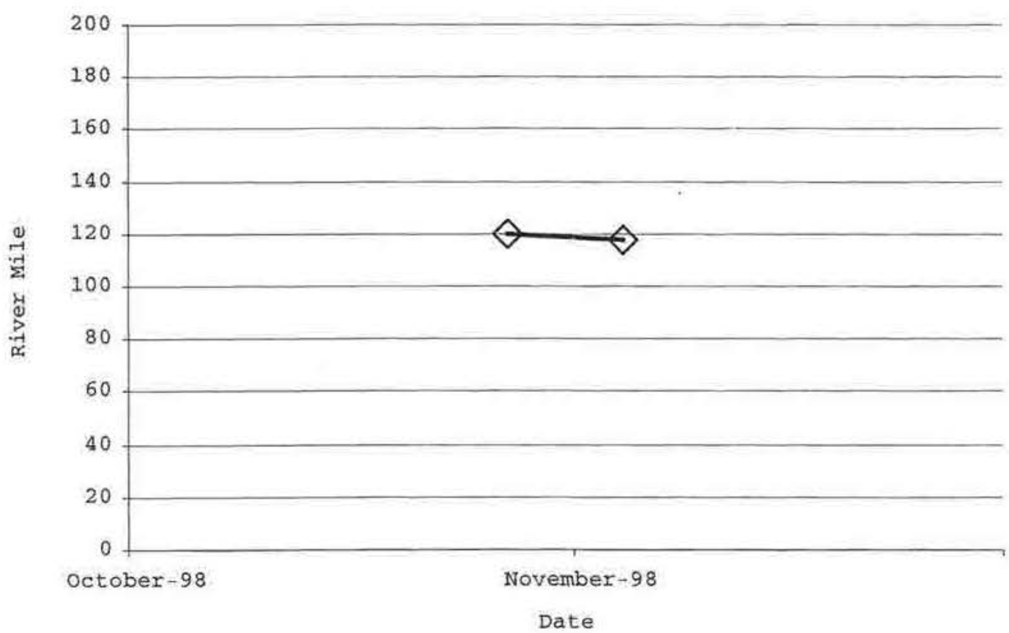


Figure 28. Observed movements of pallid sturgeon 2264 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

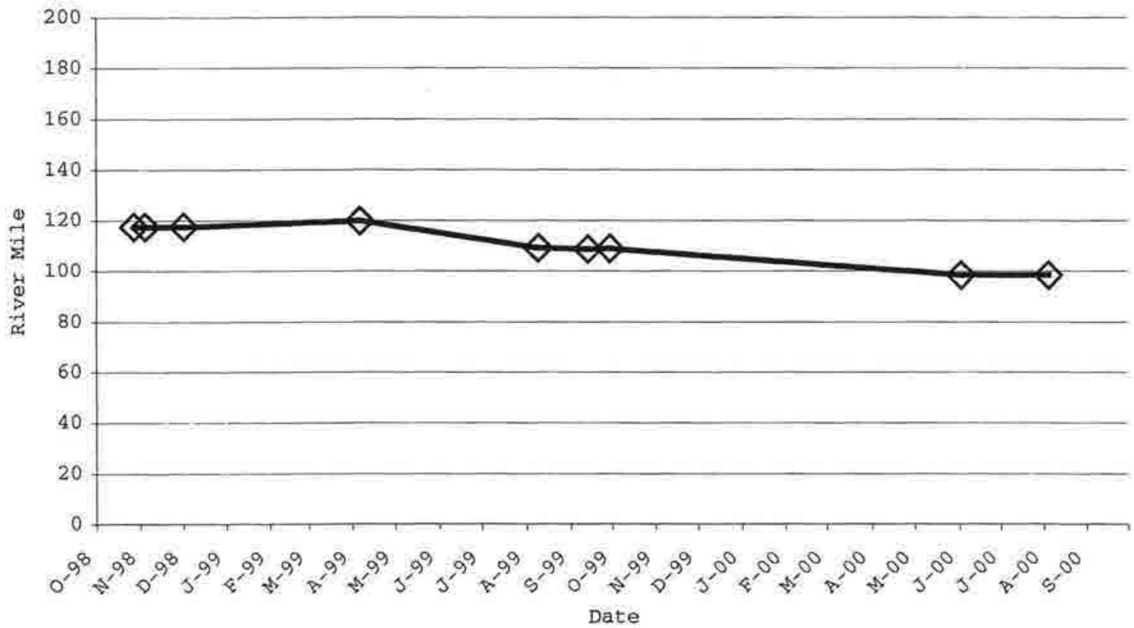


Figure 29. Observed movements of pallid sturgeon 2273 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

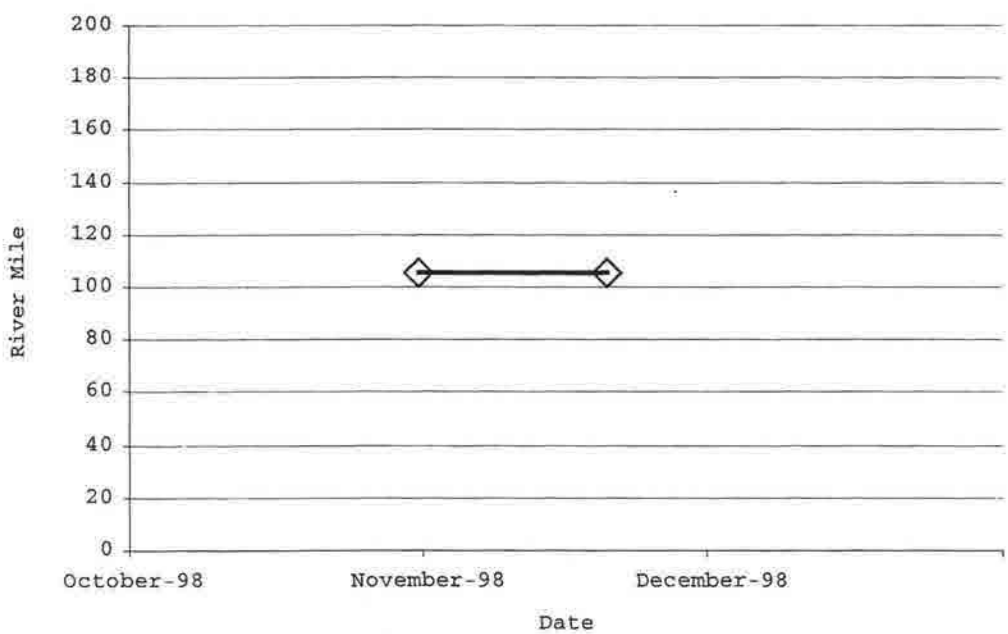


Figure 30. Observed movements of pallid sturgeon 5--10 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

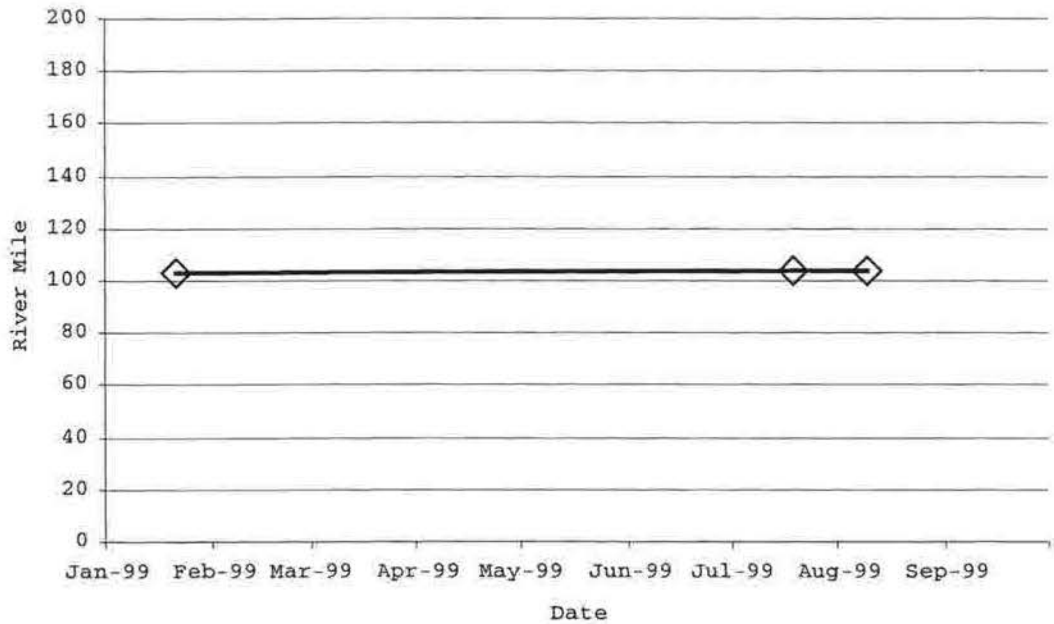


Figure 31. Observed movements of pallid sturgeon 7--8 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

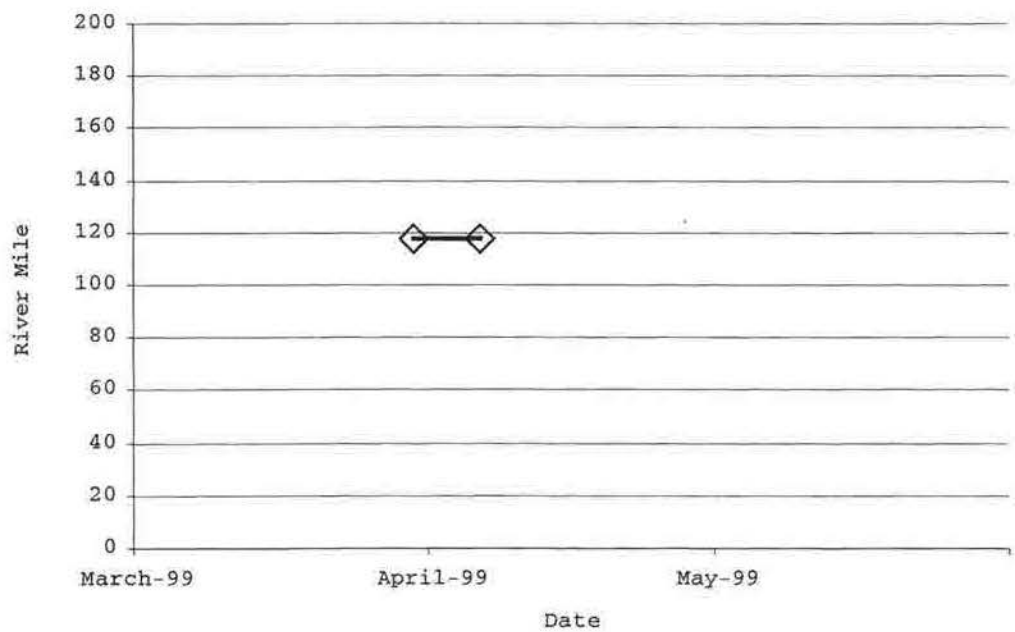


Figure 32. Observed movements of pallid sturgeon 3334 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

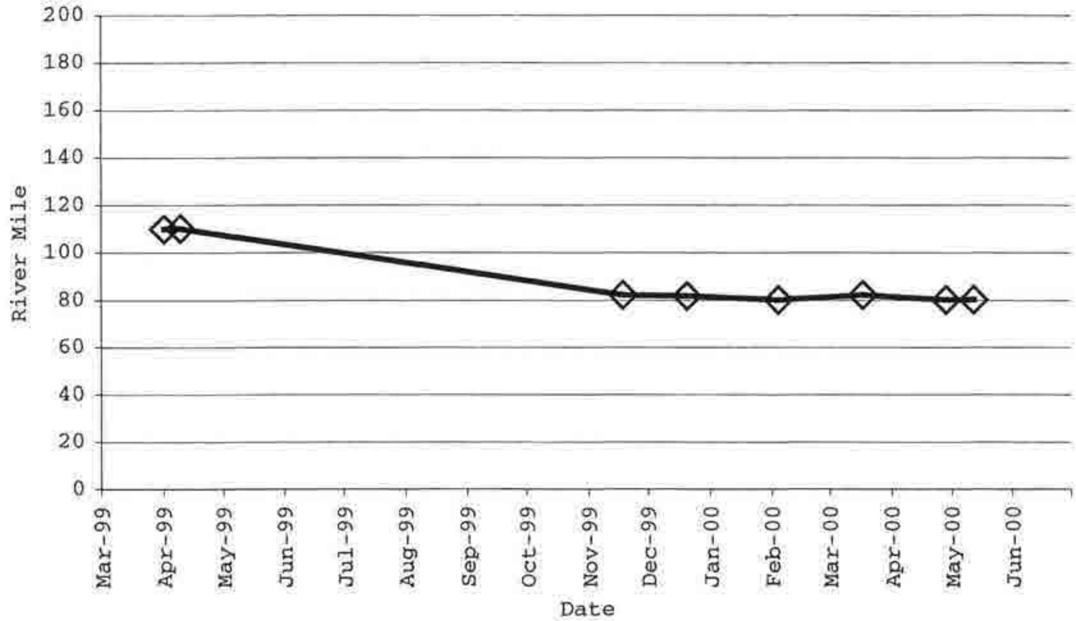


Figure 33. Observed movements of pallid sturgeon 338 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

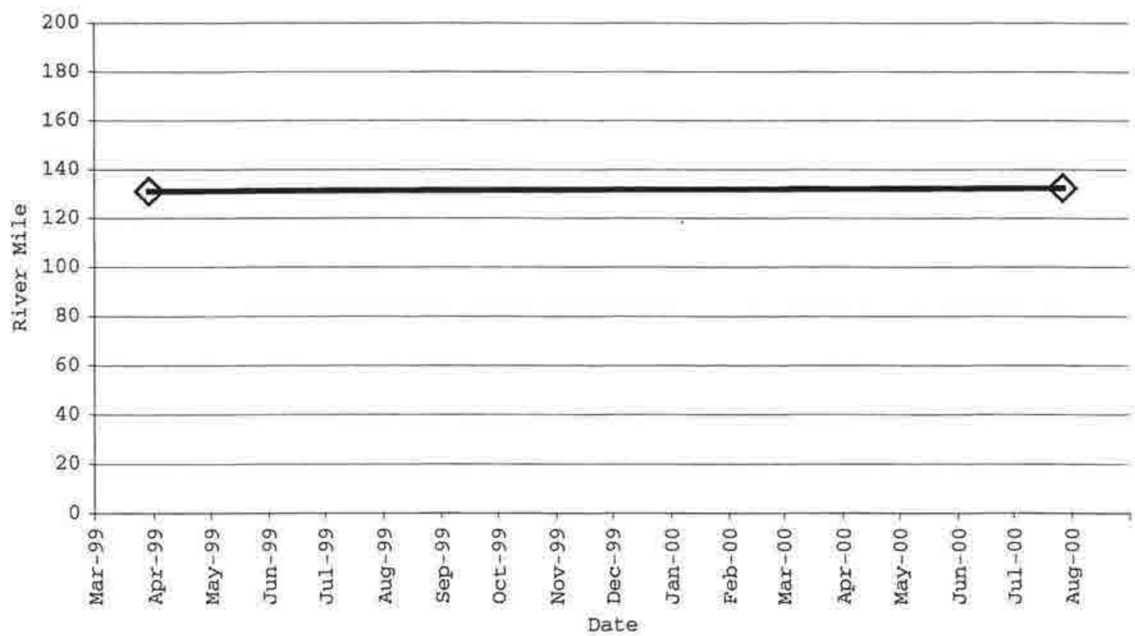


Figure 34. Observed movements of pallid sturgeon 2363 in the middle Mississippi River from transmitter implantation until latest contact. Diamonds indicate individual contacts.

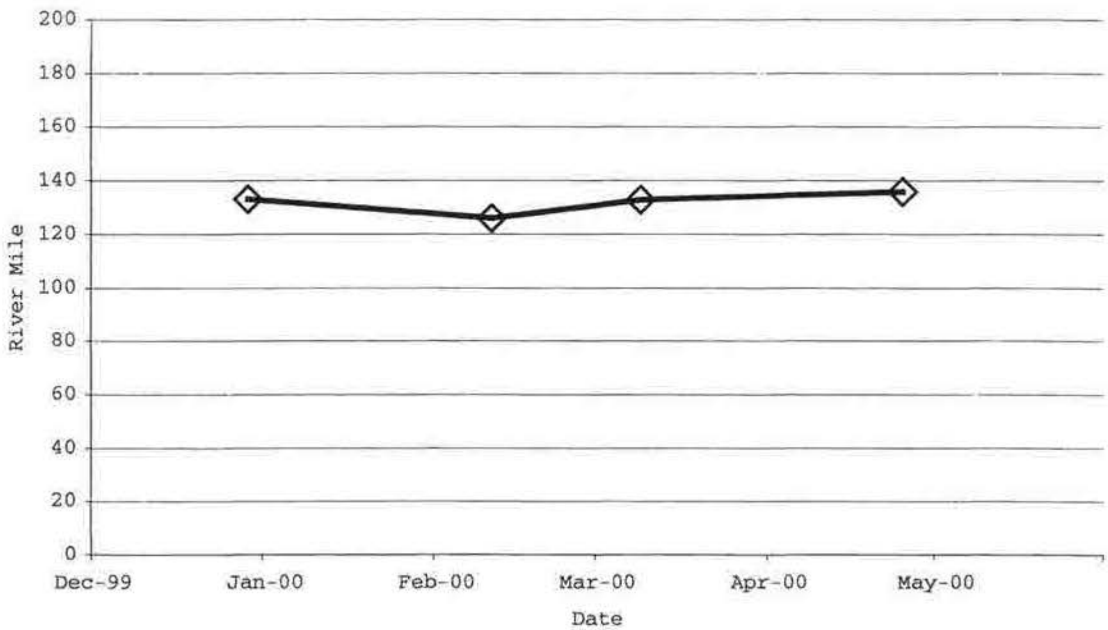


Figure 35. Daily mean discharge values from January 1, 1996 through December 31, 2000. Discharge values were obtained from the U.S. Geological Survey and taken at the Chester, IL gauging station on the Mississippi River.

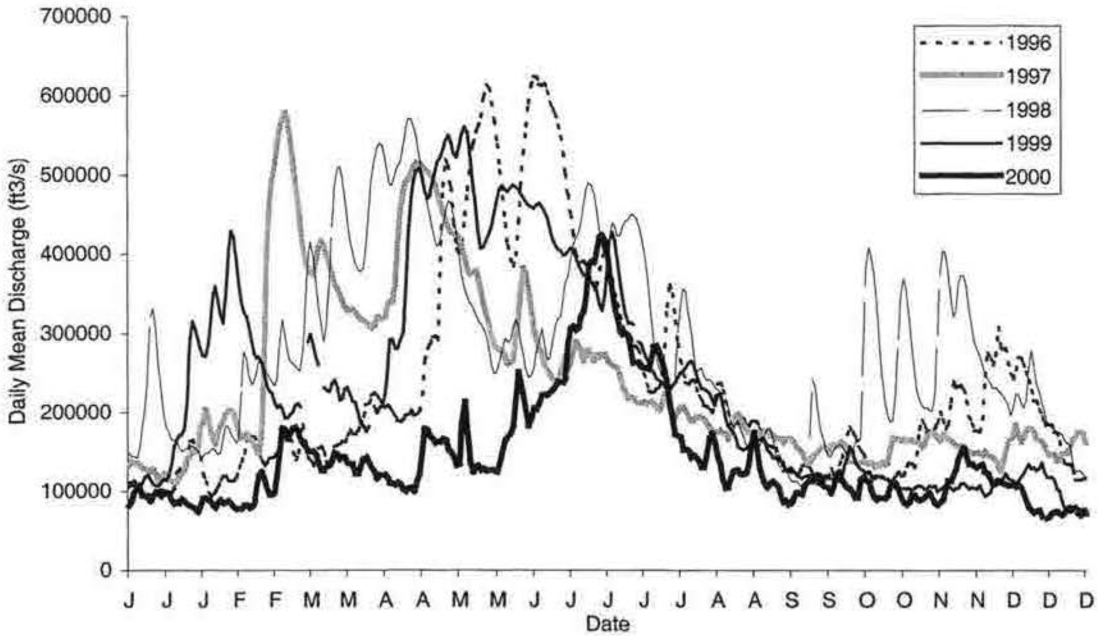


Figure 36. Differences in weight as measured before the gastric lavage procedure and immediately after lavage. Similar letters indicate significant differences (ANOVA, p>0.05).

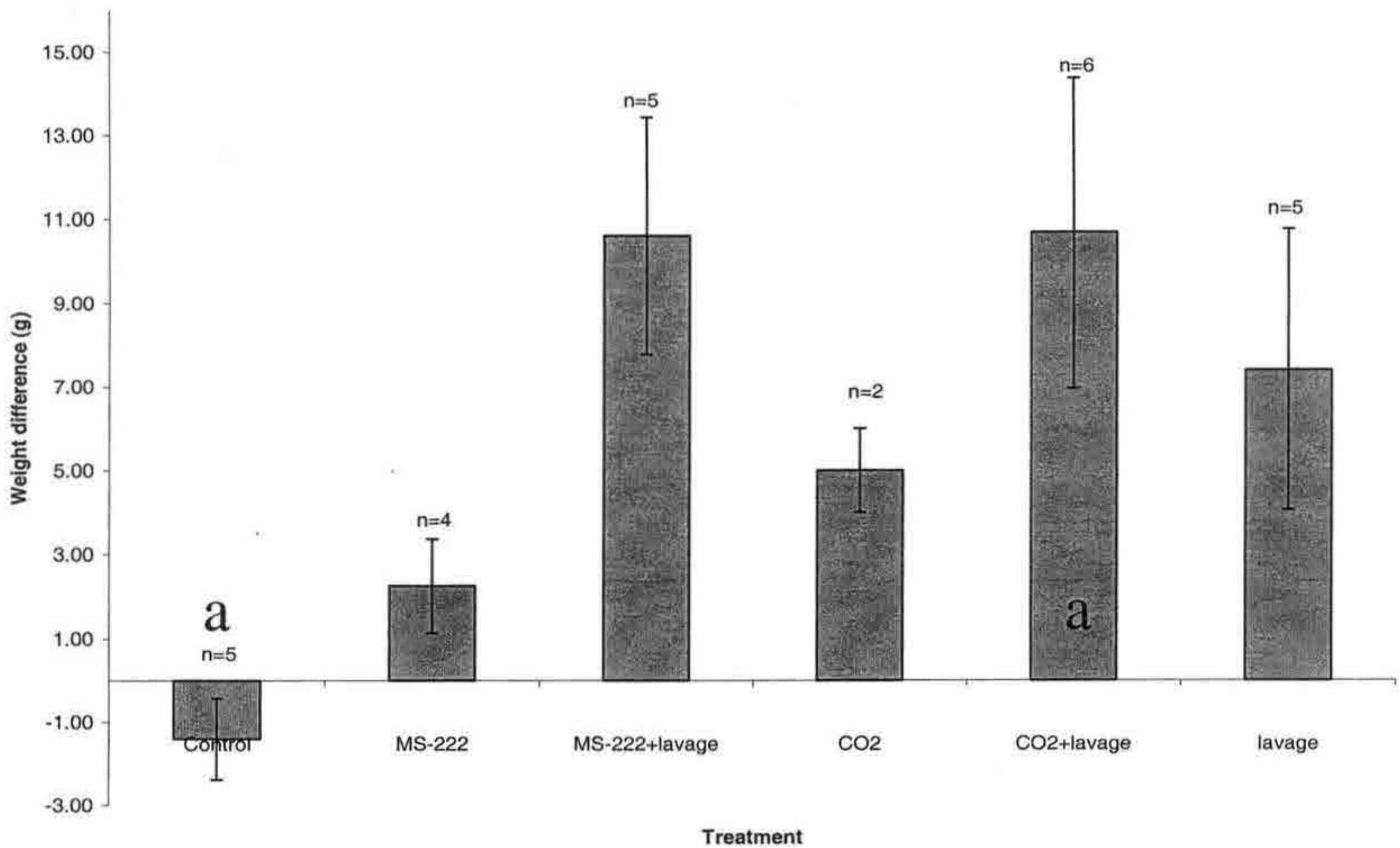


Figure 37. Differences in weight as measured before the gastric lavage procedure and 1-hour post procedure. No significant differences were found among the treatment groups (ANOVA, $p>0.05$).

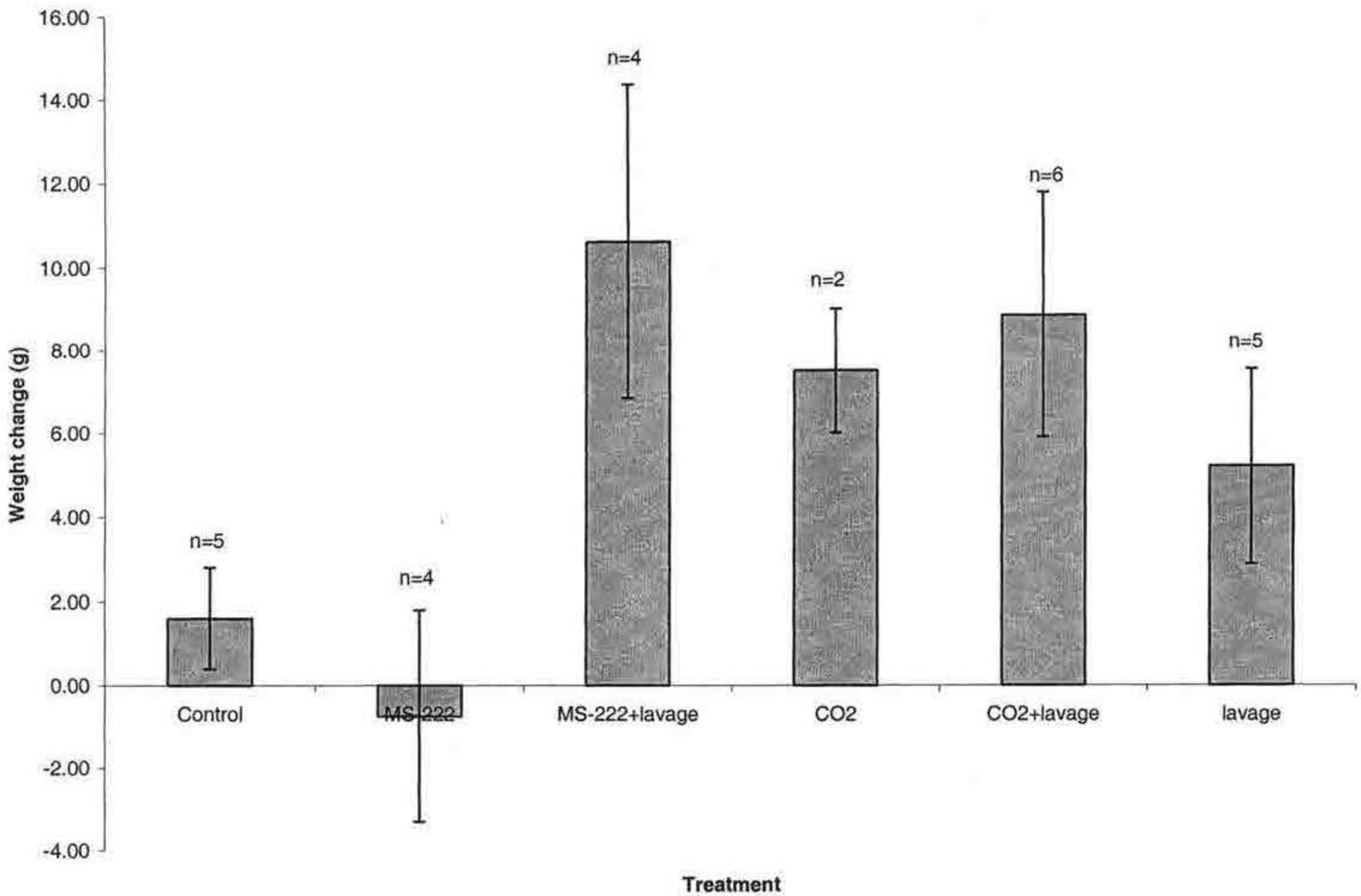


Figure 38. Percent hematocrit as measured 24 hours after the gastric lavage procedure. No significant differences were found among the treatment groups (ANOVA, p>0.05).

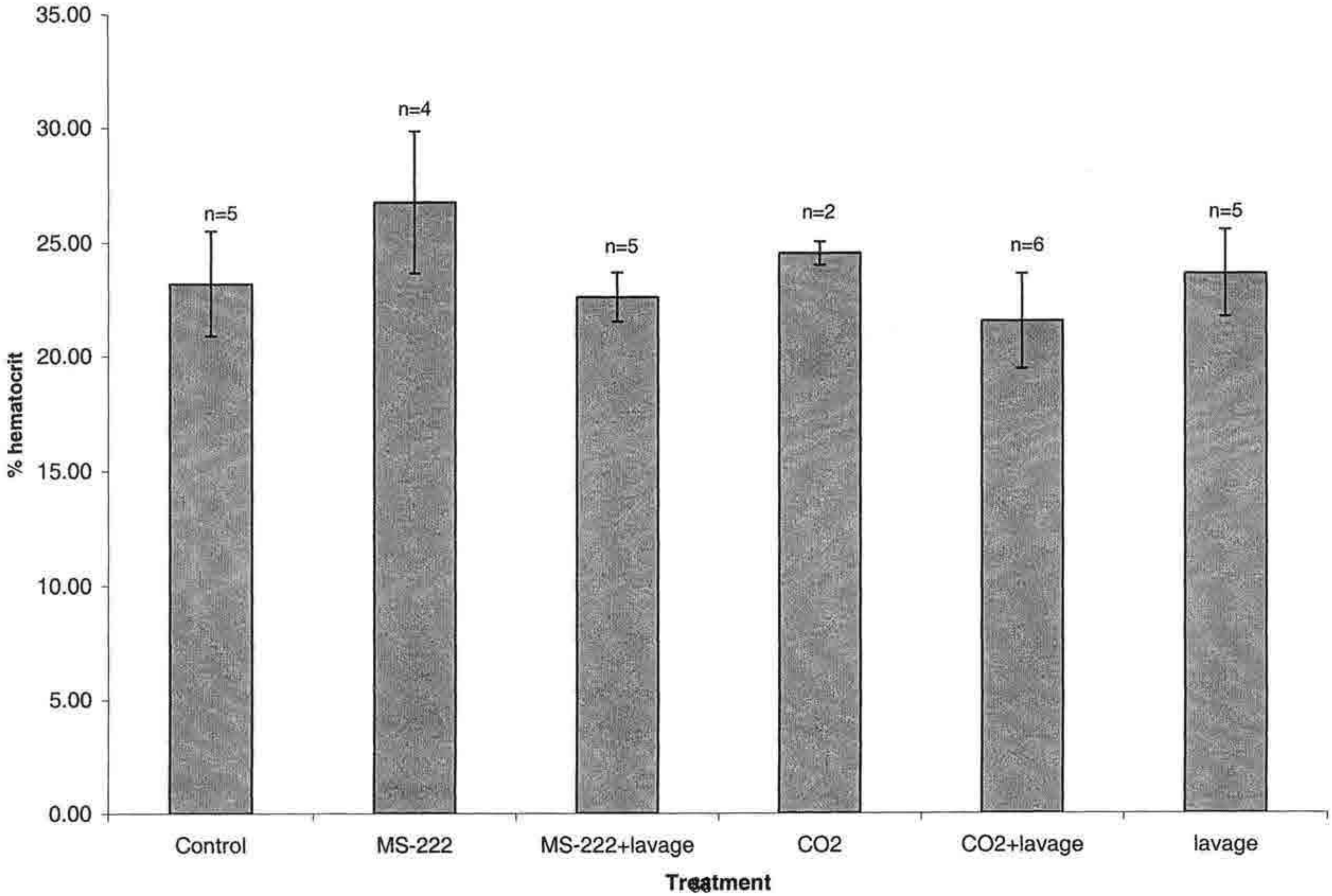


Figure 39. Percent leucocrit as measured 24 hours after the gastric lavage procedure. No significant differences were found among the treatment groups (ANOVA, p>0.05).

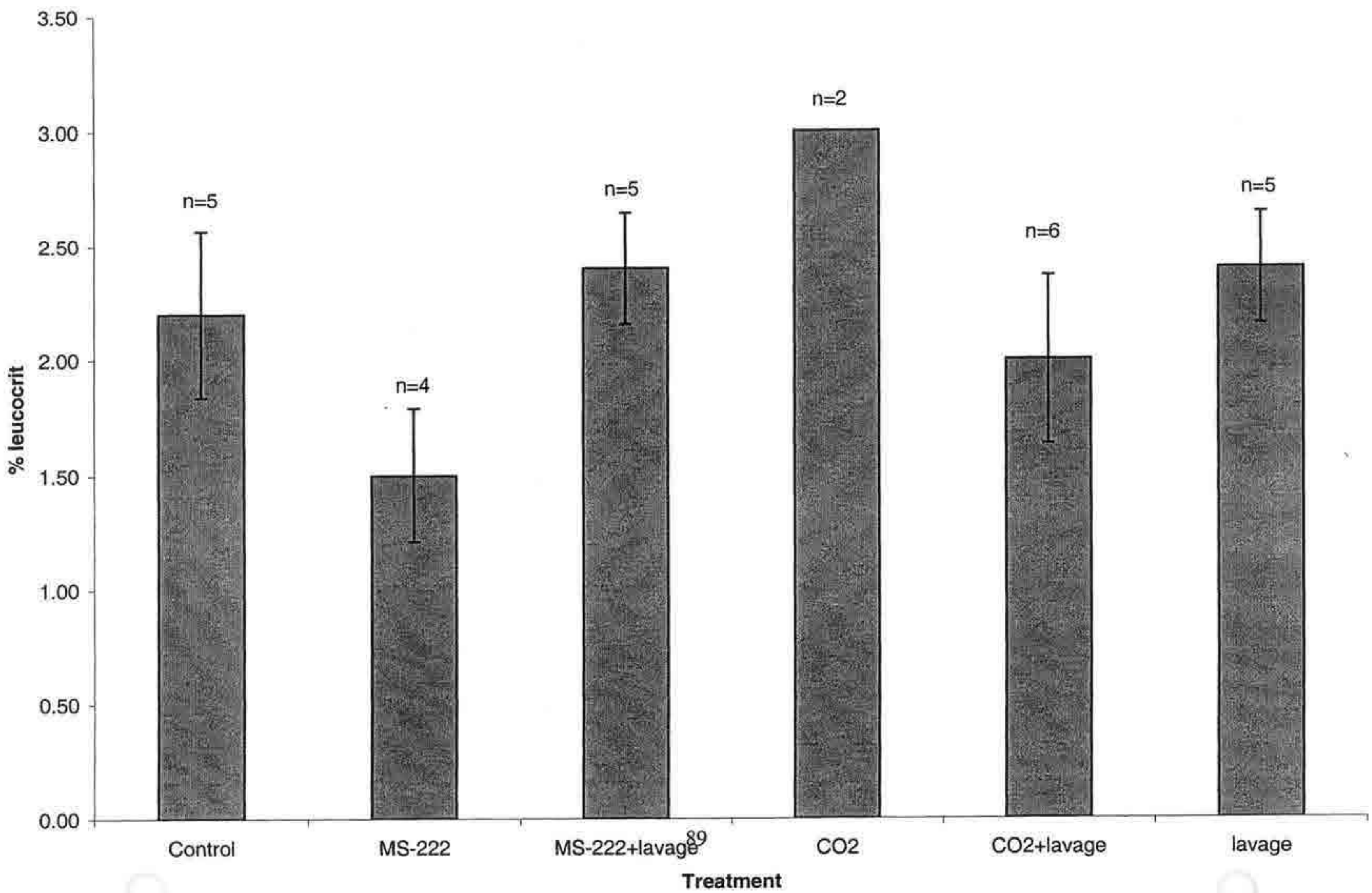
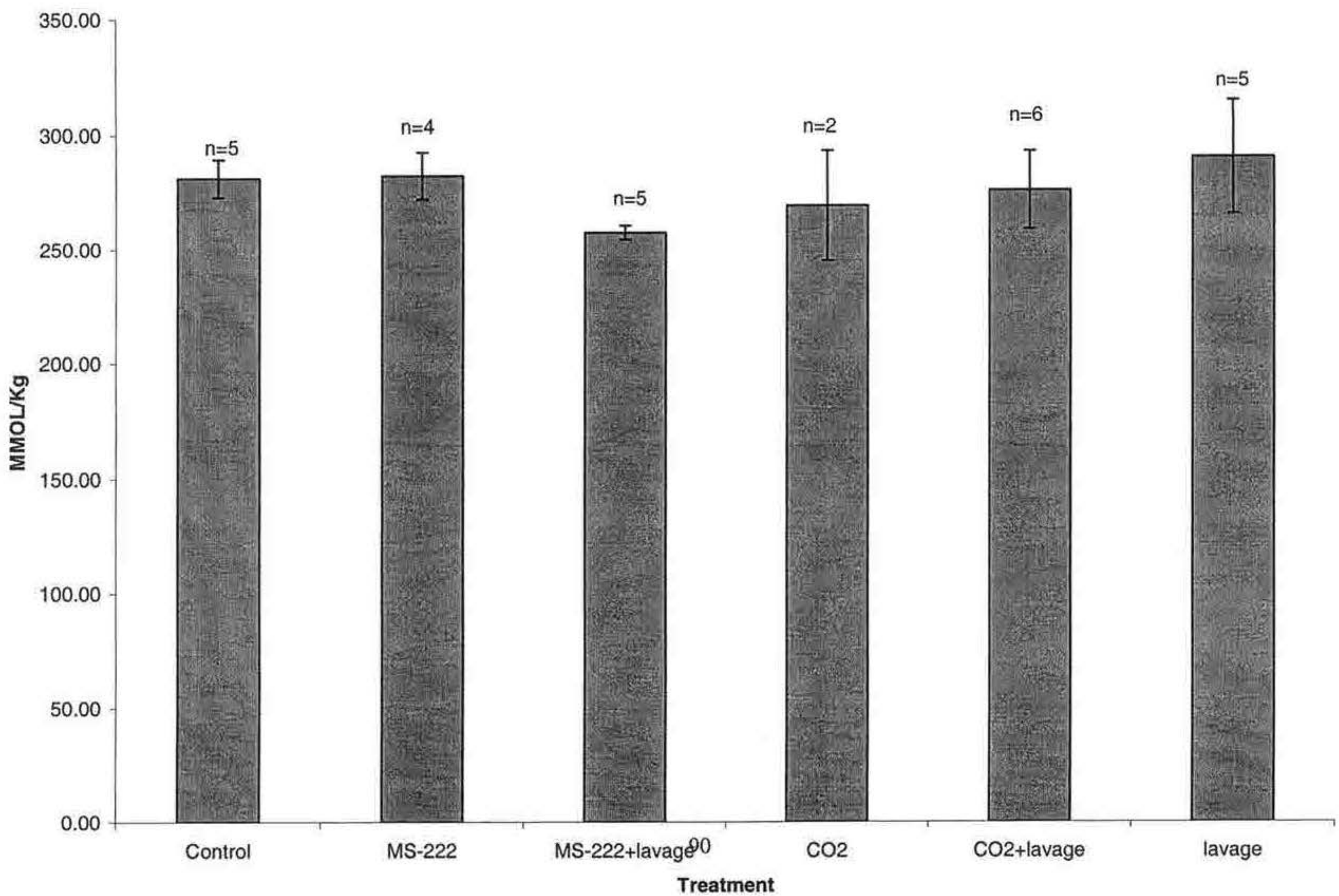


Figure 40. Blood osmolality as measured 24 hours after the gastric lavage procedure. No significant differences were found among the treatment groups (ANOVA, $p>0.05$).



Appendix F.

2001 Summary Letter Report - Lock and Dam 25 Fish Passage Project. U.S. Army Corps of Engineers, St. Louis District

Lock and Dam 25 Fish Passage Project
2001 Summary Letter Report

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

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

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

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

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

The results of this study through 2000 had shown that fish do move through Lock and Dam 25 but movement appears to be limited to periods of open river. Manipulating the gates to extend the period of open river is possible, but as originally tested also increased velocities in gate bay 17. Fish movement data is inconclusive. Changes in gate operations do not appear to affect tow traffic.

Work in 2001 involved manipulating gates as Lock and Dam 25 headed towards a spring open river event (versus coming out of open river like in 2000). Testing at that time better coincided with spring fish movement and should give a better indication of the true effects of gate manipulation on fish movement, than the work in June 2000. Fish passage work began on 8 April, in 2001. On that date springs flows were rising to the point that Lock and Dam 25 was likely to go to open river within 48 hrs. As Lock and Dam 25 progresses towards open river, the standard procedure is to make gate adjustments on all 17 gates relatively uniformly across the dam. This assures a fairly even distribution of flows across the channel. In 2001, we altered the gate adjustment procedure to determine if we could induce fish passage prior to the Lock and Dam going to open river. Just after noon on April 8th, gates 13 through 17 were raised completely out of the water, while gates 7 through 12 were lowered to compensate for the gate raises. Further adjustments (gate raises) were made at 1745 and 1945 to compensate for increasing flows. Raises were not made uniformly. In both cases, the gates closest to gates 13 through 17 were raised higher than the gates closest to the lock. Lock and Dam 25 went to complete open river on 9 April at 0300 hrs.

Fish and velocity data were set to be analyzed in FY2002. Unfortunately, the A&M program experienced a decreased level of funding in 2002. That data is now scheduled to be analyzed in FY2003. A preliminary look at the data suggests that altering gate patterns can improve fish passage prior to the Lock and Dam going to open river. Very few fish were seen moving through prior to the gate shifts at 1745 or 1945. Fish numbers appeared to greatly increase soon afterward. It appears that fish movement can be induced 5 to 7 hours earlier than by traditional operating procedures. The significance of that increased length of time will be determined in 2003 by evaluating the length of time of previous open river events.

Several new methodologies were attempted in 2001. In past seasons the hydroacoustic equipment was aimed downward to count fish numbers and determine fish direction. On several days in 2001 the hydroacoustic equipment was aimed sideways across the gate bay. Aiming the beam sideways resulted in a larger beam, and as a result we could track fish longer, which should improve our ability to assess directionality of movement through the gate bay. In addition, on 18 April, with the help of the Missouri

Department of Conservation, we attempted to electro-fish in gate bay 17 to determine what fish species were moving through the gate bay. Those attempts were unsuccessful.

No new fieldwork is scheduled beyond 2001. Future work will consist of data analysis and report preparation. The need for any future fieldwork will be determined after completion and review of the existing information.

Submitted: 11 September 2002

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

Appendix G.

2001 Progress Reports - Wood Structure Construction and Placement - U.S. Army Corps of Engineers, St. Louis District.

US Army Corps of Engineers, St. Louis District
Avoid and Minimize Program
Progress Report
12 July 2001

Placement of wood structure in Mississippi River side channels.

On 9 and 10 July 2001, the St. Louis District, under authority of our Avoid and Minimize Program, placed 12 wood structures (log bundles) in Calico chute in the Middle Mississippi river. Four locations within Calico chute (river miles 148.3- 147.3) were selected for placement during an earlier onsite meeting with the US Fish and Wildlife Service, Missouri Department of Conservation, and Illinois Department of Natural Resources. The unanimous sentiment from our partner agencies was that we place the log bundles in deeper areas of the side channels so that the newly created habitat would continue to be available to fish and aquatic insects as water levels in the chute dropped.

The bundles are being placed to increase habitat diversity in the side channels. Habitat will be improved through the placement of the wood itself (many fish species are attracted to structure in the water as areas of cover, reproduction, or forage), through the creation of localized scour holes below the bundles, and through the collection of organic debris, like leaves and drifting wood, which in turn provide a fertile food bed for aquatic insects.

Placement of the wood bundles also begins to help the St. Louis District meet our obligations under the Endangered Species Act, Biological Opinion for the Operation and Maintenance of the 9 foot Navigation Channel on the Upper Mississippi River, Reasonable and Prudent Alternative #4. That alternative calls for several habitat and restoration and enhancement measures for the pallid sturgeon, including restoring woody debris and restoring side channels.

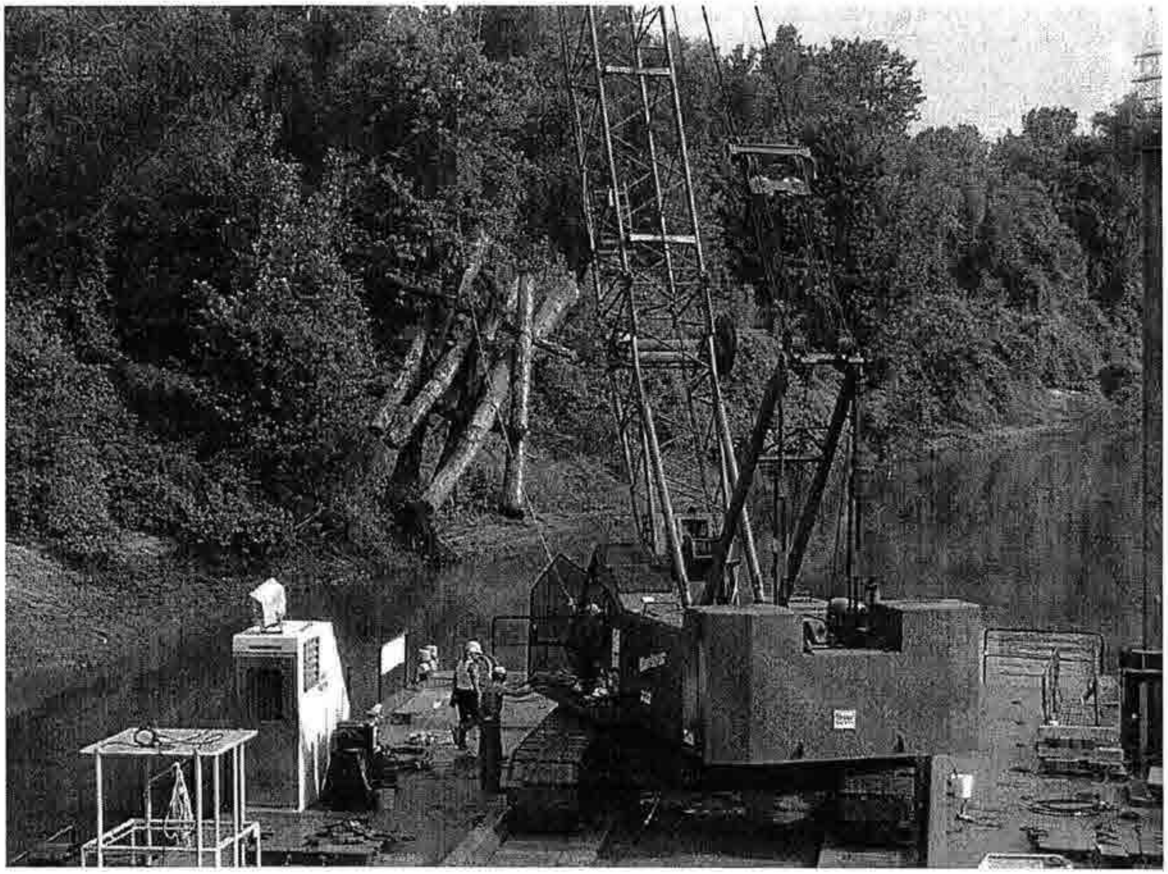
Logs for the project were donated by the Westvaco Corp., which could not use the logs at their Wyckliffe, Ky mill because of metal in the wood. Each bundle consisted of 4 to 10 interlaced logs attached to at least one, and often two or three, 1400 lb concrete anchors. Log bundles were placed in groups of three at each location. Placement was such that one large woodpile was formed at each site. GPS locations were taken at each site. Water depths at the placement sites ranged from 18 to 35 ft. Placement work was done using the Corps of Engineers M.V. Grand Tower and crane barge, Fisher. In addition to the crew of the Grand Tower, Brian Johnson, a fisheries biologist with the St. Louis District, was present to help with site selection.

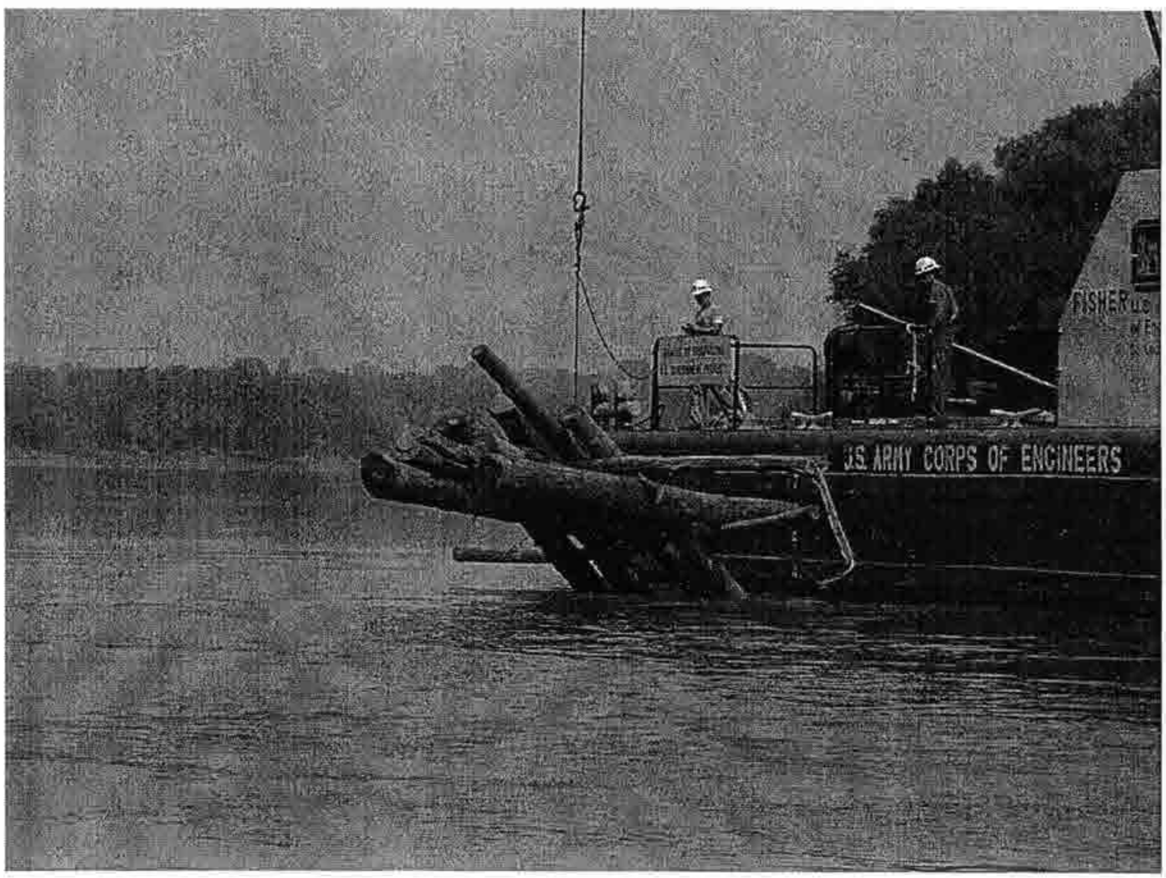
Post construction monitoring is a critical tool in assessing the value and impact of these structures. That work will include a bathymetric survey of the chute to assess changes in the chute as the result of the wood bundles. The St. Louis District, in cooperation with the Illinois Department of Natural Resources, will also be conducting post construction monitoring at the sites to determine fish use of the log bundles.

Osborne chute (river miles 146.4-144.1) was also selected for placement of woody structure. Unfortunately, dropping water levels precluded the M.V. Grand Tower from accessing that chute. Work in Osborne chute will be completed at a future date. In addition to the side channel sites, woody structure is scheduled to be placed at several main channel border sites below St. Louis. These sites have been selected in areas that will not impact navigation traffic, but will provide aquatic habitat benefits. That work, to be completed yet this summer, will take place in existing dike fields.

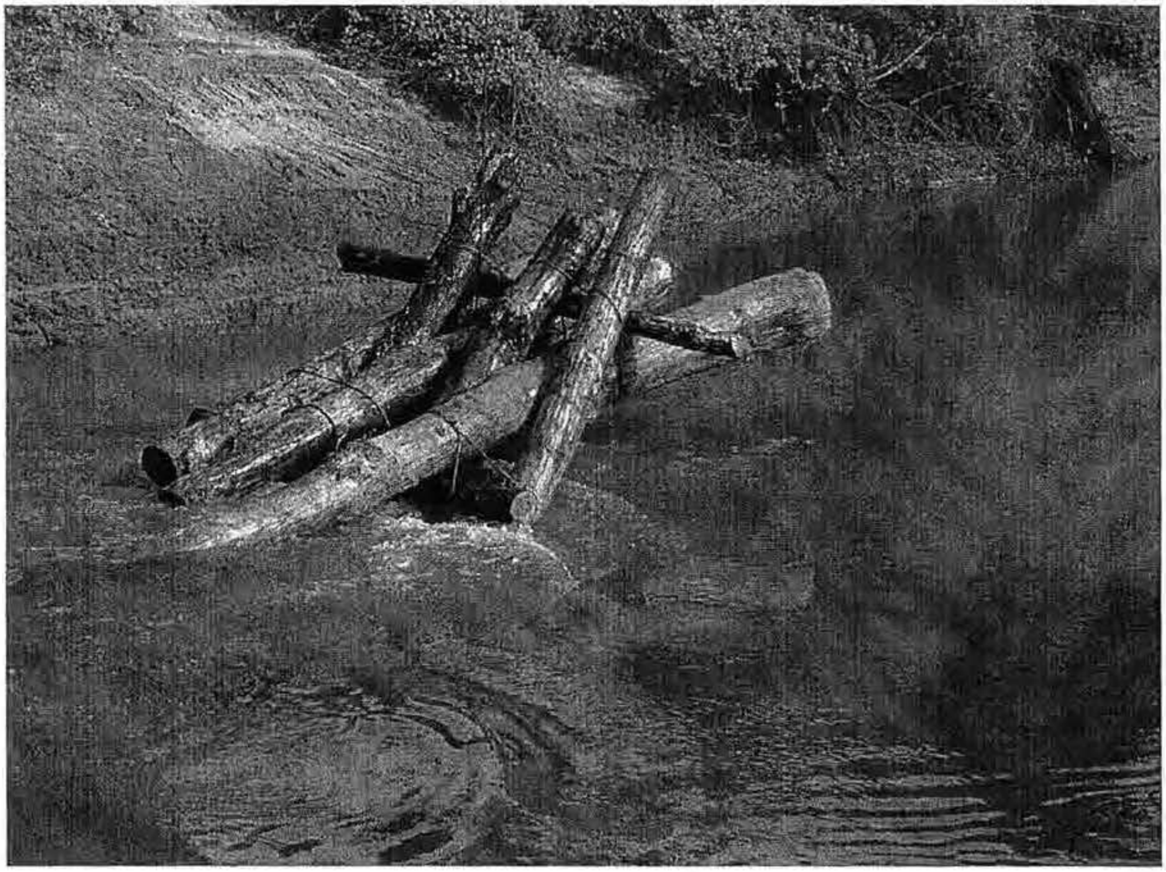
Submitted 12 July 2001

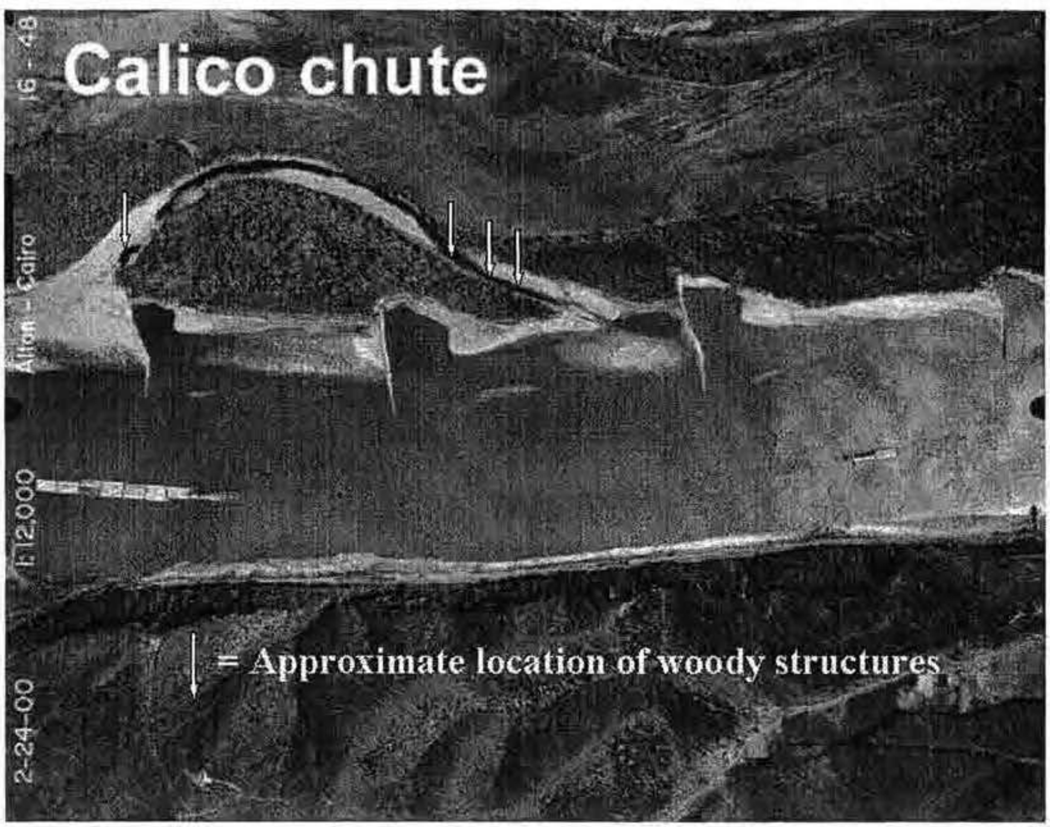
BRIAN JOHNSON
Fishery Biologist
US Army Corps of Engineers
Planning, Programs, and Project Management
Environmental Branch
314-331-8146





FISHER
J.S. ARMY CORPS OF ENGINEERS





Calico chute
16 - 48
Alton - Cairo
1:12,000
2-24-00
= Approximate location of woody structures

US Army Corps of Engineers, St. Louis District
Avoid and Minimize Program
Progress Report
13 August 2001

Placement of wood structure along the main channel border of the Mississippi River below St. Louis, Missouri.

On 7 and 8 August 2001, the St. Louis District, under authority of our Avoid and Minimize Program, placed 15 wood structures (log bundles) in two locations along the main channel border of the Middle Mississippi River. Site one was behind an L-dike located at river mile 165.5. Nine log bundles were placed to form one large wood pile. Bundles were placed in the approximately 20 foot of water. The St. Louis water gage was at a stage of 9.4 feet. The location of the bundles is shown in Figure 1.

Site two was just downstream from site one, between dike 165.3 and 165.1. At this site 6 log bundles were placed to form one wood pile. Bundles were placed in approximately 20 foot of water. The location of those bundles is also shown in Figure 1.

Site one was selected through earlier coordination with the US Fish and Wildlife Service, Missouri Department of Conservation, and Illinois Department of Natural Resources. Site two was selected just prior to installation and was coordinated with the US Fish and Wildlife Service. The unanimous sentiment from our partner agencies was that we place the log bundles in deeper areas of the main channel border so that the newly created habitat would continue to be available to fish and aquatic insects as water levels drop. Both sites are within existing dike fields.

The main channel border work is the St. Louis District's second round of wood structure placements. In July 2001, 12 wood structures were placed in Calico Chute at river mile 147. That work is summarized in an earlier progress report.

The bundles are being placed to increase habitat diversity in the main channel border. Habitat will be improved through the placement of the wood itself (many fish species are attracted to structure in the water as areas of cover, reproduction, or forage), through the creation of localized scour holes below the bundles, and through the collection of organic debris, like leaves and drifting wood, which in turn provide a fertile food bed for aquatic insects.

Placement of the wood bundles also begins to help the St. Louis District meet our obligations under the Endangered Species Act, Biological Opinion for the Operation and Maintenance of the 9 foot Navigation Channel on the Upper Mississippi River, Reasonable and Prudent Alternative #4. That alternative calls for several habitat and restoration and enhancement measures for the pallid sturgeon, including restoring woody debris.

Logs for the project were donated by the Westvaco Corp., which could not use the logs at their Wyckliffe, Ky mill because of the presence of metal in the wood. Each bundle consisted of 4 to 10 interlaced logs attached to at least two, and often three or four, 1400 lb concrete anchors. GPS locations were taken at each site. Placement work was done using the Corps of Engineers M.V. Grand Tower and crane barge, Fisher. In addition to the crew of the Grand Tower, Brian Johnson, a fisheries biologist with the St. Louis District, was present to help with final site selection.

Post construction monitoring is a critical tool in assessing the value and impact of these structures. That work will include a bathymetric survey of the new sites to assess changes in the main channel border as the result of the wood bundles. The St. Louis District, in cooperation with the Missouri Department of Conservation and the Illinois Department of Natural Resources, will also be conducting post construction monitoring at these two sites to determine fish use of the wood piles.

As part of this experimental wood structure effort, the St. Louis District will be attempting to drive some of the logs donated by Westvaco Corp. directly into the river. The structures will appear somewhat similar to the old wood pile dikes still seen at some locations on the Mississippi River. It is expected that these structures will trap organic debris and create fish habitat. Once in place, the St. Louis District will also evaluate the potential of these new structures as localized river training devices. That work will take place the week of August 13, 2001, near river mile 164.

Submitted 13 August 2001

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US Army Corps of Engineers
Planning, Programs, and Project Management
Environmental Branch
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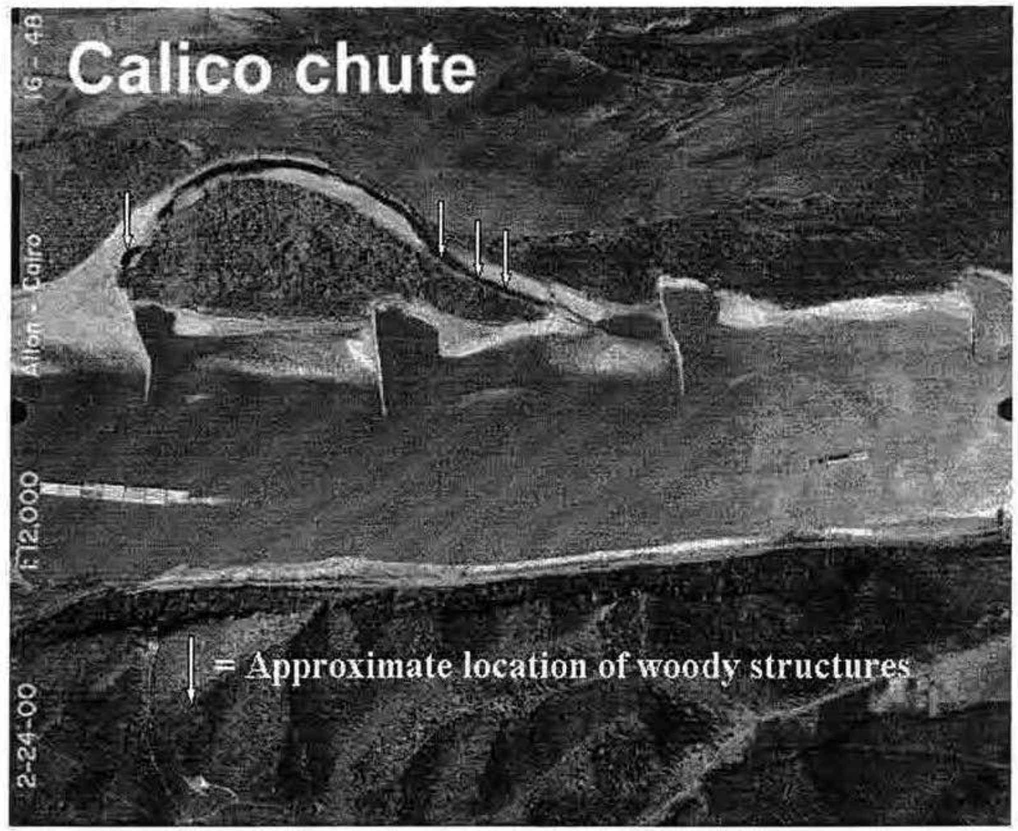
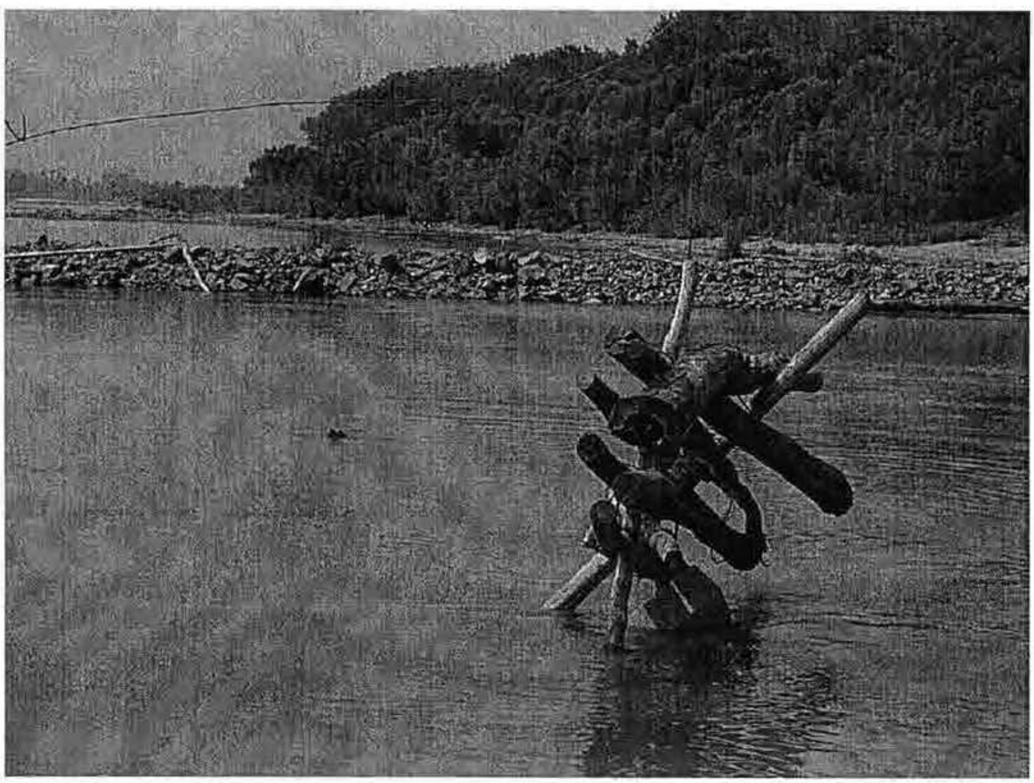
rm 165.5, 9 wood bundles
rm 165.1, 6 wood bundles


Calico chute
16 - 48
Alton - Cairo
1:12,000
2-24-00
= Approximate location of woody structures



US Army Corps of Engineers, St. Louis District
Avoid and Minimize Program
Progress Report
22 August 2001

Construction of two wood pile structures along the main channel border of the Mississippi River below St. Louis, Missouri.

During the week of 13 August 2001, the St. Louis District, under authority of our Avoid and Minimize Program, constructed two wood pile structures along the main channel border of the Middle Mississippi River. This work begins the second phase of the District's woody structure placement effort. The first phase took place earlier in the summer and consisted of placing log bundles along the main channel border and in a side channel below St. Louis. Information on those efforts is contained in earlier progress reports that are available from the St. Louis District. Phase two consists of driving logs, 16 to 24 foot in length, into the river bottom at previously selected locations to collect organic debris and provide fisheries habitat. The St. Louis District will also evaluate the potential of these new structures as localized river training devices.

Location one was between dike 165.1 and 164.9. This area served as a practice site for the field crew. At this site the construction crew familiarized itself with the operation of the pile driving equipment and the physical limitations of driving log piles into the Mississippi River. Once comfortable with the pile driving operation, the crew constructed a log pile structure near the head of a high bar between the two dikes. In all 23 logs were driven at the site. Logs were driven to a top elevation of about 7.0 feet on the St. Louis water gage. Logs were driven in a loosely structured line at the head of the high bar, with logs staggered within the line. The high bar was at an elevation of about 3 feet on the St. Louis gage and actually became exposed through time as work at the site continued. At the start of the work the water level was about 5.4 feet on the St. Louis gage. At completion, water levels were below 1 foot. Piles were initially driven in 2 to 3 feet of water. Substrate at the site was mud. Photos of the site are attached.

Location two was located downstream from location one, below dike 163.8. This location is a large shallow sandy area on the off channel side of the river. At this site 27 logs were driven to form a more structured log pile structure. Distance between logs varied from about 3 to 6 feet and the logs were placed in a much straighter line than at location one, though still bunched on both ends of the structure. The pile structure spanned almost 60 feet. At the site the work vessel pushed as far inshore as possible before constructing the structure. Logs were driven in about 3 feet of water. Water levels on the St. Louis gage fluctuated between 1 and 2 feet. Velocity was much greater at this site than at location one and after completion, scour was already apparent below some of the logs. Substrate at this site was sand. Photos of the site are attached.

Both sites were selected through earlier coordination with the US Fish and Wildlife Service, Missouri Department of Conservation, and Illinois Department of Natural Resources. Structures were placed where they would not impede navigation. GPS locations were taken at each site.

Completion of this work marks the first time in over 50 years that the St. Louis District has driven log piles. The pile driving equipment was rented and placed on the crane barge Fisher, which was accompanied by the motor vessel Grand Tower. All work was performed using personnel from the District's Service Base. Piles were driven using a hydraulic powered vibrating head with the power supplied by an independent unit on the deck of the crane barge. Logs for the effort were donated by the Westvaco Corp., which could not use the logs in their Wyckliffe, KY plant because of metal in the logs. Logs ranged in diameter from 8 to 16 inches, which was the largest diameter the pile driving equipment could handle, and anywhere from 16 to 24 feet in length. Logs were pre-marked to aid in determining how far they were driven into the substrate. When possible logs were driven into the substrate such that no more than 40% of the log was above the substrate. Some of the shorter logs could not be driven in that far. Logs were initially driven with blunt ends, but the crew eventually switched to pointed ends, cut with a chainsaw, which seemed to make driving the logs easier. By the end of the week the crew had become very efficient at grasping and driving the logs with the equipment.

As mentioned earlier, the wood piles are being placed to increase habitat diversity in the main channel border. Habitat will be improved through the placement of the wood itself (many fish species are attracted to structure in the water as areas of cover, reproduction, or forage), through the creation of localized scour holes below the piles, and through the collection of organic debris, like leaves and drifting wood, which in turn provide a fertile food bed for aquatic insects.

Placement of the wood piles also helps the St. Louis District meet our obligations under the Endangered Species Act, Biological Opinion for the Operation and Maintenance of the 9 foot Navigation Channel on the Upper Mississippi River, Reasonable and Prudent Alternative #4. That alternative calls for several habitat and restoration and enhancement measures for the pallid sturgeon, including restoring woody debris.

Post construction monitoring is a critical tool in assessing the value and impact of these structures. That work will include a bathymetric survey of the new sites to assess changes in the main channel border as the result of the wood piles. The St. Louis District, in cooperation with the Missouri Department of Conservation and the Illinois Department of Natural Resources, will also be conducting post construction monitoring at these sites to determine fish use of the wood piles.

The St. Louis District intends to continue the woody structure work through the end of September. Additional work will be coordinated with our natural resource partner agencies and the navigation industry. Questions about the work should be directed to Brian Johnson.

Submitted 22 August 2001

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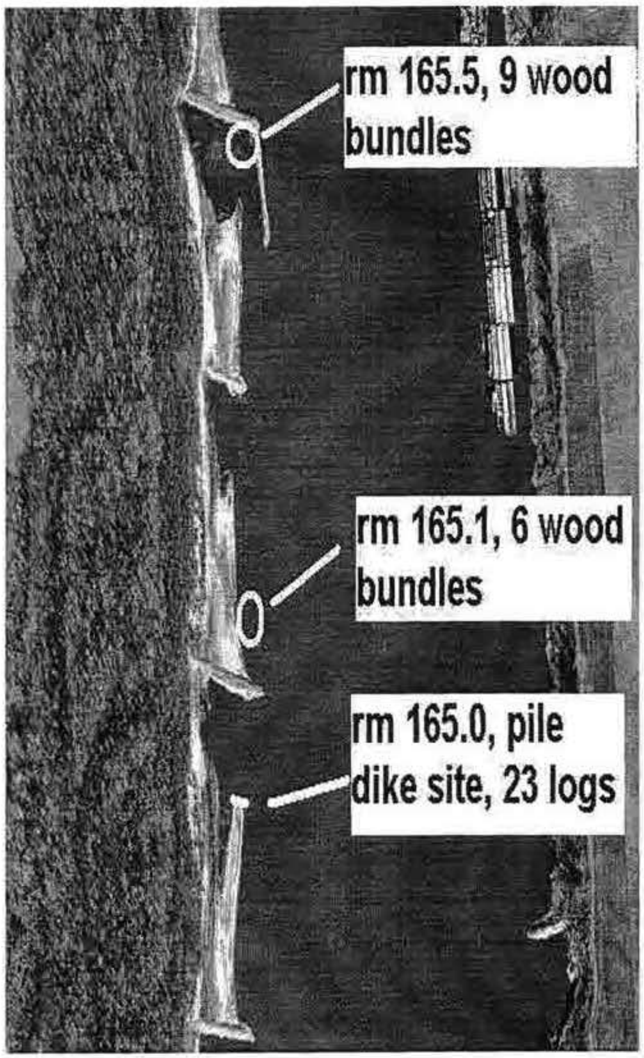
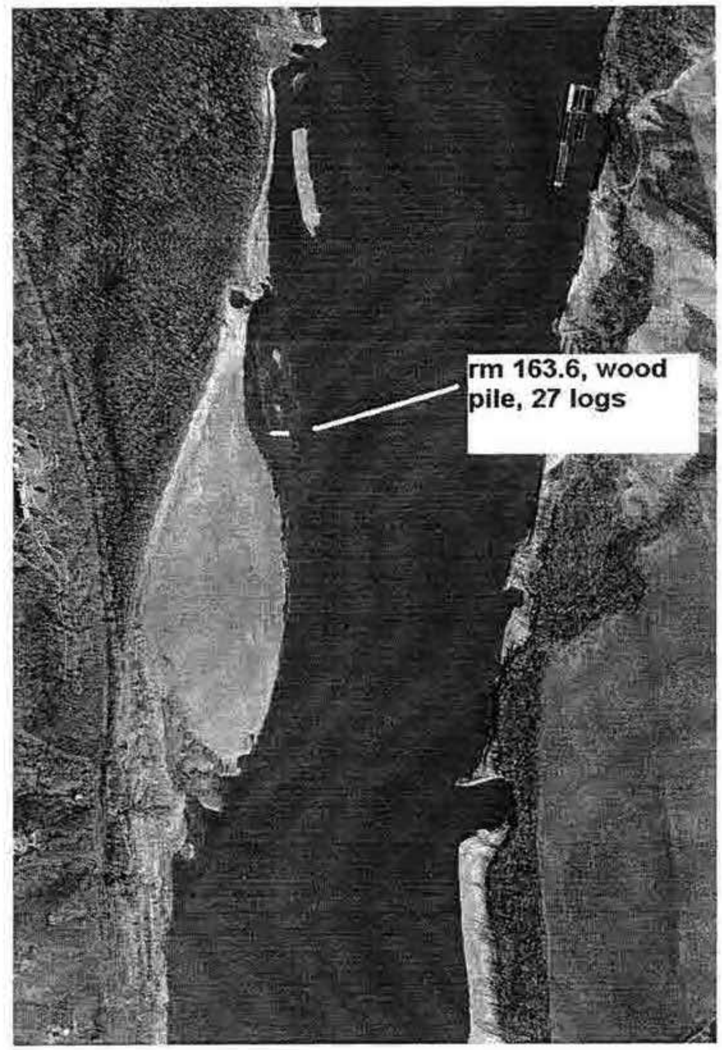
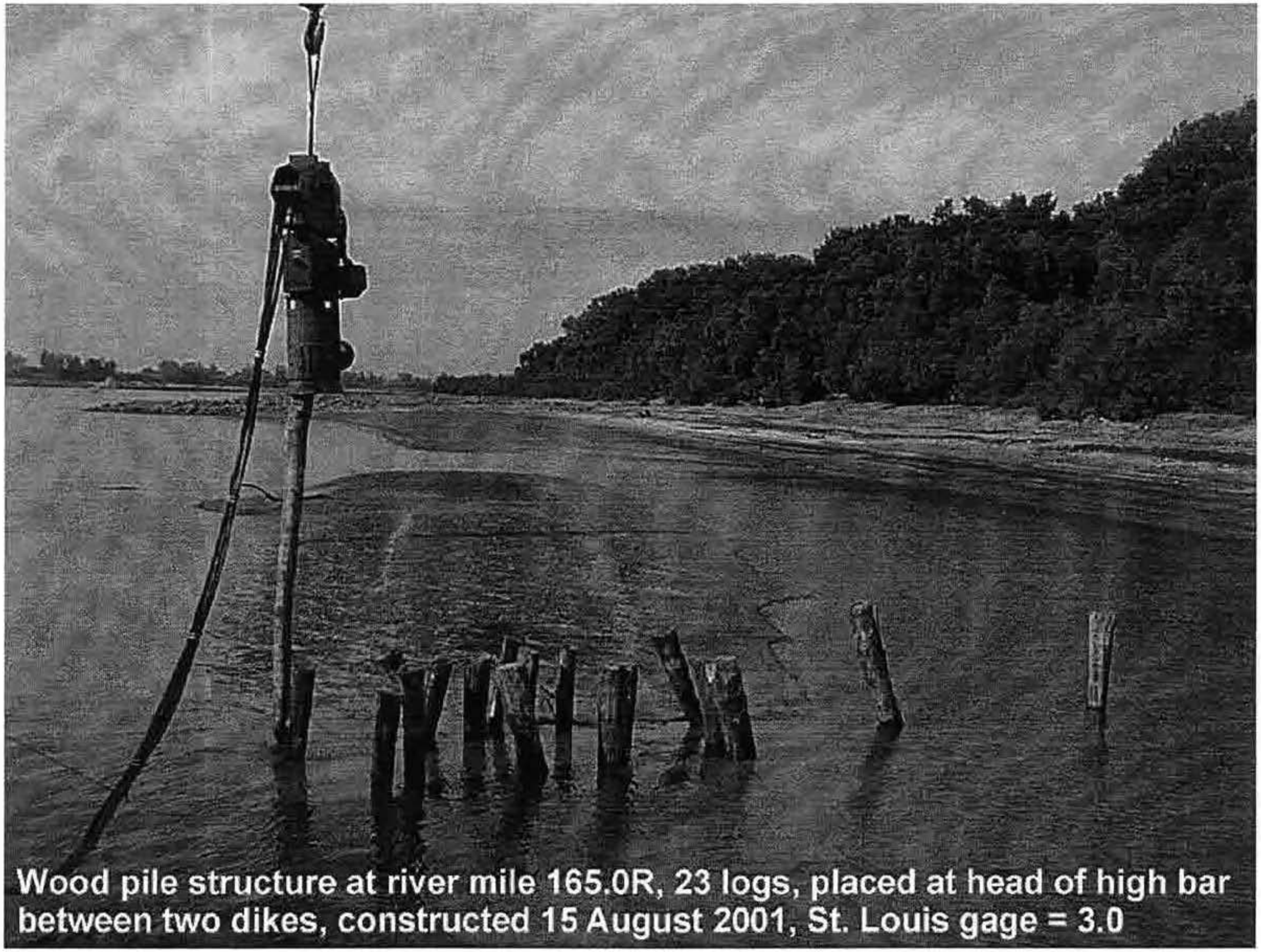
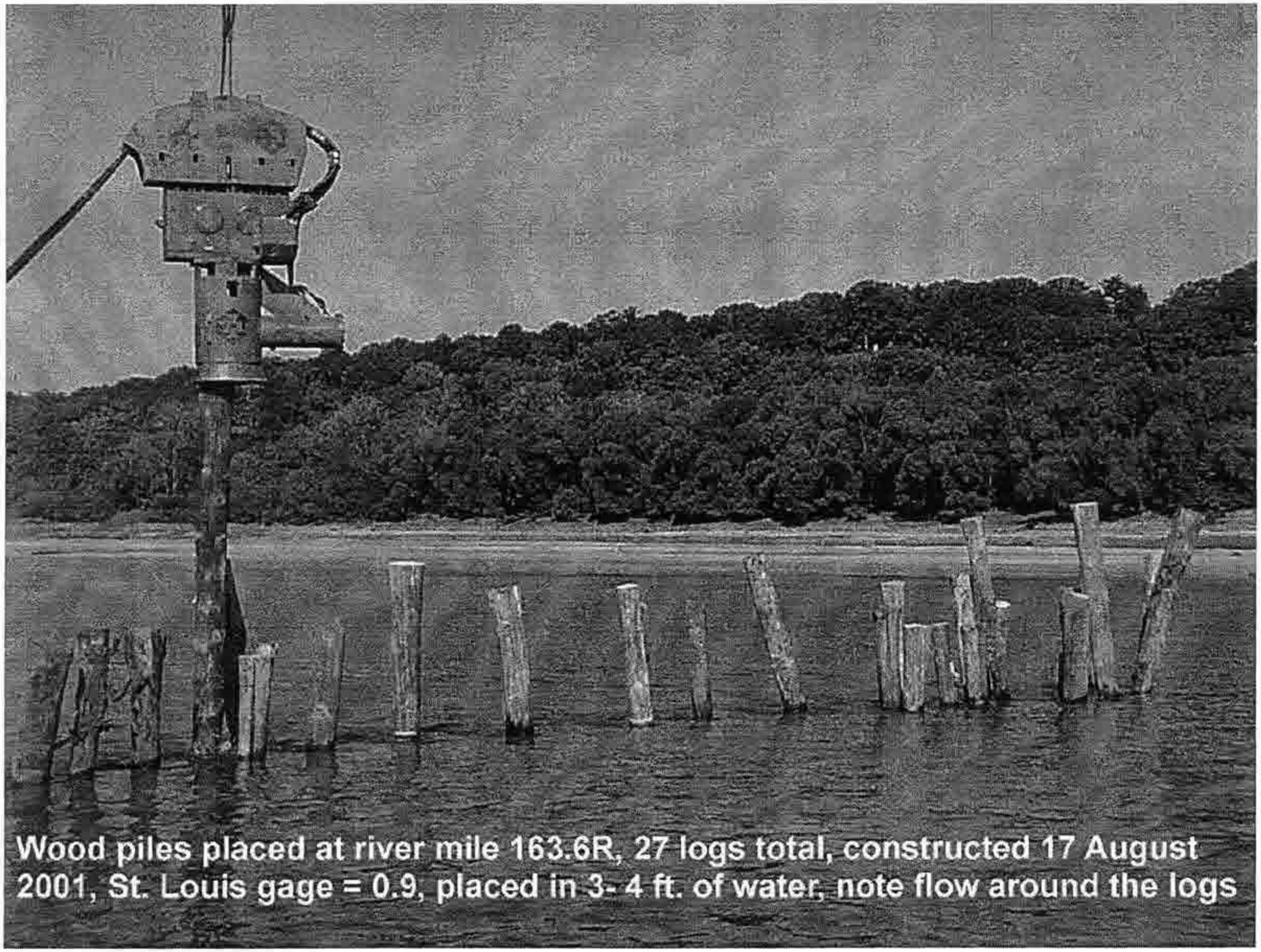

rm 165.5, 9 wood bundles
rm 165.1, 6 wood bundles
rm 165.0, pile dike site, 23 logs


rm 163.6, wood pile, 27 logs



Wood pile structure at river mile 165.0R, 23 logs, placed at head of high bar between two dikes, constructed 15 August 2001, St. Louis gage = 3.0



Wood piles placed at river mile 163.6R, 27 logs total, constructed 17 August 2001, St. Louis gage = 0.9, placed in 3- 4 ft. of water, note flow around the logs

ST. LOUIS POST-DISPATCH

Corps of Engineers project provides fish habitat

This story was published in Metro on Tuesday, July 10, 2001.

By William Allen
Of The Post-Dispatch
* Fifteen bundles of logs -- each with a 1,400-pound anchor -- are being dropped this week into two Mississippi River channels.

Paul Schmidt, project manager, stands with one of the log bundles the Corps of Engineers began placing in side channels of the Mississippi River.
Andrew Cutraro/P-D

The Army Corps of Engineers began lowering bundles of logs Monday into two Mississippi River side channels near Crystal City to create habitat for fish and to trap sediment.

A barge-mounted crane dropped the bundles, which promptly sank out of sight.

"I guarantee fish are going to love them," said Brian Johnson, fisheries biologist with the corps in St. Louis.

The project is the first of its kind on the Mississippi.

Fifteen such bundles will be lowered this week in three or four spots just south of Crystal City. The side channels are the Osborne chute and Calico chute, both on the Illinois side of the river.

The bundles consist of nine or 10 logs tied together with steel cable and attached to a 1,400-pound concrete anchor.

The logs were donated by Westvaco Corp., which runs a mill in Wyckliffe, Ky., just below the Mississippi's confluence with the Ohio River. The logs contain barbed wire, nails and other kinds of metal that make them useless for the mill.

The logs are mostly cottonwood. When submerged, they'll form prime habitat for catfish, minnows, sunfish, bass and other aquatic animals, Johnson said. The logs also will redirect the river current in the side channels so that the water scours out deep holes nearby - more habitat fish like.

Biologists with the corps and the Illinois Department of Natural Resources will monitor the effects of the log bundles on life in the side channels.

"We know we're going to increase diversity because we're increasing habitat diversity," Johnson said.

Among other agencies involved in the project are the Missouri Department of Conservation and the U.S. Fish and Wildlife Service. The project is part of the corps' Avoid and Minimize program to add environmental benefits to the river.

Reporter William Allen:\E-mail: wallen@post-dispatch.com\Phone: 314-340-8133

Published in the Metro section of the St. Louis Post-Dispatch on Tuesday, July 10, 2001.

Appendix H.

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

US Army Corps of Engineers, St. Louis District
Avoid and Minimize Program
Trip Report
Dike 53 post-modification monitoring

Trip Date: 5-7 February 2001

Purpose: Conduct post-modification monitoring of a wing dike (RM 53.0L) converted to a weir dike. This work is being completed under Avoid and Minimize measure A-16, dike configuration studies. Pre-construction monitoring of the dike occurred in January 2000.

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

Summary: On 5 and 6 February 2001 we collected multi-beam bathymetry, velocity, and hydroacoustic fisheries data at a modified dike located at RM 53.0L. As originally constructed, the dike extended 600 ft. into the river and had an elevation of +15 ft. LWRP (310.48). A pre-modification survey was conducted at the site in January 2000. The dike, which extended into the navigation channel and was considered a navigation hazard, was modified in August 2000. Several modification alternatives were discussed, including (1) removing the last 300 ft. of the dike, (2) lowering the entire dike down to –15 ft. (creating a weir), or (3) lowering the last 300 ft. of the dike to –15 ft. while leaving the rest of the dike intact. Through coordination with regional resource agencies, the decision was made to implement option 3.

To collect hydroacoustic and velocity data, forty-seven transects were run crosscurrent over the area, each approximately 30 ft apart. Velocity and hydroacoustic data were collected simultaneously. Hydroacoustic data were collected using a split beam 208 kHz transducer, with a lower threshold of -70.0 dB, a pulse width of 0.2 ms, and at a rate of 7 pings per second. Differential Global Positioning System (DGPS) coordinate readings and depth readings were taken continually along each transect. Boat speeds were between 3-4 knots. The water temperature was 35°F. Sampling conditions were excellent. Transects were numbered from downstream to upstream. Data sheets (6) were completed on-site. Hydroacoustic and velocity data were collected on 6 February 2001. Multi-beam bathymetry was collected 5 February 2001. A bathymetry map of the site is attached.

Water level on the Cape Girardeau gage was 18.1 ft. on 6 February. That stage was about 9 ft higher than the water levels during the January 2000 sample (9.0 ft). It should be noted that during the February monitoring trip, that the river was falling, having crested just a few days earlier. Water levels like those seen during the February sampling are unusual for that time of year.

Results of the bathymetric survey show a distinct difference between years. The pre-modification survey showed the presence of two holes below the dike. One hole extended behind and riverward of the tip of the dike. The second hole, which appeared to have been created by the plunging action of water overtopping the dike, was located outward from the toe of the dike. The post-modification survey indicated that the outer hole had largely disappeared and was replaced with a smaller deep hole directly below the weir. The inner hole has extended further down the inside bank. The hydroacoustic and velocity results collected in February have not been analyzed yet, but field observations showed fish using the entire area behind the dike, with the majority of the fish concentrated near the ridge formed directly below where the dike and weir meet. Fish densities did not appear to be as high as they were in 2000. The Corps intends to continue monitoring at this site to assess how the modification has changed habitat around the dike.

On 6 February 2001 the Missouri Department of Conservation set four experimental gill nets (mesh openings ranged from 1-5 inches) below the dike and weir. Each 300-ft. net was set on the bottom. Coverage was likely limited to the bottom six feet of the water column. These nets were retrieved on 7 February. Two nets (#1 & #2) were set starting in the lower end of the inner hole then running over the ridge and out towards the lower end of the outer hole. There was quite a bit of organic matter collected in these two nets. One net (#3) was set angling off the inside corner of the dike through the inner hole, and one net (#4) was set angling off the tip of the dike through the outside hole below the weir. In all 123 fish were collected. One hundred and one fish were collected in nets 1 and 2 (lower end and ridge set). The collection included 85 shovelnose sturgeon, 10 paddlefish, 3 blue catfish, 2 flathead catfish, and 1 gizzard shad. One of the fish, a shovelnose sturgeon, was tagged by the Department of Conservation last winter (February 2000) at dike 62.8R. Between captures the fish had grown 4 mm. Sixteen fish (7 paddlefish and 9 shovelnose sturgeon) were collected in net 3 extending out from the inside corner of the dike. Six fish were collected in net 4 set off the dike tip. This area likely had flows higher than either of the other net set locations. The 6 fish included 2 paddlefish, 2 blue catfish, a common carp, and a shovelnose sturgeon. Lengths were collected on all fish. Results are attached.

Catch numbers from February are similar to catch numbers from last January. Using the same net types and lengths in 2000, we collected 126 fish comprised of 5 species (shovelnose sturgeon, blue catfish, paddlefish, goldeye, and sauger). New species collected in February were the flathead catfish, gizzard shad, and the common carp. Goldeye and sauger were absent from the February sample. One fish believed to be a pallid sturgeon/shovelnose sturgeon hybrid was collected in January 2000.

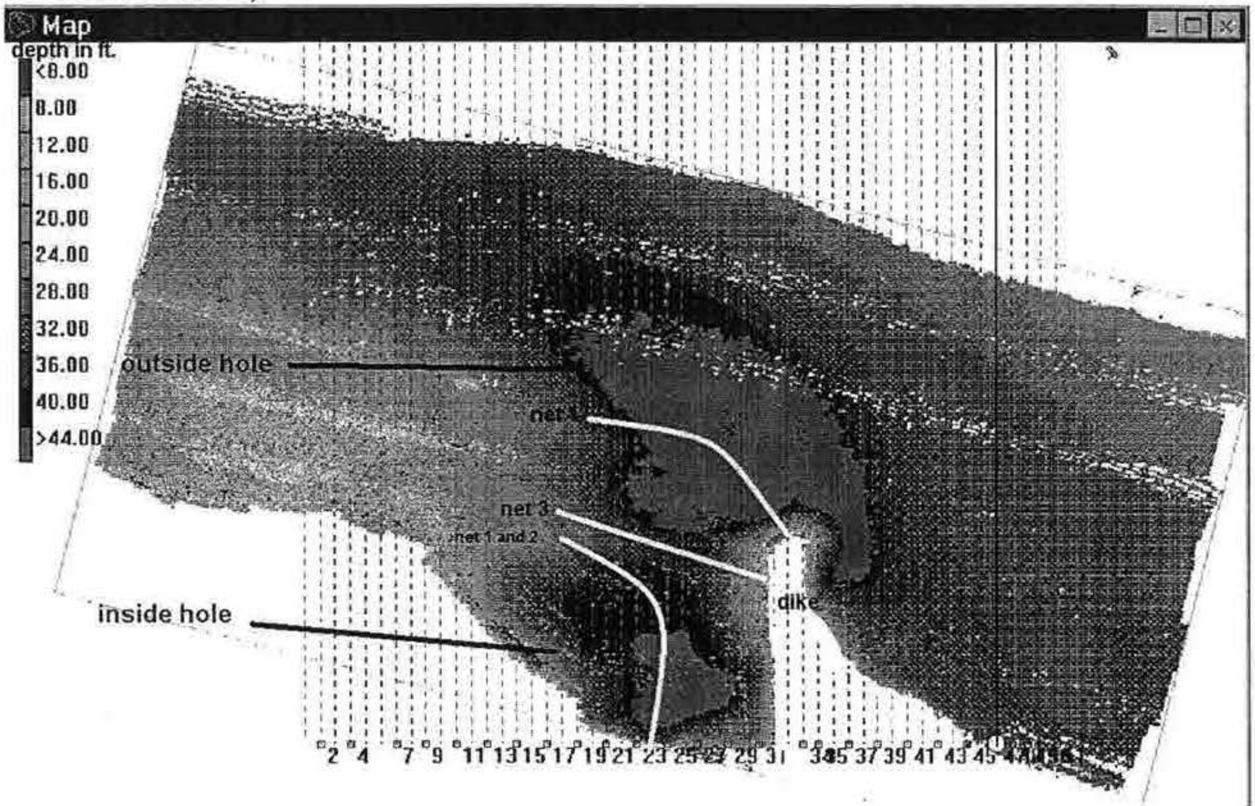
The hydroacoustic fisheries data collected in February has not been analyzed. Data from the pre-modification survey found an average density of 835 fish per acre at the site in 2000. The fisheries data for this project are being analyzed by Aquacoustics, Inc. Detailed bathymetric and velocity maps will be created by ED-S. This information is being compiled and will be presented in a more complete report upon receipt.

Brian Johnson

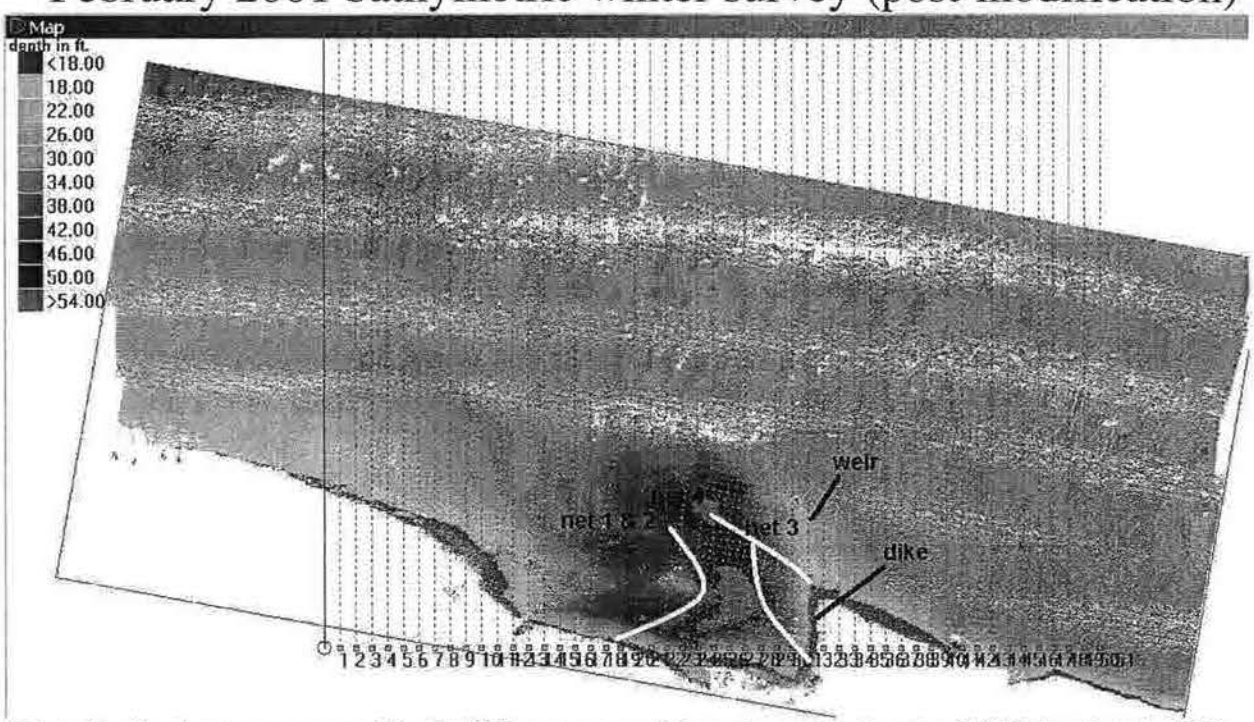
BRIAN JOHNSON
Fishery Biologist
Planning, Programs, and Project Management
Environmental and Economics Branch
Environmental Section

Submitted 20 March, 2001

January 2000 winter netting bathymetric survey (pre-modification)



February 2001 bathymetric winter survey (post-modification)



*** Note depth colors are comparable, the 2001 survey was taken at a water elevation 9 ft higher than in 2000.**

Dike 53 Sampling 2/07/01

Water temperature: 1.7 C

Date: 2/07/01

NET 1 & 2
experimental gill net 300 ft x 2
depth 10.3 m
location: off lower end toe dike

species	fork length (mm)
Blue catfish	589
Blue catfish	710
Blue catfish	837
Flathead catfish	459
Flathead catfish	958
Gizzard shad	223
Paddlefish	234
Paddlefish	398
Paddlefish	545
Paddlefish	600
Paddlefish	640
Paddlefish	650
Paddlefish	700
Paddlefish	717
Paddlefish	730
Paddlefish	880
Shovelnose sturgeon	285
Shovelnose sturgeon	298
Shovelnose sturgeon	302
Shovelnose sturgeon	362
Shovelnose sturgeon	377
Shovelnose sturgeon	382
Shovelnose sturgeon	398
Shovelnose sturgeon	400
Shovelnose sturgeon	405
Shovelnose sturgeon	419
Shovelnose sturgeon	442
Shovelnose sturgeon	451
Shovelnose sturgeon	463
Shovelnose sturgeon	466
Shovelnose sturgeon	482
Shovelnose sturgeon	486
Shovelnose sturgeon	490
Shovelnose sturgeon	501
Shovelnose sturgeon	520
Shovelnose sturgeon	524
Shovelnose sturgeon	527
Shovelnose sturgeon	527
Shovelnose sturgeon	532
Shovelnose sturgeon	538
Shovelnose sturgeon	539
Shovelnose sturgeon	548
Shovelnose sturgeon	550
Shovelnose sturgeon	551
Shovelnose sturgeon	553
Shovelnose sturgeon	560
Shovelnose sturgeon	568

number	species	fork length (mm)
51	Shovelnose sturgeon	578
52	Shovelnose sturgeon	578
53	Shovelnose sturgeon	579
54	Shovelnose sturgeon	582
55	Shovelnose sturgeon	582
56	Shovelnose sturgeon	588
57	Shovelnose sturgeon	592
58	Shovelnose sturgeon	595
59	Shovelnose sturgeon	600
60	Shovelnose sturgeon	601
61	Shovelnose sturgeon	603
62	Shovelnose sturgeon	604
63	Shovelnose sturgeon	605
64	Shovelnose sturgeon	611
65	Shovelnose sturgeon	613
66	Shovelnose sturgeon	615
67	Shovelnose sturgeon	619
68	Shovelnose sturgeon	620
69	Shovelnose sturgeon	621
70	Shovelnose sturgeon	622
71	Shovelnose sturgeon	622
72	Shovelnose sturgeon	627
73	Shovelnose sturgeon	627
74	Shovelnose sturgeon	628
75	Shovelnose sturgeon	629
76	Shovelnose sturgeon	629
77	Shovelnose sturgeon	632
78	Shovelnose sturgeon	635
79	Shovelnose sturgeon	636
80	Shovelnose sturgeon	638
81	Shovelnose sturgeon	640
82	Shovelnose sturgeon	648
83	Shovelnose sturgeon	648
84	Shovelnose sturgeon	648
85	Shovelnose sturgeon	650
86	Shovelnose sturgeon	655
87	Shovelnose sturgeon	657
88	Shovelnose sturgeon	675
89	Shovelnose sturgeon	679
90	Shovelnose sturgeon	680
91	Shovelnose sturgeon	680
92	Shovelnose sturgeon	681
93	Shovelnose sturgeon	685
94	Shovelnose sturgeon	685
95	Shovelnose sturgeon	692
96	Shovelnose sturgeon	704
97	Shovelnose sturgeon	709

NET 3
experimental gill net 300 ft
depth 9.1 m
location: corner of wing dam

number	species	fork length (mm)
1	Paddlefish	615
2	Paddlefish	659
3	Paddlefish	609
4	Paddlefish	621
5	Paddlefish	553
6	Paddlefish	704
7	Paddlefish	563
8	Shovelnose sturgeon	678
9	Shovelnose sturgeon	524
10	Shovelnose sturgeon	553
11	Shovelnose sturgeon	643
12	Shovelnose sturgeon	588
13	Shovelnose sturgeon	602
14	Shovelnose sturgeon	654
15	Shovelnose sturgeon	609
16	Shovelnose sturgeon	587

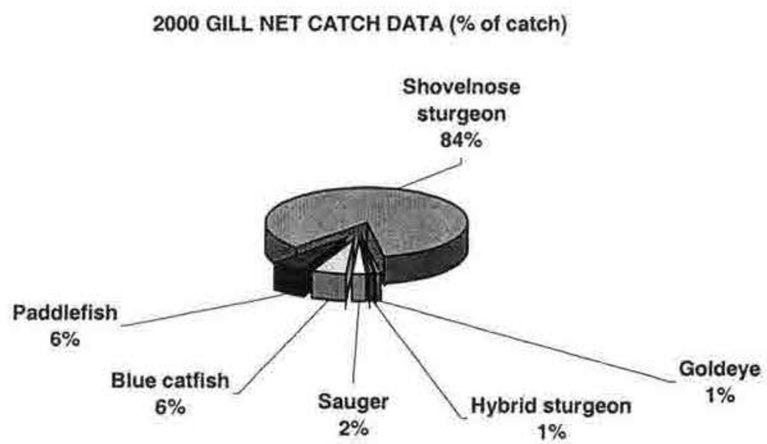
NET 4
experimental gill net 300 ft
depth 15.2 m
location: tip of wing dam

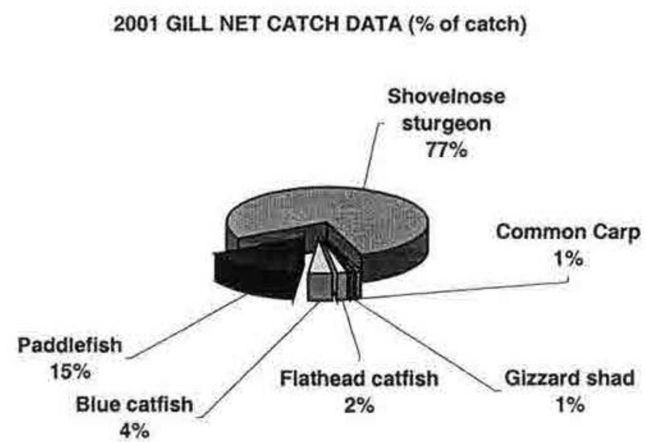
number	species	
1	Paddlefish	932
2	Paddlefish	720
3	Blue catfish	588
4	Blue catfish	462
5	Common Carp	586
6	Shovelnose sturgeon	518

Gill net catch data, Mississippi River dike 53.0

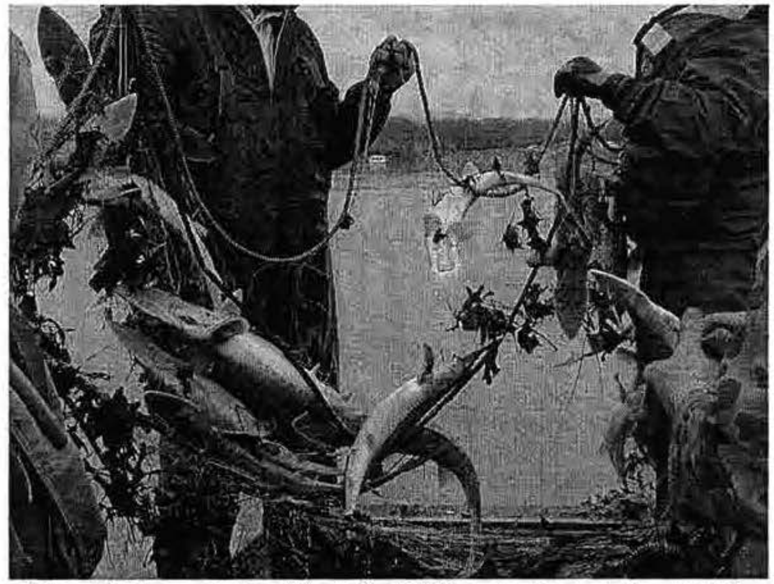
January 2000 and February 2001

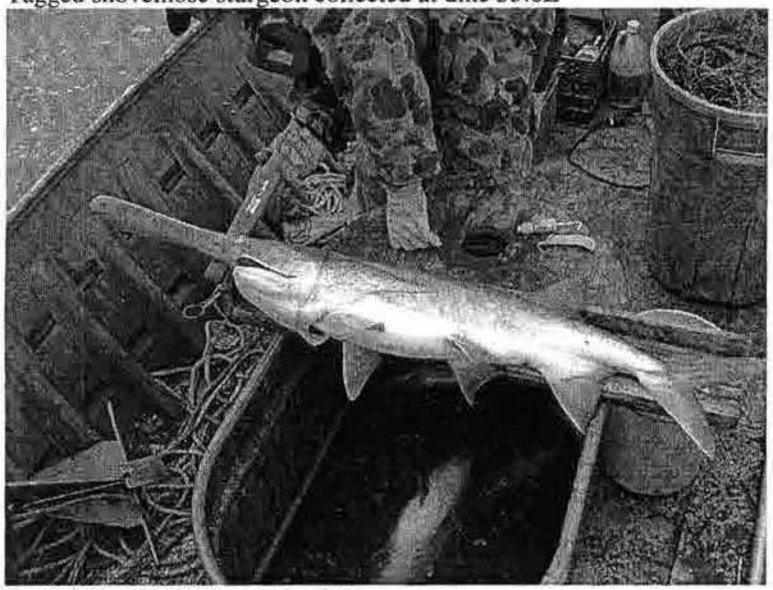
2000 (pre-modification)	Number	2001 (post-modification)	Number
Goldeye7	1	Common Carp	1
Hybrid Pallid/Shovelnose	1	Gizzard shad	1
Sauger	3	Flathead catfish	2
Blue catfish	7	Blue catfish	5
Paddlefish	7	Paddlefish	19
Shovelnose sturgeon	107	Shovelnose sturgeon	95
TOTAL	126	TOTAL	123






Tagged shovelnose sturgeon collected at dike 53.0L


Fish catch from nets 1 and 2 at dike 53.0L, note the organic material


Paddlefish collected at dike 53.0L


Flathead catfish collected at dike 53.0L

Appendix I.

Papers Presented

River Training Structures: New Ways of Doing Old Business. - U.S. Army Corps of Engineers, St. Louis District.

RIVER TRAINING STRUCTURES: NEW WAYS OF DOING OLD BUSINESS

Brian L. Johnson
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ABSTRACT

The St. Louis District Corps of Engineers is under congressional mandate to maintain a 9-ft. navigation channel on the Upper Mississippi River from Saverton, Illinois to the river's confluence with the Ohio River. The Corps has traditionally used two river engineering structures to maintain the navigation channel, dikes and revetment. These structures have been used for channel improvement for well over 100 years. A growing realization of the role that channel improvement structures can play in altering and creating habitat can be seen as far back as 1972 when the St. Louis District began notching dikes to increase habitat diversity. In 1996, the St. Louis District implemented the Avoid and Minimize Program. This program was put in place to avoid and minimize the possible effects of increased navigation traffic resulting from the construction of a second lock at Melvin Price Locks and Dam. Measures implemented under the Avoid and Minimize program include the construction and monitoring of innovative river training structures. These innovative structures include bendway weirs, chevron dikes, bullnose dikes, off-bank revetment, multiple roundpoint structures, and notched dikes. Physical monitoring of these structures has shown them to be effective river training structures. Biological monitoring of these structures has found that they have increased habitat diversity in the river, compared to habitat produced by traditional measures. Innovative structures are not only being found to provide valuable aquatic habitat, like over-wintering and nursery areas, but can also be used to create wetland habitat, islands, and side channels. While these new structures will not completely replace the need for traditional dike and revetment work, they have become a normal part of the St. Louis District's channel maintenance program.

Many of these innovative river training structures also have application on the Illinois River. Most of the existing islands on the Illinois are subject to flow and ice scour. Structures like bullnose dikes would protect the heads of islands from erosion, and at the same time create valuable off-channel habitat. Similarly, off-bank revetment can be used to shield islands from tow and recreational boat wave wash while providing off-channel habitat. Selective placement of chevron dikes in commonly dredged reaches could be used to create new islands and also provide over-wintering habitat for fish.

INTRODUCTION

The Corps of Engineers influence on the Middle Mississippi River and it's tributaries dates as far back as the 1820's when snag boats began removing logs from the river to allow safe passage to St. Louis for steamboats. In an effort to keep the Mississippi River from shifting to the Illinois bank, and consequently maintaining a harbor for the city of St. Louis, the Corps of Engineers in 1838, under the direct supervision of Robert E. Lee, built what is believed to be the first dike on the Middle Mississippi River. Though the methodologies have changed dramatically since 1838, the Corps has continued to use river training structures to maintain harbors and provide for safe navigation of the Mississippi River and it's tributaries.

Traditionally, the Corps has relied upon three main tools in their maintenance of the navigation channel, dikes, bankline revetment, and dredging. Through knowledge and experience, the Corps has become proficient at understanding how these tools could be used to create changes in the riverbed and alter water flows to help maintain the navigation channel. Understanding and appreciating how training structures affect habitat for fish and wildlife, however, has taken longer to develop.

A growing realization of the role these structures play (or can play) in altering and creating habitat can be seen as far back as 1972 when the St. Louis District began notching dikes to increase habitat diversity (Neimi and Strauser, 1991). Since 1972, environmental river engineering has become increasingly commonplace within the St. Louis District. In 1996, a major step was taken with the implementation of the St. Louis District's Avoid and Minimize (A&M) Program. This program was put in place to avoid and minimize the possible effects of increased navigation traffic resulting from the construction of a second lock at Melvin Price Locks and Dam. One of the chief measures implemented under the A&M program is the construction and monitoring of innovative river training structures. Six types of innovative structures have been built to date. This mix includes both new structures like bendway weirs, chevron dikes, bullnose dikes, and multiple roundpoint structures and proven structures like off-bank revetment and notched dikes. Physical monitoring of these structures has shown them to be effective river training structures. Meanwhile, biological monitoring of these structures has found that they can be used to increase habitat diversity in the river when compared to the habitat produced by traditional measures. A closer look at each of the six listed innovative structures provides a greater appreciation for the role each play in both river regulation and fish and wildlife habitat creation and preservation.

BENDWAY WEIRS

As the name implies, bendway weirs are a series of submerged dikes placed in the selected river bends of the Middle Mississippi River. The necessity for bendway weirs is a direct result of the need to stabilize and control the lateral or meandering movement of the Mississippi River to protect the property of private landowners and maintain the navigation channel. This is done by controlling erosion on the outside of the bend by placing revetment along the outside bankline. With the river's energy now unable to erode the outside bank, that energy is forced downward and erodes the river bed, while at the same time causing more deposition along the inside bankline, resulting in a deeper and narrower channel through the bend. As conditions continued to degrade, the currents in these areas became to swift, and the river to narrow, for safe navigation. Similarly, flows through the outside of these bends were to swift to provide suitable aquatic habitat for most riverine fishes.

Bendway weirs have provided a solution to this navigation problem and at the same time have improved aquatic habitat within the bendway. By placing a series of upstream slanted underwater dikes in the bend, flow has been redirected back towards the encroaching sandbar on the inside of the bend. This movement, along with the disruption of the lateral flows through the outside of the bend, creates a wider, shallower channel. This redirection of flow has provided for safer navigation conditions and fewer accidents in each bend (Davinroy et al., 1998). Improvements in aquatic habitat are also realized through both the placement of the structures in the bends and through the disruption of the lateral flows. There are 19 bendway weir fields in the

Middle Mississippi River, comprising 163 individual weirs. The number of weirs in a field ranges from 3 to 14. All weirs are angled 30° upstream and are placed at least 4 meters below the low water reference plane to avoid interfering with navigation. Physical monitoring of river bends has shown a widening and shallowing of the river channel does occur after placement of bendway weirs.

Figure A. A conceptualized drawing of a bendway weir field. Individual weirs are placed at least 4 meters below the lower water reference plane and are angled 30° upstream.

Post placement studies have found that bendway weirs field provide habitat for both fish and macroinvertebrates. Hydroacoustic work by Kasual and Baker (1996) on a bendway weir field in the Middle Mississippi River showed that placing weirs in river bends does increase the abundance of fish in those bends. Keevin et al. (2001) reported that using high explosives in a bendway weir field resulted in the collection of 217 fish, representing 12 species. Catch was dominated by freshwater drum, gizzard shad, and blue catfish. Also of interest was the collection of two freckled madtoms and two slender madtoms, species likely using the interstitial spaces provided by the rocks forming the weirs. A study assessing macroinvertebrate use of bendway weir rocks (Ecological Specialists, Inc, 1997) found that the community contained 34 taxa, compared to 7 taxa in the sand substrate of a bendway without weirs.

CHEVRON DIKES

Chevron dikes are 'V' or 'U' shaped rock dikes placed in the river to help direct flows in the navigation channel. The dikes are built so that the apex of the structure is upstream, with the wings extending downstream. In the St. Louis District chevron dikes have been used to accomplish three objectives; to help maintain existing flow splits at locations where the river's flow is divided between the main channel and large side channels, as beneficial locations for dredge material placement, and as alternatives to traditional wing dikes in focusing flows in the river channel. There are three chevron dikes fields in the St. Louis District.

At river mile 289, a series of three chevron dikes was constructed in 1993 across the mouth of a major side channel in an effort to maintain the existing flow split at that site between the side channel and the main channel. Traditionally the Corps has attempted to regulate flow into side channels by constructing large closing structures across the mouth of the side channel.

In this case, by building chevron dikes instead of a closing structure, continued flow was allowed through the side channel. After construction, dredge material was placed behind all three of the chevron dikes to create island habitat. Through time these islands have not only maintained themselves, but have started to establish vegetation. In addition, during periods of high water, flows have overtopped the structures and created large scour holes directly behind the dikes. These areas, which are protected during normal flows, are known to provide over-wintering, nursery, and rearing habitat for fish. Post-construction monitoring work (Atwood, 2001a) has collected over 48 species in association with the chevron dikes, with the determination that the chevrons were providing useful and valuable habitat for a variety of riverine fishes.

Figure B. Chevron dike field at Mississippi River mile 289. Note the dredge material islands formed behind each chevron.

In 1998 the St. Louis District constructed a set of chevron dikes at river mile 266. The dikes at this location were located along the main channel border to increase flows in the main channel. These three dikes, placed in a downstream line, were constructed instead of traditional wing dikes. Like the dikes at river mile 289, each of these dikes has deep scour holes below them, which provides habitat for fish throughout the year. Hydroacoustic fisheries monitoring work behind these dikes (US Army Corps of Engineers, 2001) has documented fish use of the holes created below the dikes. Sampling during the winter showed fish densities nearly six times those outside of the over-wintering period. Depths in the upper scour holes exceeded 8 meters.

Figure C. Chevron dike field at Mississippi River mile 266. The deep slack water habitat formed behind these structures has been shown to be used extensively by fish in the winter.

MULTIPLE ROUNDPOINT STRUCTURES

In 1998, the St. Louis District constructed a multiple roundpoint structure in Pool 25 (river mile 265). This innovative training structure (Figure D) consists of six separate round rock points, or cones, on 100 ft centers extending from the bank in a fashion similar to a wing dike. The round point structure was developed to function as a wing dike and appears at the water surface to be a heavily notched wing dike. Each of the six points stands alone and is not connected to the other points. Future plans call for the construction of a series of multiple roundpoint structures with the notches offset such that the second row of rock points will be behind the first row of notches. This type of configuration will improve the overall ability of the structures to modify flows patterns and at the same time increase aquatic diversity.

The multiple roundpoint structure has been monitored since construction for both fish use and bathymetric changes. Electro-fish sampling at the site (Atwood, 2001b) has resulted in the collection of 21 species, with gizzard shad, emerald shiners, carp, freshwater drum, and flathead catfish making up the majority of the collected fish. The blue sucker, a species of concern in Illinois, has been collected on four occasions. Bathymetric surveys conducted by the St. Louis District have shown that the multiple roundpoint structures have increased habitat diversity at the site by creating a series of individual scour holes directly downstream of the structures.

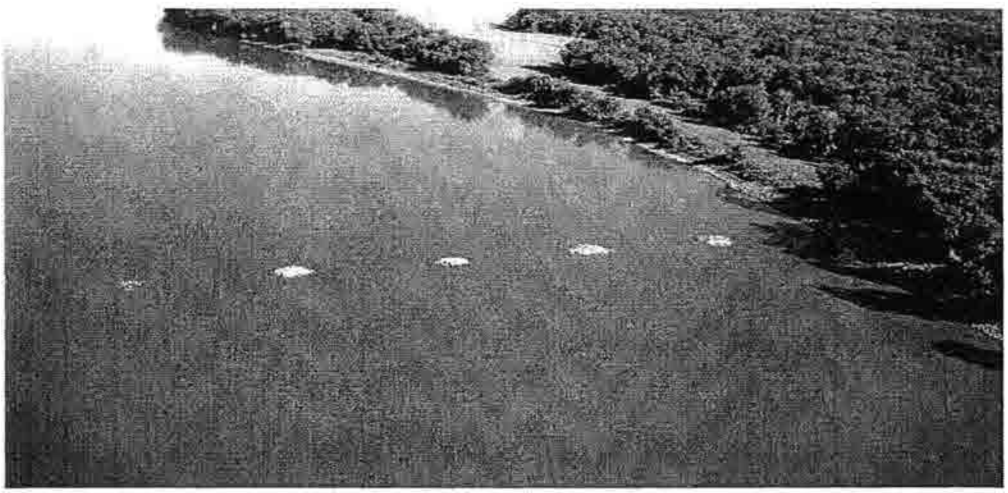


Figure D. Multiple roundpoint structure at Mississippi River mile 266.

OFF-BANKLINE REVETMENT

The St. Louis District has traditionally used bankline revetment to stabilize caving banklines along the Mississippi River. Revetment has proven to be an effective means of stabilizing the navigation channel but often results in the clearing and grading of the bankline. Off-bankline revetment provides an alternative to the traditional bankline revetment techniques. Instead of placing revetment on the bank, a parallel stone structure is built riverward of the bankline. The length and height of the structure is dependent on each situation, but when used on islands, often runs the length of the island. In most cases the upstream end of the structure is tied into the bank. Notches are placed throughout the off-bankline revetment to allow an exchange of water and allow both fish and boat access to the newly created off-channel habitat. There are five sites within the St. Louis District where off-bankline revetment has been used instead of traditional revetment.

From 1991 to 1995 the Illinois Department of Natural Resources conducted fish sampling on the Gosline Island off-bankline revetment in Pool 24 of the Mississippi River (Atwood, 2001c). The results of that work showed that the off-bankline revetment, placed in the mid-1980s, was providing valuable habitat for a variety of fishes. A total of forty-eight species of fish was collected during sampling, with 47 species associated with the habitat created by off-bankline revetment. Seven species of centrachids (sunfish and bass species generally considered off-channel fishes) were collected inside the off-bankline revetment. The report stated that the off-bankline revetment provided excellent habitat for quality sized catfish. Species composition and number of young of the year fish present indicated that the inside of the off-bankline revetment was providing backwater habitat in a reach where such habitat was limited.

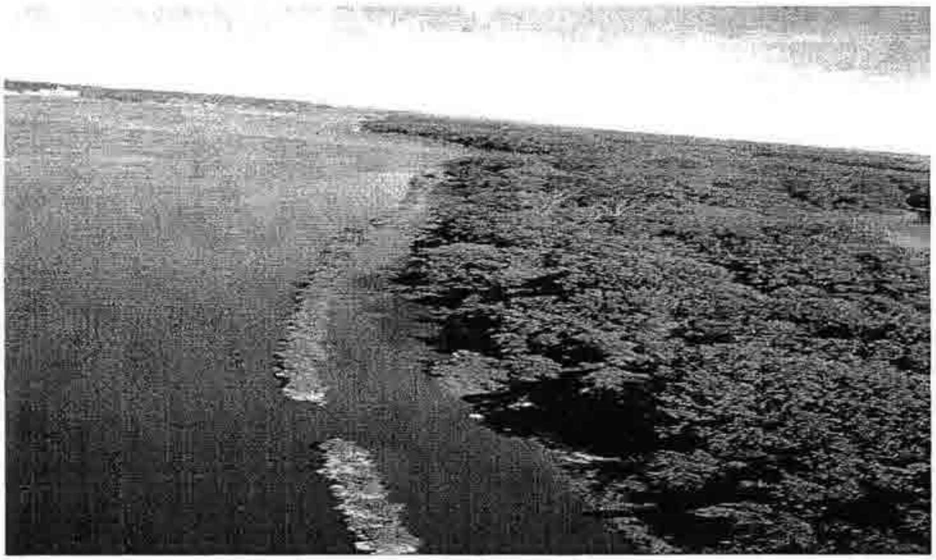


Figure E. Off-bankline revetment at Crider Island, Mississippi River mile 280. Note the notch in the structure to allow water exchange and angler and fish access.

BULLNOSE DIKES

Bullnose dikes are rock structures placed at the heads of degraded or eroding islands to protect the islands from further damage. Bullnose dikes, which look similar to chevron dikes, are placed upstream of islands to eliminate the erosion resulting from water or ice flows hitting and scouring the head of the islands. Like chevron dikes, during high flows bullnose dikes are overtopped, which creates a scour hole directly behind the dike. The material from the hole is deposited just downstream against the head of the island, further protecting the island from erosion. To allow fish access to the resulting scour holes and to the habitat created behind the dikes, either the dikes are notched or the dikes are left unconnected to the island. Prior to bullnose dikes, conventional maintenance would have been to place revetment on the head of the island. Revetment in those cases would have involved bank clearing and grading because the island heads had eroded to a vertical face. Bullnose dikes avoid further disturbance to the island, encourage deposition at the head of the island, and create off-channel habitat for fish and waterfowl. The St. Louis District has installed bullnose dikes at three locations on the Mississippi River.

Bullnose dikes have not been extensively monitored. Physical monitoring by the St. Louis District of a bullnose dike at river mile 267 found that depths behind the dike ranged from less than one meter to over five meters. Electro-fishing work completed by the Illinois Department of Natural Resources at the same dike collected 21 species of fish during one sampling trip (Atwood, pers. comm.). Work conducted by the Missouri Department of Conservation at a bullnose dike at river mile 292 (Brummett, 2001) also noted a diversity of depths behind the dike and an accumulation of woody debris which "will likely benefit aquatic organisms".

Figure F. Bullnose dike at the head of Peruque Island, Mississippi River mile 235. Note the notch in the structure and the deposition along the head of the island.

NOTCHED DIKES

The first notched dike in the St. Louis District was completed in 1972. Dikes were originally notched to try and create a pattern of flow through dike fields which would reduce deposition in those fields (Neimi and Strauser, 1991). What resulted was not reduced deposition but rather the formation of small bars in the middle of the dike fields, with the development of small chutes or side channels between the bars and the bank. In addition, the areas below notched dikes began to show a greater diversity of depths, and consequently greater habitat diversity than dikes without notches. Since those original efforts, almost 200 dikes have been modified within the District. Notches have been cut in closing structures to facilitate greater flow in side channels, below side channels to allow greater fish access to backwater habitat, to create islands within dike fields, and to create greater habitat diversity within dike fields.

Smith et al. (1982) found that while fish communities were similar between notched and unnotched dikes, there appeared to be a broader array of life stages using the notched dike fields. This is likely a result of the greater variety of habitats created below notched dikes. Smith et al. (1982) also found greater macroinvertebrate numbers associated with notched dikes.

Figure G. Islands created at Mississippi River mile 100 by notched dikes.

INNOVATIVE RIVER STRUCTURES ON THE ILLINOIS RIVER

Innovative river training structures have proven to be successful tools for both maintaining the navigation channel and for preserving, creating, and enhancing habitat on the Mississippi River. The same opportunities exist within the Illinois River. While all six structures have application on the Illinois River, three structures (chevron dikes, off-bankline revetment, and bullnose dikes) have widespread applicability. A closer look at three sites on the lower Illinois River demonstrates the potential of these structures for habitat improvement.

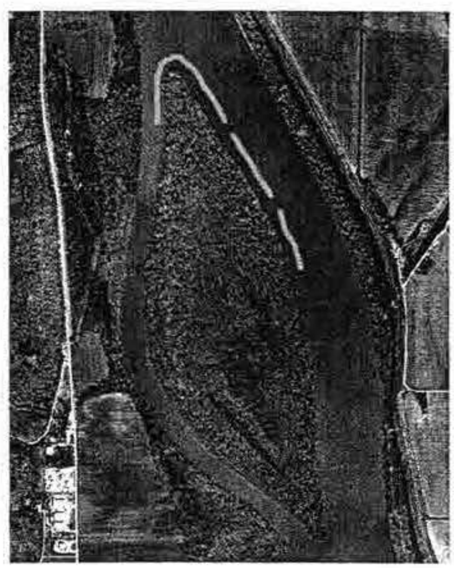
Twin Islands (River mile 38)

Twin Islands are representative of many of the islands on the lower Illinois River. The upper ends of both islands are severely eroded from ice and flow scouring. Scouring is to such a degree that trees have started to fall into the water, which only accelerates the erosion problem. If left unchecked, both islands will continue to erode, and will eventually disappear. The riverward side of the smaller upstream island also exhibits bankline erosion caused by passing tow and recreational traffic. At this site a bullnose dike placed across the head of these two islands would greatly curtail the existing erosion problem. Extending the bullnose dike down along the bank of the smaller riverward island would also protect that bank from further erosion. Notching the dike would still allow flow between the two islands. A bullnose dike at this location would also provide protected, slack water, off-channel habitat for fish.

Figures H. and I. Figure H shows erosion at the head of the smaller island at Twin Islands. Figure I. shows the potential location of a bullnose dike at the site to protect the islands from further erosion.

Mortland Island (River mile 20)

Mortland Island is very similar to Twin Islands. The head of the island is severely eroded and a vertical bank is present along much of the upper riverward side of the island. At this site a bullnose dike would provide much needed protection for the head of the island. Off-bankline revetment along the upper end of Mortland Island would protect the island from further erosion by navigation and recreational vessel wave wash and create shallow protected off-channel habitat for both fish and wildlife. Notching of the off-bankline revetment would allow access for small boats and fish and also ensure an adequate exchange of water with the backwater area.



Figures J. and K. Figure J shows the vertical bankline present along the upper end of Mortland Island. Figure K. shows the potential alignment of a bullnose dike and off-bankline revetment on Mortland Island.

Panther Creek Reach (river mile 38 to 35)

The Panther Creek stretch of the Illinois River provides an excellent opportunity to create deep off-channel habitat, improve the navigation channel, and provide an area for beneficial placement of dredge material. The river at this location is very wide. Because of that width, water velocities decrease in this stretch, dropping sediment out of the water column, resulting in deposition across the channel. What has resulted is the need for frequent dredging. Placement of the chevron dike, or a series of chevron dikes, along the shallow right descending bank would help increase conveyance through this reach by directing flows into the navigation channel. Placement of dredge material behind these dikes would result in island formation, creating not only new terrestrial habitat but new side channels as well. Once created, the chevron dikes would help protect the newly formed islands from being washed away, functioning similar to bullnose dikes. In addition, during high flows scour holes would form directly behind the chevron dikes, creating much needed deep, slack water over-wintering habitat for fish.

CONCLUSION

Innovative river training structures have been proven to be effective river training tools. Biological monitoring of these structures has shown increased habitat diversity in the river when compared to the habitat produced by traditional measures. Innovative structures have not only been found to provide valuable aquatic habitat, like over-wintering and nursery areas, but also used to create wetland habitat, islands, and side channels. Selective use of these structures on the Illinois River would protect and provide both terrestrial and aquatic habitat within the system. Many of the mechanisms needed to get these structures placed in the Illinois River are already available, although they have been rarely utilized.

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