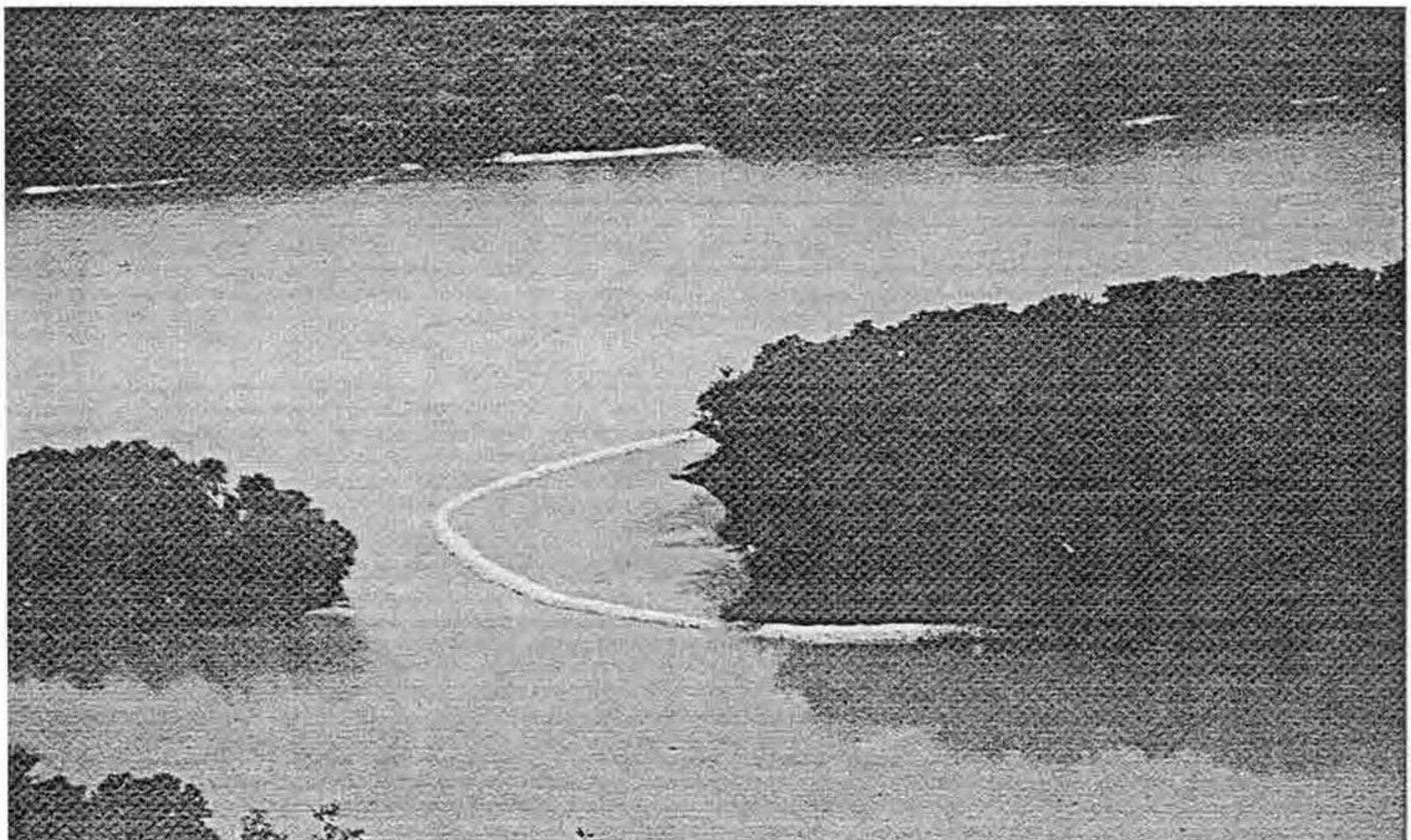
MELVIN PRICE LOCKS AND DAM

UPPER MISSISSIPPI RIVER BASIN
MISSISSIPPI RIVER MISSOURI AND ILLINOIS

PROGRESS REPORT 1997



DESIGN MEMORANDUM NO. 24
AVOID AND MINIMIZE MEASURES

"Good engineering enhances the environment"

US Army Corps of Engineers
St. Louis District

DECEMBER 1997

Photo complements of Ken Brummett, Missouri Department of Conservation. Photo taken June 19, 1997. A&M structure, bull-nose dike, Blackbird Island Pool 24, Mile 292.1, left bank. Constructed spring 1996. The notched bull-nose, stone structure was built to protect the head of the island from further erosion. Biologically, the structure is similar to off-bankline revetment and creates valuable aquatic habitat.

AVOID AND MINIMIZE MEASURES

DESIGN MEMORANDUM #24

PROGRESS REPORT--1997

MELVIN PRICE LOCKS AND DAM
MISSISSIPPI RIVER - MISSOURI AND ILLINOIS

Prepared by;

U. S. Army Engineering District

1222 Spruce Street

St. Louis, Mo. 63103-2833

December 1997

AVOID AND MINIMIZE PROGRAM
ST. LOUIS DISTRICT, MISSISSIPPI VALLEY DIVISION
PROGRESS REPORT - 1997

In October of 1992, the St. Louis District issued Design Memorandum No. 24, "Avoid and Minimize Measures". The document was developed as a commitment made in the Record of Decision (1988) attached to the Melvin Price Locks and Dam, Environmental Impact Statement for the Second Lock. The St. Louis District set-aside O&M funds from 1989 to 1995 to implement some measures recommended by the study team (Table I). Implementation of measures in this part of the program was reported in the 1995 Progress Report. In fiscal year 1996, the Avoid and Minimize Environmental Impacts (A&M) was fully funded and planned major implementation began. The planning and implementation team, consisted of staff from the St. Louis District, U. S. Fish and Wildlife Service (FWS)-Rock Island Field Office, Illinois Department of Natural Resources (IDNR), River Industry Action Committee (RIAC), Missouri Department of Conservation (MDOC), and the Long Term Resource Monitoring Station (LTRM/MDOC) at Cape Girardeau, Missouri. Each group contributed staff time to plan and attend meetings, collect data as part of a monitoring program, and spend considerable time in the micro-model lab at District facilities.

A&M 1) **Short stub dikes and bank revetment was placed in Santa Fe Chute, Upper Mississippi River, between river mile 35 left (east) and mile 40. The side channel parallels the main channel. The side channel restoration was designed by the A&M team, utilizing the District's moveable bed micro-model.** The chosen alternative consisted of nine alternating dikes placed on the left and right descending banks and riprap on the bank opposite the dikes to reduce bank erosion. Due to deeper water that had been previously mapped, only 6 of the 9 planned dikes were constructed. The A&M team will consider building the other planned dikes after investigation of the side channel bottom conditions after high water in the spring of 1998. Pre-and post-construction biological monitoring has been conducted in the side channel by the LTRM station at Cape Girardeau and a channel sweep survey by the District. The team chose Santa Fe Chute for restoration because the chute had silted in and the bottom was flat with little aquatic diversity. The dikes created a more meandering flow pattern with scour holes as the ends of the dikes (Appendix A). The upper two dikes (where the most energy occurred) had scour holes 20 feet deep. The rehabilitation effort is considered a success and biological and physical monitoring will continue for several more years.

A&M 2) **Mid-channel mooring buoys were set below locks and dams #24 and #25 in 1993 as an A&M measure. The locations of the anchors and buoys were established by the A&M team. During the last 4 years the round buoys have been moved several times and discussions with the tow boat captains has revealed that an unloaded tow had difficulty tieing to the ring on top of the buoy. Several modifications have been attempted, with little success. As a result of this frustration, RIAC volunteered to design and construct a prototype mooring buoy as a part of the A&M program. The buoy will be in place below L&D 25 in the spring of 1998.** In "Design Memorandum #24, Avoid and Minimize Measures", staff from MDOC estimated the habitat

TABLE I

DESIGN MEMORANDUM NO. 24

AVOID AND MINIMIZE MEASURES RECOMMENDED FOR IMPLEMENTATION

NUMBER	MEASURE
A-3	Designate locks approach waiting areas--provide on-bank anchor points or mooring buoys.
A-10	Reduce open water dredge material disposal--create recreation beaches.
A-11	Reduce open water dredge material disposal--create wetlands.
A-13	Place dredge material in the thalweg.
A-16	Continue dike configuration studies (i.e.., notched dikes, chevron dikes and bullnose dikes.
A-17	Place off-bank revetment on islands.
A-19	Monitor bendway weirs.
B-8	Study reduction of tow waiting times.

suitability index (1 to 10) of the 70 acres of river around each lock where tows normally moored. They estimated that the present situation, random waiting and tie-off locations, to have a habitat suitability index of only 3. With the tows remaining in the mid-channel and not nosing into the bank, the habitat suitability index increased to a 7. This estimate by professional aquatic biologists establishes the importance of having a mooring buoy which the tows can easily utilize. The lock masters also noted that lockage times could be improved by 30 minutes or so and the tow captains, who did tie to the old round buoys noted less fuel consumption during waiting times. The River Industry Action Committee contacted Bollinger Shipyards, Inc. of Lockport, La., who agreed to build the prototype buoy (Appendix B). The river industry will pick up the buoy and deliver to the District Service Base as a contribution to the A&M program. The buoy will be set by the District and RIAC will develop a questionnaire for the captains to fill out to test the design. If the buoy design is successful, the Corps will consider purchasing additional buoys to locate at traditional mooring sites. RIAC has expressed their desire to see the same type of buoy throughout the Upper Mississippi River system.

***A&M 3)* Creation of Least Tern nesting habitat by isolating an existing sand bar was conducted in a side channel between the main land and the sand bar at Owl Creek, river mile 84.0 to 85.9 right bank.** Concern for the endangered least tern's nesting sites has been expressed by the natural resource agencies. The terns nest on bare sandbars and can have predation as a negative factor for success of the nesting effort. If the sandbar is separated from the land side by water, it may reduce the presence of predators, such as coons. Hard points (piles of rock) were placed in the Owl Creek side channel to create a flow which would induce scour and a more deep channel. The sand bar is presently being monitored by the natural resource agencies.

***A&M 4)* Dredge material placement.** The A&M team continued to work on the placement of dredge material and to experiment with thalweg disposal and with investigations of potential thalweg "holes" for aquatic organisms (Appendix C). While on the fall river trip, in 1996, the A&M team decided to try thalweg disposal from dredging of a point bar into a downstream deep part of the channel at mile 289. Hydroacoustic fishery sampling and mussel brailling was performed during the summer of 1997. No significant aquatic organisms were found. Placement of dredge material did not occur during the Fall season. Instead, the team decided to place material in the two lower chevron dikes and no material to be placed in the upper chevron because of the quality of fisheries found by IDNR (see Appendix E). A question arose, during the July 23, 24 trip, as to where the remainder of the material should be placed. An area on the right bank was chosen. The next day, an IDNR/Corps team of biologists brailled the site and found no mussels. This was reported to the team and the placement site was approved. Dredging was completed the next week. An excellent example of the A&M partnering effort.

***A&M 5)* Pallid Sturgeon monitoring.** 1997 is the second year that the St. Louis District, through the A&M program, have shared expenses with the FWS for a contract with Southern Illinois University-Carbondale, Cooperative Fisheries Research Laboratory to monitor the relationship of river training structures and the endangered pallid sturgeon (Appendix D). The sturgeon, implanted with transmitters, were located 103 times from November 1995 through September 1997. The fish were found in: main channel/45% of the time, main channel border/20% of the time and associated with river training structures/27% of the time. The location of fish in the main channel varied from 67% to 6% dependent upon water temperature.

A&M 6) **Micro-modeling of side channels.** The 1996 A&M Progress Report explained that the A&M team had made a decision to move activities into the open Middle River from the pooled portion of the District. The Hydrologic and Hydraulics Branch developed a moveable bed physical model and established the Applied River Engineering Center at the Service Base on the Mississippi River. In 1996, the team utilized the model to design the restoration features for the Santa Fe Chute, constructed in 1997, and Schenimann Chute, the construction of which has not begun. Both of these side channels had enough flow for stone dikes to create a more diverse bottom configuration. In 1997, Marquette Chute (RM 53 to 47L), across from Cape Girardeau, Mo. was chosen for modeling. Thirteen alternatives were modeled and discussed. It became apparent to the team of biologists and river engineers that diversion of large amounts of flow from the river caused the main channel to silt up faster--the navigation channel was lost. Historical studies of this reach of the river revealed that earlier in the century that most of the flow passed through what is now called Marquette Chute. Congress and State of Missouri recommended to the Corps that more flow be diverted to the west Missouri bank past the City of Cape Girardeau. Upper and lower closure dikes were installed to move the majority of the flow to the west bank. Thus, it became apparent to the design team that it would be difficult to divert enough flows to allow the energy of the river and stub dikes to create a more diverse aquatic habitat. The accepted plan consists of cutting two notches in the upper closure structure to allow for the creation of plunge pools at the base of the dike. Also, there is a large deep hole below the lower closure structure which is cut off from the river during low water. It was found that if small dikes were placed below the lower closure structure that a channel could be created so there will be an opening from the river to the deep water. During the fall and early winter, of 1997, the LTRM station at Cape netted two Pallid Sturgeon and a Lake Sturgeon from the deep hole below the lower closure structure. One of the notches will be cut by Corps staff in February, 1998 and the remainder of the work will be scheduled in the future.

A&M 7) **The Tow Waiting Time Study continued in 1997 by an economist in the Planning Division. The study identifies and evaluates non-structural alternatives, i.e., small scale improvement measures for reducing tow waiting times at lock facilities to reduce environmental impacts adjacent to the facilities.** This work complements the Upper Mississippi River and Illinois Waterway System Navigation Study. As usual, this part of the A&M program is coordinated with our partners and will be reviewed by our partners before release. Tow waiting time at locks, also known as delay time, results in higher transportation costs and environmental degradation above and below the locks. A more efficient river traffic system will result in less waiting time for a given tow movement and therefore, less possibility for impacts to the aquatic ecosystem. The small scale measures have been qualitatively evaluated under the following criteria: environmental impacts, cost, time savings, implementation, safety and technical feasibility. The initial qualitative screening process, involving constant effectual communication with river system experts , has reduced to fourteen the original list of small scale measures requiring further review. The secondary quantitative screening involves the determination of benefits and costs for these fourteen measures. Costs will be determined through life cycle cost analysis. Overall benefits will be determined by combining environmental benefits, lockage time benefits and safety benefits. An incremental cost curve will be derived by incorporating the costs and benefits for all the measures.

The incremental cost curve will present the most beneficial, cost effective measures for final recommendation under the Avoid and Minimize Program.

A&M 8) **Biological monitoring of the aquatic ecosystems of the Mississippi River continued in 1997. The Natural Resource Agencies monitored side channels, aquatic resources in and around river training structures and Corps staff and contractors continued to sample and analysize data. Some of the data is placed in this report in Appendix E.** Macroinvertebrates collected in the Middle River in 1996 have been analysized and portions of the contract reports are placed in the Appendix. Concerning bendway weirs in the Middle River the contractor stated: "Bendway weirs provide benefits for navigation channel maintenance, while at the same time provide complex habitat for macroinvertebrate communities. The weir field provides a more hetrogeneous environment than the surrounding homogenous sand substrate, resulting in a greater species richness and diversity". Mr. Butch Atwood, IDNR, continued his fisheries work around the three chevron dikes, which is also included in the Appendix. In 1996, the A&M program, through a Corps equipment purchasing system, purchased high technology hydro-accoustic equipment for fisheries studies. The equipment has been utilized in the thalweg disposal program and around the bendway weirs in the open river. Corps staff have been trained to operate equipment and interpretate the graphs of data. During the winter of 1998, the equipment will be transferred to the Motor Vessel Boyer a trailerable planeing vessel which is utilized for hydrographic surverying. The Boyer has electronic equipment which will complement the aquatic ecosystem monitoring mission. The Boyer has electronic GPS, water current profiler, RoxAnne equipment to identify bed material types (there is also equipment to collect bottom samples), can record salinity, temperature and velocities and channel sweep for surveying. The Boyer will provide an excellent, modern platform to monitor the relationship of District training structure construction and operation and maintance practices and aquatic habitats.

Avoid and Minimize Environmental Impacts Program Plans for 1998 and 1999.

The rock structures planned in 1995 and to be constructed in 1996, which were not built due to contractor problems, will be completed in 1998. This includes, multiple round point structures at RM 265.7 L, five small chevron dikes at mile 250.2 L and a bullnose dike at mile 234.8 R. There has been a proposal to complete the three stub dikes, with revetment, at Santa Fe Chute and to build a stone structure, dredged material filled, in Ellis Bay at the Riverlands Project at Melvin Price Locks and Dam. The endangered least tern has been observed attempting to nest on a small sand bar in the Bay. Other ideas and proposals will be discussed by the team and a decision, as to expenditure of funds will be firmed up during the summer of 1998.

Budgets

Due to the reduction of the Corps O&M budget, the A&M budget has also fallen and the program will need to be extended. The original budget, submitted in DM # 24 requested $1.5M per year for seven years. Funding has fallen to approximately $1.0M in 1998 and probably will remain at that level for the foreseeable future. Thus, with a 1/3 cut in funds less construction can occur. Attached are the time line and a budget table.

A & M MEASURES TO END OF FY 1997

CORPS OF ENGINEERS, ST. LOUIS

DESCRIPTION	ACTUAL		ONGOING	FUTURE
	FY96 $	FY97 $	FY98 $	
MOORING BUOYS, ANCHORAGES	116,000	0	0	
MOORING MAINTENANCE	0	42,000	44,000	
THALWEG DISPOSAL	72,000	96,000	82,000	
DIKE CONSTRUCTION	318,000	552,000	256,000	
DIKE MONITORING	121,000	181,000	128,000	
OFF BANK REVETMENT	210,000	309,000	250,000	
MONITORING	44,000	71,000	86,000	
MONITORING BENDWAYS	62,000	109,000	109,000	
WAITING TIME STUDY	31,000	24,000	5,000	
PED	80,000	114,000	82,000	
TOTAL	$1,054,000	$1,498,000	$1,042,000	0

03/06/98

AVOID AND MINIMIZE PROGRAM

1997 AND 1998--River Trip, July 23-24, 1997

Progress for 1997--Ron Yarbrough

Santa Fe Chute Construction--Claude Strauser

--Almost completed during high water--spring, 1997. Channel Sweep of the chute after construction revealed that scour holes at the end of the dikes were in place as predicted by the micro model. LTRM--Cape is conducting biological monitoring.

Biological Monitoring--T. Miller and Brian Johnson

--Rock Structures Sampling--final reports are available for the macroinvertebrate work on the bendway weirs at Carl Baer Bend and Price's Bend.

--Chevron Dikes--final report on the macroinvertebrates for the chevron dikes (3d year) available

--Rock Hopper trawl--Bendway Weirs

Least Tern Sand Bar Isolation--Claude Strauser

--The Owl Creek (M. 84) rock work was completed during high water--spring 1997.

Marquette Chute Micro Model Study--Rob Davinroy, Jennie Frazier

--The A&M team have met at the District's Applied River Engineering Center on several occasions to work with the micro model. Approximately 15 alternatives have been recommended and reviewed by the team. Some construction will begin this fall and the remainder of the recommended plan will be included in an 1135 request.

Schenimann Chute--RY

--Micro modeling of the chute in 1996 resulted in the team recommending a plan for construction. A 1135 request has been prepared and the team is waiting on verication of cost sharing by a private group.

Beneficial Use of Dredge Material--Steve Dierker and Tracy Butler

--A "Strawman" 204 proposal was approved by MRD and Headquarters. The formal proposal is presently being prepared. The draft 204 proposal is available.

Mooring Buoy--RY, Dan Erickson

--During 1997, the River Industry Action Committee recommended a design for a new mooring buoy. The proto-type was design by structural engineers at the District and the final plans and specifications were approved by the River Industry. RIAC is gathering funds to build the buoy and donate it to the St. Louis District. Hopefully, the buoy will be set below L&D 25 during the fall, 1997. Addition chain and anchors for the buoys was added to the District inventory.

Thalweg Disposal, Pool 24--Roger Myhre

Pallid Sturgeon Monitoring--T. Miller and Bob Clevenstine

--This is the second year of the monitoring by SIU Carbondale.

<u>The Proposed 1998 A&M Program</u>--Phil Eydmann, RY

--Estimated Budget--$1.0M+- for the fiscal year.

--Work in the pools--about $400k for the small chevrons, round points and bull-nose dikes planned for FY 1996, which were not constructed by the contractor.

Items discussed by the team include:

Micro modeling of another side channel

Continuation of Pallid Sturgeon Monitoring.

Lab analysis of macroinvertebrates collected in FY 1997.

Possible Contract to compile data of biological monitoring of bendway weirs.

Possible additional rock for Santa Fe Chute

Avoid and Minimize Team	
Name	**Organization**
Ron Yarbrough	Corps of Engineers
Phil Eydmann	Corps of Engineers
Norm Stucky	Missouri Department of Conservation
Steve Dierker	Corps of Engineers
Tommy Seals	Brown Water Towing (RIAC)
Dan Erickson	Corps of Engineers
T. Miller	Corps of Engineers
Bob Clevenstine	Fish and Wildlife Service
Jenny Frazier	Missouri Department of Conservation/LTRM
Bob Hrabek	Missouri Department of Conservation/LTRM
Joyce Collins	Fish and Wildlife Service
Claude N. Strauser	Corps of Engineers
Gordon Farabee	Missouri Department of Conservation
Rob Davinroy	Corps of Engineers
Gene Buglewicz	Corps of Engineers/LMVD
Roger Myhre	Corps of Engineers
Buddy Compton	Orgulf Transport (RIAC)
Tracy Butler	Corps of Engineers
Steve Redington	Corps of Engineers
Mike Kruckeberg	Corps of Engineers
Ron Messerli	Corps of Engineers
Butch Atwood	Illinois Department of Natural Resources
Ken Dalrymple	Missouri Department of Conservation
Ted Postol	Corps of Engineers
Ken Brummett	Missouri Department of Conservation
Brian Johnson	Corps of Engineers
Bob Sheehan	SIU-Carbondale
Dave Kelly	Corps of Engineers

APPENDIX A

SANTA FE CHUTE

1). Santa Fe Chute Restoration Report--Rob Davinroy
Applied River Engineering Center, St. Louis District

2). Santa Fe Chute Biological Report--Robert Hrabik
Long Term Resource Monitoring Program, MDOC

From:	Robert Davinroy
To:	LESTAT.Yarbroug
Date:	8/6/97 9:00am
Subject:	Report of Channel Restoration Measures in Sante Fe Chute, Spring 1997

AVOID AND MINIMIZE REPORT, SANTE FE CHUTE RESTORATION, MISSISSIPPI RIVER

1. A side channel restoration project of Sante Fe Chute, Mississippi River Miles 40 and 35, was conceptualized using a hydraulic micro model by the St. Louis District Avoid and Minimize team. The micro model study was conducted at the Applied River Engineering Center (AREC) during the period between February 1996 and April 1996.

2. In September of 1996, a final report detailing the findings of the model study were submitted by AREC for public release. During this study, a variety of channel restoration measures were evaluated by model tests and discussed and demonstrated at two different meetings among interagency partners (SLD,USFW,MDOC,IDNR). The particular alternative plan measure in the model study that showed the greatest potential for aquatic diversity (as decided by partners) was the implementation of 9 perpendicular, alternating dikes (Plates 17 and 18 of Report).

3. In October of 1996, the Potamology Section, River Engineering Unit, initiated plans and specs from the model study recommendations. During this study phase, river engineers formalized that bank protection measures would be required at various key locations along both sides of the side channel, due to the alternating flow pattern created from the dike field as verified by the flow visualization of the micro model (Plate 18).

Because of budget constraints, 6 of the 9 dikes and the bankline protection were designed for an estimated construction cost of $500,000.00. The dike elevations were modified from what was recommended in the model study for further cost reductions (the model study recommended all dikes be built "level crested" to a "top of bank" height). The dikes were actually designed with a sloped height, tying into the bankline at "top of bank" and sloping toward the center of the channel to +20 LWRP. The effective length of each dike was approximately 250 feet.

4. Because high stages are typically required for side channel construction, the construction contractor (Luhr Brothers) did not move into the job site until 9 April 1997. On 24 April, 1997, the construction of the 6 dikes and bankline revetment was completed. 83,000 tons of graded A stone was required for the total job. The total cost of construction was $499,660.00.

5. On May 28, 1997, a multi-sweep, high resolution hydrographic survey of the area was taken by the St. Louis District Geodesy Section. The bathymetry developed from this survey showed that the bed response initiated from the constructed dike plan was similar to the bed response observed from the micro model test. The upper two dikes were initiating scour holes approximately 20 feet in depth. The next 4 dikes were generating minimal scour. Monitoring after the next high water event will be conducted to study any future bed response development near the lower 4 dikes. River engineers will analyze this data and determine if additional dike height is required as recommended by model tests for future construction.

6. Infrared photography was recently collected in Sante Fe Chute in July of 1997. This data is currently being analyzed for the remote sensing of flow patterns. A supplementary report summarizing these results will be sent by AREC at a later date.

7. Any questions or comments to this report may be submitted to the undersigned.

Rob Davinroy, EDHP/AREC,263-4714

CC: potamology, AREC,davinroy

AVOID AND MINIMIZE PROGRAM
BIOLOGICAL REPORT
Sante Fe Chute Side Channel Habitat Improvement Project
Summary of Observations and Progress, April - October 1997

October 1997

Robert A. Hrabik
Long Term Resource Monitoring Program
Open River Field Station
Missouri Department of Conservation
Jackson, MO 63755

The Santa Fe Chute habitat improvement initiative began in January 1996. Various design alternatives were tested using the St. Louis Corps of Engineers micro model technique. The chosen alternative consisted of nine alternating dykes (hardpoints) placed off the left and right descending banks within the upper one half of the side channel. This configuration was expected to increase thalweg sinuosity, and improve depth and substrate diversity in the side channel.

Because of budget constraints, only 6 of 9 structures were built in April 1997, and these six structures were built to only one half their original specifications. In May, T. Miller (St. Louis Corps) and Open River field station staff flew over Santa Fe Chute to document physical developments in the side channel. At that time, Corps hydroacoustic soundings showed scour holes developing below the three upper most hardpoints, and suggested that the desired thalweg meander was developing. During our fly over, the water was too high to observe these physical changes. The chute was flown again in August. Although the water was lower than in May, it was still too high to document any changes in the side channel's morphology.

The lower end of Santa Fe Chute was accessed by Open River field station staff in September. The upper end of the chute could not be accessed during the low flow period (<16 feet, Cape Girardeau gage), similar to past years. Field station staff noted that scour holes occurred at the tips of the hardpoints and sand had been displaced in the channel, but no meandering thalweg developed. Some gravel was exposed and deposited on a sand bar, but no quantitative data were collected. The rock contractors "spilled" rip-rap throughout the chute, making travel by boat tenuous at lower stages.

Santa Fe Chute has been sampled for fish community data continuously since 1991. In 1997, fishery sampling in Santa Fe Chute began in June as part of our routine monitoring program. Paddlefish were reported in Santa Fe Chute and other side channels in August and September. Paddlefish were historically found in Santa Fe Chute. We speculate that higher than normal flows through the summer allowed paddlefish to access these side channels. Typically, these side channels are isolated from the main channel during summer and paddlefish are usually not found in them during this period. Due to a sampling design artifact, only gill nets were fished within the dyke field. Full gear samples were taken above and below the dyke field. Fishery data collected in the side channel have not been summarized to date. No unusual species or shifts in community structure were noted by Open River staff.

Limited water quality data has been taken in parts of Santa Fe Chute. In 1991 and 1992, a fixed sampling site was located in the chute in close proximity to the dyke field. Sampling at that site was discontinued when the LTRMP implemented a new (random) sampling design. Since 1993, the upper end of the chute has not been sampled because it was not generally accessible, thus, that portion was not included in the randomized design. Beginning in fall, 1997, Open River staff will quarterly sample the entire chute for water quality, and will sample the fish community during winter in addition to routine monitoring from June through October.

At this time, we have insufficient data to assess the project's impact on biological communities and the chute's limnology.

Respectfully submitted,

Bob

Robert A. Hrabik
Team Leader

APPENDIX B

MOORING BUOYS

1). Mooring Buoy--Fact Sheet

2). Mid-Channel Mooring Buoy, Questionnaire

3). Preliminary Drawing of Mooring Buoy Design

4). Photos of Mooring Buoy

11 March 1998

FACT SHEET

RIVER INDUSTRY'S PROTOTYPE MOORING BUOY AN EXAMPLE OF PARTNERING

The River Industry Action Team/Bollinger prototype mooring buoy is now complete and will be placed downstream (RM 241.1 L) 1000 ft. below Lock and Dam #25 as a part of the St. Louis District's Avoid and Minimize Environmental Impacts Program (A&M). When the A&M team, consisting of the U.S. Fish and Wildlife Service, U. S. Coast Guard, Illinois Department of Natural Resources, Missouri Department of Conservation, River Industry Action Committee (RIAC) and the U.S. Army Corps of Engineers, St. Louis District began to review the 43 A&M alternatives proposed by the natural resource agencies, one of the first items of concern was the random mooring of tows adjacent to the locks and dams. The team decided to make available on-bank anchor points and floating mooring buoys as permanent points for the tows to tie-off while waiting to lock through. The major items of discussion as to location included: 1) the mooring site must be close to traditional mooring sites or the tows would not utilize them, 2) the site must have adequate water depth and be close to the lock, 3) the site must not be located over existing mussel beds, next to heron rookeries or adjacent to homes. The natural resource agencies were interested in the tow remaining in the thalweg or sailing line and not nosing into the bank or creating excessive turbidity in the main channel border area. A mooring buoy was the best answer to the above concerns.

The first buoys were placed below Lock and Dam 24 and 25 in 1992. These buoys were once placed below old L&D 26 while Melvin Price Locks and Dam was under construction. The buoys were round, with no keel, sat low in the water and had a ring on top for a tie-off point. They were attached to a 100-180 foot chain and a ten ton sand anchor. The tow boat captains did not like them as they were almost impossible to tie-off from an unloaded barge due to the distance from the top of the barge to the buoy ring. The buoys shifted position in low water and were "hard to catch" and if the captains could tie-off they liked them. They saved fuel, locking time and the time and effort of "backing away from the bank".

RIAC, through the towing industry, offered to design and construct a buoy that would be more user friendly and donate the prototype to the St. Louis District as a part of the A&M program. Bollinger Shipyards, Inc., Lockport, La. volunteered to construct the buoy at their expense. Orgulf Transport Co., St. Louis, volunteered to pick up the buoy and deliver the prototype to the St. Louis District's Service Base. The District will attach chain and anchor and will set the buoy. The A&M team has approved the location for placing the buoy. RIAC has volunteered to assist District staff in developing a questionnaire, for the tow captains who utilize the buoy, to determine if they like it or if modifications will need to be made. RIAC will process the questionnaires and report the results to District staff and the A&M team. The towing industry has requested, that if a buoy design can be agreed upon, that the same type of buoy be available through out the Upper Mississippi System, as funds become available.

MID-CHANNEL MOORING BUOY
QUESTIONNAIRE

Bollinger Shipyards, Inc., Lockport, La., has constructed a new prototype mid-channel mooring buoy for the River Industry Action Committee as a part of the St. Louis District, ACOE "Avoid and Minimize Environmental Impacts Program". The prototype was designed by industry representatives (Tow Boat Captains and Pilots), marine engineers from Bollinger and structural engineers from the Corps. Most of you are familiar with the round mooring buoys that were placed below Lock and Dam #26 during construction of Mel Price and later below Lock and Dam #24 and 25. Information from Tow Boat crews indicated that the round mooring buoys were extremely difficult to tie-off and presented a safety hazard for deckcrew. The prototype mooring buoy was designed, constructed and donated to the St. Louis District to help eliminate this problem.

RIAC and the St. Louis District, COE need your assistance by utilizing the buoy that will be set immediately below L&D 25 at mile 241.1L or about 1000 feet below the dam. Will you please answer the following questions:

Date________ Time________ M/V________________________

1) Number of barges in tow-- Total________ Loads________ Empties________

2) Did you experience any difficulties during your approach to the mooring buoy?
Yes / No (Circle one)
If yes, please explain________________________

____

____

3) Which kevel was used? High or Low (circle one)
Did your crew experience any problems tying-off on the mooring buoy?
Yes / No (circle one)
If yes, please explain________________________

____

____

4) Was the location of the mooring buoy suitable for your needs? Yes / No
If no, please explain________________________

____

____

5) Would you use this type of mooring buoy again? Yes / No (circle one) If no, please explain.

____

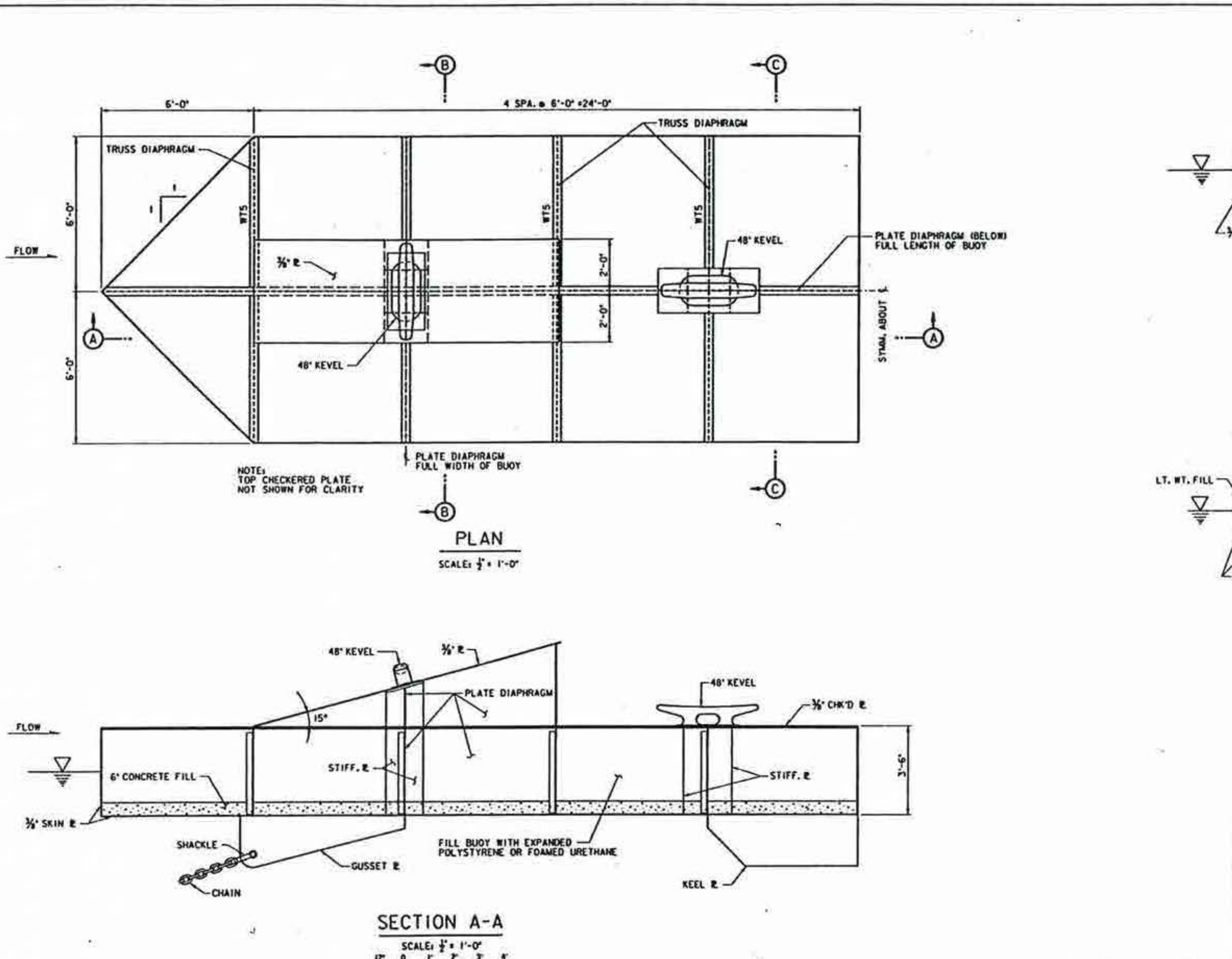
____

____

Please **FAX** the completed questionnaire to Captain Tommy Seals at this number.

314-992-0175

THANKS FOR YOUR HELP



PRELIMINARY
SUBJECT TO CHANGE

DRAWINGS ARE CONCEPTUAL. STRUCTURAL COMPUTATIONS HAVE NOT BEEN PERFORMED ON CONCEPTS SHOWN ON THIS DRAWING

SYMBOL	DESCRIPTION	DATE	APPROVED
	REVISIONS		

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

MISSISSIPPI RIVER BASIN
RIVER INDUSTRY ACTION COMMITTEE

DESIGNED BY:
DRAWN BY:
CHECKED BY:
DATE:

MID-RIVER MOORING BUOY

D | DACW 43 | PLATE 1

Bolinger/RIAC Mooring Buoy.
Delivered to District Service Base on nose of
Orgulf Transport Company Barge from Lockport, LA.

Prototype Buoy
30 Feet Long, 12 Feet Wide, Weight - 15 Tons

APPENDIX C

THALWEG SAMPLING
AND
THALWEG PLACEMENT OF DREDGE MATERIAL

1). Invertebrate Sampling in the Thalweg, River Mile 121

2). Field Work Summary--Thalweg Survey, River Mile 289

3). Field Report--Thalweg Disposal Site, River Mile 289

4). Final Report--Executive Summary, Mile 289

5). Field Report--Mussel Survey, Mile 289.8 to 288.8 R

CELMS-PD-A **18 March 1997**

MEMORANDUM FOR PD-A (Yarbrough)

SUBJECT: Avoid and Minimize invertebrate substrate sampling and results in the thalweg at River Mile 121.

1. On 21 October 1996, the Pathfinder and crew took three substrate samples at River Mile 121 (near Ste. Genevieve, Missouri) using the Corps specially designed and operated collection box. The substrate collector consists of an open ended, heavy metal, rectangular box which when operated with a series of cables can drag along the river bottom and collect substrate samples with very little disturbance from wash.

2. One sample was taken in the middle of the channel (course sand substrate) (8671-1), one sample was taken in the middle of the channel near the Illinois side (course sand substrate) (8671-2), and the last sample was taken on the Illinois side (course sand substrate) (8671-3). No velocity measurements were taken. Water depth ranged from 17-22 feet.

3. Portions of each sample were put into sealable containers and fixed in formalin for laboratory analysis. Mr. Roger Myhre (CELMS-ED-HQ) was responsible for providing laboratory analysis, and result organization and distribution.

4. Results of the laboratory analysis for the 11 June 1996 (see CELMS-PD-A memo dated 22 July 1996) (sample 8659-1 - mid. channel and sample 8659-2 - main channel, IL side) and the 21 October 1996 samples are attached.

5. The most prevalent benthic organism found was the Platyhelminthes - Neorhabdocoela. This Order of Turbellaria is known as a microturbellarian. Extremely small, rarely longer than 4 mm and typically found in shallow water, although a few species have been collected from lake bottoms as deep as 100 m (Pennak 1989). Turbellaria is seldom used as an important food source for other benthic organisms. Dragon fly nymphs occasionally feed on turbellaria. Likewise, nematodes, annelids, and a few crustaceans and aquatic insects may feed on turbellaria (Pennak 1989).

6. The family Chironomidae was the second most commonly found benthic organism. Chironomids occur in many types of aquatic ecosystems. The conditions under which chironomids can exist is more extensive than any other group of aquatic insect (Coffman and Ferrington 1984). Most aquatic predators feed on chironomids at some stage in their life cycle with young-of-the-year predatory fish species relying less on chironomids as the fish increases in size (Coffman and Ferrington 1984).

7. Two species of the Order Ephemeroptera (mayflies) were found in the samples taken 11 June 1996. Mayflies can occur in a wide variety of aquatic habitats (Edmunds 1984). One species of

the Phylum Coelenterata was recorded. They are typically found in littoral and shallow stream associations, however, they have been found in waters as deep as 40 to 350 m (Pennak 1989).

8. References for the above include:

A. Coffman, W. P. and L. C. Ferrington, Jr. 1984. Chironomidae. Pages 551-652 in R. W. Merritt and K. W. Cummins, ed. An Introduction to the Aquatic Insects of North America, 2nd Ed. Kendall/Hunt Publishing Co. Dubuque, Iowa.

B. Edmunds, Jr, G. F. 1984. Ephemeroptera. Pages 94-125 in R. W. Merritt and K. W. Cummins, ed. An Introduction to the Aquatic Insects of North America, 2nd Ed. Kendall/Hunt Publishing Co. Dubuque, Iowa.

C. Pennak, R. W. 1989. Fresh-Water Invertebrates of the United States, 3rd Ed. John Wiley & Sons, Inc. New York. 628 pp.

9. Please contact me at 331-8148 if you have any questions.

Sherrie Zenk-Reed

Encl

SHERRIE ZENK-REED
Wildlife Biologist

CF:
PD-A/Ragland
PD-A/Johnson
ED-HQ/Postol
ED-HQ/Myhre

TABLE 1. AQUATIC ORGANISMS FROM THALWEG DISPOSAL ~~9/6/96~~ 11 June96 AND GROUP 4, 10/21/96

SPECIES	T.V.	F.F.G.	8659-1	8659-2	TOTAL	8671-1	8671-2	8671-3	TOTAL
COELENTERATA									
Hydrozoa									
Hydroida									
Hydridae									
Hydra americana	5	P	1		1				
PLATYHELMINTHES									
Turbellaria									
Neorhabdocoela			189	244	433	124	160	217	501
Insecta									
Ephemeroptera									
Heptageniidae									
Stenonema sp.	4	SC		1	1				
Tricorythidae									
Tricorythodes sp.	5	CG	1		1				
Diptera									
Chironomidae			4		4				
Corynoneura sp.	2	CG	1		1				
Paratendipes basidens	3	CG						1	1
Polypedilum convictum	6	SH	1		1				
Rheotanytarsus sp.	6	FC	13		13				
Robackia claviger							1	9	10
Robackia demeijeri			1		1				
Thienemannimyia sp. gp.	6	P						1	1
TOTAL NO. OF ORGANISMS			211	245	456	124	161	228	513
TOTAL NO. OF TAXA			8	2	9	1	2	4	4

FIELD WORK SUMMARY

PROJECT: AVOID AND MINIMIZE
THALWEG SURVEY
RIVER MILE 289

SUMMARY

The Thalweg at Mississippi River Mile 289 was surveyed for Benthic Invertebrates, mussel population and grain size analysis on October 8, 1996. A field water quality profile was also conducted in conjunction with the survey.

Bottom sediment samples were collected from nine (9) locations within the Thalweg. Three (3) samples were collected from each of the three (3) transects running from upstream to downstream through the Thalweg. Sediment samples were collected and preserved for Benthic Invertebrate analysis and for gain size analysis. Table 1 provides a summary of the sediment samples collected, depth of water and approximate GPS location of each sampling point. The river stage at Louisiana, Missouri on October 8, 1996 was 11.9 feet.

The Thalweg site was surveyed for mussel populations along the same transcet lines as the Benthic Invertebrate as well as the eastern shoreline. A dual mussel brail system was utilized to conduct the survey. The total span width of the brail system was sixteen (16) feet.

The mussel survey retrieved one (1) "Washboard" and one (21) "Three Horn" mussel along the eastern shoreline. No other mussels were retrieved in the survey conducted through the primary section of the Thalweg at River Mile 289.

The Benthic Invertebrate analysis revealed a variety of species and populations within the Thalweg site. The total number of organisms detected within the nine (9) samples was 990 with a total of 24 different TAXA.

Grain size analysis revealed typical river sediments in the area.

The field water quality survey is summarized in Table 2. Results revealed water quality typical of the river for the season in which the sampling was conducted.

TABLE 1
Sediment Sample Locations Summary
River Mile 289

Transect	Site/Sample Designation	Water Depth *	GPS Coordinates **
1	TD89-1	24'	N39° 31.534' W91° 05.281'
	TD89-2	29'	N39° 31.436' W91° 05.260'
	TD89-3	24'	N39° 31.293' W91° 05.218'
2	TD89-4	21'	N39° 31.323' W91° 05.219'
	TD89-5	30'	N39° 31.405' W91° 05.238'
	TD89-6	24'	N39° 31.297' W91° 05.249'
3	TD89-7	18'	N39° 31.354' W91° 05.268'
	TD89-8	22'	N39° 31.456' W91° 05.327'
	TD89-9	21'	N39° 31.327' W91° 05.248'

* River stage at Louisiana, Missouri on 10/08/96 was 11.9 feet.

** GPS coordinates are considered approximate since poor GPS reception was being received. Accuracy of ± 200 feet at time of sampling and logging of data.

TABLE 2
Water Quality Summary
River Mile 289

Site Designation	Depth (ft.)	Temp.	DO	S. Cond.	pH	Redox	Time
TD89-1	0	16.6	9.7	426	7.8	-86	0830
	5	16.6	9.5	422	7.8	-87	-
TD89-3	0	16.6	10.1	423	7.8	-93	0920
	5	16.6	9.5	423	7.8	-96	-
	8	16.6	9.4	423	7.8	-96	-
TD89-5	0	16.6	10.1	423	7.9	-106	0936
	5	16.6	9.6	423	7.8	-107	-
	9	16.6	9.5	422	7.8	-107	-

CEMVS-ED-HQ 25 July 1997

MEMORANDUM FOR CEMVS-PD-A (Yarbrough)

SUBJECT: Mississippi River mile 289 - Thalweg Disposal Site

Summary

River hydroacoustic sampling was performed at Mile 289 on the Mississippi River. Data was collected during the period of 14 July 1997 through 15 July 1997.

This survey was performed to determine fish population at a deep hole at mile 289 to assess fish populations prior to dredge and fill activities. Six transacts of the subject location were performed. Data was collected for evaluation using Biosonic equipment and the associated computer data recording system. Data was stored for further evaluation.

No significant problems were encountered during the data collection activities. Minor problems were encountered with the Hypack Navigation equipment. The equipment was experiencing minor computer delays, which did not impact the data collection activities. This problem was addressed in the field and a solution was determined.

Follow-up Actions

Evaluation of the raw data is required to determine fish populations identified in the river transacts. Preliminary evaluation indicates a maximum of 10 fish were found. The largest fish was only 7 inches in length. Four fish are at the threshold limit of 3 inches in length. All fish were found near the shore line. No fish were found in the deep Thalweg hole. Final evaluation is in progress. Expected completion of the final report is 15 September 1997.

Roger Myhre

Roger E. Myhre
Hydrologist
Environmental Quality Section

CF:
PD-A Ragland, Miller, Johnson
CO-D Dierker
PM-M Eydmann
ED-HP Strauser

FINAL REPORT

THALWEG DISPOSAL
MISSISSIPPI RIVER MILE 289
AVOID AND MINIMIZE PROJECT

Prepared for:
U.S. Army Engineer District, St. Louis
Corps of Engineers
1222 Spruce Street
St. Louis, MO 63103-2033

Prepared by:
ARDL, Inc.
P.O. Box 1566
Mt. Vernon, IL 62864

Contract No. DACW-43-96-D-0519
Delivery Order No. 0005

Prepared by:

Todd Gentles
Field Services Manager
ARDL, Inc.

Approved by:

L.V. Gibbons, Ph.D.
President and Laboratory Director
ARDL, Inc.

Date Prepared: 2 September 1997

Date of Approval: 8 Sep 97

Approved by:

Theodore S. Postol, P.E.
Chief, Environmental Quality Section
U.S. Army Corps of Engineers
St. Louis District (CEMVS-ED-HQ)

1.0 EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers St. Louis District, with assistance of ARDL, Inc., performed a general assessment of the habitat at Mississippi River Mile 289 on the upper river. The Thalweg Disposal site is located at Mile 289.

Surveys conducted as a part of this investigation were as follows:

1. Mussel Abundance Survey
2. Benthic Invertebrate Survey
3. Grain Size Survey
4. Water Quality Survey
5. Multi-Beam Hydrographic Survey
6. Hydroacoustic Survey

This evaluation was performed to assess the habitat of the scour holes prior to the placement of dredged material.

Mussels were not found within the scour hole at River Mile 289. A total of two (2) live mussels were found along the shoreline at River Mile 289. One (1) "Washboard" and one (1) "Three Horn" mussel was retrieved within sixteen (16') feet of the eastern shoreline at River Mile 289.

The Benthic Invertebrate analysis revealed a variety of species and populations within the Thalweg site. The total number of organisms detected within the nine (9) samples was 990 with a total of 24 different TAXA.

Analytical results revealed that the sediments were primarily sands, ranging from 87.2% to 99.5%. The material description on all samples was a poorly graded sand.

Water quality was typical of the river for the season in which the sampling was performed.

Multi-Beam Hydrographic Survey revealed the coordinates of the Thalweg area.

The Hydroacoustic Survey resulted in the detection of eleven (11) total fish within the transected Thalweg area.

A & M TRIP REPORT

Date: 25 July 1997

Purpose: Survey for the presence of mussels in a proposed dredge disposal area (Mississippi R.M. 289.8-288.8 RDB).

Participants: Present from the Illinois Department of Natural Resources, Division of Fisheries - Butch Atwood. Present from the St. Louis District, Corps of Engineers, Environmental Planning Branch - T. Miller.

Background: The annual Mississippi River coordination trip among representatives of COE, IDNR, MDOC and FWS to discuss dredge disposal, river engineering, the Avoid and Minimize program and other items of mutual interest was held on 23 and 24 July. The area around the chevron dikes, near Cottonwood Island, was a major item of discussion because of a chronic dredging problem in the river reach from R.M. 291 - 289. The chevrons were originally constructed as disposal sites and experimental river engineering structures. In addition, thalweg disposal was being considered for part of the dredge material from this reach. The discussion centered around the excellent fisheries habitat the chevron dikes had created, especially the upper and lower chevrons, and the possibility of utilizing alternative dredge disposal sites allowing the aquatic habitat around the chevrons to remain unspoiled. The RDB between R.M. 290 and 288.5 was discussed as a possible alternative. A concern was expressed by FWS about the presence of a mussel bed in the vicinity and especially about the possible presence of the fat pocketbook, Potamilus capax, a Federally listed endangered species that had been reintroduced into the area several years earlier at an upstream location near Blackbird Island (Approximate R.M. 292). An agreement was reached to place dredge material on the middle chevron (which has the poorest aquatic habitat), in the thalweg hole near R.M. 289 and between the dikes on the RDB if the area was found to be free of live mussels.

Summary: A mussel survey of the area was conducted on the afternoon of 25 July utilizing a five foot experimental crowfoot bar carrying 21 gangs of three crowfoot hooks each. Seven three to five minute hauls were conducted beginning just below the dike at R.M. 289.8 RDB, immediately across the river from the upstream end of the upper chevron dike, and continuing downstream to approximately R.M. 288.8 in the vicinity of the thalweg disposal hole. Hauls varied between 100 and 200 feet off the RDB. No live mussels were collected. Two relic shells were collected (one valve each) of the fragile paper shell, Leptodea fragilis, along with a part of a third relic shell believed to be the same species. Water depth in the survey area was approximately 12 feet. The bottom appeared to be comprised almost exclusively of sand as waves were apparent in the bottom profile on the depth finder screen and could be felt through the line attached to the bar. Rust covered areas on the surface of the bar and hooks were quickly abraded to shiny metal. A map of the surveyed area is attached. The survey crew concluded that the surveyed area was an appropriate dredge disposal site. This information was telephoned to Mr. Steve Dierker of the St. Louis District at approximately 0630 on 28 July 1997 to facilitate the timely initiation of channel dredging in the vicinity of R.M. 289.

T. MILLER
Ecologist
Environmental Planning Branch
St. Louis District, COE

APPENDIX D

PALLID STURGEON MONITORING

1). Middle Mississippi River--Pallid Sturgeon Studies
R.J. Sheehan, et. al., Southern Illinois University-Carbondale

2). Middle Mississippi River--Pallid Sturgeon Habitat Use Project
R. J. Sheehan, et. al., SIU-C

Southern Illinois University at Carbondale
Carbondale, Illinois 62901-6511

Cooperative Fisheries Research Laboratory
Mailcode 6511
Phone and FAX: 618-536-7761

April 29, 1997

Y 1 May 1997

T. Miller, PD-A
Army Corps of Engineers
1222 Spruce Street
St. Louis, MO 63103

RE: Pallid Sturgeon

Enclosed are locations of pallid sturgeon between river miles 113 and 121 by month. Seven of our fish implanted with sonic transmitters were found between those river miles sometime between November 1995 to the present. No tracking data is available for December 1995 and the latter half of May, as well as early June of 1996, due to ice cover or high water conditions.

To briefly summarize our findings, 48 of 132 total contacts with pallid sturgeon were in this river reach.

Yours truly,

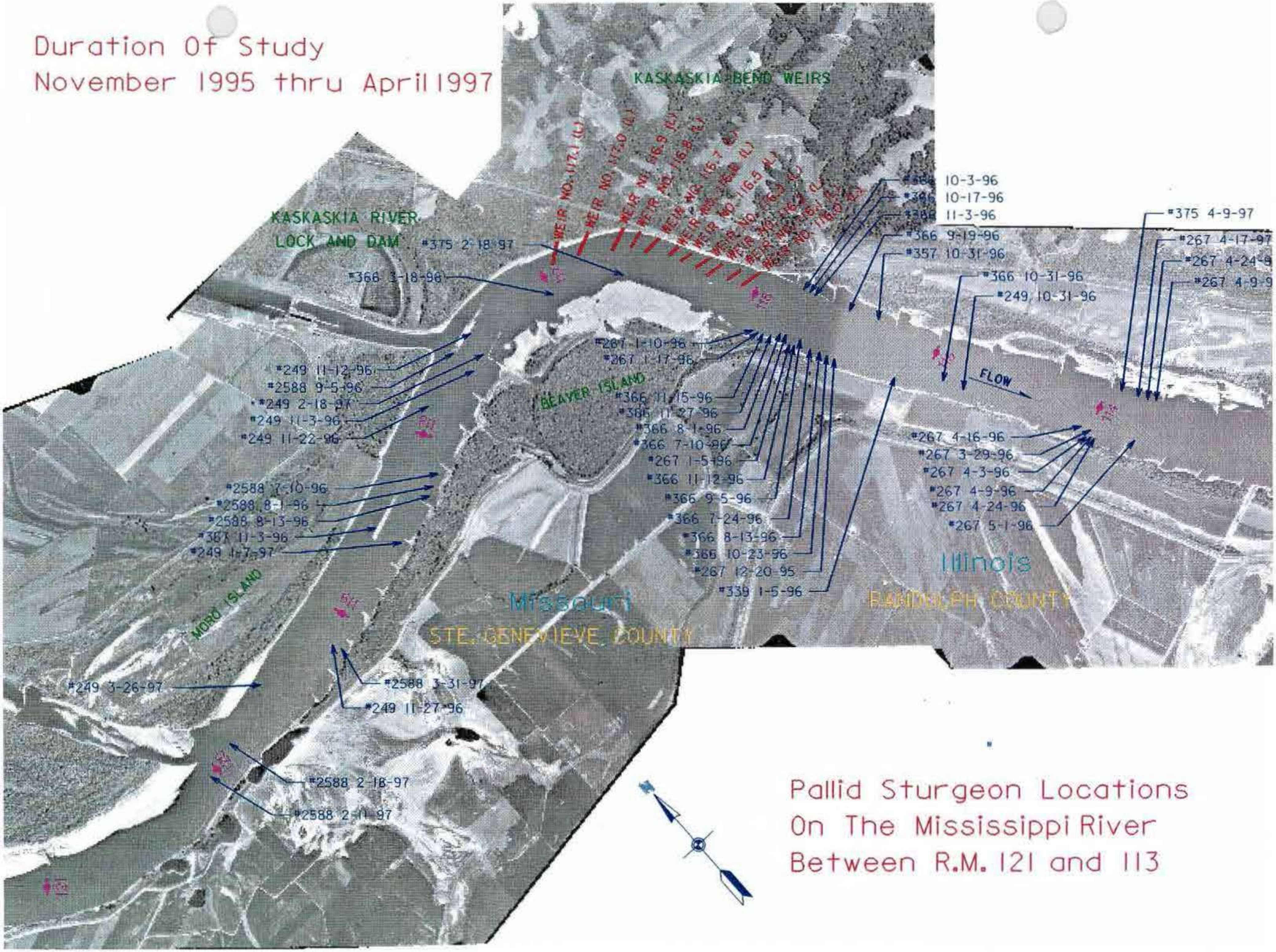
Bob (sw)

Robert Sheehan
Fisheries Research Lab

sw

Enclosures

Duration Of Study
November 1995 thru April 1997



Pallid Sturgeon Locations
On The Mississippi River
Between R.M. 121 and 113

Middle Mississippi River Pallid Sturgeon Studies

R.J. Sheehan, R.C. Heidinger, K.L. Hurley,
P.S. Wills, and M.A. Schmidt

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

Pallid Sturgeon Habitat Associations and Movements:

Pallid sturgeon (614-837 mm, 950-3,039 g) were obtained from commercial fishers, Missouri Department of Conservation, and our sampling. Twelve sturgeon were given sonic transmitter implants and released in the Middle Mississippi River (MMR) at capture locations.

The study sturgeon were located 103 times from November 1995 through May 1996. They were found in the main channel (MCL) 46%, the main channel border (MCB) 12%, and in areas between wing dams (WDB) 19% of the time.

At water temperatures between 10° and 4°C, 67% and 25% of the sturgeon were located in the MCL and MCB, respectively. At water temperatures < 4°C, the sturgeon were in the MCL and WDB 48% and 17% of the time, respectively. They were in maximum depths of 3 to 12 m 88% of the time. Movements of individuals ranged from 2.0 to 60.5 mi.

Hatchery-Reared Sturgeon Behavior and Use of Bendway Weir Fields:

A bendway-weir field is scheduled for construction in the St. Genevieve Bend upstream of Chester, IL, during 1997-1998. Ten hatchery-reared pallid sturgeon from Blind Pony Fish Hatchery, MO, were given sonic transmitter implants and released into this bend during July 1997. We plan to track ten more hatchery-reared pallid sturgeon released in the same area after completion of the weir field.

The objective of this study is to determine how pallid sturgeon use of river bends is affected by bendway weirs. This is also an opportunity to compare behavior, habitat use, and movements of hatchery-reared pallid sturgeon to wild sturgeon.

Although this study is in its initial stages, six of the hatchery sturgeon have been located at least once. Within three days of release, all but two of them had moved from the vicinity of their release sites. Most moved downstream; one was located approximately 20 mi downriver from its release site, while only one has been found upstream. Several were found downstream in the Kaskaskia Bend, a bend which already has a bendway-weir field. Only one of the ten hatchery sturgeon has been found in the St. Genevieve Bend during recent sampling trips.

Examination of a Commercial Sturgeon Catch from the MMR:

On 28 March 1997, a commercial fisher's sturgeon catch from the MMR was examined at Schafers Fish Market, Fulton, IL. The catch was comprised of 179 *Scaphirhynchus* (466-765 mm fork length), including one pallid sturgeon which had been captured before from the MMR and used in our telemetry study. Meristic measurements were taken on all 10 specimens we believed to be pallid or hybrid sturgeon and on 10 shovelnose sturgeon in the catch. Based on the character index we developed (Sheehan et. al. 1997), 4 of the 10 specimens showing pallid sturgeon characteristics appeared to be pallid sturgeon and 6 were probably hybrids.

Literature Cited

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

Middle Mississippi River Pallid Sturgeon Habitat Use Project

Robert J. Sheehan, Roy C. Heidinger, Keith L. Hurley,

Paul S. Wills, and Michael A. Schmidt

Fisheries Research Laboratory and Department of Zoology

Southern Illinois University

Carbondale, IL 62901-6511

Year 2

Annual Progress Report

December 1997

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. Sonic telemetry was used to determine the movements, locations, and habitat use of pallid sturgeon. 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. The specific project objectives are to identify and obtain information on habitats used by wintering and spawning 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 second year of the study. We continued to collect movement and habitat use data from MMR pallid sturgeon in which we had implanted sonic transmitters. Two additional study activities were conducted this year. First, we implanted transmitters in ten hatchery-reared pallid sturgeon (Missouri Department of Conservation, Blind Pony Fish Hatchery) and placed them in the vicinity of the St. Genevieve Bend. This bend is scheduled to have bendway weirs placed in it during Fall 1997 and Spring 1998. Ten more hatchery-reared sturgeon will be given transmitter implants and placed in the St. Genevieve Bend after the bendway-weir field is completed. We are monitoring the movements and habitat use of the hatchery-reared sturgeon for two reasons: 1) to compare pallid sturgeon use of the St. Genevieve Bend before and after the weir field is in place, and 2) to compare habitat use and movements of hatchery-reared pallid sturgeon to wild conspecifics. During this study year, we also examined the catch of sturgeon by a MMR commercial fisher. These sturgeon were sold to a fish market, and we were informed by the U.S. Fish and Wildlife Service that one of the fish in the catch was a wild pallid sturgeon in which we had implanted a transmitter.

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 utilize sand and avoided gravel-cobble substrates. They ranged as far as 331.2 miles and moved up to 21.4 km/d. Bramblett 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 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 man's effects 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 impacts on the ecology of the MMR come from the extensive drainage and leveeing of floodplain wetlands (Sheehan and Konikoff, in press). Isolation of the River from its historical floodplain reduces river/floodplain interactions during periods of high water. Many workers 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.

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

Depth (m)	Contacts	Percent
<3	5	5.0
3 - 6	28	20.1
6 - 9	52	37.4
9 - 12	42	30.2
12 - 15	7	5.0
15 - 18	1	0.7
>18	2	1.4

Table 5. Range of river miles over which individual pallid sturgeon were contacted.

Fish Number	Miles	Observations
267	2	15
366	8.2	19
249	10.9	15
294	18.7	18
276	19.9	2
357	19.9	22
339	26.6	5
375	29.4	11
2588	31.9	17
465	34.0	11
384	60.3	6

Figure 2. 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.

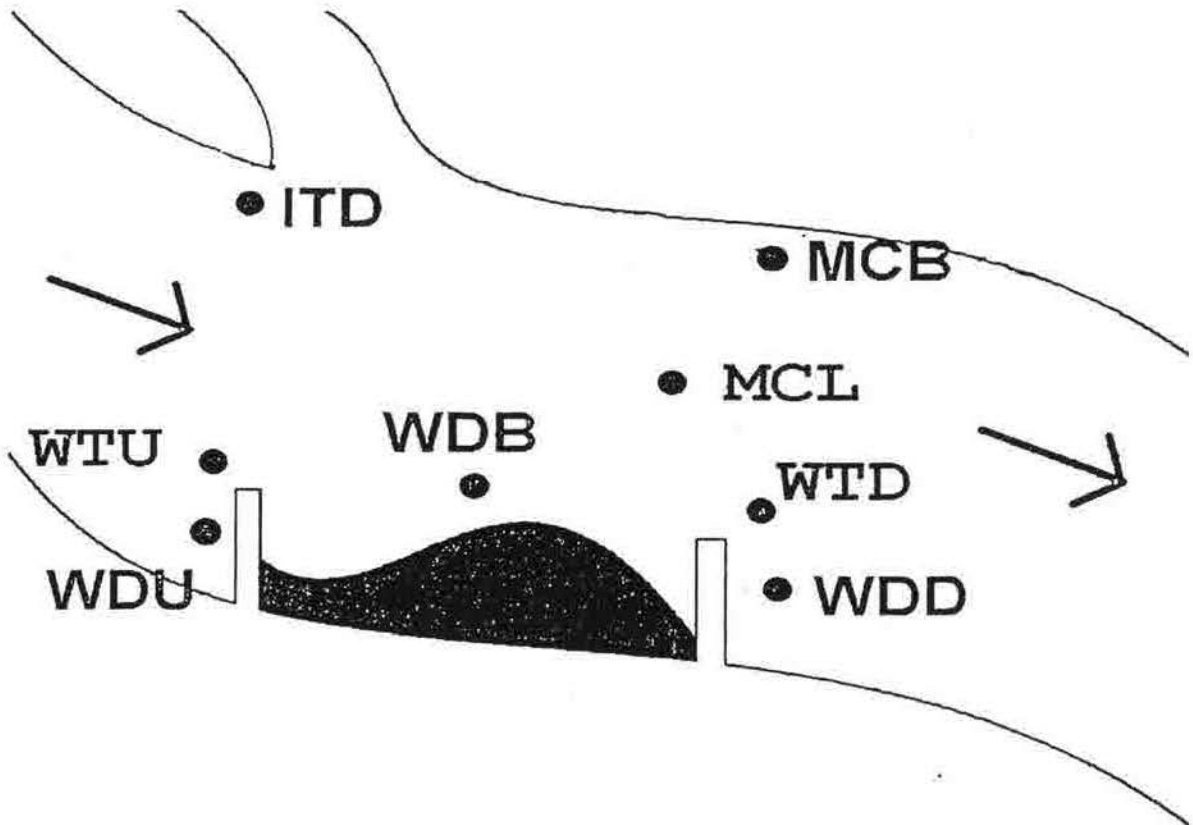


Figure 3. Pallid sturgeon habitat associations in the middle Mississippi River from November 1995 through September 1997. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 142.

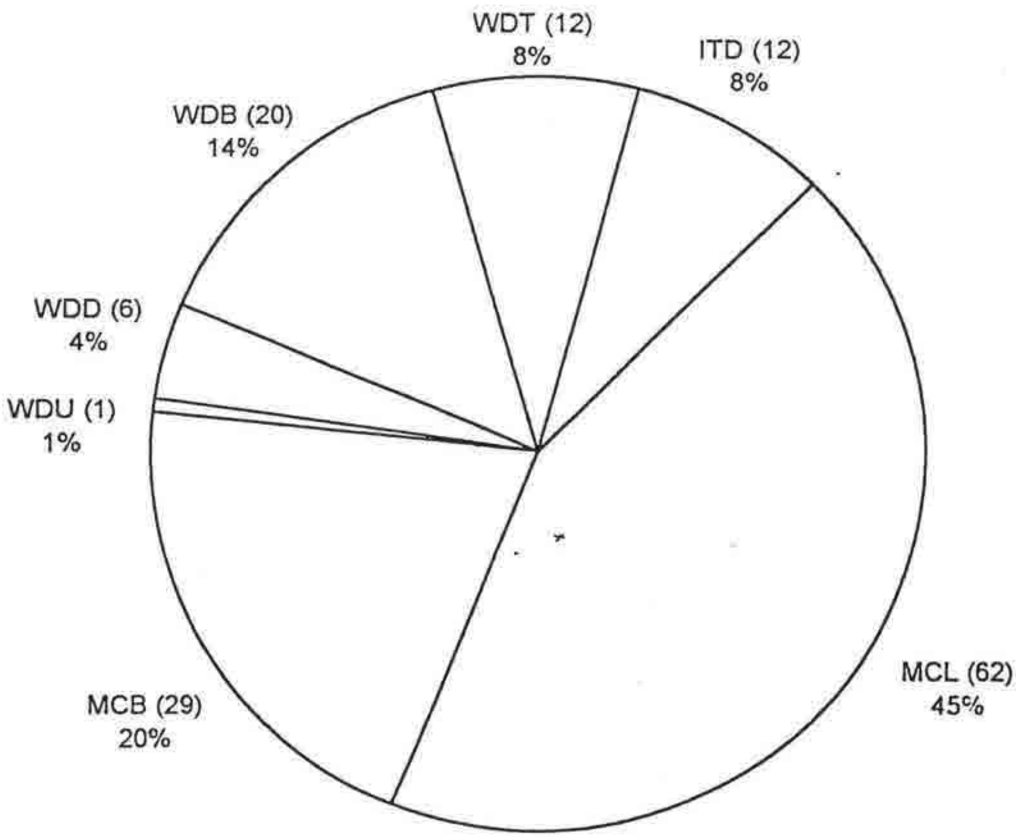


Figure 4. Pallid sturgeon habitat associations at surface water temperatures at or above 4° C and below 10° C in the middle Mississippi River from November 1995 through September 1997. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N =28.

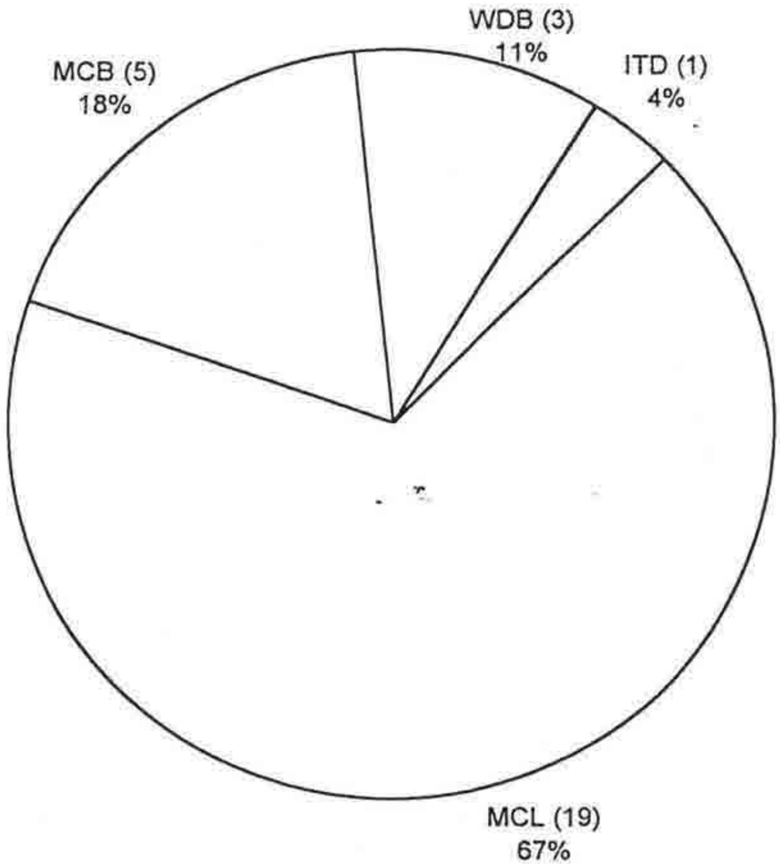


Figure 5. Pallid sturgeon habitat associations at surface water temperatures below 4° C in the middle Mississippi River from November 1995 through September 1997. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 33.

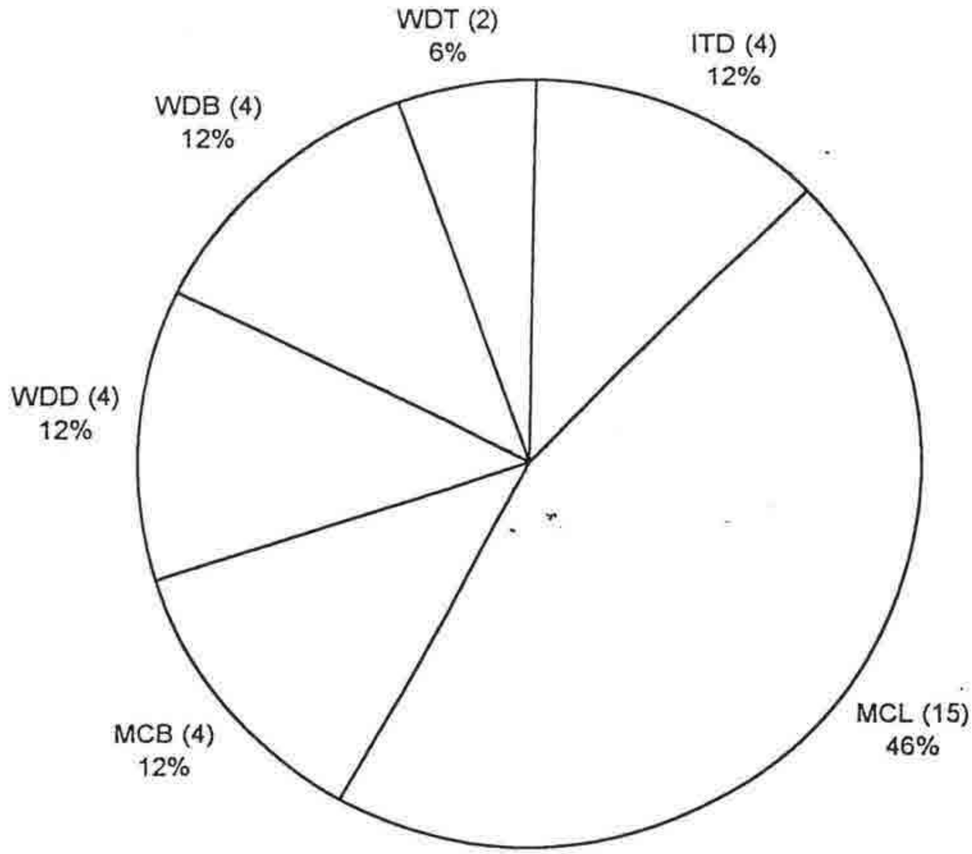


Figure 6. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River from March through May, 1996, and from April through June, 1997. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 16.

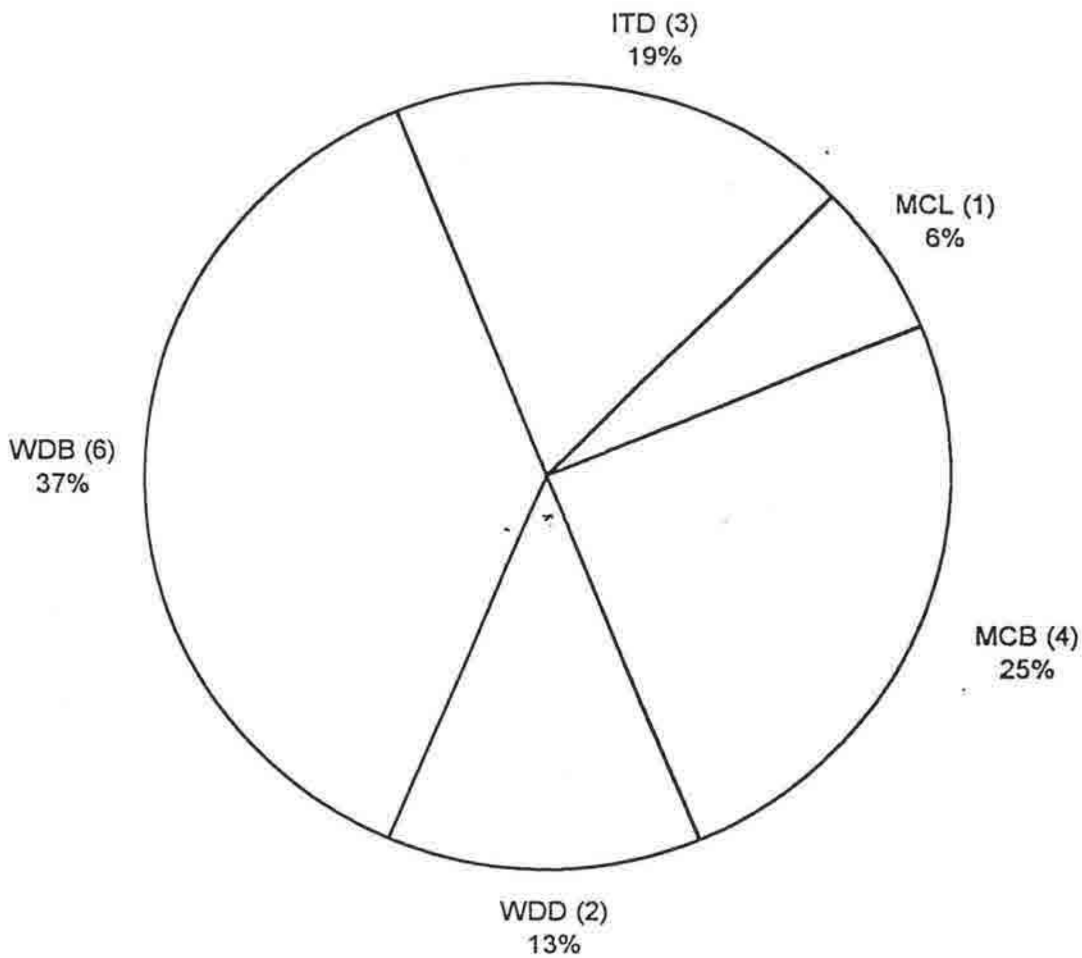


Figure 7. Pallid sturgeon habitat associations at surface water temperatures at or above 10° C and below 20° C in the middle Mississippi River from October 1996 and August 1997. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 26.

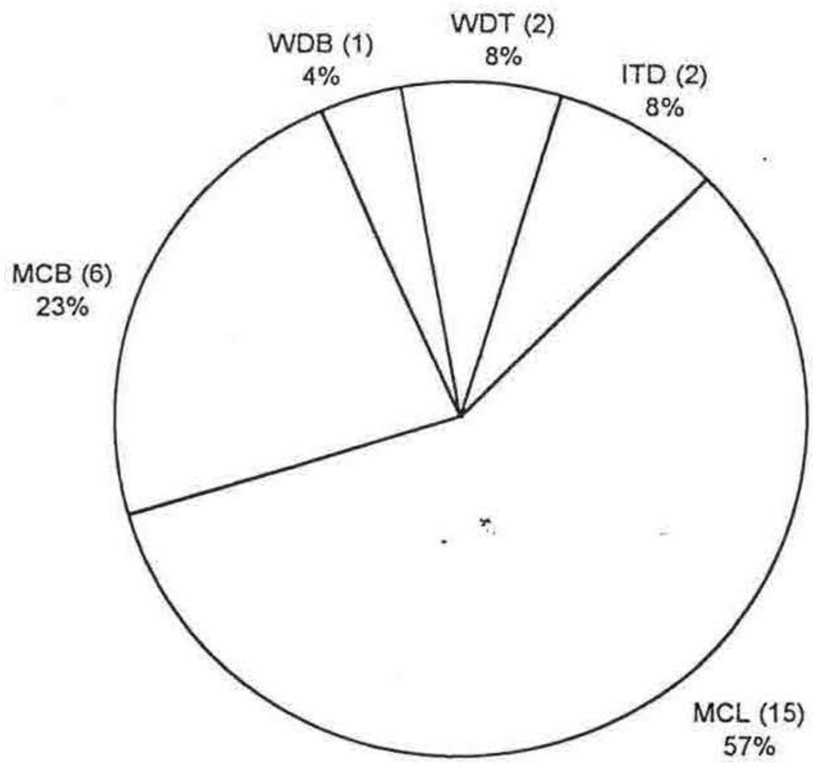
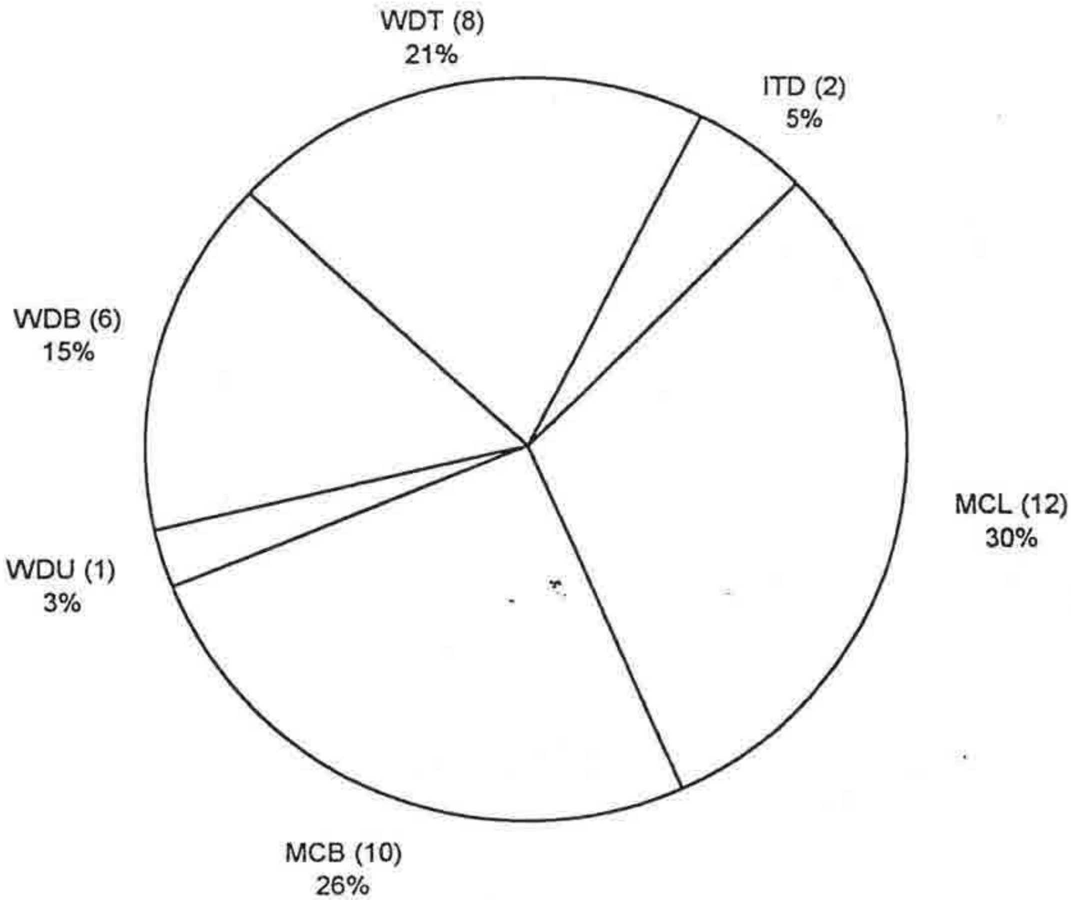


Figure 8. Pallid sturgeon habitat associations at surface water temperatures at or above 20° C in the middle Mississippi River from November 1995 through September 1997. MCL = main channel, MCB = main channel border, WDU = wing dam upstream, WDD = wing dam downstream, WTU = wing dam tip upstream, WTD = wing tip downstream, WDB = between wing dams, ITD = downstream island tip. N = 39.



APPENDIX E

BIOLOGICAL MONITORING

1). Chevron Dike--Fisheries Evaluation Update
Butch Atwood, Illinois Dept. of Natural Resources

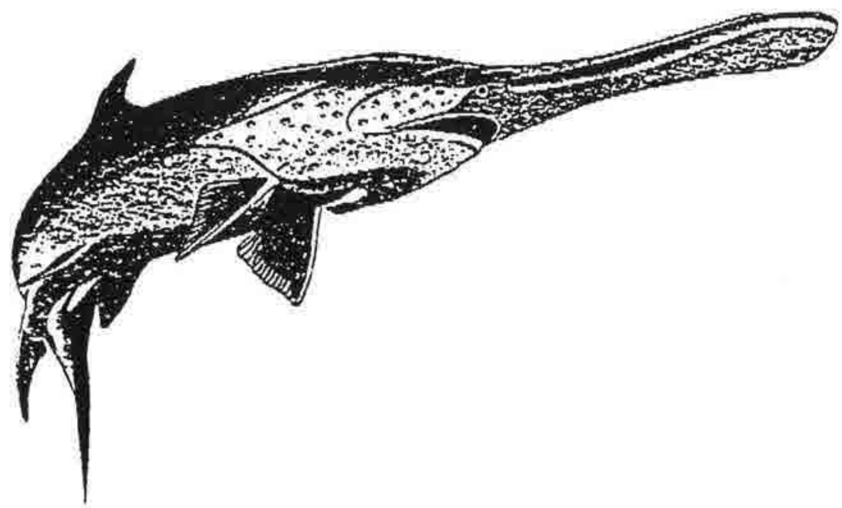
2). Macroinvertebrates Associated With Habitats of Chevron Dikes
In Pool 24 of the Mississippi River*

3). Final Report:Macroinvertebrates Associated with Carl Baer Bendway
Weirs in the Mississippi River*

4). Final Report: Macroinvertebrates Associated with Bendway Weirs at
Mississippi River Mile 30*

5). Water Level Manipulation/Vegetation Project, Mississippi River
Pools 24, 25, 26, R.C. Heidinger, et. al. Cooperative Fisheries
Research Lab, SIU-C. This study was funded by the U.S. Fish
and Wildlife Service, Rock Island.

*If you wish to obtain a complete copy of the above reports please contact Mr. Brian Johnson, Fisheries Biologist, PD-A--314-331-8146.



From: Butch Atwood
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Middle Mississippi River Project
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Cottonwood Island Chevron Dike Fisheries Evaluation Update

The Illinois Department of Natural Resources, Division of Fisheries, Middle Mississippi River Project, with assistance from the St. Louis District, Corps of Engineers has conducted electrofishing sampling (EF) on the Cottonwood Island Chevrons since October 1993. The upstream and downstream most chevrons have been sampled, along with a small backwater slough at Drift Island as a control site. The dates of sampling for these areas, as well as EF time period for each site are shown in Figure 1.

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

To date, a total of 2957 fishes representing 44 species have been collected during 416 minutes of electrofishing (106.62 fish/15 ef min). When these data are summarized by habitat type (inside, outside, Drift Is.) over all sampling periods (Table 2), the highest catch rate was observed inside the chevrons (154.04 fish/15 min EF), followed by Drift Island Slough (105.5 fish/15 min EF) and outside the chevrons (66.2 fish/15 min EF). The number of species collected was also highest from the inside (Table 2).

When the number of species collected per site are compared (Figure 1), the highest species richness was observed from inside the upper chevron (34 species) followed co-equally by upper outside and lower inside (25 species). When catch rates for each site (over all sampling periods) are compared, upper inside chevron is higher than all other sites at 166.22 fish/15 min EF, followed by lower inside (126.82 fish/15 min) and Drift Island Slough (105.50 fish/15 min) [Figure 2]. These data conservatively suggest that the habitat inside the chevron dikes are holding more fish that either the habitat immediately outside of the chevrons or the slough habitat.

A similar picture emerges when the catch rates by site of selected individual fish species are compared. The catch rates for gizzard shad (Figure 3), river shiner (Figure 4), and bullhead minnow (Figure 5) were all higher inside chevrons than elsewhere. The catch rate for smallmouth buffalo was highest in the slough followed by inside lower and inside upper (Figure 6). The catch rates for channel catfish (Figure 7) and flathead catfish (Figure 8), however were highest on the outside of the chevrons. The largemouth bass catch rates were higher (and similar) on the inside of chevrons and in the slough than from the outside of chevrons (Figure 9). The bluegill catch rate in the slough habitat was much higher than elsewhere, but was higher inside chevrons than outside (Figure 10).

These data strongly suggest that chevron dikes are providing useful and valuable habitat for a large 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 have also been collected along the outside of chevrons. From the species composition and the number of young of the year sport fishes present, the inside of chevrons appear to be providing excellent backwater type habitat in a reach of river where such habitat is limited.

Submitted by:
Elmer R. Atwood
Middle Mississippi River Project
Ill Dept of Natural Resources
Division of Fisheries

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

DATE	Station name	Electrofishing period
14-Oct-93	Lower Chevron Inside	9
14-Oct-93	Lower Chevron Outside	9
14-Oct-93	Upper Chevron Inside	9
14-Oct-93	Upper Chevron Outside	9
02-Aug-95	Upper Chevron Inside	14
02-Aug-95	Upper Chevron Outside	14
12-Sep-95	Lower Chevron Inside	16
12-Sep-95	Lower Chevron Outside	16
12-Sep-95	Upper Chevron Inside	16
12-Sep-95	Upper Chevron Outside	16
11-Oct-95	Upper Chevron Inside	14
11-Oct-95	Upper Chevron Outside	14
14-Aug-96	Lower Chevron Inside	15
14-Aug-96	Lower Chevron Outside	15
14-Aug-96	Upper Chevron Inside	15
14-Aug-96	Upper Chevron Outside	15
09-Sep-96	Drift Island Slough	15
09-Sep-96	Lower Chevron Outside	15
09-Sep-96	Upper Chevron Inside	15
09-Sep-96	Upper Chevron Outside	15
08-Oct-96	Drift Island Slough	15
08-Oct-96	Lower Chevron Outside	15
08-Oct-96	Upper Chevron Inside	15
08-Oct-96	Upper Chevron Outside	15
16-Jul-97	Lower Chevron Inside	15
16-Jul-97	Lower Chevron Outside	15
16-Jul-97	Upper Chevron Inside	10
16-Jul-97	Upper Chevron Outside	10
26-Sep-97	Upper Chevron Inside	15
26-Sep-97	Upper Chevron Outside	15
	Total	416

Table 2. Composition of fishes collected with boat electrofishing at Cottonwood Island Chevron Dikes, 1993 - 1997.

	Total Inside		Total Outside		Drift Is. Slough		All Stations	
sampling effort (min)	178		208		30		416	
Species	N	no./15min	N	no./15min	N	no./15min	N	no./15min
Shortnose gar	3	0.25					3	0.11
Bowfin					3	1.50	3	0.11
American eel			1	0.07			1	0.04
Skipjack herring	1	0.08					1	0.04
Gizzard shad	428	36.07	51	3.68	2	1.00	481	17.34
Threadfin shad	1	0.08					1	0.04
Mooneye			3	0.22			3	0.11
Goldfish	1	0.08					1	0.04
Carp	19	1.60	69	4.98	13	6.50	101	3.64
Central stoneroller			1	0.07			1	0.04
Suckermouth minnow	5	0.42					5	0.18
Silver chub	7	0.59	11	0.79	8	4.00	26	0.94
Spotfin shiner	69	5.81	148	10.67	2	1.00	219	7.90
Red shiner	4	0.34	13	0.94			17	0.61
Emerald shiner	255	21.49	295	21.27	1	0.50	551	19.87
River shiner	46	3.88	27	1.95			73	2.63
Bigmouth shiner			1	0.07			1	0.04
Sand shiner	6	0.51	14	1.01			20	0.72
Mimic shiner	57	4.80	15	1.08	1	0.50	73	2.63
Spottail shiner	4	0.34					4	0.14
Shiner spp.	13	1.10					13	0.47
Bluntnose minnow	3	0.25	2	0.14			5	0.18
Bullhead minnow	374	31.52	17	1.23	12	6.00	403	14.53
Bigmouth buffalo	13	1.10			2	1.00	15	0.54
Smallmouth buffalo	47	3.96	22	1.59	13	6.50	82	2.96
Black buffalo	1	0.08					1	0.04
Quillback	13	1.10			1	0.50	14	0.50
River carpsucker	47	3.96					47	1.69
Carpsucker spp.	14	1.18					14	0.50
Shorthead redhorse	4	0.34	6	0.43			10	0.36
Golden redhorse	3	0.25					3	0.11
Channel catfish	14	1.18	93	6.71	4	2.00	111	4.00
Flathead catfish	3	0.25	64	4.62	1	0.50	68	2.45
Mosquitofish	14	1.18			28	14.00	42	1.51
White bass	28	2.36	10	0.72	1	0.50	39	1.41
Yellow bass			1	0.07			1	0.04
Black crappie	5	0.42			5	2.50	10	0.36
White crappie					3	1.50	3	0.11
Largemouth bass	30	2.53	3	0.22	5	2.50	38	1.37
Smallmouth bass			2	0.14			2	0.07
Warmouth	1	0.08					1	0.04
Green sunfish	42	3.54	3	0.22			45	1.62
Bluegill	115	9.69	10	0.72	66	33.00	191	6.89
Orangespotted sunfish	31	2.61			36	18.00	67	2.42
Logperch	1	0.08					1	0.04
Freshwater drum	106	8.93	36	2.60	4	2.00	146	5.26
Totals	1828	154.04	918	66.20	211	105.50	2957	106.62
No. species collected	36		26		21		44	

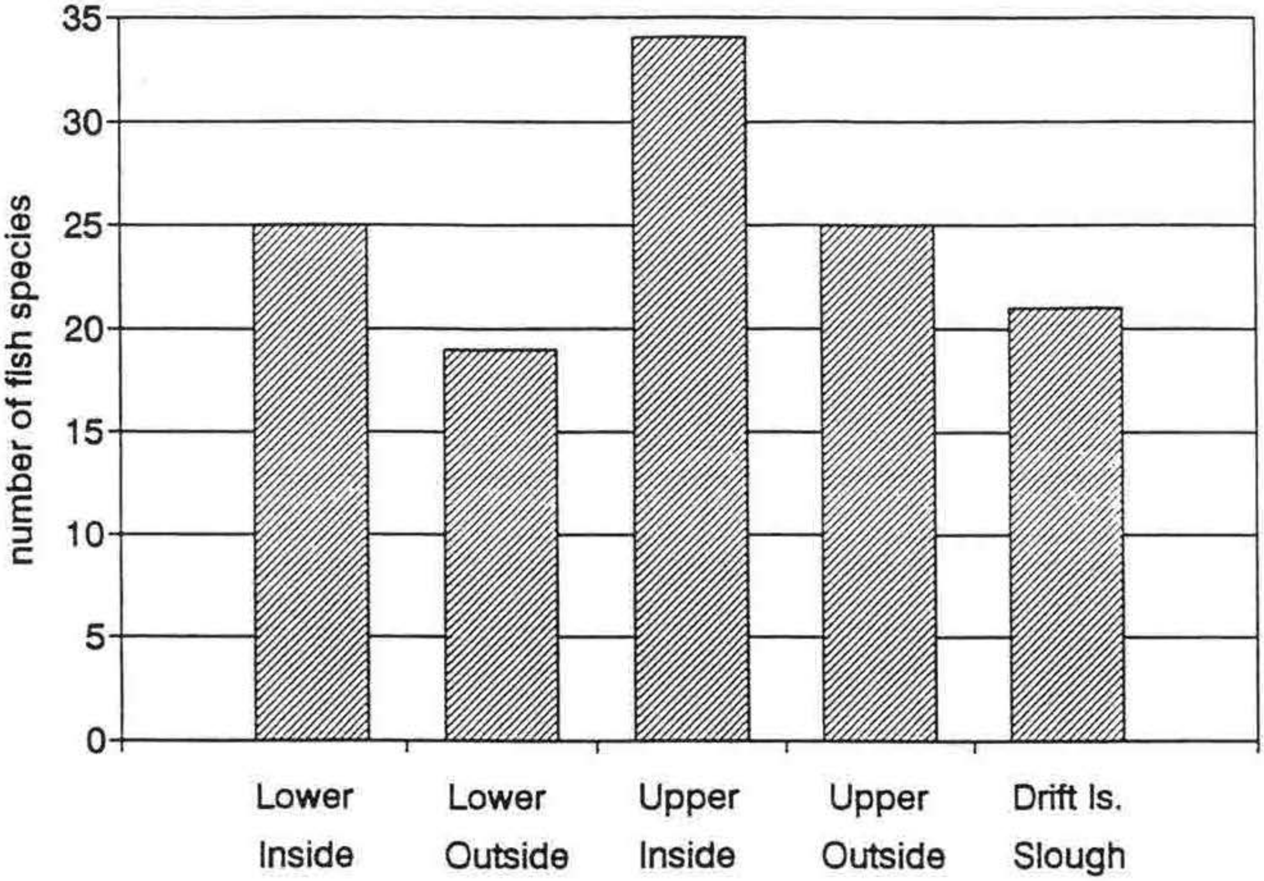


Figure 1. Total number of fish species collected with electrofishing at Cottonwood Island chevron dikes and control station.

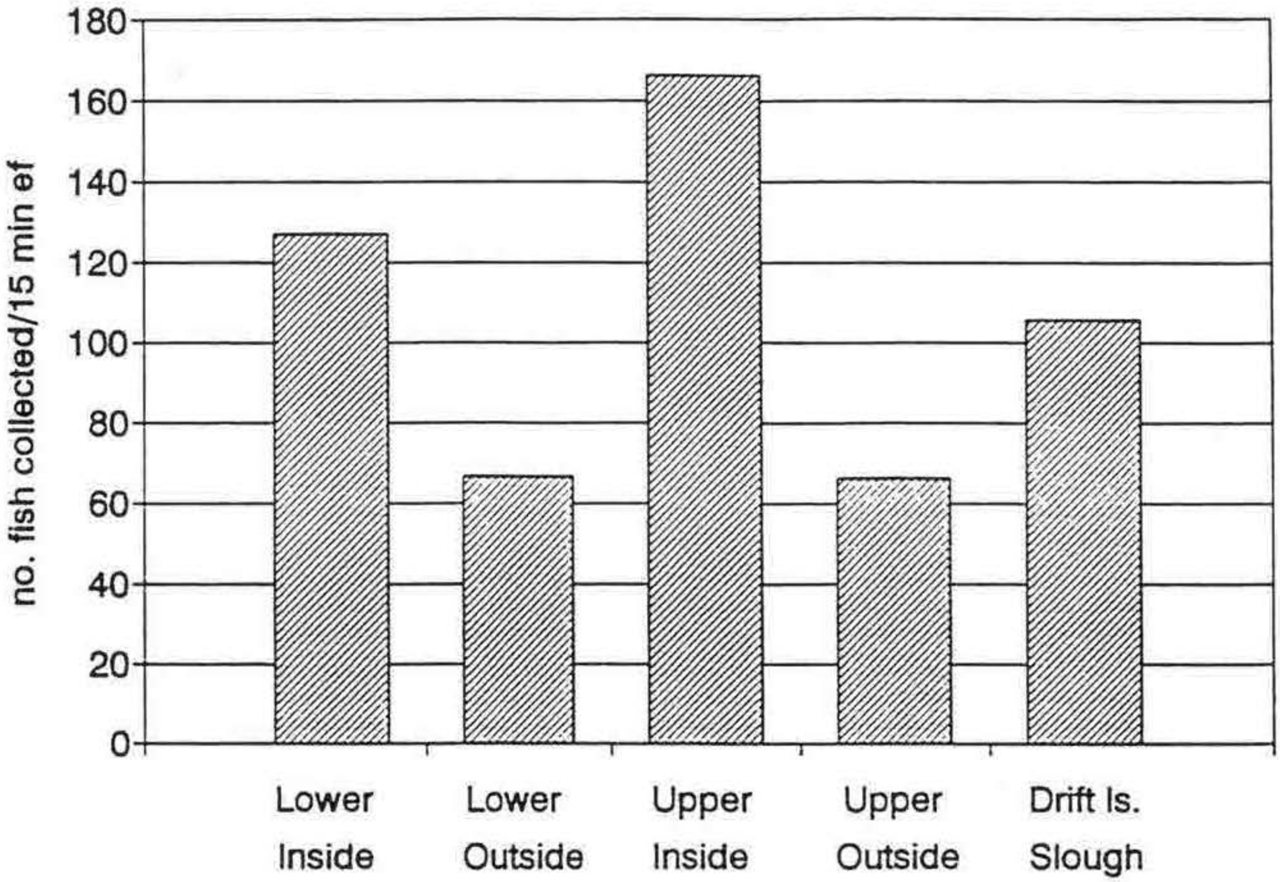


Figure 2. Total number of fish collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

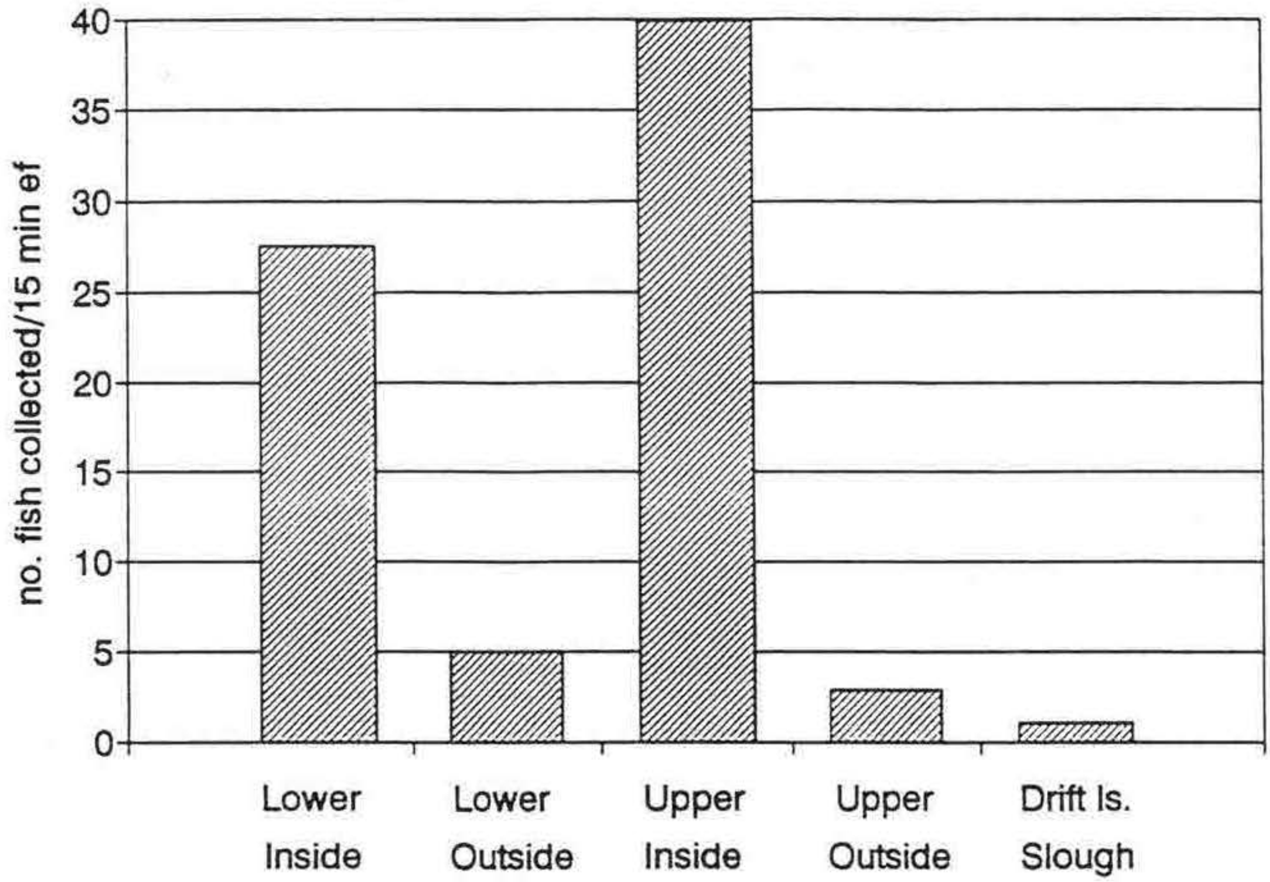


Figure 3. Total number of gizzard shad collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

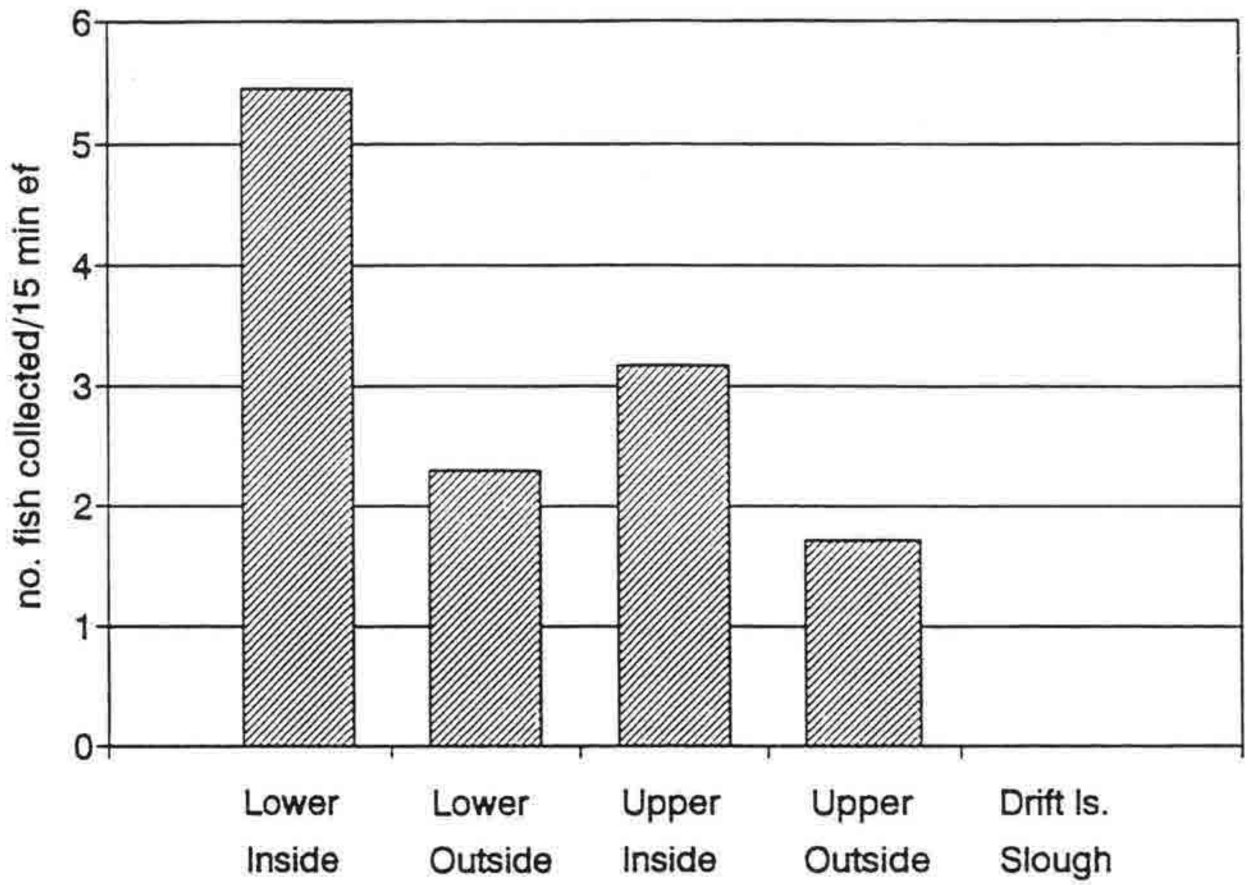


Figure 4. Total number of river shiner collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

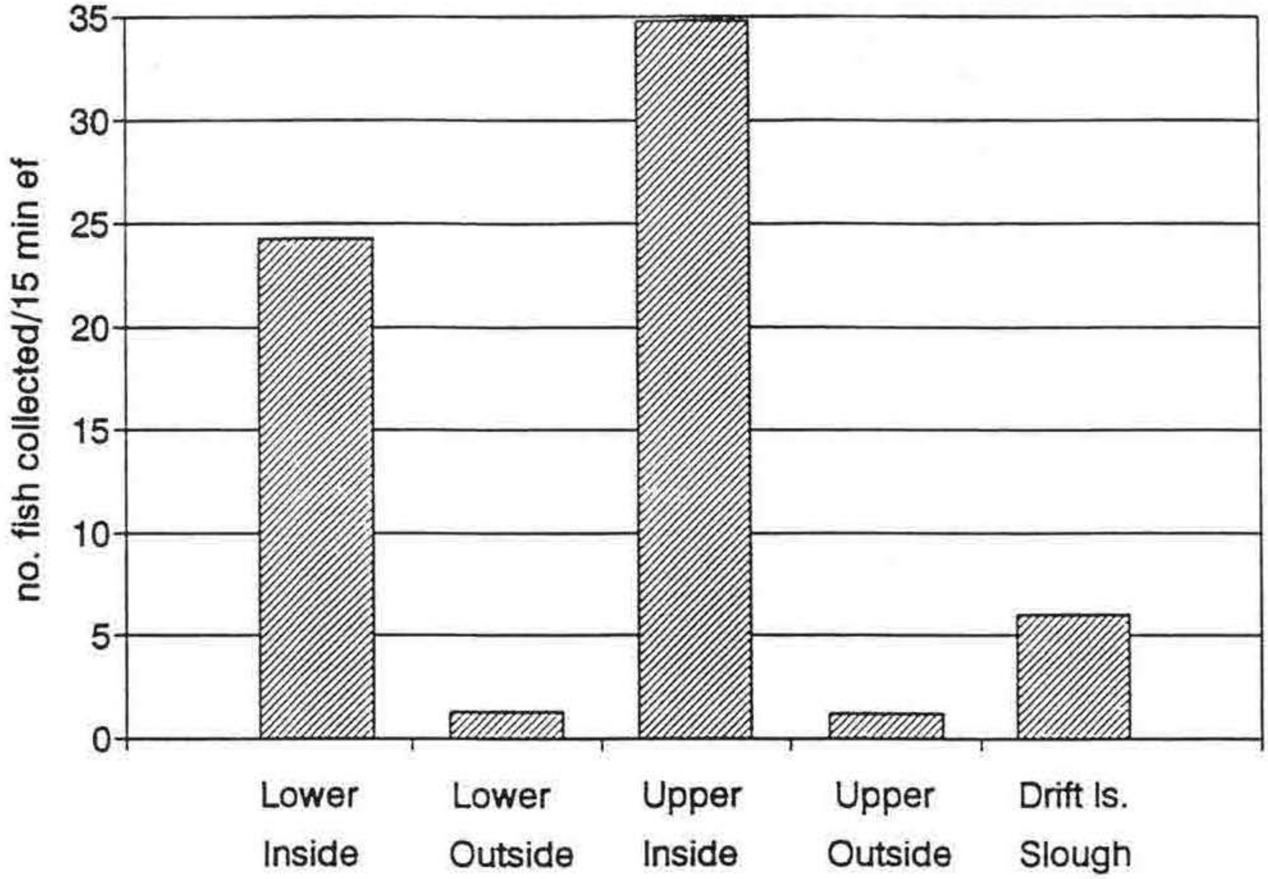


Figure 5. Total number of bullhead minnow collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

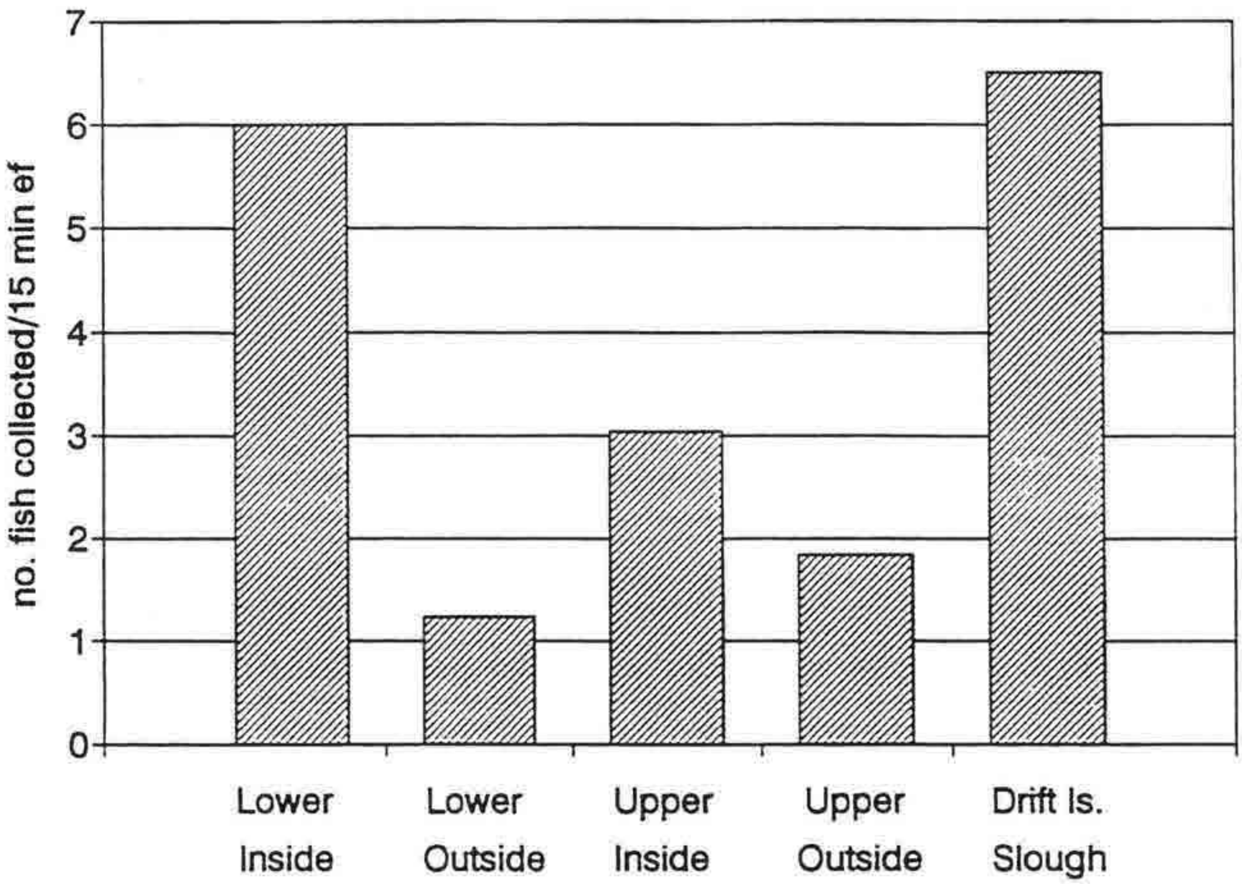


Figure 6. Total number of smallmouth buffalo collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

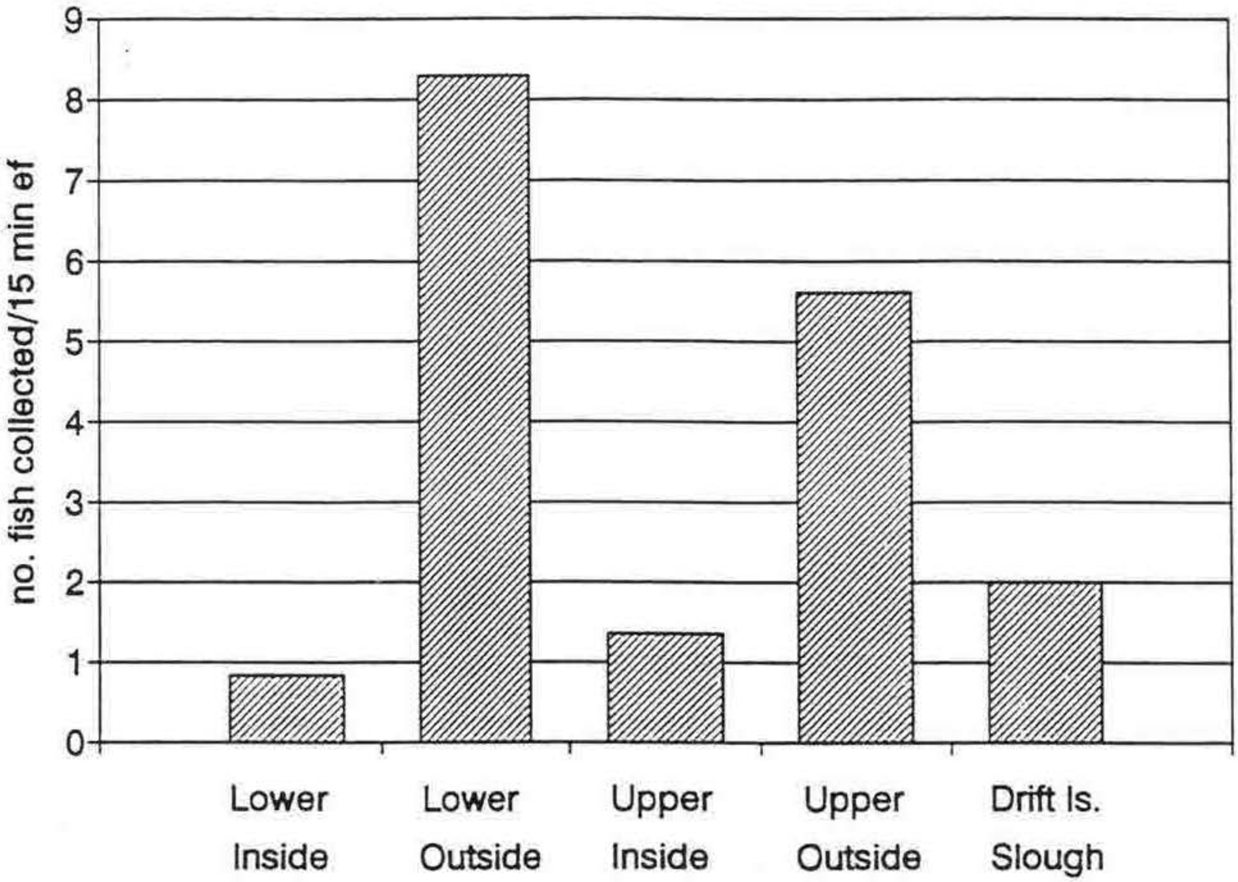


Figure 7. Total number of channel catfish collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

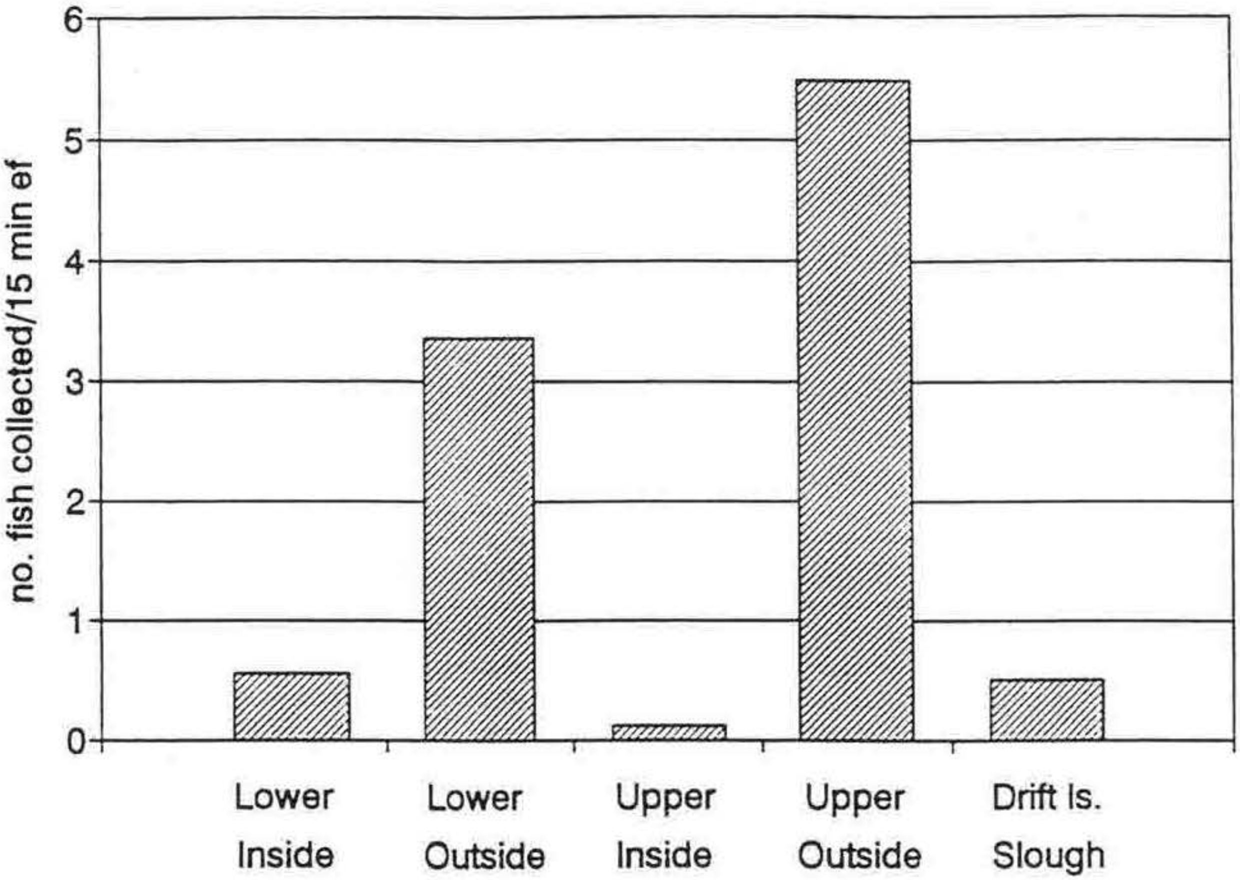


Figure 8. Total number of flathead catfish collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

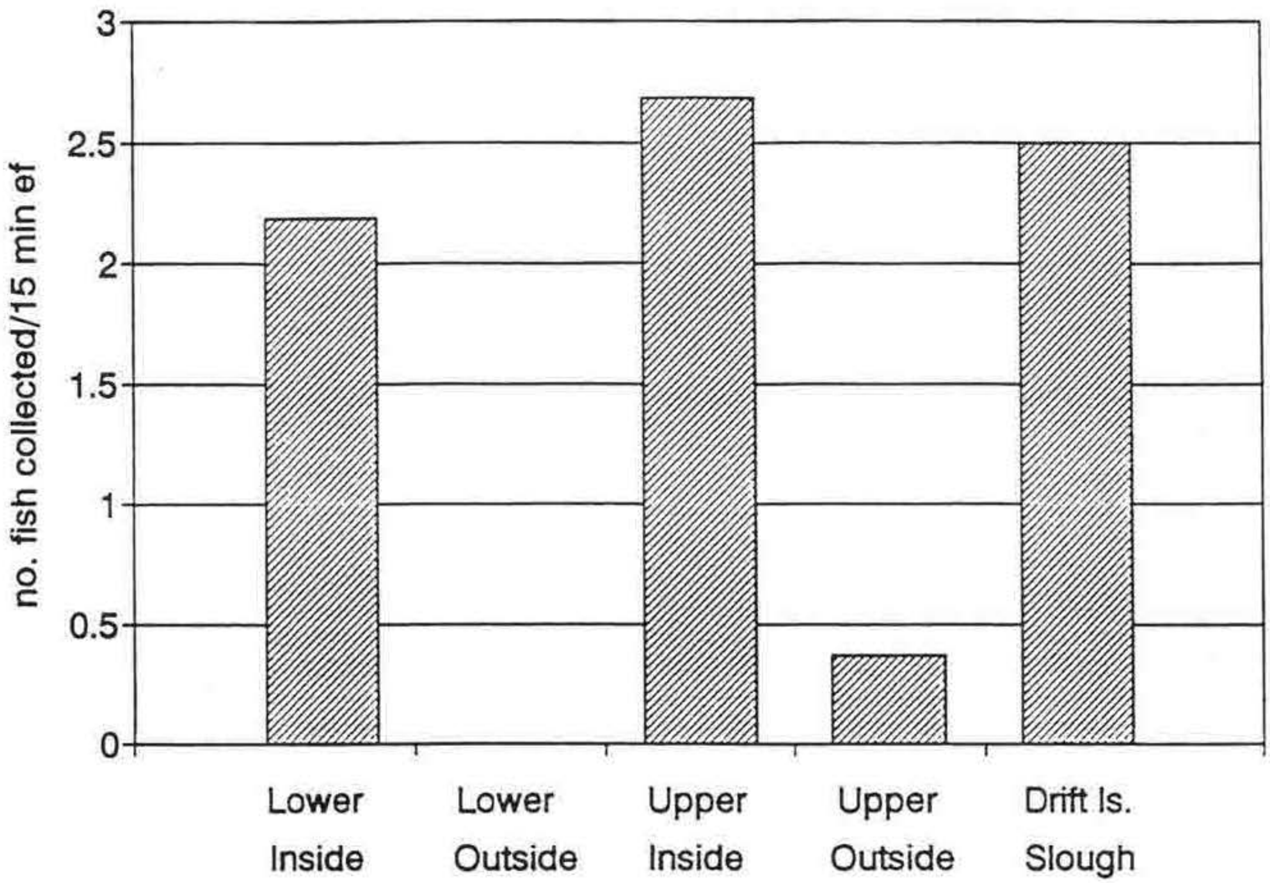


Figure 9. Total number of largemouth bass collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

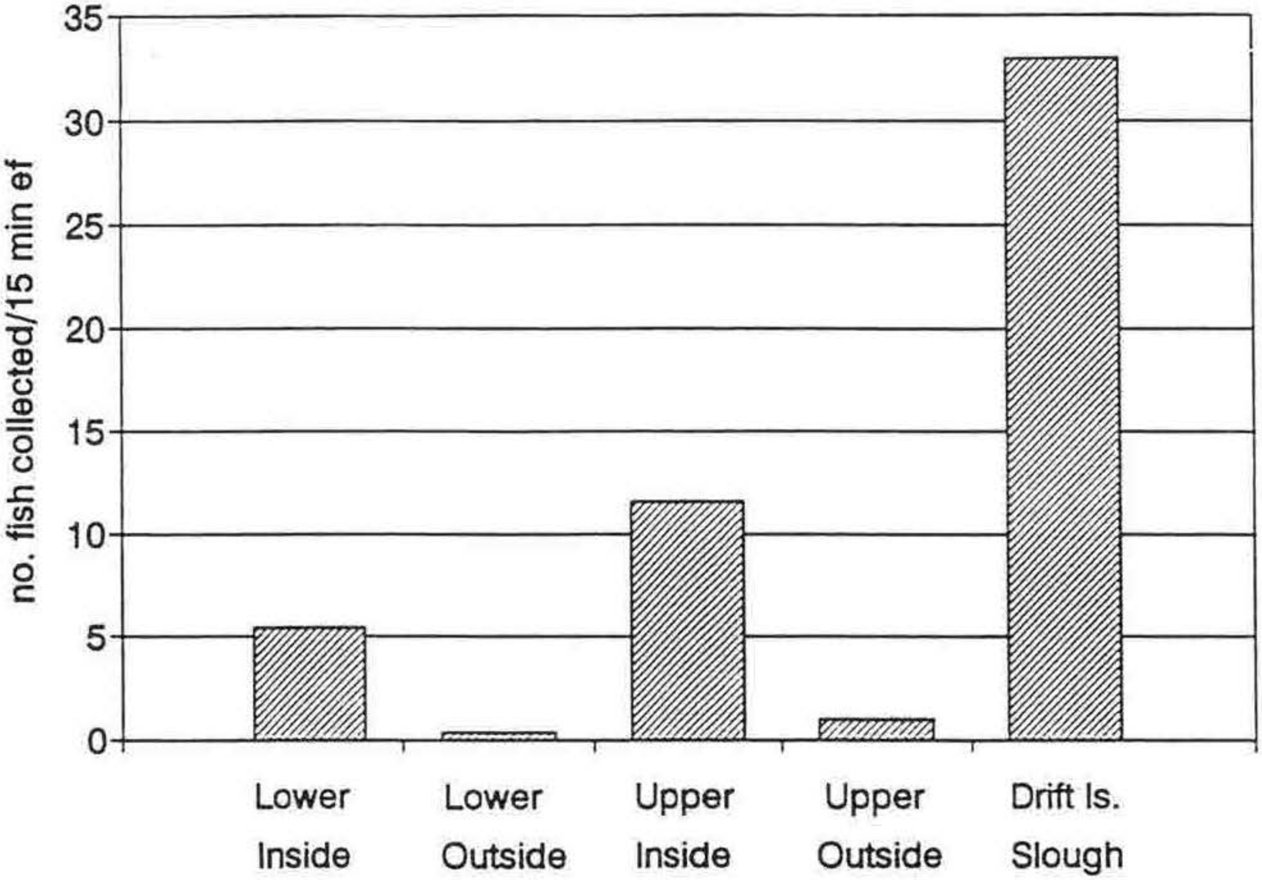
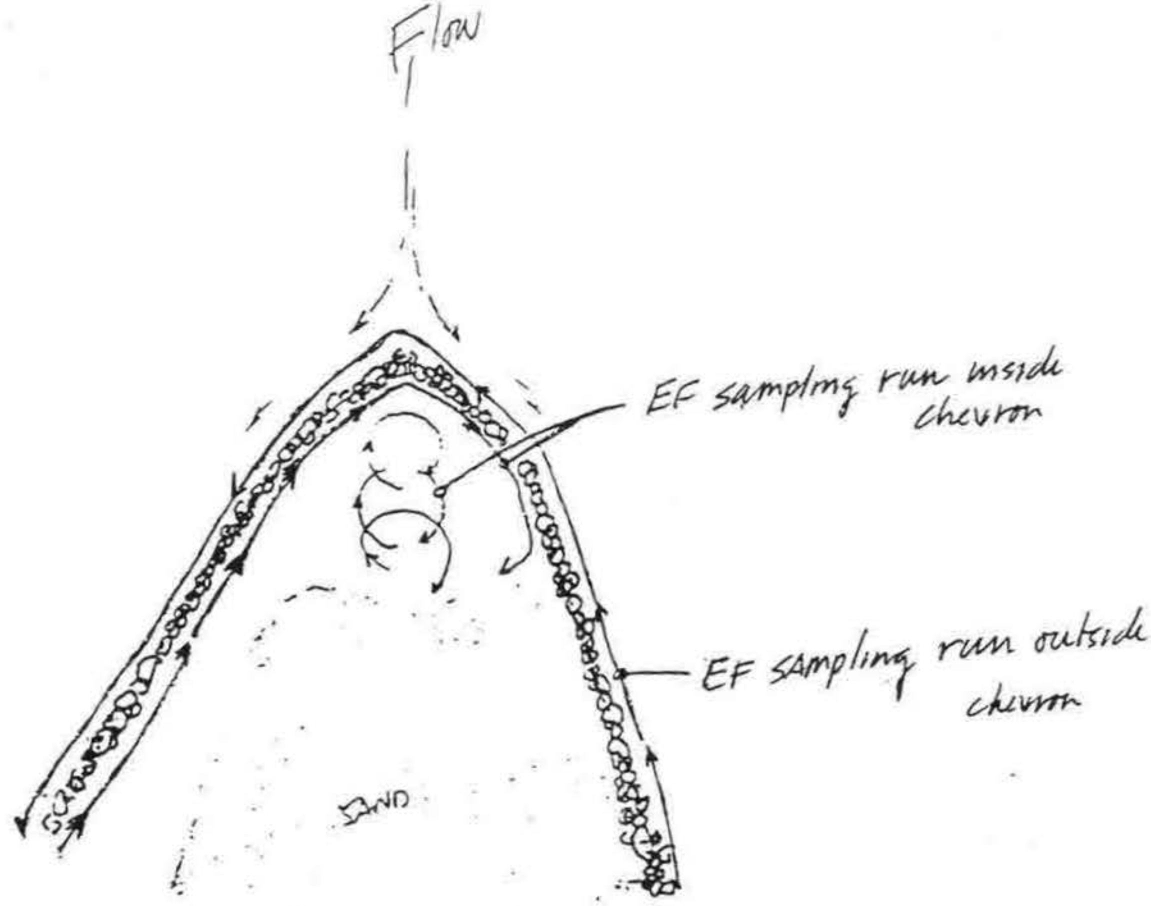


Figure 10. Total number of bluegill collected per 15 min of electrofishing at Cottonwood Island chevron dikes and control station.

Sketch of typical electrofishing run @ chevron dikes



Macroinvertebrates Associated with Habitats of Chevron Dikes in Pool 24 of the Mississippi River

Prepared for:

Parsons Engineering Science, Inc.
Chesterfield, Missouri

Under contract to:

U.S. Army Corps of Engineers
St. Louis District

Prepared by:

Ecological Specialists, Inc.
St. Peters, Missouri

July 1997

(ESI Project #96-034)

Acknowledgments

Funds for this study were provided by Parsons Engineering Science, Inc. under contract with the U.S. Army Corps of Engineers, St. Louis District as part of the Avoid and Minimize Program. Ms. Heidi Dunn of Ecological Specialists, Inc. initiated the study in 1994 and was project director from 1995 to 1997. Mr. Charles Theiling served as project manager in 1995 and 1996, and Mr. Eric Nelson served as project manager in 1997. Ms. Melissa Moore assisted with field, laboratory, and reporting efforts. Eric Nelson and Heidi Dunn authored this report.

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1.0 Introduction

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

- A. Operations of the locks and navigation channel.
- B. Measures related to towing operations.
- C. Measures related to induced development.
- D. Measures to rectify impacts.

Eight measures were selected for implementation:

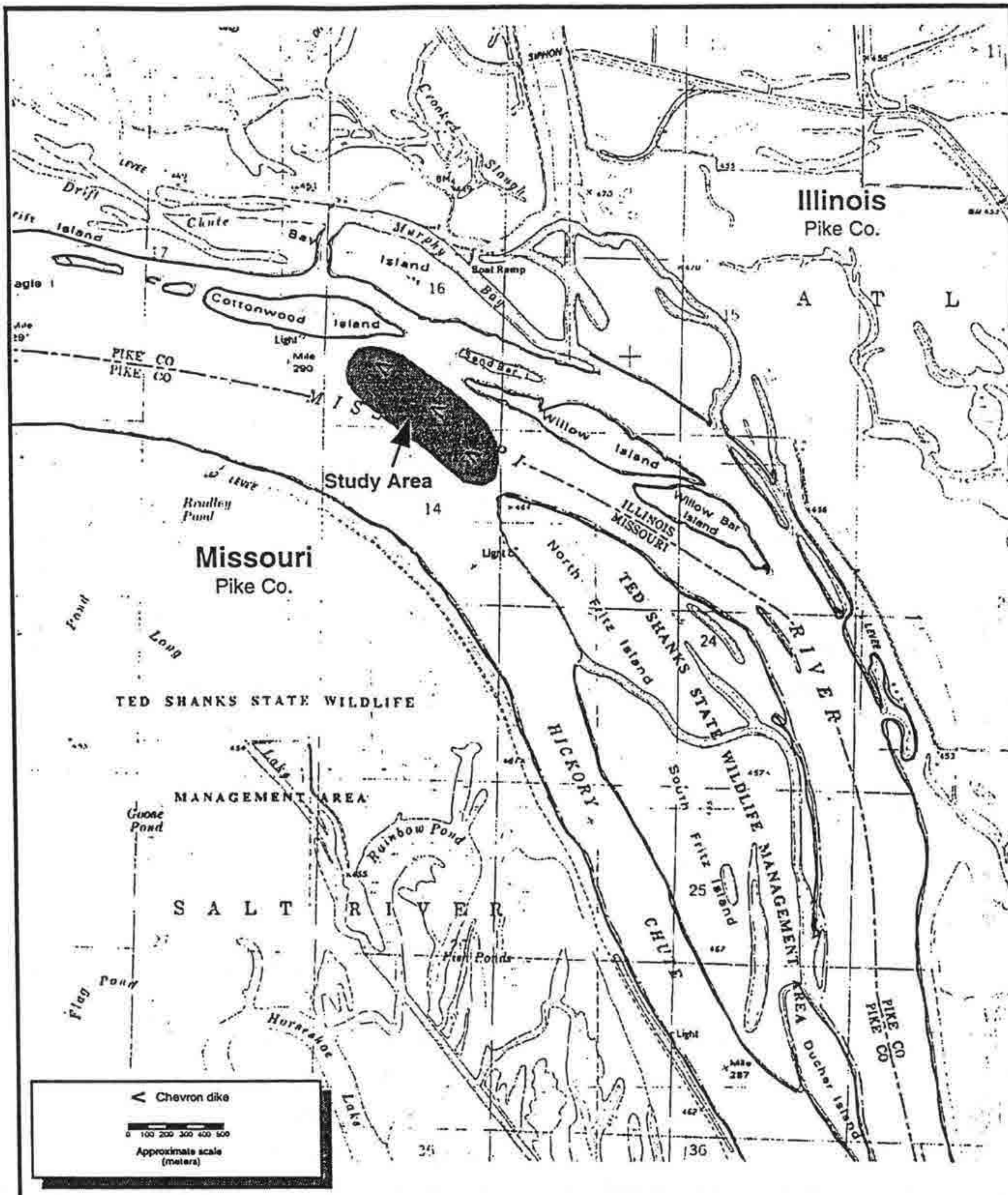
- A- 3. Designate lock approach waiting area or provide special mooring sites.
- A-10. Reduce open water dredge material disposal by creating beaches.
- A-11. Reduce open water dredge material disposal through wetland creation.
- A-13. Place dredge material in the thalweg.
- A-16. Continue dike configuration studies (i.e., notched dikes, chevrons and bullnose dikes).
- A-17. Place off-bank revetment on islands.
- A-19. Monitor bendway weirs.
- B- 8. Study reduction of tow waiting times.

Dike configuration studies (A-16) are ongoing joint river engineering research efforts between the St. Louis District (SLD) and Waterways Experiment Station (WES). The SLD introduced the idea of chevron dikes to the River Regulatory Team in 1991, and suggested building a prototype in a particularly troublesome spot in Pool 24, near Mississippi River Mile (MRM) 289.5. This area consists of a split channel with a point bar encroaching on the thalweg. Annual dredging was required and dredge material was disposed in the open water of the channel border along the left descending bank.

Placing dredge material behind the dike structures rather than in open water should benefit fish and invertebrates. Open water disposal of dredge material can negatively affect fish and invertebrate habitat in several ways (Colbert *et al.*, 1975; Morton, 1977). Possible immediate effects include increased turbidity, smothering of benthic organisms, and reduced dissolved oxygen (DO) due to nutrient and chemical release from the disposal material. Additionally, habitat diversity is reduced, and river bottom geometry and substrate can be altered. A diverse, stable benthic community rarely develops in an unstable sand substrate. Dike construction results in more favorable invertebrate habitat, by protecting unconsolidated dredge material from river flow. Boulders also provide a stable substrate for colonization, entrap organic debris, and provide a diversity of microhabitats for invertebrates and fish.

Resource agencies agreed that establishing dikes in this area should enhance invertebrate and fish habitat by diverting flow into the thalweg, reducing open water dredge disposal, and providing stable habitat (USCOE, 1992). When dredging is needed, material will be placed behind the dikes, creating islands. The dike structures should also provide substrate for invertebrate colonization, and food and cover for fish. In addition, after islands have formed and are colonized by vegetation, they should reduce barge wave impacts on nearby islands and riverbanks.

Three chevron dikes were constructed in Pool 24 of the Mississippi River near MRM 289.5 in October 1993 (see Figure 1-1). Although it was generally agreed that the dikes should enhance river habitat, monitoring was established to confirm benefits to fish and invertebrates. Monitoring was initiated in November 1994 and continued through 1996. The 1994 study characterized the invertebrate assemblages on the exterior dike face (exterior rock), on the interior dike face (interior rock), in the substrate behind the dike (interior substrate), and in the river bed surrounding the chevron dikes (exterior substrate) (ESI, 1995). The 1995 study examined seasonal differences (spring vs. fall), and temporal changes between 1994 and 1995 (ESI, 1996). The objective of 1996 monitoring was to characterize the present invertebrate assemblages on the dike rocks and in the substrate near the dikes and compare these assemblages to those found in previous years.



ECOLOGICAL SPECIALISTS, INC.

Figure 1-1. Approximate location of chevron dikes, Mississippi River mile 289.5.

ESI

2.0 Methods

2.1 Field Effort

The interior of, exterior of, and area surrounding three chevron dikes, located along the left descending bank near MRM 289.5, were sampled for macroinvertebrates in November 1994, May and September 1995, and September 1996. A total of 148 samples were collected among years using two sampling techniques. Fifty-seven (57) standard ponar samples were collected in substrate surrounding the dikes (17, 20, and 20 in 1994, 1995, and 1996, respectively) and 23 were collected in the dike interior (3, 10, and 10 in 1994, 1995, and 1996, respectively) to characterize soft substrate benthic invertebrates. Forty-eight (48) rock basket samples were analyzed from the exterior face (16, 18, and 14 in 1994, 1995, and 1996, respectively) and 20 from the interior face of the rock dikes (4, 10, and 6 in 1994, 1995, and 1996, respectively) to characterize the epilithic community.

2.1.1 Ponar Samples

A standard ponar ($0.05m^2$) was used to sample the macroinvertebrate community in the interior and exterior substrate. One sample per location in 1994 and two samples per location in 1995 and 1996 were collected in a variety of flow and substrate conditions; upstream, along side, and directly downstream of dikes, between dikes, between dikes and islands, and between dikes and the thalweg (Figures 2-1, 2-2, and 2-3). Samples were also collected in quiet water within each dike structure. Samples were rinsed in a standard sieve bucket (no. 30), and the remaining invertebrates, debris, and substrate were rinsed into a 1L jar. Samples were preserved in 10% formalin stained with rose bengal and returned to the laboratory for processing.

2.1.2 Rock Basket Samples

Artificial samplers have been criticized because they may not reflect natural substrate, and collected animals may not represent the native community (Anderson and Mason, 1968). However, they appear to be the best method of sampling difficult habitats, such as large rock (Dickson *et al.*, 1971). Rock baskets were used in this study to characterize epilithic communities rather than standard Hester-Dendy samplers. River rocks are similar to the dike's boulder substrate and should provide similar habitat.

Baskets were constructed from one-half of a standard minnow trap. Each basket was filled with 35 rocks of approximately the same size. Rock surface area was crudely estimated by calculating the surface area of shapes similar to the rocks (cones and cylinders in most cases). Rock surface area in each basket averaged $0.29m^2$. Baskets were covered with 6mm hardware cloth secured with plastic ties. Baskets were anchored to the dikes with cinder blocks (1994 and 1995) or rebar (1996) and were allowed to colonize for 30 days. Baskets were scooped out of the water with a standard sieve bucket to prevent animal loss. The baskets and animals retained in the sieve were placed into an 11L bucket, preserved in 10% formalin, and returned to the laboratory for processing.

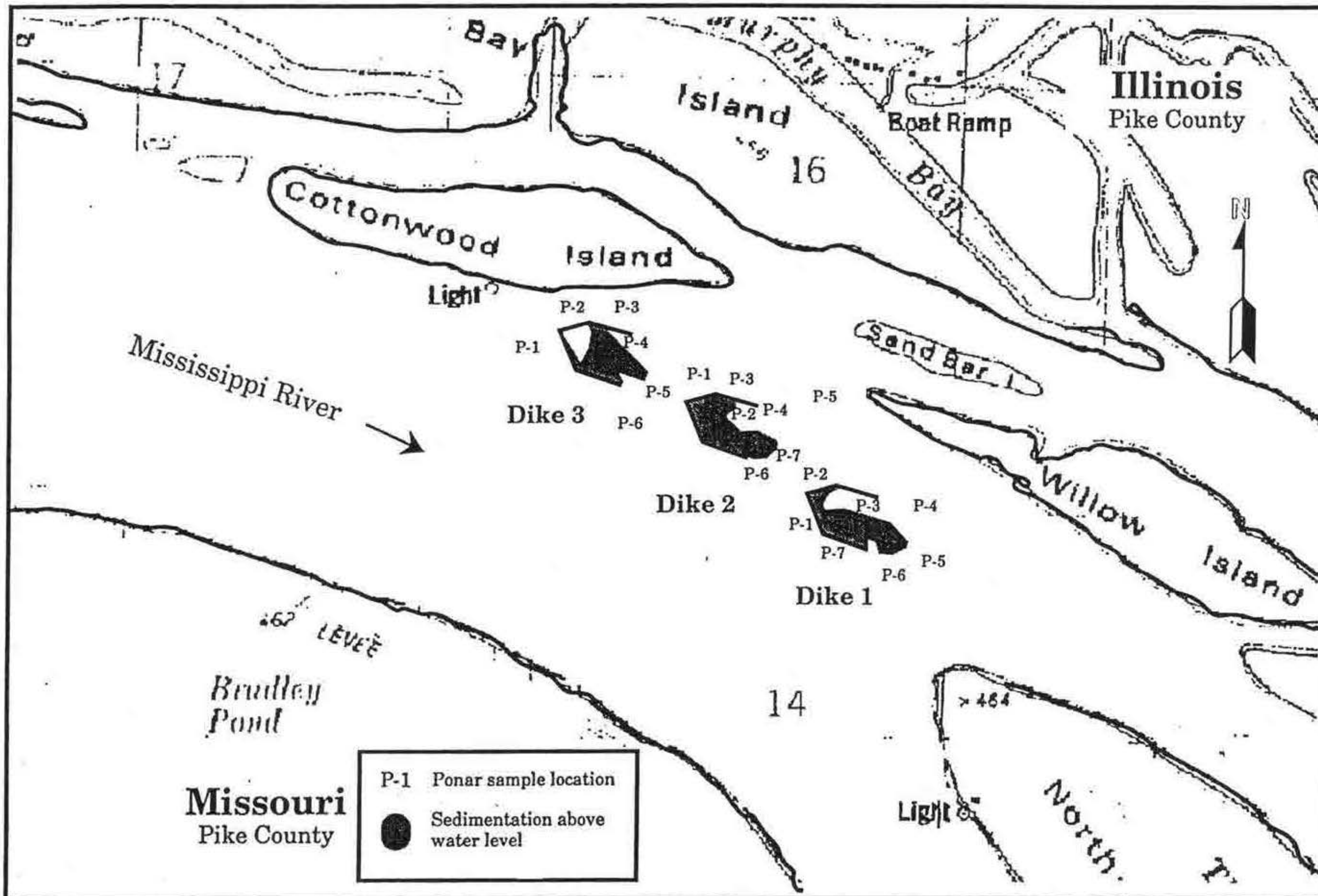


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Figure 2-1. Ponar sample locations near chevron dikes, November 1994.

ESI

3.0 Results and Discussion

3.1 Habitat Characteristics

The chevron dikes are located in the middle portion of Pool 24 in the upper Mississippi River, which has been modified by a series of locks and dams. Historically, this section of the river consisted of deep pools separated by shallow bars and rapids with a greater proportion of rocks and gravel in the substrate (Pflieger, 1989). Although some flow is generally present in the dike area, current varies from moderately swift (when dams are open) to slack water (when dam discharge is minimal). The dikes are along an outside bend, where flow is generally swifter than along inside bends.

The dikes are primarily large boulders (>256mm diameter) with cobble (64 - 256mm), gravel (2 - 64mm), sediment, and debris settled in the interstices between large rocks. Finer sediment and debris has settled in the dike interiors and substrate is a more heterogeneous mix of sand, silt, clay, and detritus (Tables 3-1, 3-2, and 3-3). However, substrate in the area is still unstable, as the flow of water over the dikes, particularly in 1995, shifted sand, resulting in the filling of some areas and scouring of others. Prior to construction of the chevron dikes, the study area was used for open water dredge material disposal, therefore exterior substrate surrounding the dikes is primarily unconsolidated sand (see Tables 3-1, 3-2, and 3-3), which appears to have shifted considerably in the past three years (see Figures 2-1, 2-2, and 2-3).

Shifting of sand has resulted in variation in water depth in both the dike interior and exterior. Average water depth in the area surrounding dikes varied from 1.7 to 2.9m, with the greatest depths encountered on the thalweg side of the dikes (1.5 - 4.4m; see Tables 3-1, 3-2, and 3-3). In general, depth on the Illinois side of the dikes ranged from 0.9 to 3.8m, and depth was greatest between Dike 3 and the island where scouring may be significant. Average water depth within dikes varied from 0.4 to 1.8m with deeper areas occurring where substrate was scoured by flow over the structures at high river stages.

Average temperature and dissolved oxygen (DO) were similar inside and outside of the dikes within each study year (see Tables 3-1, 3-2, and 3-3).

3.2 Benthic Macroinvertebrates

3.2.1 Interior and Exterior Substrate

The chevron dikes appear to be diverting flow, resulting in some variability in substrate and flow in the study area. However, presently the interior and exterior substrate is primarily sand. Unconsolidated sand generally supports low macroinvertebrate density, possibly due to low organic content, and low diversity due to little microhabitat variation and substrate instability (DeMarch, 1976). Anderson and Day (1986) and Wells and Demas (1979) found low invertebrate diversity and density in the upper Mississippi River (Pools 19 and 26) and lower Mississippi River, respectively. However an increase in microhabitats and therefore species diversity and density is expected over time near the chevron dikes. The dike interiors are expected to provide more of a lentic habitat and stabilization of exterior substrate is expected with time. Invertebrate density was high but extremely variable in both areas and no trend toward increase in density was observed, however, taxa richness has increased over time in both areas and diversity has increased in exterior substrate. Additionally, taxonomic composition in both areas has varied among study years.

Density in both interior and exterior substrate was similar, but appeared to be higher than previous studies in this area and other Mississippi River areas. Macroinvertebrate density in dike interiors averaged 1643/m^2 ±946, while density in surrounding substrate averaged 2076/m^2 ±1138 (Table 3-4). Colbert *et al.* (1975) estimated invertebrate density in this area (main channel border, left descending bank MRM 289.3) at 315/m^2 in July and 124/m^2 in September. Macroinvertebrate density averaged 965/m^2 ±1711 at Thompson's Bend (MRM 20) in August 1996 (ESI, 1997a).

Although density appeared somewhat higher than other Mississippi River areas, estimates were extremely variable and no trends toward increase in density were observed. Macroinvertebrate density averaged 2456/m^2 ±2356 in 1994, 817/m^2 ±670 in 1995, and 1655/m^2 ±813 in 1996 in dike interiors and averaged 3153/m^2 ±1995 in 1994, 1858/m^2 ±1778 in 1995, and 1218/m^2 ±457 in 1996 in surrounding substrate (Tables 3-4, 3-5, 3-6, 3-7).

Taxa richness was also similar in both interior and exterior substrates, and higher than other Mississippi River areas. An average of 35 and 34 taxa were collected from dike interior and exterior substrates between 1994 and 1996, respectively (see Table 3-4). However, Colbert *et al.* (1975) only collected eight and one species in this area in July and September, respectively, and only seven species were collected at Thompson's Bend (MRM 20) (ESI, 1997a). Richness, however, appears to be increasing with time in both dike interior and exterior substrate, suggesting that communities are becoming more complex with time, perhaps due to increasing habitat stability and complexity. Taxonomic richness was 22 in 1994, 44 in 1995, and 38 in 1996 in dike interiors and was 31 in 1994, 29 in 1995, and 42 in 1996 in surrounding substrate (see Table 3-4).

Diversity, which is a measure of taxa richness and evenness and therefore community complexity, appears to be consistently high within dike interior substrates. Shannon-Wiener diversity from dike interiors averaged 3.50 and was 3.24 in 1994, 4.20 in 1995, and 3.07 in 1996 (see Table 3-4). This suggests that dike interiors are providing several microhabitats and that these areas are not stressed by increasing siltation and periods of low DO. Diversity was somewhat lower in dike exterior substrates, however, diversity appears to be increasing with time. Shannon-Wiener diversity from surrounding

Table 3-4. Mean density (no./m^2), taxonomic richness (TR), and diversity (SW) on, within, and around chevron dikes in 1994, 1995, and 1996.

		1994	1995	1996	Mean[1]	±2SE
Interior substrate	Density	2456	817	1655	1643	946
	TR	22	44	38	35	13
	SW	3.24	4.20	3.07	3.50	0.70
Exterior substrate	Density	3153	1858	1218	2076	1138
	TR	31	29	42	34	8
	SW	2.57	2.03	3.47	2.69	0.84
Interior rock	Density	1223	1853	6169	3082	3109
	TR	60	78	65	68	11
	SW	4.34	3.61	1.94	3.30	1.42
Exterior rock	Density	1025	20111	25080	15405	14664
	TR	93	83	94	90	7
	SW	4.32	2.30	3.08	3.23	1.18

[1] n = 3.

Table 3-5. Macroinvertebrate assemblage characteristics on and around chevron dikes, November 1994.

Phylum	Class	Order	Family	Species	Interior rock				Exterior rock				Interior substrate				Exterior substrate			
					Total (no.)	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)	Total (no.)	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)	Total (no.)	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)	Total (no.)	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)
Annelida	Aeolosomatida	Aeolosomatida	Aeolosomatidae	spp.																
	Hirudinea	Rhynchobdellida	Glossiphoniidae	*Placobdella parasitica*					3	0	1	0.02								
	Oligochaeta	Haplotaxida	Enchytraeidae	*Barbidrilus paucisetus*													23230	1366	1870	43.54
			Enchytraeidae	spp.	7	2	0	0.14	10	1	1	0.06								
			Naididae	*Chaetogaster diaphanus*	215	54	63	4.40	31	2	1	0.19								
				Chaetogaster diastrophus	21	5	1	0.43	45	3	3	0.28								
				Dero digitata	681	170	178	13.91	10	1	0	0.06	1320	440	984	17.92				
				Nais behningi					465	29	25	2.84								
				Nais bretscheri					83	5	21	0.51								
				Nais communis					3	0	1	0.02								
				Nais elinguis					17	1	2	0.11								
				Nais pardalis	139	35	1	2.84	358	22	34	2.18								
				Nais pseudobtusa					7	0	1	0.04								
				Nais simplex	222	56	38	4.54	146	9	11	0.89								
				Nais variabilis	694	174	164	14.19	125	8	9	0.76								
				Ophidonais serpentina	3	1	1	0.07	3	0	1	0.02								
				Paranais frici	14	3	1	0.28	3	0	1	0.02								
				Piguetiella michiganensis					17	1	2	0.11					77	6	0	0.14
				Pristina aequiseta	28	7	1	0.57	3	0	1	0.02	19	6	1	0.26				
				Pristina breviseta	3	1	1	0.07	3	0	1	0.02								
				Pristina leidyi	7	2	1	0.14	31	2	2	0.19								
				Pristinella osborni					10	1	1	0.06								
				Pristinella sima					17	1	2	0.11								
				Slavina appendiculata					17	1	0	0.11								
				Stephensoniana trivandrana	28	7	1	0.57	3	0	1	0.02								
				Stylaria lacustris	31	8	1	0.64	7	0	0	0.04								
			Tubificidae	*Aulodrilus limnobius*					3	0	1	0.02	421	140	1	5.71				
				Aulodrilus pigueti	361	90	248	7.38	7	0	1	0.04	670	223	516	9.09				
				Branchiura sowerbyi									77	26	1	1.04				
				immature w/o capilliform setae	288	72	116	5.89	42	3	1	0.25	2239	746	746	30.39	364	21	53	0.68
				Limnodrilus hoffmeisteri	10	3	2	0.21					172	57	109	2.34	19	1	0	0.04
				Limnodrilus maumeensis									19	6	1	0.26				
				Limnodrilus udekemianus	7	2	1	0.14					57	19	16	0.78				
Arthropoda	Arachnida	Acarina		spp.													19	1	0	0.04
	Crustacea	Amphipoda	Crangonyctidae	spp.	97	24	29	1.99	10	1	0	0.06								
			Gammaridae	*Gammarus lacustris*	17	4	1	0.35												
				Gammarus minus					3	0	1	0.02								
			Talitridae	*Hyalella azteca*					3	0	1	0.02								
		Isopoda	Asellidae	spp.					3	0	1	0.02								
				Caecidotea spp.	142	36	27	2.91	108	7	7	0.66								
	Insecta	Collembola	Isotomidae	*Semicerura* spp.	115	29	56	2.34	7	0	0	0.04								
		Diptera		spp (pupae)					10	1	1	0.06								
			Ceratopogonidae	*Bezzia* spp.									19	6	1	0.26	115	7	9	0.21
			Ceratopogonidae	spp.					3	0	1	0.02					19	1	0	0.04
				Culicoides spp.					3	0	1	0.02								
				Nilobezzia spp.													38	2	0	0.07
			Chironomidae	*Ablabesmyia annulata*									287	96	1	3.90				
				Axarus spp.													364	21	0	0.68
				Chernovskiia spp.	3	1	1	0.07									8037	473	238	14.99
				Chironomini	24	6	12	0.50	7	0	1	0.04					96	6	5	0.18
				Chironomus spp.	115	29	27	2.34					631	210	211	8.57	38	2	0	0.07
				Cladotanytarsus spp.	635	159	248	12.99	10	1	1	0.06	38	13	1	0.52				
				Cricotopus bicinctus group	28	7	7	0.57	184	12	6	1.12								
				Cricotopus sylvestris group	24	6	12	0.50	139	9	4	0.85								
				Cryptochironomus spp.	14	3	1	0.28					172	57	47	2.34	498	29	115	0.93
				Dicrotendipes neomodestus					21	1	1	0.13								
				Dicrotendipes spp.	7	2	0	0.14	3	0	0	0.02					19	1	0	0.04
				Glyptotendipes spp.	28	7	2	0.57	52	3	2	0.32								
				Hydrobaenus spp.	7	2	1	0.14	56	3	3	0.34								
				Lipiniella spp.									402	134	266	5.45				
				Lopescladius spp.													19	1	0	0.04
				Microspectra spp.					3	0	1	0.02								
				Nanocladius spp.	3	1	1	0.07	208	13	9	1.27								
				Parachironomus spp.	73	18	15	1.49	10	1	1	0.06								
				Parakiefferiella spp.					3	0	1	0.02					38	2	0	0.07
				Paralauterborniella spp.						0			19	6	1	0.26				
				Paratanytarsus spp.					17	1	1	0.11								
				Paratendipes spp.					14	1	1	0.08					1072	63	30	2.00
				Polypedilum convictum	7	2	1	0.14	507	32	39	3.09								
				Polypedilum illinoense	7	2	1	0.14												
				Polypedilum scalaenum	14	3	1	0.28					210	70	18	2.86	899	53	118	1.68
				Polypedilum spp.	7	2	1	0.14									19	1	0	0.04
				Procladius (Holotanypus)									19	6	1	0.26				
				Pseudosmittia spp.	7	2	1	0.14												
				Rheotanytarsus spp.	28	7	7	0.57	2535	158	101	15.46	19	6	1	0.26				
				Robackia spp.									19	6	1	0.26	6142	361	294	11.46
				Tanytarsus guerlus group													38	2	0	0.07
				Tanytarsus spp.	10	2	2	0.21	49	3	2	0.30								
				Thienemanniella spp.					3	0	1	0.02								
				Thienemannimyia spp.					83	5	5	0.51					38	2	0	0.07
			Chironomidae	spp.					28	2	2	0.17								
			Chironomidae	spp (pupae)	7	2	0	0.14	3	0	1	0.02								
			Empididae	*Hemerodromia* spp.					14	1	0	0.08					77	5	0	0.14
			Tipulidae	spp.					3	0	1	0.02								

Table 3-5. Continued.

Phylum	Class	Order	Family	Species	Interior rock Total (n)	Interior rock Mean Density (no./m²)	Interior rock ±2 SE (no./m²)	Interior rock Relative abundance (%)	Exterior rock Total (n)	Exterior rock Mean Density (no./m²)	Exterior rock ±2 SE (no./m²)	Exterior rock Relative abundance (%)	Interior substrate Total (n)	Interior substrate Mean Density (no./m²)	Interior substrate ±2 SE (no./m²)	Interior substrate Relative abundance (%)	Exterior substrate Total (n)	Exterior substrate Mean Density (no./m²)	Exterior substrate ±2 SE (no./m²)	Exterior substrate Relative abundance (%)
		Ephemeroptera	Caenidae	*Caenis* spp.					3	0	1	0.02								
			Ephemeridae	*Hexagenia* spp.	3	1	1	0.07					517	172	391	7.01	38	2	0	0.07
			Heptageniidae	spp.					111	7	5	0.68								
				Stenacron spp.	3	1	1	0.07	7	0	0	0.04								
				Stenonema integrum	2	1	1	0.07	247	15	12	1.50								
				Stenonema spp.					7	0	1	0.04								
		Hemiptera	Corixidae	*Trichocorixa* spp. (adult)	3	1	1	0.07												
		Odonata	Coenagrionidae	*Argia* spp.					3	0	1	0.02								
			Coenagrionidae	spp.	3	1	1	0.07												
		Plecoptera		spp.					7	0	1	0.04								
			Chloroperlidae	spp.					38	2	1	0.23								
				Haploperla brevis					278	17	27	1.69								
			Perlidae	*Acroneuria* spp.					3	0	1	0.02								
			Perlodidae	spp.					170	11	43	1.04								
				Isoperla spp.	73	18	15	1.49	1997	125	68	12.17					19	1	0	0.04
			Taeniopterygidae	*Taeniopteryx* spp.	45	11	9	0.92	705	44	19	4.30								
		Trichoptera	Hydropsychidae	*Cheumatopsyche* spp.					389	24	24	2.37								
				Hydropsyche orris	3	1	1	0.07	267	17	34	1.63								
				Hydropsyche simulans					63	4	5	0.38								
				Hydropsyche spp.					14	1	0	0.06								
				Potamyia flava	10	3	2	0.21	1653	103	86	10.08					1684	99	440	3.14
			Hydropsychidae	spp.	3	1	1	0.07	778	49	47	4.74								
			Hydroptilidae	spp.					31	2	9	0.19								
				Hydroptila spp.	122	30	38	2.48	2493	156	68	15.20								
			Leptoceridae	*Nectopsyche* spp.					3	0	1	0.02								
				Triaenodes spp.					10	1	0	0.06								
			Philopotamidae	*Dolophilodes* spp.	14	3	5	0.28	14	1	1	0.08								
			Polycentropodidae	*Dolophilides* spp.					14	1	1	0.06								
				Cyrnellus spp.					76	5	3	0.47								
				Neureclipsis spp.	3	1	1	0.07	104	7	5	0.64								
Chordata	Osteichthyes	Siluriformes	Ictaluridae	*Noturus nocturnus*					10	1	0	0.06								
Cnidaria	Hydrozoa	Hydroida	Hydridae	*Hydra* spp.	292	73	139	5.96	465	29	13	2.84								
Mollusca	Bivalvia	Veneroida	Corbiculidae	*Corbicula fluminea*					3	0	1	0.02					96	6	5	0.18
			Dreissenidae	*Dreissena bugensis*					14	1	0	0.08					19	1	0	0.04
				Dreissena polymorpha					10	1	0	0.06					19	1	0	0.04
	Gastropoda	Lymnophila	Lymnaeidae	*Pseudosuccinea* spp.	17	4	7	0.35												
			Physidae	*Physa* spp.	28	7	0	0.57												
				Physella spp.	28	7	7	0.57	14	1	1	0.08	19	6	1	0.26				
Nematoda				spp.													1722	101	96	3.21
Platyhelminthes	Turbellaria	Macrostomida		spp.													8726	513	581	16.28
		Tricladida	Planariidae	*Dugesia tigrina*	56	14	15	1.14	813	51	25	4.96								
				Total	4892	1223	1053	100	16299	1025	476	100	7367	2456	2356	100	53597	3153	1995	100
				Taxonomic richness	60	28	10		93	28	5		22	11	4		31	7	1	
				Diversity (SW)	4.34	3.31	0.73		4.32	3.50	0.21		3.24	2.50	0.30		2.57	1.94	0.29	
				Sample size (n)	4				16				3				17			

Table 3-6. Macroinvertebrate assemblage characteristics on and around chevron dikes, May and September 1995.

Phylum	Class	Order	Family	Species	Interior rock: Total (n)	Interior rock: Mean Density (n/m²)	Interior rock: ±2 SE (n/m²)	Interior rock: Relative abundance (%)	Exterior rock: Total (n)	Exterior rock: Mean Density (n/m²)	Exterior rock: ±2 SE (n/m²)	Exterior rock: Relative abundance (%)	Interior substrate: Total (n)	Interior substrate: Mean Density (n/m²)	Interior substrate: ±2 SE (n/m²)	Interior substrate: Relative abundance (%)	Exterior substrate: Total (n)	Exterior substrate: Mean Density (n/m²)	Exterior substrate: ±2 SE (n/m²)	Exterior substrate: Relative abundance (%)
Annelida	Aeolosomatida	Aeolosomatida	Aeolosomatidae	spp.					14	1	0	0.00								
	Hirudinea	Rhynchobdellida	Glossiphoniidae	*Helobdella*	3	0	1	0.02												
	Oligochaeta	Haplotaxida	Enchytraeidae	*Barbidrilus paucisetus*									364	36	145	4.45	21297	1065	1606	57.31
			Enchytraeidae	spp.	3	0	1	0.02	3	0	0	0.00								
			Naididae	*Dero digitata*									230	23	30	2.81				
				Dero nivea	14	1	1	0.07					19	2	1	0.23				
				Nais behningi					17	1	3	0.00								
				Nais communis	10	1	1	0.06												
				Nais pardalis					14	1	0	0.00	344	34	0	4.22				
				Nais variabilis	7	1	1	0.04					19	2	1	0.23				
				Piguetiella michiganensis									38	4	1	0.47				
				Pristina leidyi	14	1	1	0.07	14	1	0	0.00	38	4	1	0.47				
				Pristina osborni					14	1	0	0.00								
				Stylaria lacustris									19	2	1	0.23				
			Tubificidae	*Aulodrilus limnobius*									19	2	1	0.23				
				Aulodrilus pigueti									57	6	1	0.70				
				Branchiura sowerbyi	167	17	62	0.90					38	4	1	0.47				
				Ilyodrilus templetoni									38	4	0	0.47				
				immature w/o capilliform setae	229	23	39	1.24	66	4	11	0.02	1052	105	104	12.88	38	2	0	0.10
				Limnodrilus cervix	3	0	1	0.02	3	0	0	0.00	153	15	34	1.87				
				Limnodrilus claparedianus									57	6	0	0.70				
				Limnodrilus hoffmeisteri	7	1	1	0.04	10	1	1	0.00	612	61	61	7.49				
				Limnodrilus udekemianus	7	1	1	0.04												
Arthropoda	Arachnida	Acarina		spp.					174	10	44	0.05								
	Arachnida			spp.					3	0	0	0.00								
	Crustacea	Amphipoda	Gammaridae	*Gammarus fasciatus*	7	1	1	0.04	63	3	6	0.02								
		Decapoda	Cambaridae	*Orconectes virilis*	10	1	2	0.06	14	1	2	0.00								
			Cambaridae	spp.	7	1	1	0.04	14	1	0	0.00								
		Isopoda	Asellidae	*Asellus intermedius*	17	2	5	0.09	3	0	0	0.00								
	Insecta	Coleoptera	Carabidae	spp.													19	1	0	0.05
			Elmidae	*Dubiraphia* spp.									19	2	1	0.23				
				Stenelmis spp (adult)	49	5	6	0.26	194	11	17	0.05								
				Stenelmis spp (larvae)	24	2	1	0.13												
			Heteroceridae	spp.	7	1	1	0.04												
			Lampyridae	spp.													19	1	0	0.05
		Collembola	Isotomidae	spp.	7	1	0	0.04												
		Diptera		spp (pupa)	177	18	18	0.96	3181	177	158	0.88	77	8	7	0.94	210	11	14	0.57
			Ceratopogonidae	*Bezzia* spp.									115	11	17	1.41	1819	91	68	4.89
			Chironomidae	*Ablabesmyia mallochi*	160	16	13	0.86	76	4	4	0.02								
				Ablabesmyia spp.	35	3	7	0.19									19	1	0	0.05
				Chernovskiia spp.									19	2	1	0.23	268	13	37	0.72
				Chironomini harnischia complex													38	2	0	0.10
				Chironomini spp.					3	0	0	0.00					77	4	5	0.21
				Chironomus spp.	285	28	18	1.54	21	1	1	0.01	536	54	72	6.56				
				Cladotanytarsus spp.	63	6	6	0.34	7	0	0	0.00	976	98	147	11.94				
				Coelotanypus spp.	21	2	4	0.11												
				Corynoneura spp.	14	1	1	0.07	49	3	2	0.01								
				Cricotopus bicinctus group	87	9	11	0.47	837	46	57	0.23								
				Cricotopus sylvestris group	7	1	1	0.04	340	19	68	0.09								
				Cricotopus tremulus					122	7	29	0.03								
				Cryptochironomus spp.	35	3	5	0.19	49	3	5	0.01	153	15	18	1.87				
				Dicrotendipes neomodestus	920	92	99	4.96	135	8	9	0.04								
				Dicrotendipes spp.	188	19	30	1.01	7	0	0	0.00					19	1	0	0.05
				Glyptotendipes spp.	1885	189	291	10.17	177	10	8	0.05	19	2	1	0.23				
				Labrundinia spp.	28	3	6	0.15	17	1	3	0.00								
				Lipiniella spp.									115	11	34	1.41				
				Lopescladius spp.													861	43	41	2.32
				Nanocladius spp.	106	11	11	0.58	206	11	8	0.06					19	1	0	0.05
				Parachironomus spp.	292	29	58	1.57	66	4	2	0.02								
				Paracladopelma spp.					3	0	0	0.00								
				Parakiefferiella spp.	3	0	1	0.02												
				Paralauterborniella spp.									38	4	0	0.47				
				Paratendipes spp.									96	10	28	1.17	2488	124	231	6.69
				Polypedilum convictum	101	10	11	0.54	2542	141	121	0.70								
				Polypedilum illinoense	104	10	13	0.56	146	8	19	0.04	19	2	1	0.23				
				Polypedilum scalaenum	7	1	1	0.04	7	0	0	0.00	1607	161	121	19.67	19	1	0	0.05
				Polypedilum spp.	73	7	14	0.39	226	13	23	0.06	19	2	1	0.23				
				Procladius spp.									77	8	17	0.94				
				Rheosmittia spp.													19	1	0	0.05
				Rheotanytarsus spp.	257	26	40	1.39	17694	983	922	4.89								
				Robackia spp.													116	6	15	0.31
				Stictochironomus spp.					14	1	0	0.00								
				Tanytarsus spp.	97	10	7	0.52	21	1	2	0.01	115	11	12	1.41				
				Thienemanniella spp.					90	5	0	0.02								
			Chironomidae	spp (pupa)	38	4	6	0.21	628	35	44	0.17								
			Chironomidae	spp.	10	1	2	0.06	42	2	2	0.01					38	2	0	0.10
				Thienemannimyia spp.	94	9	9	0.61	1378	77	49	0.38								
			Empididae	*Hemerodromia* spp.	17	2	5	0.09	1063	60	61	0.30								
			Simuliidae	*Simulium* spp.					63	3	16	0.02								
			Tipulidae	spp.					14	1	0	0.00								

Table 3-6. Continued.

Phylum	Class	Order	Family	Species	Interior rock				Exterior rock				Interior substrate				Exterior substrate			
					Total no.	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)	Total no.	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)	Total no.	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)	Total no.	Mean Density (no./m²)	±2 SE (no./m²)	Relative abundance (%)
		Ephemeroptera	Baetidae	*Baetis* spp.					153	8	36	0.04								
			Caenidae	*Brachycercus* spp.									38	4	1	0.47				
				Caenis spp.	6226	623	1243	33.59	12281	682	613	3.39	38	4	0	0.47	19	1	0	0.05
			Ephemeridae	*Hexagenia limbata*									115	11	12	1.41				
				Hexagenia spp.	7	1	1	0.04	10	1	1	0.00								
			Heptageniidae	*Stenacron* spp.																
				Stenonema integrum	66	7	10	0.36	49	3	6	0.01								
			Heptageniidae	spp.	59	6	10	0.32	644	47	23	0.23								
			Oligoneuridae	*Isonychia* spp.	167	17	50	0.90	15260	848	1246	4.22	38	4	1	0.47	38	2	0	0.10
			Tricorythidae	*Tricorythodes* spp.	646	65	112	3.48	1472	82	66	0.41								
		Ephemeroptera		spp.					250	14	46	0.07								
		Odonata	Coenagrionidae	*Argia* spp.	206	20	18	1.11	170	9	11	0.05								
			Coenagrionidae	spp.	21	2	1	0.11	28	2	0	0.01								
			Gomphidae	*Dromogomphus* spp.	7	1	1	0.04												
				Gomphurus crassus	3	0	1	0.02												
				Gomphurus hybridus	3	0	1	0.02												
			Gomphidae	spp.					3	0	0	0.00								
			Macromiidae	*Macromia* spp.	3	0	1	0.02	14	1	1	0.00								
		Plecoptera	Perlidae	*Neoperla* spp.					14	1	0	0.00								
				Perlesta placida					222	12	0	0.06								
			Perlidae	spp.					7	0	0	0.00								
		Plecoptera		spp.					920	51	73	0.25	19	2	1	0.23				
		Trichoptera	Hydropsychidae	*Cheumatopsyche* spp.	7	1	1	0.04	2153	120	87	0.59								
				Hydropsyche orris	167	17	19	0.90	66601	3700	2261	18.40	19	2	1	0.23				
				Potamyia flava	830	83	79	4.48	209490	11638	7064	57.87	153	15	51	1.87	96	5	0	0.26
			Hydropsychidae	spp.									19	2	1	0.23				
			Hydroptilidae	*Hydroptila* spp.	243	24	64	1.31	2405	133	221	0.66					19	1	0	0.05
				Hydroptila spp.													19	1	0	0.05
			Hydroptilidae	spp.	3	0	1	0.02	1194	66	139	0.33								
			Leptoceridae	*Nectopsyche* spp.	233	23	34	1.26	243	14	12	0.07								
				Oecetis spp.	7	1	1	0.04	278	15	0	0.06	19	2	1	0.23				
			Polycentropodidae	*Cyrnellus* spp.	3	0	1	0.02												
				Polycentropus spp.	63	6	6	0.34	405	22	16	0.11								
			Polycentropodidae	spp.	3	0	1	0.02												
		Trichoptera		spp (pupa)	7	1	1	0.04	743	41	38	0.21								
Chordata	Osteichthyes	Perciformes	Centrarchidae	*Lepomis humilis*	3	0	1	0.02	3	0	0	0.00								
				Lepomis macrochirus	8	0	1	0.02												
		Siluriformes	Ictaluridae	*Noturus nocturnus*					7	0	0	0.00								
				Pylodictus olivaris					3	0	0	0.00								
Cnidaria	Hydrozoa	Hydroida	Hydridae	*Hydra americana*	38	4	5	0.21	14	1	0	0.00	191	19	1	2.34	38	2	0	0.10
Mollusca	Bivalvia	Veneroida	Corbiculidae	Corbicula													19	1	0	0.05
			Dreissenidae	*Dreissena polymorpha*	128	13	25	0.69	5212	290	226	1.44					38	2	0	0.10
			Sphaeriidae	*Sphaerium* spp.	3	0	1	0.02	3	0	0	0.00								
	Gastropoda	Lymnophila	Physidae	*Physa* spp.	3	0	1	0.02												
				Physella spp.					3	0	0	0.00								
Nematoda				spp.	3	0	1	0.02	7	0	0	0.00	325	33	65	3.98	8018	401	617	21.58
Nematomorpha				spp.	14	1	0	0.07	2524	140	157	0.70								
Platyhelminthes	Turbellaria	Macrostomida	Macrostomidae	*Macrostomum* spp.					111	6	0	0.03								
		Macrostomida		spp.									96	10	14	1.17	1301	65	86	3.50
		Tricladida	Planariidae	*Dugesia tigrina*	3660	366	225	19.75	9045	503	695	2.50					172	9	0	0.46
				Total	18535	1853	1506	100	362003	20111	10956	100	8171	817	670	100	37160	1858	1778	100
				Taxonomic richness	78	27	7		83	23	4		64	18	3		29	9	2	
				Diversity (SW)	3.61	2.47	0.68		2.30	2.34	0.44		4.20	3.43	0.33		2.03	1.63	0.37	
				Sample size (n)	10				18				10				20			

Table 3-7. Macroinvertebrate assamblage characteristics on and around chevron dikes, September 1996.

Phylum	Class	Order	Family	Species	Interior rock Total (no.)	Interior rock Mean Density (no./m²)	Interior rock ±2 SE (no./m²)	Interior rock Relative abundance (%)	Exterior rock Total (no.)	Exterior rock Mean Density (no./m²)	Exterior rock ±2 SE (no./m²)	Exterior rock Relative abundance (%)	Interior substrate Total (no.)	Interior substrate Mean Density (no./m²)	Interior substrate ±2 SE (no./m²)	Interior substrate Relative abundance (%)	Exterior substrate Total (no.)	Exterior substrate Mean Density (no./m²)	Exterior substrate ±2 SE (no./m²)	Exterior substrate Relative abundance (%)
Annelida	Hirudinea	Pharyngobdellida	Erpobdellidae	*Moorobdella fervida*					49	3	1	0.01					153	8	0	0.63
		Rhynchobdellida	Glossiphoniidae	*Alboglossiphonia heteroclita*					14	1	1	0.00								
				Placobdella parasitica	7	1	1	0.02												
			Glossiphoniidae	spp.					14	1	1	0.00								
	Oligochaeta	Haplotaxida	Enchytraeidae	*Barbidrilus paucisetus*													115	6	4	0.47
			Naididae	*Chaetogaster diaphanus*					97	7	11	0.02								
				Dero digitata	531	89	84	1.44	69	5	15	0.01	804	80	206	4.86				
				Nais behningi	3	1	1	0.01	674	48	61	0.13								
				Nais pardalis	49	8	11	0.13	1288	92	85	0.26	57	6	9	0.35	19	1	0	0.08
				Nais pseudobtusa					42	3	1	0.01								
				Nais variabilis	10	2	1	0.03	167	12	15	0.03	19	2	1	0.12				
				Piguetiella michiganensis					56	4	4	0.01	19	2	1	0.12				
				Pristina leidyi	3	1	1	0.01	111	8	1	0.02								
				Pristinella spp.									19	2	1	0.12				
				Slavina appendiculata					56	4	0	0.01								
				Stylaria lacustris	56	9	17	0.15	14	1	1	0.00								
			Tubificidae	*Aulodrilus pigueti*	3	1	1	0.01					57	6	9	0.35				
				Branchiura sowerbyi					14	1	1	0.00	77	8	17	0.46				
				immature w/ capilliform setae									19	2	1	0.12				
				immature w/o capilliform setae	10	2	2	0.03	128	9	17	0.03	402	40	31	2.43				
				Limnodrilus cervix	3	1	1	0.01					38	4	1	0.23				
				Limnodrilus hoffmeisteri	2	1	1	0.01	10	1	1	0.00	230	23	30	1.39				
				Limnodrilus udekemianus	7	1	0	0.02												
Arthropoda	Arachnoidea	Hydrachnellae		spp.	3	1	1	0.01												
	Crustacea	Amphipoda	Gammaridae	*Gammarus troglophilus*					28	2	1	0.01								
		Decapoda	Cambaridae	*Orconectes luteus*	66	11	4	0.18	24	2	4	0.00								
	Insecta	Coleoptera	Chrysomelidae	*Disonycha* spp (adult)									19	2	1	0.12				
			Dryopidae	*Helichus basalis* (adult)	3	1	1	0.01												
			Elmidae	*Dubiraphia* spp. (larvae)	10	2	0	0.03												
				Stenelmis spp (adult)	52	9	8	0.14	28	2	1	0.01								
				Stenelmis spp. (larvae)	3	1	1	0.01	14	1	1	0.00								
			Heteroceridae	spp. (larvae)									19	2	1	0.12				
			Hydrophilidae	*Berosus* spp (larvae)	10	2	2	0.03												
			Tenebrionidae	spp. (larvae)					14	1	1	0.00								
		Collembola		spp.					7	0	1	0.00								
		Diptera	Ceratopogonidae	*Probezzia* spp.	21	3	8	0.06					325	33	35	1.97	57	3	6	0.24
				Sphaeromias spp.					3	0	1	0.00					19	1	0	0.08
			Ceratopogonidae	spp.	49	8	20	0.13					364	36	111	2.20	57	3	6	0.24
			Chaoboridae	*Chaoborus* spp.													19	1	0	0.08
			Chironomidae	*Ablabesmyia* spp.	56	9	1	0.15	389	28	40	0.08					19	1	0	0.08
				Chernovskiia spp.													5664	283	120	23.25
				Chironomus spp.	233	39	30	0.63	14	1	1	0.00	5128	513	389	30.98	230	11	61	0.94
				Cladotanytarsus spp.	229	38	124	0.62					325	33	33	1.97	19	1	0	0.08
				Coelotanypus spp.					97	7	11	0.02								
				Corynoneura spp.					14	1	1	0.00					57	3	0	0.24
				Cricotopus bicinctus group					206	15	15	0.04								
				Cricotopus spp.	28	5	0	0.08												
				Cryptochironomus spp.	7	1	1	0.02	14	1	1	0.00	115	11	5	0.69	153	8	6	0.63
				Dicrotendipes spp.	181	30	17	0.49	514	37	36	0.10								
				Glyptotendipes spp.	23753	3959	3374	64.17	15816	1130	1115	3.15	38	4	0	0.23	57	3	6	0.24
				Harnischia spp.													19	1	0	0.08
				Labrundinia spp.	14	2	1	0.04	14	1	1	0.00								
				Lipiniella spp.									4784	478	248	28.90	96	5	0	0.39
				Lopescladius spp.													38	2	0	0.16
				Nanocladius spp.	35	6	12	0.09	1444	103	55	0.29					38	2	0	0.16
				Parachironomus spp.	444	74	43	1.20	236	17	79	0.05								
				Paratendipes spp.													1148	57	41	4.71
				Polypedilum convictum	49	8	4	0.13	14278	1020	504	2.85					38	2	0	0.16
				Polypedilum illinoense	153	25	43	0.41	111	8	0	0.02					19	1	0	0.08
				Polypedilum scalaenum					250	18	64	0.05	77	8	0	0.46	325	16	14	1.34
				Polypedilum spp.					56	4	1	0.01								
				Rheotanytarsus spp.	319	53	7	0.86	110368	7883	3666	22.00	77	8	7	0.46	804	40	45	3.30
				Robackia spp.													5377	269	371	22.07
				Saetheria spp.													1033	52	49	4.24
				Tanytarsus spp.	76	13	12	0.21	444	32	31	0.09	1531	153	100	9.25	938	47	32	3.85
				Thienemannimyia group spp.	21	3	4	0.06	4875	348	144	0.97								
			Chironomidae	spp. (pupae)	889	148	171	2.40	14587	1042	481	2.91	268	27	17	1.63	478	24	13	1.96
			Empididae	*Hemerodromia* spp.					969	69	148	0.19								
				Hemerodromia spp. (pupae)					56	4	1	0.01								
			Empididae	spp.					1361	97	148	0.27								
			Empididae	spp. (pupae)					556	40	1	0.11								

Table 3-7. Continued.

Phylum	Class	Order	Family	Species	Interior rock Total (n)	Interior rock Mean Density (n/m²)	Interior rock ±2 SE (n/m²)	Interior rock Relative abundance (%)	Exterior rock Total (n)	Exterior rock Mean Density (n/m²)	Exterior rock ±2 SE (n/m²)	Exterior rock Relative abundance (%)	Interior substrate Total (n)	Interior substrate Mean Density (n/m²)	Interior substrate ±2 SE (n/m²)	Interior substrate Relative abundance (%)	Exterior substrate Total (n)	Exterior substrate Mean Density (n/m²)	Exterior substrate ±2 SE (n/m²)	Exterior substrate Relative abundance (%)
		Ephemeroptera	Baetidae	*Baetis* spp.					889	63	84	0.18								
				Labiobaetis spp.	3	1	1	0.01	2736	195	226	0.55								
			Baetidae	spp.	3	1	1	0.01	56	4	3	0.01								
			Caenidae	*Caenis* spp.	10	2	0	0.03	535	38	34	0.11	57	6	0	0.35	19	1	0	0.08
			Ephemeridae	*Hexagenia limbata*					21	1	3	0.00	115	11	12	0.69	19	1	0	0.08
				Pentagenia spp.					7	0	1	0.00	19	2	1	0.12	957	48	22	3.93
			Ephemeridae	spp.													19	1	0	0.08
			Heptageniidae	*Stenacron* spp.					7	0	1	0.00								
				Stenonema femoratum					28	2	1	0.01								
				Stenonema integrum	38	6	6	0.10	4028	288	122	0.80								
				Stenonema modestum					56	4	1	0.01								
				Stenonema spp.					14	1	1	0.00								
			Heptageniidae	spp.					194	14	1	0.04								
			Isonychiidae	*Isonychia* spp.					417	30	20	0.08	19	2	1	0.12	19	1	0	0.08
			Potamanthidae	*Anthopotamus* spp.					14	1	1	0.00								
			Tricorythidae	*Tricorythodes* spp.	3	1	1	0.01	132	9	5	0.03								
		Hemiptera	Corixidae	*Trichocorixa* spp. (adult)	448	75	55	1.21	31	2	9	0.01	1282	128	137	7.75				
			Saldidae	spp.	10	2	1	0.03												
		Megaloptera	Corydalidae	*Corydalus* spp.	3	1	1	0.01	69	5	16	0.01								
		Odonata	Coenagrionidae	*Argia* spp.	184	31	13	0.50	778	56	23	0.16								
				Enallagma spp.					319	23	32	0.06								
			Corduliidae	*Neurocordulia molesta*					76	5	2	0.02								
				Neurocordulia spp.					28	2	1	0.01								
			Gomphidae	*Arigomphus* spp.	21	3	4	0.06	56	4	1	0.01								
				Dromogomphus spp.	21	3	8	0.06	10	1	1	0.00					19	1	0	0.06
				Gomphus spp.	7	1	1	0.02												
				Stylurus plagiatus	3	1	1	0.01												
				Stylurus spp.	7	1	1	0.02												
			Gomphidae	spp.	14	2	0	0.04	14	1	1	0.00								
			Libellulidae	*Ladona* spp.					28	2	0	0.01								
		Plecoptera	Perlidae	*Acroneuria* spp.	7	1	0	0.02	31	2	1	0.01								
				Neoperla spp.	3	1	1	0.01	229	16	14	0.05								
		Trichoptera	Hydropsychidae	*Cheumatopsyche* spp.					674	48	61	0.13								
				Hydropsyche orris	42	7	10	0.11	60170	4298	2866	12.00	19	2	1	0.12	153	8	5	0.63
				Hydropsyche simulans					972	69	144	0.19								
				Potamyia flava	104	17	18	0.28	133024	9502	4912	26.52	57	6	9	0.35	1416	71	77	5.81
			Hydropsychidae	spp.													134	7	18	0.55
			Hydroptilidae	*Hydroptila* spp.					49	3	13	0.01								
			Leptoceridae	*Nectopsyche* spp.	587	98	37	1.59	1834	138	69	0.39	19	2	1	0.12	19	1	0	0.08
			Philopotamidae	*Dolophilodes* spp.					56	4	1	0.01								
			Polycentropodidae	*Cyrnellus fraternus*	52	9	8	0.14	1392	99	39	0.28					57	3	0	0.24
		Trichoptera		spp. (pupa)	3	1	1	0.01	1806	129	106	0.36	38	4	1	0.23				
Chordata	Osteichthyes	Clupeiformes	Clupeidae	*Dorosoma cepedianum*									19	2	1	0.12				
		Perciformes	Centrarchidae	*Lepomis cyanellus*	14	2	2	0.04												
			Percidae	*Percina shumardi*					3	0	1	0.00								
		Siluriformes	Ictaluridae	*Noturus flavus*					3	0	1	0.00								
				Noturus nocturnus					28	2	2	0.01								
				Pylodictis olivaris	3	1	1	0.01												
Mollusca	Bivalvia	Veneroida	Dreissenidae	*Dreissena polymorpha*	240	40	33	0.65	93500	6679	2606	18.64	19	2	1	0.12	4057	203	166	16.65
			Sphaeriidae	*Musculium* spp.					28	2	1	0.01								
				Sphaerium spp.									38	4	1	0.23	134	7	0	0.55
			Sphaeriidae	spp.					7	0	1	0.00								
	Gastropoda	Lymnophila	Physidae	*Physella* spp.					76	5	1	0.02								
Nematoda				spp.	3	1	1	0.01	56	4	1	0.01	19	2	1	0.12	153	8	7	0.63
Nematomorpha				spp.					247	18	10	0.05	19	2	1	0.12	191	10	15	0.79
Platyhelminthes	Turbellaria	Tricladida	Dendrocoelidae	*Procotyla fluviatilis*					28	2	1	0.01								
			Planariidae	*Dugesia tigrina*	7771	1295	1126	20.99	24618	1758	836	4.91								
			Planariidae	spp.	14	2	1	0.04	2528	181	390	0.50								
				Total	37014	6169	4509	100	501590	25080	11618	100	16552	1655	813	100	24359	1218	457	100
				Taxonomic richness	65	27	6		94	29	2		38	12	3		42	9	2	
				Diversity (SW)	1.94	1.86	0.29		3.08	2.59	0.17		3.07	2.35	0.26		3.47	2.20	0.36	
				Sample size (n)	6				14				10				20			

substrate averaged 2.69 and was 2.57 in 1994, 2.03 in 1995, and 3.47 in 1996. This suggests that microhabitat diversity and stability is increasing in the exterior substrate.

Additionally, taxonomic composition differed between areas and appears to be changing with time, which is further evidence of increased habitat diversity and stability in this area. Both the dike interiors and surrounding substrates were primarily dominated by burrowing worms and midges that feed by collecting and gathering fine particulate matter (Pennak, 1989; Merritt and Cummins, 1996). Substrate within dikes was dominated by species typical of slack water areas, whereas, substrates exterior to the dikes were dominated more by species that prefer flowing water (rheophilic). Species typical of large river sand deposits dominated most interior and exterior samples in all years. However, taxa typical of coarser substrates were increasingly abundant in both areas in 1996 in suitable microhabitats. Clinging taxa were among the dominant taxa at both dike interiors (*Tanytarsus* spp. and *Trichocorixa* spp.) and surrounding substrates (*Dreissena polymorpha* and *Potamyia flava*) in 1996.

Oligocheates and chironomids dominated the interior dike substrates in all years, however, abundant taxa were different among years. Oligocheates (immature without capilliform setae 30%, *Dero digitata* 18%, *Aulodrilus pigueti* 9%, *Aulodrilus limnobius* 6%), chironomids (*Chironomus* spp. 9% and *Lipiniella* spp. 5%) and mayflies (*Hexagenia* spp. 7%) dominated in 1994 (see Table 3-5). In 1995, chironomids (*Polypedilum scalaenum* 20%, *Cladotanytarsus* spp. 12%, and *Chironomus* spp. 7%) were more abundant, although oligochaetes (immature without capilliform setae 13% and *Limnodrilus hoffmeisteri* 7%) were still common (see Table 3-6). In 1996 chironomids (*Chironomus* spp. 31%, *Lipiniella* spp. 29%, and *Tanytarsus* spp. 9%) still dominated, but only a few oligochaetes were collected, while water boatmen (*Trichocorixa* spp. 8%) were fairly abundant (see Table 3-7).

Exterior substrates were dominated by oligocheates (*Barbidrilus paucisetus* 43%), roundworms (Nematoda 16%), and chironomids (*Chernovskiia* spp. 15% and *Robackia* spp. 12%) in 1994 (see Table 3-5). Similarly, oligocheates (*B. paucisetus* 57%), roundworms (Nematoda 22%), chironomids (*Paratendipes* spp. 12%), and biting midges (*Bezzia* spp. 5%) were abundant in 1995 (see Table 3-6). In 1996, chironomids (*Chernovskiia* spp. 24% and *Robackia* spp. 22%) remained dominant, however, freshwater mussels (*D. polymorpha* 17%) and caddisflies (*P. flava* 6%) became increasingly dominant in the community (see Table 3-7).

The difference in taxonomic composition between dike interiors and surrounding substrates is most likely due to differences in microhabitat between the two areas. The dike interiors were somewhat protected from direct water flow and averaged less sand substrate (48%) compared to the exterior surrounding substrates (97%) (see Tables 3-1, 3-2, and 3-3). Additionally, higher algal growth was observed in dike interiors compared to the exteriors, which may account for the slightly higher average

DO in the dike interiors (9.4) compared to the surrounding substrates (8.4). The increase in species more typical of coarse substrates in both dike interior and exterior substrates, suggests that the heterogeneity of substrate may be increasing with time in both areas. Thus, the dikes do appear to be influencing habitat complexity in the project area and substrate may be stabilizing in some areas.

3.2.2 Interior and Exterior Rock Dike

The chevron dikes are constructed of large limestone boulders, and boulders are typically good habitat for a variety of benthic animals (DeMarch, 1976). Because of their size, boulders (>256mm) provide a refuge for larger animals such as fish, turtles, and crayfish, and stable habitat for a variety of invertebrates. They offer a variety of flow regimes, accumulate sediment and organic matter, and provide a surface for periphytic growth. Additionally, they provide refugia from high flow conditions, and usually provide open water during winter because of turbulence created around the dikes. Rocks would therefore be expected to support a higher diversity and taxa richness than either interior or exterior substrate. Interior rock is similar to the exterior dike rock, but subject to lower water velocities and less continuous flow than exterior rock. Therefore, invertebrate assemblages were expected to differ between habitat types. As expected taxa richness was higher on rocks than in substrate, and taxonomic composition differed between rock and substrate and between interior and exterior rock. Density was higher on exterior rock surfaces, however all density estimates were extremely variable.

Exterior rock surfaces appear to be capable of supporting a higher density, taxa richness, and diversity of invertebrates than interior surfaces. Although all density estimates were extremely variable, density on the interior rock surfaces (3082/m^2 ±3109) was higher than interior substrate density and increased with time (see Table 3-4). Macroinvertebrate density on interior dike rock averaged 1223/m^2 ±1053 in 1994, 1853/m^2 ±1305 in 1995, and 6169/m^2 ±4509 in 1996. Taxa richness remained fairly stable, with 60, 78, and 65 taxa collected in 1994, 1995, and 1996, respectively. However, diversity appears to be declining on the interior rock surfaces; 4.34 in 1994, 3.61 in 1995, and 1.94 in 1996 (see Table 3-4). In contrast, density on the exterior rock (15,405/m^2 ±14,664) was much higher and tended to increase with time, taxa richness was higher (90), and diversity has remained fairly stable. Macroinvertebrate density on exterior dike rock averaged 1025/m^2 ±476 in 1994, 20,111/m^2 ±10,956 in 1995, and 25,080/m^2 ±11,618 in 1996. Taxa richness was high but stable with time; 93, 83, and 94 taxa collected in 1994, 1995, and 1996, respectively. Shannon-Wiener diversity from exterior dike rock was 4.32 in 1994, 2.30 in 1995, and 3.08 in 1996 (see Table 3-4).

Exterior rock density was similar to other rock structures sampled with similar methods, however, taxonomic richness was much higher on chevron dikes than in other sampled areas. Macroinvertebrate density averaged 26,998/m^2 but only 25 taxa were collected from rock baskets collected at Carl Baer Bendway Weir (MRM 163.5) in August 1996 (ESI, 1997b), and macroinvertebrate density averaged

21,748/m^2 and 59 taxa were collected from rock baskets collected at Lock and Dam 26 (MRM 202.9) intermediate lock wall (I-wall) rubble in August 1996 (ESI, 1997c). The increased taxonomic richness at the chevron dikes maybe due to the age of these structures (approximately four years old) compared to the Carl Baer Bendway Weir and the Lock and Dam 26 I-wall rubble (both approximately one year old).

In contrast to the unstable sand and silt substrate that is present throughout much of the upper Mississippi River, the rock of the chevron dikes provides habitat for large river species that occupy rock substrates; various caddisflies, stoneflies, worms, fly larvae, and flatworms. Interior rock surfaces were colonized predominately by worms and midges, while caddisflies were more abundant on exterior surfaces. Species dominating the interior dike rock were burrowing worms (*D. digitata*, *Nais variabilis*, and *A. pigueti*) and midges (*Cladotanytarsus* spp., *Glyptotendipes* spp. and *Dicrotendipes neomodestus*), and sprawling flatworms (*Dugesia tigrina*) and mayflies (*Caenis* spp.) that collect fine particulate organic matter (Merritt and Cummins, 1996). These burrowing species reflect the reduced flow and increased sedimentation in the interior dike rock compared to the exterior dike rock.

While burrowing species were abundant on the interior rock, net spinning caddisflies (*P. flava* and *Hydropysche orris*) and midges (*Rheotanytarsus* spp.) that collect drifting particulate organic matter (Merritt and Cummins, 1996) were the predominant species collected on dike exteriors. Density of these species was high, since dike exteriors provide surfaces for net spinning and clinging and access to drifting organic matter. Dominant taxa on exterior dike rock were comparable to rock substrates sampled in other areas of the Mississippi River. Large river epilithic communities are typically dominated by a few taxa (Mason *et al.*, 1973) and hydropsychid caddisflies appear to dominate the macroinvertebrate community at most Mississippi structures (e.g. stone dikes [Hall, 1982; Mathis *et al.*, 1982 and Payne *et al.*, 1989 in Way *et al.*, 1995]; hard substrates in pools [Anderson and Day, 1986]; or articulated concrete mattress blocks [Way *et al.*, 1995]). Chevron dike exteriors, however, appeared to support a much higher species richness than other samples areas, as many other species were present, primarily clingers and sprawlers adapted to life in high flow environments. This suggests that the exterior of chevron dikes may provide more habitat diversity than other riverine rock structures.

Similar to substrate, dominant taxa on both dike interior and exterior rocks appears to be changing with time. Dominant taxa on the interior dike rocks in 1994 were worms (*D. digitata* 18%, *N. variabilis* 14%, *A. pigueti* 7%, and immature tubificids without capilliform setae 6%), midges (*Cladotanytarsus* spp. 13%) and hydroids (*Hydra* spp. 6%), somewhat similar to the interior substrate in 1994 (see Table 3-5). Dominant taxa changed to mayflies (*Caenis* spp. 34%) and flatworms (*D. tigrina* 20%) in 1995, which are more typical of rock surfaces. However, midges (*Glyptotendipes* spp. 10% and *Dicrotendipes neomodestus* 5%) were also still fairly abundant (see Table 3-6). In contrast, 1996 interior dike rock was dominated by only two taxa, *Glyptotendipes* spp. (64%) and *D. tigrina* (21%) (see Table 3-7).

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4.0 Summary

1. Three Chevron dikes were constructed along the outside bend near Mississippi River Mile 289.5 to test their efficacy as environmentally sympathetic replacements for typical side channel closing structures that can isolate side channels from the river during low flow periods. These experimental river training structures had been modeled, but never before constructed in a river. Their purpose was to divert flow into the thalweg, reducing the need for dredging and therefore the need for open water dredge material disposal, create islands with dredge material, and create habitat for invertebrates and fish.

2. Macroinvertebrates were sampled in the river bed surrounding dikes, on the exterior dike face, on the interior dike face, and within the substrate behind the dike structures in November 1994, May and September 1995, and September 1996.

3. Detrended Correspondence Analysis and Pearson Correlation indicated that species composition at sites was related to sample location (interior or exterior), depth and year, but not with substrate or dike.

4. Correspondence Analysis indicated that species composition was related to sample locations (interior or exterior) which differed in flow conditions and substrate composition.

5. Macroinvertebrate density and taxonomic richness from substrate surrounding the dikes was higher than previous estimates from this area and from an area on the middle Mississippi at Thompson's Bend (MRM 20). Dominant taxa were worms (*B. paucisetus*), roundworms (Nematoda), and midges (*Chernovskiia* spp., *Robackia* spp., *Paratendipes* spp.), biting midges (*Bezzia* spp.), freshwater mussels (*D. polymorpha*), and caddisflies (*P. flava*) which are primarily burrowing species generally associated with sandy substrate in large rivers. Dominant taxa in this habitat have changed somewhat among sample years, and diversity and taxa richness have increased. Species more typical of coarse substrate (*D. polymorpha* and *P. flava*) were more abundant in 1996.

6. Macroinvertebrate density and taxonomic richness from interior dike substrate was higher than previous estimates from this area or from an area lower down on the middle Mississippi at Thompson's Bend (MRM 20). Dominant taxa were worms (immature without capilliform setae, *D. digitata*, *A. pigueti*, *A. limnobius*, and *L. hoffmeisteri*), midges (*Chironomus* spp., *Lipiniella* spp., *P. scalaenum*, *Cladotanytarsus* spp., and *Tanytarsus* spp.), mayflies (*Hexagenia* spp.) and water boatmen (*Trichocorixa* spp.); most of which are burrowing species generally associated with sandy substrate in large rivers. Dominant taxa in dike interior substrate has also varied among study years and taxa richness has increased somewhat, although density, and diversity have remained

fairly constant.

7. Macroinvertebrate density and taxonomic richness from exterior dike rock was similar to other areas of the middle Mississippi at Carl Baer Bendway Weir (MRM 163.5) and Lock and Dam 26 (MRM 202.9) intermediate lock wall (I-wall) rubble. Dominant taxa were midges (*Rheotanytarsus* spp.), caddisflies (*Hydroptila* spp., *P. flava*, *H. orris* and Hydropsychidae), stoneflies (*Isoperla* spp.), flatworms (*D. tigrina*) and mussels (*D. polymorpha*), but many other taxa typically associated with fast flowing, rocky streams, and rock or vegetated littoral areas were also found. The high diversity in this area reflects habitat heterogeneity. Dominant taxa on exterior rocks has changed among study years and density has increased. Diversity and taxa richness, however, have remained fairly stable.

8. Macroinvertebrate density and taxonomic richness from interior dike rock was lower compared to exterior dike rock and other areas of the middle Mississippi at Carl Baer Bendway Weir (MRM 163.5) and Lock and Dam 26 (MRM 202.9) intermediate lock wall (I-wall) rubble. Dominant taxa were worms (*D. digitata*, *N. variabilis*, *A. pigueti*, and immature tubificids without capilliform setae), midges (*Cladotanytarsus* spp., *Glyptotendipes* spp. and *D. neomodestus*), hydroids (*Hydra* spp.), mayflies (*Caenis* spp.), and flatworms (*D. tigrina*). The abundance of burrowing species reflects the reduced flow and increased sedimentation in the interior dike rock compared to the exterior dike rock. Dominant taxa on interior rocks has changed among study years, although density and taxa richness has been fairly constant. However, diversity has declined from >4 in 1994 to <2 in 1996.

9. The interior and exterior dike rock appears to provide a source for food and refugia for at least a few fish species. Juvenile or adult orangespotted sunfish (*L. humilis*), bluegill (*L. macrochirus*), green sunfish (*L. cyanellus*), flathead catfish (*P. olivaris*), freckled madtoms (*N. nocturnus*), stonecat madtoms (*N. flavus*), gizzard shad (*D. cepedianum*), and river darters (*P. shumardi*) were present in the rock basket samplers. Stomach contents for sunfish and catfish collected from interior dike rock showed that they fed primarily on Chironomidae midges which were dominant taxa in this habitat, while madtoms collected from exterior dike rock fed primarily on caddisflies (*P. flava* and *H. orris*) which were dominant taxa in this habitat.

5.0 Conclusions

Chevron dikes represent an innovative approach to navigation system management that benefits both navigation and wildlife (Theiling, 1995). They were designed to divert flow into a portion of the navigation channel impacted by sediment accumulation on the point bar at a river bend where the river channel splits. The dikes divert flow into the main channel by presenting the hydraulic appearance of a solid object without isolating the side channel with a closing dam. Flow between the structures maintains a permanent side channel connection, which provides important off-channel habitat for fishes.

As the rock dike substrate ages, it provides habitat for epilithic macroinvertebrates that are capable of colonizing in very high densities and providing an important food source for fish.

Habitat surrounding the dikes has shown signs of changing over time as sediments are scoured and deposited, resulting in exposed coarser substrate in swifter areas (which provide stable habitat for benthic species) and accumulation of finer sediment in low flow areas downstream of the dikes (which provides terrestrial habitat for turtles and birds). Scour holes behind dikes provide a more lentic habitat and if organic sediments and fine clays are not scoured away during high flow events, substrates behind and within the dikes may become suitable habitat for important benthic species such as fingernail clams and *Hexagenia* spp. mayflies. Therefore, chevron dikes are creating habitat heterogeneity and appear to be increasing invertebrate abundance and diversity in this river reach.

Final Report: Macroinvertebrates Associated with Carl Baer Bendway Weirs in the Mississippi River

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1.0 Introduction

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

A. Operations of the locks and navigation channel.
B. Measures related to towing operations.
C. Measures related to induced development.
D. Measures to rectify impacts.

Eight measures were selected for implementation:

A- 3. Designate lock approach waiting area or provide special mooring sites.
A-10. Reduce open water dredge material disposal by creating beaches.
A-11. Reduce open water dredge material disposal through wetland creation.
A-13. Place dredge material in the thalweg.
A-16. Continue dike configuration studies (i.e., notched, chevron, and bullnose dikes).
A-17. Place off-bank revetment on islands.
A-19. Monitor bendway weirs.
B- 8. Study reduction of tow waiting times.

As part of measure A-19, USCOE constructed a bendway weir channel maintenance structure in April 1996, which consisted of five weirs at the Carl Baer Bendway, near Mississippi River mile (MRM) 163.5 near St. Louis, Missouri (Figure 1-1). The weirs were designed to increase the effective width of the Mississippi River navigation channel by scouring the channel at the outer edge and reducing point bar development on the inner side of the bend. In addition to their channel maintenance function, the weirs add bottom structure and create complex flow patterns. State and Federal natural resource management agencies feel that the creation of complex habitats in the relatively homogeneous main channel is beneficial to the ecosystem. However, these structures are relatively new and monitoring is needed to confirm the benefits. Fishery resources were monitored at several bendway weirs, but aquatic macroinvertebrate community monitoring is lacking. Therefore, a monitoring project was implemented at the Carl Baer Bendway Weir field to investigate invertebrate species community composition associated with the weirs. Since this was a newly built weir field, USCOE was also interested in determining how rapidly weir substrates colonize and assessing the efficacy of sampling methods.

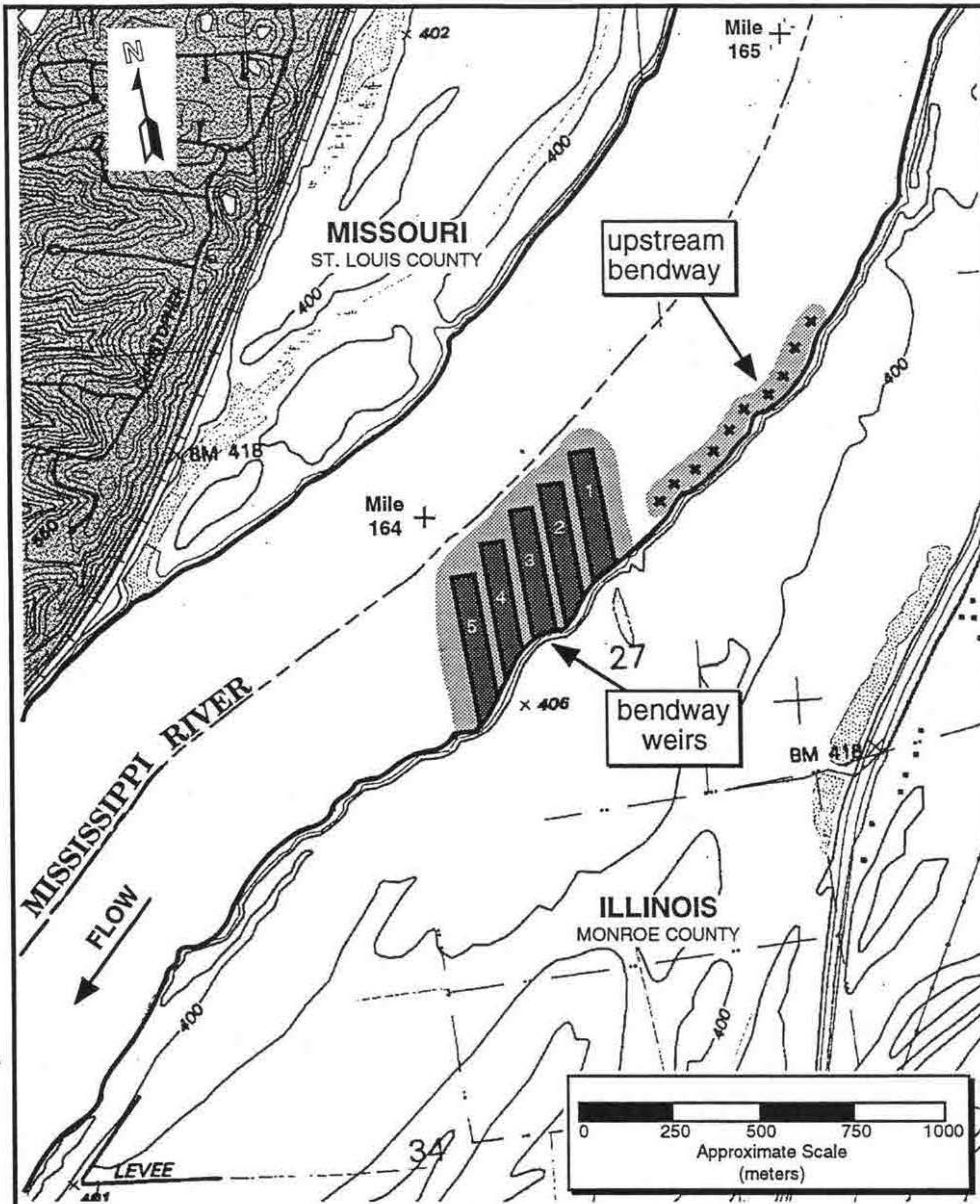

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Figure 1-1. Approximate location of Carl Baer Bendway Weirs and upstream bendway sampling areas, MRM 163.5-164.5.

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2.0 Methods

2.1 Field Effort

Macroinvertebrate samples were collected near Carl Baer Bendway Weirs in the summer of 1996 to determine species composition and diversity of epilithic communities colonizing the weirs. Sampling was attempted on the upstream and downstream sides of three weirs, and on top of four of the five weirs in the weir field (Figure 2-1). Samples were collected from buoy anchors, rock baskets, and weir rocks. Reference samples were collected from buoy anchors placed in a bendway without weirs, upstream of the weir field; MRM 164.5 (see Figure 1-1). A total of 69 samples were attempted using the three methods, however only 34 samples were collected and 33 analyzed.

2.1.1 Buoy Anchor Samplers

The weirs are composed of 0.4kg (1lb) to 2,268kg (5,000lb) limestone rocks, with the largest rocks being approximately 1m in diameter. Buoy anchors, which are approximately 680kg (1,500lb), 0.9m x 0.9m x 0.3m concrete blocks with reinforced rebar eyes on the top and one side for lifting (Figure 2-2), were considered an appropriate artificial substrate for weir rock sampling because of their size and similarity to weir rocks. However, buoy anchors have a rigid square shape with smooth sides, rather than having a rounded irregular shape like weir rocks. Using a crane on the USCOE St. Louis District work barge powered by the USCOE M.V. Pathfinder, 26 buoy anchors were placed on and adjacent to three of the five Carl Baer Bendway Weirs on 16 July 1996; BW 1 (bendway weir 1), BW 2, and BW 5 (see Figure 2-1). Groups of buoy anchors (three buoy anchors [two upstream of BW 1] tethered together and to the bank with steel cable [see Figure 2-2]) were placed in rows running parallel to weirs directly upstream, downstream, and on the weir structure.

Sample retrieval was attempted after 35 days of colonization (20 August 1996), however retrieval success was low. Cables for each set of samplers were retrieved at the bank and followed out to samplers. Several buoy anchor cable lines became entangled with lines from other samplers and with bottom debris, or were buried in the sediment; causing dangerous tension in the cable lines and forcing abandonment of ten buoy anchors. Recovery of buoy anchors was highest closer to the bank (75%), with only 33% of the buoy anchors placed furthest from the bank retrieved. Overall, 17 of the 26 deployed buoy anchors were retrieved, but 11 of those were apparently sand blasted or had been buried, and only six yielded macroinvertebrate scrape samples. Samples were scraped from the rock surface with the highest colonization within the area of a 0.0929m^2 (1ft^2) Surber sampler. To ensure minimal damage to the animals, a 10% nitric acid solution spray was used to dislodge macroinvertebrates and their cases from the rocks. The animals were lightly brushed and rinsed into the sampler, transferred to 1L plastic jars, preserved with 10% formalin, and returned to the laboratory for processing.

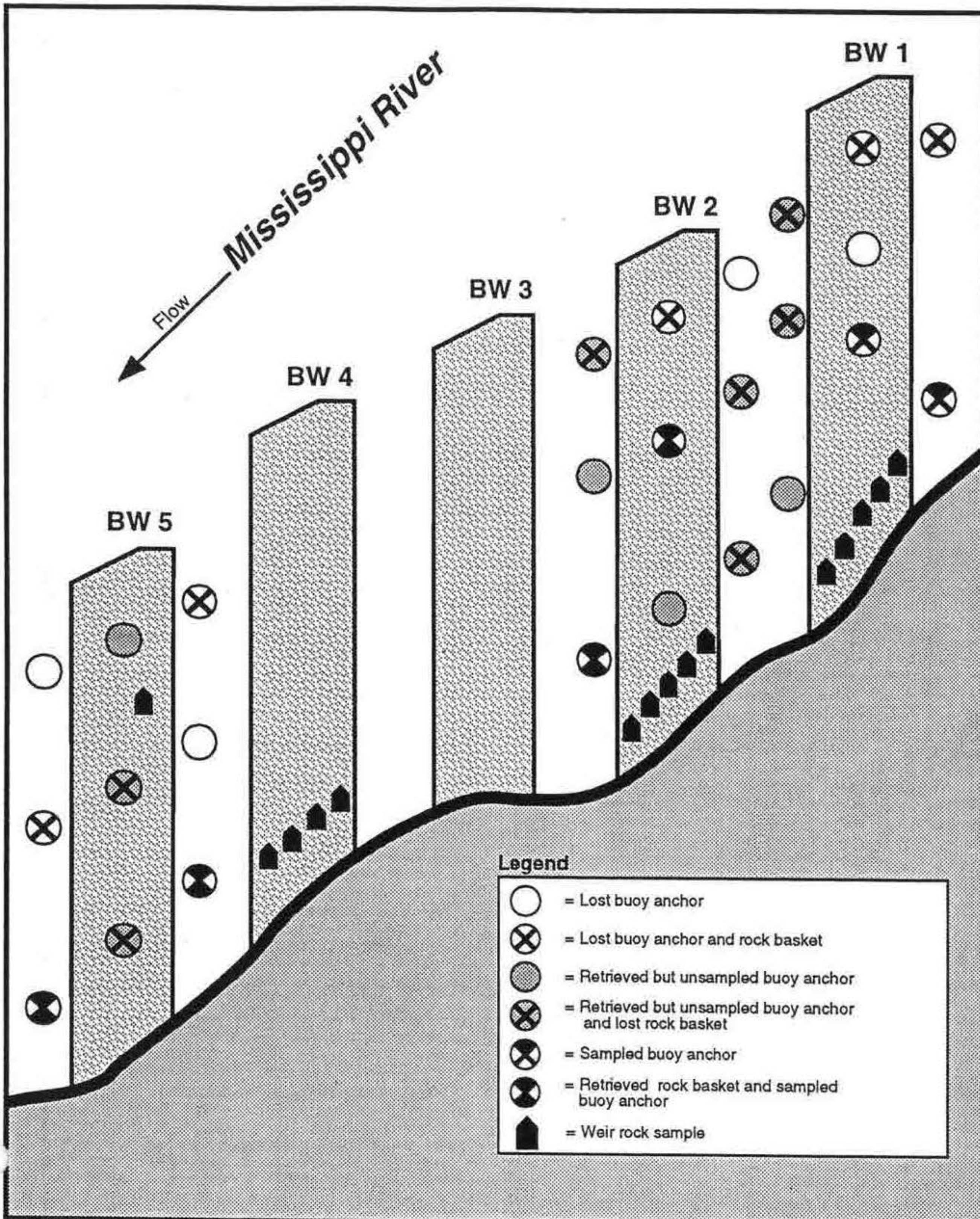

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Figure 2-1. Invertebrate sample locations within Carl Baer Bendway Weir field, summer 1996.

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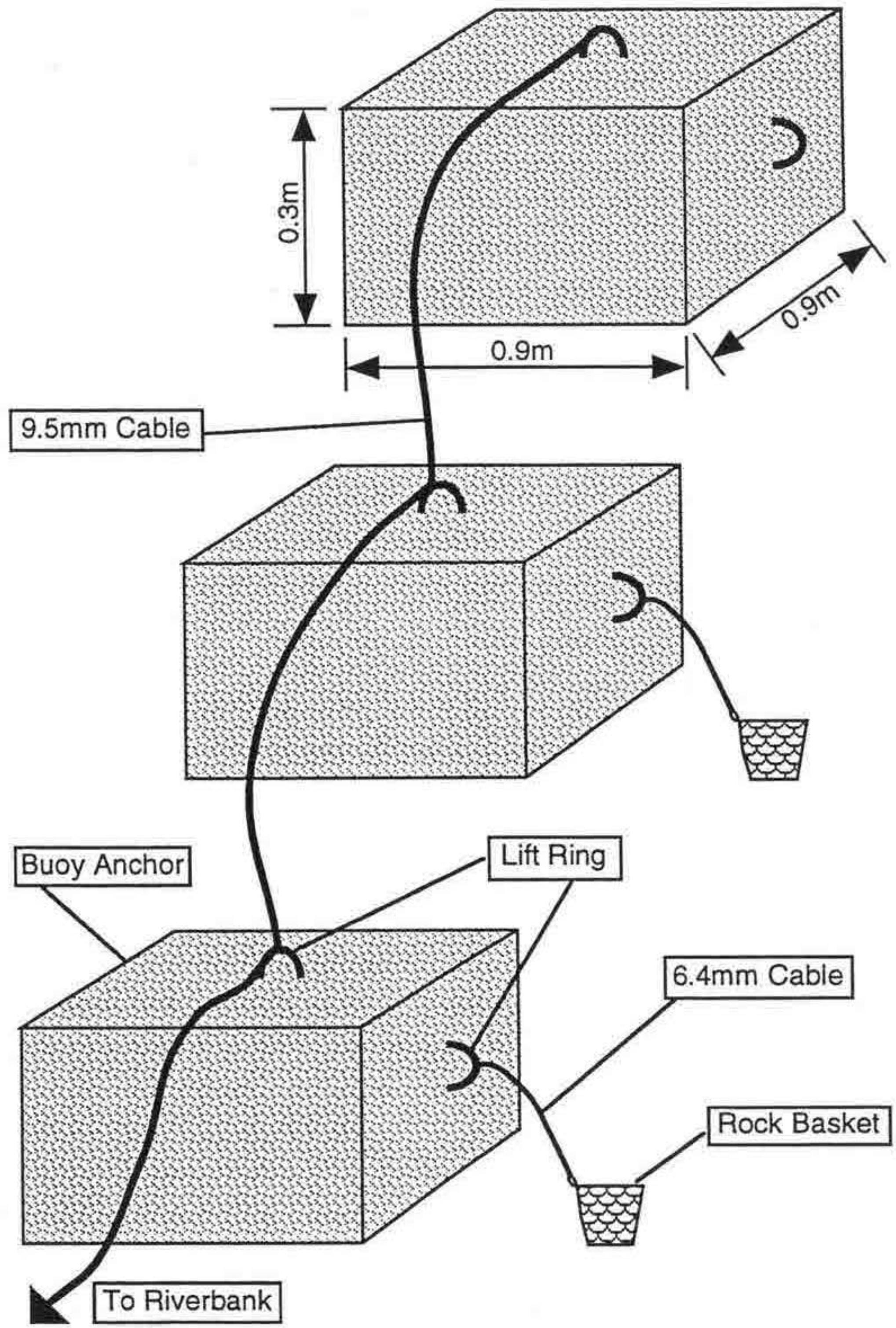

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Figure 2-2. Buoy anchor and rock basket sampler configuration.

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2.1.2 Rock Basket Samplers

Although buoy anchors are similar to weir rocks, their value as an artificial substrate invertebrate sampler is untested. Rock baskets have been previously used for monitoring invertebrates on other channel maintenance structures (ESI, 1996). Therefore, rock baskets were deployed along with buoy anchors (see Figure 2-1) to assess their efficacy in the harsh open river weir environment.

Baskets were constructed from one-half of a standard minnow trap. Each basket was filled with 35 rocks of approximately the same size. Rock surface area was crudely estimated by calculating the surface area of shapes similar to the rocks (cones and cylinders in most cases). Rock surface area in each basket averaged $0.3m^2$. Baskets were covered with 6mm hardware mesh secured with plastic ties.

Baskets were deployed at 18 locations in the weir field along with buoy anchor samplers on 16 July 1996 (see Figure 2-1). Rock baskets were connected to two of the three buoy anchors in each buoy anchor set with approximately 2m of 6mm steel cable (see Figure 2-2), resulting in two baskets directly upstream, downstream, and on top of each of the three sampled weirs; BW 1, BW 2, and BW 5 (see Figure 2-1).

Rock basket recovery was also attempted after 35 days of colonization (20 August 1996). However, as with buoy anchor retrieval success, only a few rock baskets (4 of 18) were retrieved. Three were heavily colonized, but one was apparently buried in the sediment, as colonization was minimal and the basket was full of sand. This sample was therefore excluded from analyses. Buoy anchor loss accounted for some of the low return of rock baskets, but most were lost due to basket structure failure. Buoy anchors were retrieved with torn pieces of a rock basket attached, and in all cases, the cables and clips securing the basket to the buoy anchor were still intact, indicating that baskets were torn from cables either during deployment, colonization, or retrieval. Retrieved rock baskets were placed in 13.3L (3.5gal) buckets, preserved with 10% formalin, and returned to the laboratory for processing.

2.1.3 Weir Rock Scrapes

Since previous sampling methods proved less than successful, 14 scrape samples were collected from the weir rocks on 17 September 1996. Weir rocks were collected with a clam shell dredge on a USCOE St. Louis District work barge powered by the USCOE M.V. Pathfinder. Sample collection was attempted on the three previously sampled weirs, however sampling BW 5 proved difficult due to swift current, and only one sample was obtained. Therefore, five, five, four, and one samples were collected from BW 1, BW 2, BW 4, and BW 5, respectively (see Figure 2-1). A scrape sample was collected from rock surfaces with the greatest macroinvertebrate colonization using a 0.15m (6in) diameter ($0.018m^2$) sampling frame, 10% nitric acid spray to dislodge the animals from the surface, and a pan to catch the falling debris. Samples were washed into plastic 1L jars, preserved with 10% formalin, and returned to the laboratory for processing.

2.1.4 Upstream Reference Samples

In addition to weir sampling, ten concrete buoy anchors (without rock baskets attached) were placed near MRM 164.5, in a bendway without weirs, upstream of the Carl Baer Bendway on 21 August 1996 (see Figure 1-1). The objective was to obtain comparable samples within and upstream of the weir field to assess the weir field's influence on species composition and colonization rate. Buoy anchors were attached with cable to red nun buoys, and deployed parallel to and approximately 61m (200ft) from the left descending bank. All ten buoy anchors from the upstream bendway were retrieved after 27 days (17 September 1996). Scrape samples were collected as previously described for weir rock scrapes. A sample was not collected from one of the ten buoy anchors, which was apparently buried in the sediment (presence of black deposits and devoid of invertebrates).

2.2 Laboratory Procedures

2.2.1 Sample Tracking

Upon arrival at ESI's laboratory, all samples were logged on a project-specific tracking form. Each sample was assigned and labeled (internally and externally) with a unique code that followed the sample through sorting and identification. Pertinent sample information, including collection date (set and retrieval), collection location, and collection personnel were recorded in the log book. Personnel and date were recorded following each sample processing task.

2.2.2 Sorting

Each sample was rinsed through a no. 30 sieve to remove preservative and a portion was placed in a white pan. Samples with many animals were subsampled according to procedures outlined below. Animals were sorted from debris with the aid of a magnifying lamp or dissection microscope, and placed in scintillation vials containing 75% alcohol. Abundant groups (chironomids, oligochaetes, trichopterans, ephemeropterans) were sorted into separate vials. Vials were labeled internally and externally with the sample's code. The resultant number of vials was recorded on the tracking form.

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

2.2.3 Subsampling

A Folsom sample splitter was used for all subsampling. Very large samples (>500 animals) were split before sorting. However, only samples relatively free of entangling debris (biasing the subsample) were split, and all rare and large animals were removed (fish, anisopterans, crayfish, etc.) before splitting a

3.0 Results and Discussion

3.1 Habitat Characteristics

The middle Mississippi River is characterized by primarily silt, sand, and small gravel substrate, rapid current, and high turbidity (Pflieger, 1989). Rock wing dikes and revetment along the river's banks have caused many backwater areas to fill in with silt, and the resulting channel provides little habitat diversity for fish and invertebrates (Pflieger, 1989). Water depth in this area of the river ranges from 11.0m (36ft) close to the bank to 14.0m (45ft) further toward the center of the river. Weirs in this field, which are constructed of a variety of rock sizes and extend from 0m to approximately 100m from the bank, are completely submerged. Water depth on the weir rock structure ranged from 9.5m (31ft) to 6.1m (20ft) from the end of the weir structure toward the bank respectively (see Figure 2-1 and Table 3-1). Weir rocks provide substrate diversity, and complex flow patterns should be created as water flows over the rock structures; resulting in a variety of microhabitats for invertebrate colonization (Way *et al.*, 1995).

3.2 Benthic Macroinvertebrates

3.2.1 Sample Method Comparison

The primarily objective of this study was to investigate epilithic invertebrate taxonomic composition within the weir field, and all three sample methods (rock baskets, weir rock scrape, and buoy anchor scrape samples) appeared to yield similar results with respect to taxonomic composition and relative abundance of dominant taxa. However, density, diversity, and taxa richness differed with sample type.

Some differences among methods were expected, as invertebrate communities vary with substrate particle size, flow, and detritus accumulation (Cummins, 1962; Cummins and Lauff, 1968; Rabeni and Minshall, 1977; Wells and Demas, 1979; Culp *et al.*, 1983; Lancaster and Hildrew, 1993; Way *et al.*, 1995). Smaller rock, such as in the rock baskets, provide the greatest surface area per volume, and more interstitial spaces are available for accumulation of detritus, which appear to be a factors in invertebrate colonization. Higher invertebrate density and diversity might therefore be expected in rock basket samplers. Large boulders, such as weir rocks, provide irregular surfaces for a variety of invertebrate species (DeMarch, 1976), and spaces between rocks provide protection from the current and areas for debris accumulation (invertebrate food and shelter). The invertebrate community on a weir rock surface most likely varies with orientation to the current and detritus accumulation in crevices, although collecting a representative sample of this invertebrate community is difficult (Dickson *et al.*, 1971; Hall, 1982; Ciborowski and Clifford, 1984). Buoy anchors, in contrast, have a rather smooth surface, and a less dense and diverse community might be expected.

As expected, rock baskets yielded the highest density and taxa richness, although diversity was lower than other methods. Mean density was extremely variable within sample type and the difference in density among types was not significant (P>0.05). Despite variability, density tended to be higher in rock basket samplers (26,998/m^2 ±37,885), intermediate in weir rock samples (14,803/m^2 ±8,742), and lowest in buoy anchor samples (8,144/m^2 ±10,977), even though the sample collection method on weir and buoy anchor rock surfaces was biased toward the heaviest colonized region of the rock (Table 3-2). However some animals on buoy anchors and weir rocks, particularly those without strong clinging mechanisms, may have been lost during rock retrieval.

Taxa richness was similar among sample methods (22 to 25 taxa), while diversity was moderate on the larger rocks (2.18 and 2.17 on the weir rocks and buoy anchors, respectively), and surprisingly low in rock baskets (1.49) (see Table 3-2). *Hydropsyche orris*, *Potamyia flava*, and *Polypedilum convictum* dominated all sample types. However, oligochaetes, which generally occur in swift current on stony substrate (*Nais behningi*), in littoral areas (*Nais variabilis*), and in sandy substrate (*Dero digitata* and *Barbidrulus paucisetus*), and feed primarily on organic matter (Chekanovskaya, 1981; Seagle and Wetzel, 1982), were more common in rock baskets. *Dugesia tigrina*, generally found on irregular rock surfaces (Pennak, 1989), were most abundant on weir rocks (see Table 3-2). Thus, all three methods yielded the same dominant taxa, although density was variable within all methods. Rock baskets yielded more animals typically found in interstitial spaces and animals typically more abundant on irregular surfaces (*D. tigrina*) were more abundant on weir rocks.

3.2.2 Weir Field

The macroinvertebrate community found on coarse substrate in rapid flow is expected to consist mainly of clingers, as well as taxa with other adaptations for attachment and avoiding rapid flow (Cummins and Lauff, 1968; Anderson and Day, 1986). Species composition within the weirs is characteristic of this habitat, and was similar in all sampled areas. However, only 29 taxa were collected in weir samples, diversity was only moderate (2.16), and only a few taxa were abundant. Hydropsychid caddis flies, such as *H. orris* and *P. flava*, both of which cling to rocks and filter feed, overwhelmingly dominated the samples, 42.8% and 34.7%, respectively (see Table 3-2). These taxa were also dominant on coarse substrates in other areas of the Mississippi River (Hall, 1982; Anderson and Day, 1986; ESI, 1996). Chironomids, such as *Rheotanytarsus exiguus* group and *P. convictum*, which also cling to rocks, were also abundant, 5.5% and 7.1%, respectively. Other taxa were rare (<5%), and conspicuously absent from all samples were groups intolerant of poor water quality, such as Odonata and Plecoptera.

Although dominant taxa were similar to other coarse substrate areas of the Mississippi River, species richness and diversity was less in the weir field than in Pool 24 (MRM 289.5) chevron dikes (also sampled under USCOE Avoid and Minimize program[USCOE, 1992]). Density averaged 14,662/m^2

Table 3-2. Macroinvertebrate community characteristics in Mississippi River bendway weirs (MRM 163.5) and an upstream bendway (MRM 164.5).

					MRM 163.5												MRM 164.5		
					Rock baskets			Weir rocks			Buoy anchors			Total			Buoy anchors		
Phylum	Class	Order	Family	Species	Mean[1]	2SE	%[2]	Mean	2SE	%	Mean	2SE	%	Mean	2SE	%	Mean	2SE	%
Platyhelminthes	Turbellaria										7	14	0.09	2	4	0.01			
Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia tigrina*	1	2	T[a]	680	989	4.59				425	625	2.90	6	12	0.04
Nematoda					366	636	1.35	73	68	0.49	41	61	0.50	102	90	0.69	30	61	0.20
Nematomorpha											1	1	T			T	6	12	0.04
Mollusca	Bivalvia	Veneroida	Dreissenidae	*Dreissena polymorpha*				88	75	0.59				55	49	0.37	128	142	0.83
Annelida	Oligochaeta	Haplotaxida	Enchytraeidae	*Barbidrulus paucisetus*	9	19	0.03							1	2	T			
			Naididae	*Dero digitata*	2	5	T								1	T			
				Nais behningi	9	19	0.03	62	62	0.42	3	5	0.03	41	40	0.28			
				Nais variabilis	9	19	0.03							1	2	T	6	12	0.04
				Slavina appendiculata	1	2	T									T			
Arthropoda	Arachnida	Acarina	Oribatei	*Oribatei sp.*	2	5	T								1	T			
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis sp.*	131	154	0.48	4	7	0.02	357	658	4.38	108	166	0.74	55	71	0.36
			Caenidae	*Caenis sp.*	126	183	0.47	26	37	0.17	26	47	0.32	38	35	0.26			
			Heptageniidae	(early instars)	16	32	0.06	7	15	0.05	5	8	0.06	8	10	0.05			
				Heptagenia sp.													6	12	0.04
				Stenacron sp.	2	5	T								1	T			
				Stenonema sp.	10	17	0.04	7	15	0.05	6	9	0.07	7	9	0.05	55	110	0.36
			Siphlonuridae	*Ameletus sp.*													6	12	0.04
Arthropoda	Insecta	Plecoptera		(damaged)							1	1	T	<1		T			
Arthropoda	Insecta	Coleoptera	Elmidae	*Stenelmis sp.* (larva)	2	5	T	4	7	0.02				3	5	0.02			
			Tenebrionidae	*Tenebrionidae sp.* (larva)	3	4	0.01								1	T			
Arthropoda	Insecta	Diptera		(pupa)	2	5	T	11	12	0.07	3	4	0.04	8	7	0.05	67	63	0.44
			Chironomidae					11	16	0.07	14	29	0.18	10	12	0.07	6	12	0.04
				Dicrotendipes nervosus Type I							4	7	0.04	1	2	T			
				Eukiefferiella claripennis group							2	4	0.02		1	T			
				Thienemannimyia group	13	15	0.05	22	14	0.15	9	14	0.11	18	10	0.12	30	37	0.20
				Nanocladius bicolor group				4	7	0.02				2	5	0.02	61	85	0.40
				Orthocladiinae sp.							16	28	0.20	4	7	0.03			
				Polypedilum convictum	1,567	2,630	5.80	866	854	5.85	1,188	2,095	14.58	1,034	775	7.05	1,078	1,138	7.03
				Polypedilum illinoense	2	5	T	73	108	0.49				46	68	0.31			
				Rheosmittia sp.	12	17	0.04	4	7	0.02	29	57	0.35	11	15	0.07			
				Rheotanytarsus exiguus group	179	301	0.66	1,023	418	6.91	579	478	7.12	807	310	5.50	3,941	2,896	25.68
				Robackia claviger							7	14	0.09	2	4	0.01			
			Empididae	*Hemerodromia sp.*				11	12	0.07	5	7	0.07	8	8	0.06	12	24	0.08
Arthropoda	Insecta	Trichoptera		(pupa)	289	544	1.07	804	611	5.43	47	90	0.57	550	407	3.75	201	375	1.31
			Hydropsychidae	*Hydropsyche orris*	7,250	13,423	26.85	7,357	5,114	49.70	3,058	4,707	37.56	6,269	3,703	42.76	3,777	4,712	24.61
				Hydropsyche simulans	9	19	0.03	18	23	0.12				13	15	0.09	12	24	0.08
				Potamyia flava	16,981	20,468	62.90	3,648	3,186	24.64	2,737	2,871	33.61	5,087	3,522	34.69	5,848	5,676	38.11
			Polycentropodidae	*Neureclipsis sp.*													6	12	0.04
Arthropoda	Crustacea	Isopoda	Asellidae	*Lirceus fontinalis*													6	12	0.04
				Total density	26,998	37,885		14,803	8,742		8,144	10,977		14,662	7,509		15,345	14,279	
				Minimum density	4,090			164			182			164			1,151		
				Maximum density	64,583			68,037			35,377			68,037			70,998		
				Sample size (n)	3			15			6			24			9		
				No. taxa	25			22			22			29			22		
				Diversity (SW index)	1.49			2.18			2.17			2.16			2.15		

[1]Mean = Mean (no/m^2)
[2]% = Relative Abundance
[a]T = relative abundance is less than 0.01%

±7,509 in the weir field (although sampling was biased in scrape samples; see Table 3-2) and averaged 1,025/m^2 ±476, 34,297/m^2 ±20,522, and 8,009/m^2 ±10,946 in fall 1994, spring 1995, and fall 1995, respectively, on chevron dike exteriors (ESI, 1996). However, species richness and diversity were less in weir samples than in chevron dike samples despite sampling bias. A total of 29 taxa were collected in 24 weir field samples and diversity was a moderate 2.16, whereas 94, 53, and 44 taxa were collected and diversity was 4.32, 2.08, and 2.16 in 16 fall 1994 samples, seven spring 1995 samples, and 11 fall 1995 samples, respectively, on chevron dike exteriors (ESI, 1996).

Several factors may be contributing to the low taxa richness and lack of intolerant taxa in the weir field compared to chevron dikes. Possible explanations include differences in water quality, river conditions, colonization time of rock structures, and/or sample methods. Mississippi River water quality is probably more degraded with chemicals and effluent in metropolitan St. Louis than in many other Mississippi River areas (MDNR, 1986). Groups such as Plecoptera and many Odonata are intolerant to pollution (Hilsenhoff, 1988), while many of the groups collected in the weirs are facultative to tolerant (Hilsenhoff, 1988; Klemm *et al.*, 1990). On the other hand, weirs have only been in place since April and many Plecoptera and Odonata hatch in summer (Merritt and Cummins, 1996) and would be more prevalent in the drift later in the year. Chevron dikes, in contrast, were constructed in October 1993 and sampled in November 1994, May 1995, and September 1995. The weirs are also located in the harsh environment of the middle Mississippi River (higher discharge, current velocity, and sediment load) as opposed to the pooled upper Mississippi River where the chevron dikes are located. Many invertebrate species may not be able to withstand the harsher middle river environment.

If the weir field epilithic community is not limited by water quality and harsh river conditions, it should become increasingly complex with time, as weir rocks settle and stabilize, debris accumulates between rocks, and competition occurs among invertebrate species (Peckarsky, 1986). Perhaps colonization time has not been sufficient for a complex community to develop. However even if the community becomes more complex, animals occupying crevices may be lost during retrieval of weir rocks and buoy anchors, thus biasing results. Loss of animals does not appear to be a problem in rock baskets, as taxa richness was also high (59 taxa) in rock basket samplers placed at a depth of 9m on I-wall rubble in Mississippi River Pool 26 (MRM 203) (ESI, 1997). Comparing chevron dike taxa richness and bendway weir taxa richness may therefore be invalid unless comparable sample methods (rock baskets) are used in both locations.

3.2.3 Upstream Bendway

Colonization of buoy anchors placed upstream of the weir field was not influenced by complex flow patterns and microhabitats of the weir field. If the weir field is influencing invertebrate colonization, species richness and dominant taxa would be expected to differ between upstream and weir field samples, and this did not appear to be the case. Results were similar between weir rock and buoy anchor samples collected within the weir field and buoy anchor samples collected upstream of the weir field. A total of 22 taxa were collected on buoy anchors in both areas, and on weir rocks. Diversity was also similar; 2.18 and 2.17 in the weir field and 2.15 upstream of the weir field (see Table 3-2). Mean macroinvertebrate density from the upstream buoy anchors was higher (15,332/m^2 ±14,279) than on buoy anchors in the weir field (8,144/m^2 ±10,977), but was similar to weir rock density (14,803/m^2 ±8,742). However, samples were biased toward high density areas of rocks and buoy anchors, density was extremely variable within sample type, and differences in density were not significant ($P>0.05$). However, some differences in taxa were noticeable. Although *H. orris* and *P. flava* were abundant in both areas, Chironomidae, particularly *R. exiguus* group, appeared to be more abundant in upstream samples (see Table 3-2). Early instar chironomid larvae are primarily drift organisms (Townsend and Hildrew, 1976; Merritt and Cummins, 1996), and they may be more abundant in the upstream area where flow is unimpeded by weirs.

The purpose of placing samplers upstream of the weir field was to determine if the weir field influenced rock colonization. Considering the similarity in density, diversity, taxa richness, and dominant taxa between the two areas, it appears that a rock surface would be colonized similarly within a weir field or by itself in the middle of the flow. However, if habitat complexity in the weir field increases with time, a difference in macroinvertebrate communities between these areas may become apparent.

3.2.4 Principal Components Analysis

PCA is a multivariate statistical procedure that uses relationships inherent in the data to illustrate relationships among several samples. The procedure minimizes variance between samples and ranks them along several factor axes. The first factor, typically associated with the environmental variable having the greatest influence on macroinvertebrate community development, explains the greatest variance while the other factors, associated with less important environmental variables, explain the remainder. The first two axes were plotted to illustrate the relationship among sampled sites and collected species, and to present results in a two dimensional display that can be interpreted, along with knowledge of the site and taxa, to determine what environmental variables influence macroinvertebrate community structure in this area.

PCA analysis of invertebrate samples confirms that samples did not differ with position within the weir field, position in or upstream of weirs, or by sample method. Rather, samples were distributed throughout a plot of the two main PCA factors (Figure 3-1) and factors did not significantly correlate with measured variables; within weir position, upstream or in weir, depth, weir number, or sample type (Table 3-3). However when species abundance was subjected to PCA, taxa seemed to divide into three distinct macroinvertebrate guilds along factor axes (Figure 3-2). Factor 1 explained 60% of the variance

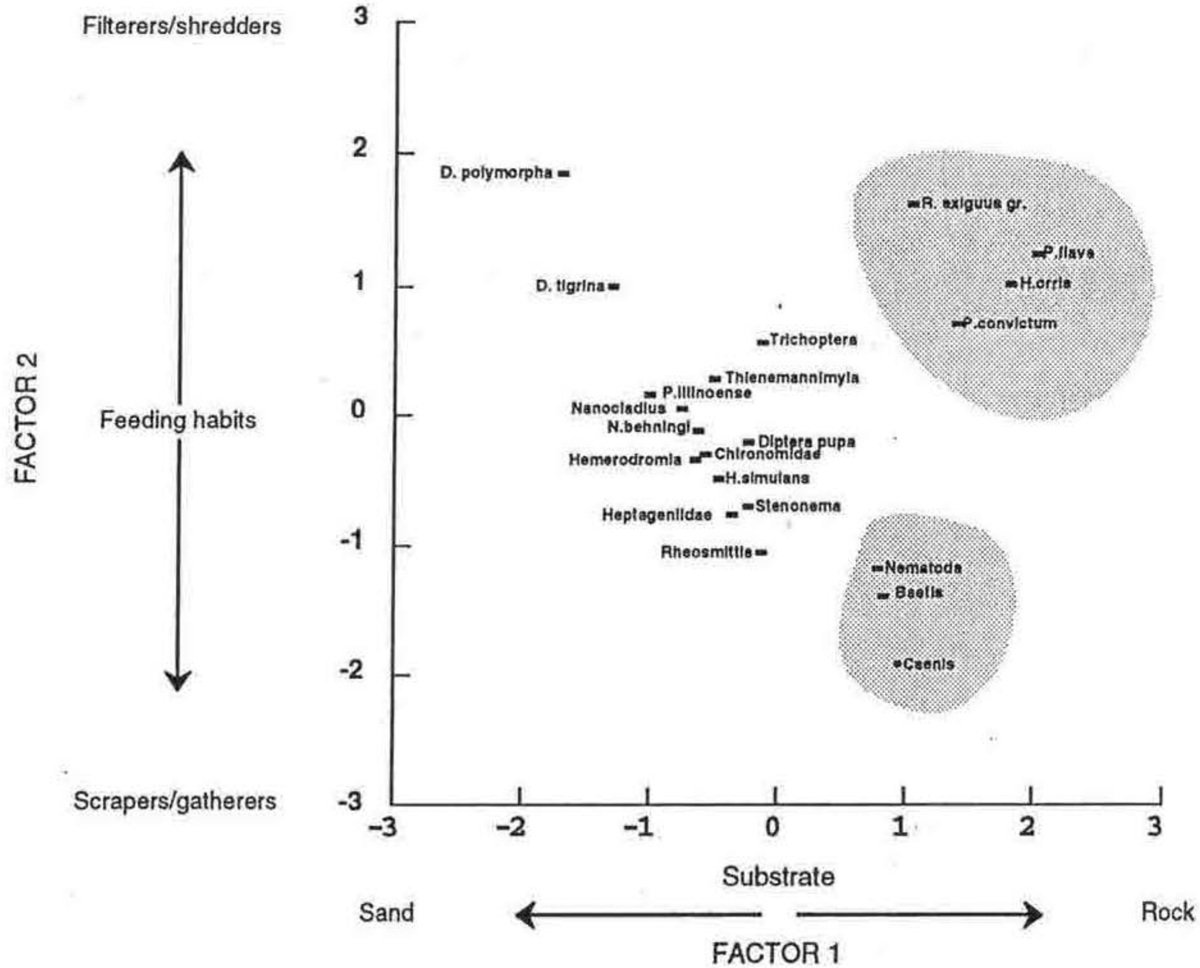

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Figure 3-1. PCA plot of invertebrate species in and upstream of Carl Baer Bendway Weir, summer 1996.

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5.0 Summary

1. Five bendway weirs were constructed at the Carl Baer Bendway near Mississippi River mile 163.5 in April 1996. Their purpose was to widen the effective width of the navigation channel by scouring the outer edge and reducing point bar development on the inner side of the bend. The addition of rock to an otherwise homogenous sand substrate should provide habitat for a more diverse invertebrate community.

2. Macroinvertebrates were sampled upstream, downstream, and directly on weirs, to determine invertebrate community characteristics and distribution within the weir field. Similar samplers were placed in a upstream bendway without weirs to determine the influence of the weir field on rock colonization.

3. Density, diversity and species composition did not differ among sampling methods. Rock basket density was somewhat higher than scrape sample density, although the difference was not significant ($P>0.05$). However, only three rock baskets were collected, and weir rocks and buoy scrapes were biased toward the heaviest colonized surface.

4. The samples were dominated mostly by hydropsychid caddis flies, *H. orris* and *P. flava*. Chironomids, such as *R. exiguus* group and *P. convictum*, were also fairly abundant. These species typically cling to rock substrate, and are not typically found in the homogenous sand substrate that was present prior to weir construction.

5. Density, diversity and species composition did not differ with position of collection in the weir field, however the position of sample collection on a rock may influence results.

6. Invertebrate communities were similar within and upstream of the weir field. Dominant species were the same, as well as species richness and diversity. This similarity in invertebrate communities suggests that at present the rock substrate and not the weir field is influencing the invertebrate community. However, if habitat complexity within the weir field increases with time, these invertebrate communities may diverge.

7. PCA was used to analyze similarities among samples and species. Although measured environmental variables did not correlate with PCA axes, PCA axes appeared to be related to substrate (sand vs. rock substrate) and macroinvertebrate feeding habits (filterers and shredders vs. scrapers). This suggests that the species collected were associated with exposed rock surfaces, protected crevices, and sand/rock interface. Since dominant taxa were associated with rock substrates and were all shredders or filterers, exposed rock surfaces appear to be the most

abundant habitat at this time.

8. Sampling difficulties yielded insights for future sampling of weir structures. Rock baskets yielded the highest density and taxa richness, however basket structure weakness limited the usefulness of this method. Weir rock scrape sampling seemed to yield the best results in the weir field, although sampling near the end of the weirs in the swifter current proved difficult and some animals (and therefore taxa richness) may have been lost during retrieval. Buoy anchor sampling upstream of the bendway yielded comparable results to weir rocks within the weir field. However, buoy anchors were difficult to retrieve in the weir field and as with weir rock scrapes, animals may have been lost during retrieval.

6.0 Conclusion

Although bendway weirs are still relatively new at this time, the benefits are already apparent, not only in the function of navigation channel maintenance, but in the improved habitat conditions for epilithic invertebrate communities within the rock structure. Where conditions are right, high densities of invertebrates can colonize and survive in the bendway weir environment, although colonization of rocks is extremely variable. At this point the rock substrate of the weirs appears to provide valuable invertebrate habitat over surrounding homogenous sand, however, the bendway weir field structure does not appear to add habitat complexity over individual rocks. As the weir field stabilizes and debris accumulates, however, the effects of the weir field may be apparent.

Final Report: Macroinvertebrates Associated with Bendway Weirs at Mississippi River Mile 30

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1.0 Introduction

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

A. Operations of the locks and navigation channel.
B. Measures related to towing operations.
C. Measures related to induced development.
D. Measures to rectify impacts.

Eight measures were selected for implementation:

A- 3. Designate lock approach waiting area or provide special mooring sites.
A-10. Reduce open water dredge material disposal by creating beaches.
A-11. Reduce open water dredge material disposal through wetland creation.
A-13. Place dredge material in the thalweg.
A-16. Continue dike configuration studies (i.e., notched, chevron, and bullnose dikes).
A-17. Place off-bank revetment on islands.
A-19. Monitor bendway weirs.
B- 8. Study reduction of tow waiting times.

As part of measure A-19, a weir field located at Price's Bend, Mississippi River mile (MRM) 30, was chosen for monitoring. The weirs were designed to increase the effective width of the Mississippi River navigation channel by reducing point bar development on the inner side of the bend. The weirs also add bottom structure and create complex flow patterns. State and Federal natural resource management agencies feel that the creation of complex habitats in the relatively homogeneous main channel is beneficial to the ecosystem. However, these structures are relatively new and monitoring is needed to confirm the benefits. Fish and water quality have been monitored at Price's Bend, however, aquatic macroinvertebrate community monitoring of bendway weirs has been lacking, with the exception of one monitoring project at Carl Baer Bendway Weirs (ESI, 1997a). Invertebrate monitoring was implemented at the Price's Bendway Weir field and a downstream bendway (Thompson's Bend, MRM 20), to investigate macroinvertebrate community characteristics associated with the weirs, and compare these communities to those of a bendway without weirs.

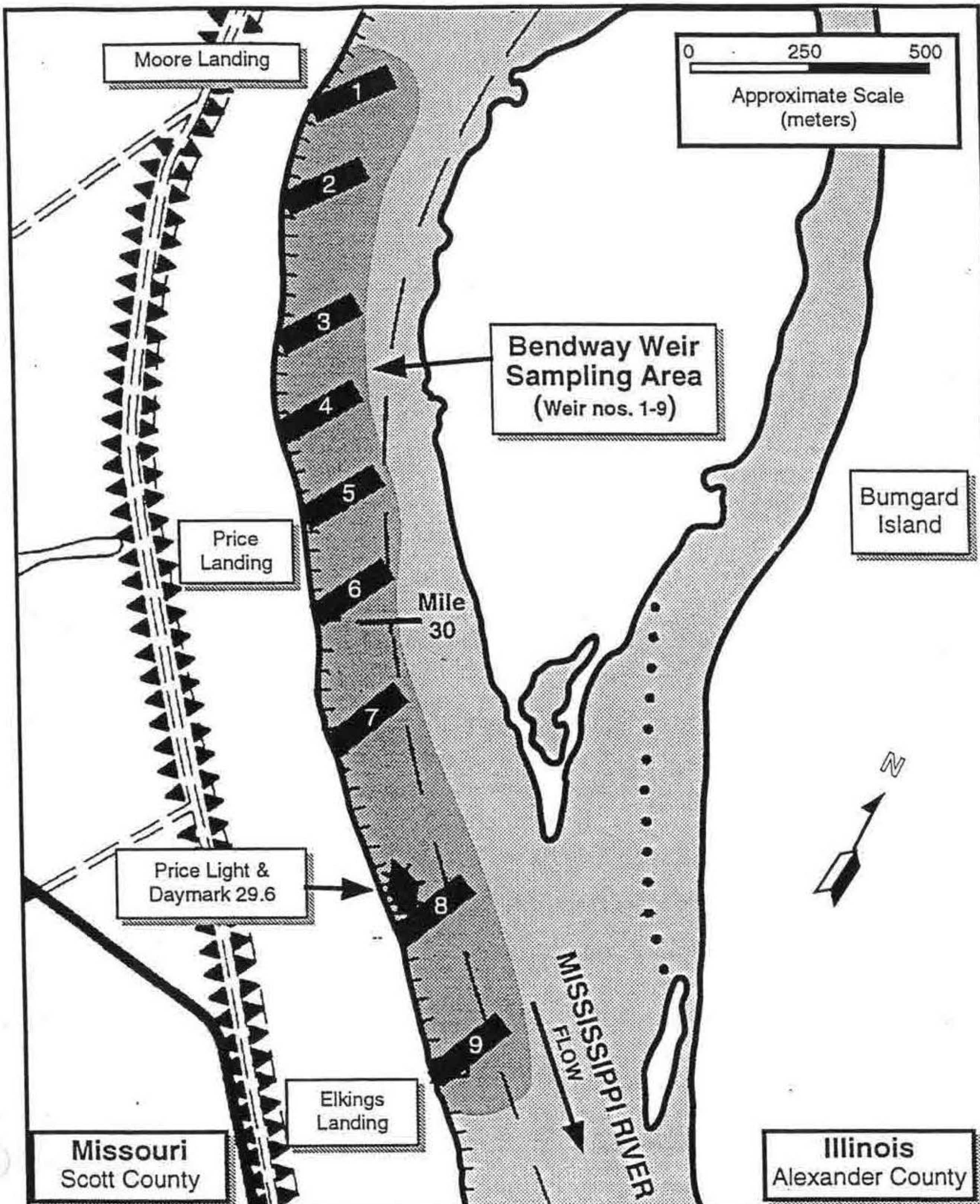

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Figure 2-1. Approximate location of Price's Bendway Weir sampling areas, MRM 29.6 - 30.6.

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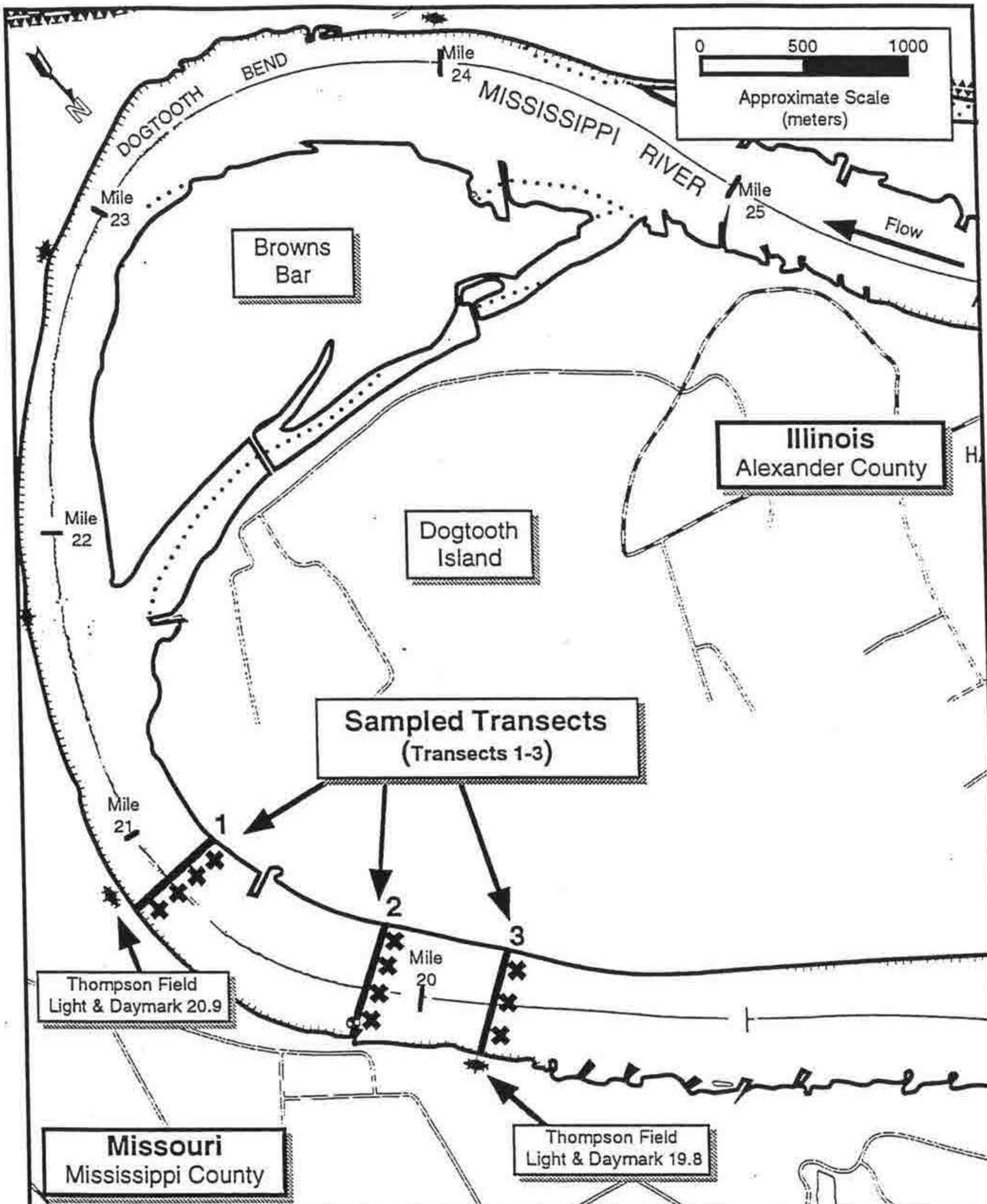

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Figure 2-2. Approximate location of Thompson's Bend sampling areas, MRM 19.8-20.8.

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3.0 Results and Discussion

3.1 Habitat Characteristics

The middle Mississippi River (MRM 0 -195.3) is characterized by primarily silt, sand, and small gravel substrate, rapid current, and high turbidity (Pflieger, 1989). Rock wing dikes and revetment along the river's banks have caused many backwater areas to fill in with silt, and the resulting channel provides little habitat diversity for fish and invertebrates (Pflieger, 1989). The Price's Bendway Weirs (MRM 30), which are constructed of a variety of rock sizes, extend from 0m to approximately 100m from the bank, and are completely submerged, add structure to this rather homogenous river reach. Water depth on the weir rock structure was approximately 9.2m (30ft) about 27.5m (90ft) from the bank. Weir rocks provide substrate diversity, and complex flow patterns should be created as water flows over the rock structures; resulting in a variety of microhabitats for invertebrate colonization (Way *et al.*, 1995).

3.2 Bendway With Weirs vs. Bendway Without Weirs

Bendway weirs appear to be providing habitat for a variety of macroinvertebrates, however communities do not appear to be as complex as those on chevron dikes and I-wall rubble. Community characteristics such as density and dominant taxa were very similar between the weir field at Price's Bend (MRM 30) and a previously sampled weir field at Carl Baer Bendway (MRM 164) (also sampled under USCOE Avoid and Minimize program [USCOE, 1992]). Macroinvertebrate density from weir rock scrapes collected at Price's Bend (MRM 30) averaged $16{,}240/m^2 \pm 7{,}246$ (Table 3-1), compared to mean density of $14{,}803/m^2 \pm 8{,}742$ at Carl Baer Bendway Weirs (MRM 164) (ESI, 1997a). Hydropsychid caddisflies (*Hydrosyche orris* and *Potamyia flava*) dominated communities at both bends. Midges (*Rheotanytarsus sp.*) were also abundant at Carl Baer Bendway Weirs and were present but not abundant at Price's Bend. However, species richness (34 taxa) was considerably higher at Price's Bend than at Carl Baer Bendway Weir (22 taxa). Species diversity was low to moderate in both areas; 1.88 and 2.18 at Price's Bend and Carl Baer Bendway, respectively. Although the number of taxa was higher at Price's Bend, *H. orris* comprised 67% of the community, while distribution of species was more even at Carl Baer Bendway (see Table 3-1).

Large river epilithic communities are typically dominated by a few taxa (Mason *et al.*, 1973) and hydropsychid caddisflies appear to dominate the macroinvertebrate community at these weirs as well as most other Mississippi River structures (e.g. stone dikes [Hall, 1982; Mathis *et al.*, 1982 and Payne *et al.*, 1989 in Way *et al.*, 1995]; hard substrates in pools [Anderson and Day, 1986]; or articulated concrete mattress blocks [Way *et al.*, 1995]). *Hydropsyche orris* was also abundant in Chevron dike (MRM 289.5) and I-wall (MRM 203) invertebrate communities, however taxa richness

Table 3-1. Macroinvertebrate community characteristics in Thompson's Bend substrate and on Price's Bend weir rocks.

Phylum	Class	Order	Family	Species	Thompson's Bend Substrate Mean	Thompson's Bend Substrate 2SE	Thompson's Bend Substrate %	Price's Bend Weir rocks Mean	Price's Bend Weir rocks 2SE	Price's Bend Weir rocks %
Platyhelminthes	Turbellaria				70	66	7.20	2	4	0.01
Platyhelminthes	Turbellaria	Tricladida	Planariidae	*Dugesia tigrina*				670	695	4.13
Nematoda								339	294	2.09
Mollusca	Gastropoda	Lymnophila	Planorbidae	*Menetus sampsoni*				10	12	0.06
Mollusca	Bivalvia	Veneroida	Dreissenidae	*Dreissena polymorpha*				1,251	1,271	7.70
	Unionoida	Unionidae			4	8	0.40			
Annelida	Oligochaeta	Haplotaxida	Enchytraeidae	*Barbidrilus paucisetus*	857	1,672	88.80			
			Naididae	*Nais behningi*				22	45	0.14
Arthropoda	Insecta	Collembola	Entomobryidae		4	8	0.40			
Arthropoda	Insecta	Ephemeroptera	Baetidae	*Baetis sp.*				227	278	1.40
			Caenidae	*Amercaenis sp.*				39	33	0.24
			Heptageniidae					16	15	0.10
				Stenonema sp.				2	4	0.01
				Stenonema femoratum				6	12	0.04
				Stenonema integrum				20	26	0.13
			Isonychiidae	*Isonychia sp.*				8	10	0.05
Arthropoda	Insecta	Diptera	Chironomidae					2	4	0.01
				(pupa)				2	4	0.01
				Cryptochironomus sp.				2	4	0.01
				Glyptotendipes sp.				4	8	0.03
				Nanocladius sp.				4	6	0.03
				Paratendipes sp.	4	8	0.40	2	4	0.01
				Polypedilum convictum				497	623	3.06
				Polypedilum scalaenum				4	6	0.03
				Rheotanytarsus sp.				138	87	0.85
				Robackia sp.	23	27	2.40			
				Tanytarsus sp.				2	4	0.01
				Thienemanniella sp.				2	4	0.01
				Thienemannimyia group				36	26	0.16
			Empididae	*Hemerodromia sp.*				2	4	0.01
Arthropoda	Insecta	Trichoptera		(pupa)	4	8	0.40	83	113	0.51
			Hydropsychidae					12	11	0.08
				Hydropsyche sp.				6	9	0.04
				Hydropsyche orris				10,813	4,290	66.58
				Hydropsyche simulans				4	6	0.03
				Potamyia flava				1,819	2,046	11.20
			Hydroptilidae	*Neotrichia sp.*				199	129	1.23
Arthropoda	Crustacea	Amphipoda	Gammaridae	*Gammarus minus*				2	4	0.01
				Total mean density	965	1,711		16,240	7,246	
				Maximum density	9,514			95,395		
				Minimum density	42			2,138		
				Sample size (n)	11			27		
				Number of taxa	7			34		
				Diversity (SW index)	0.68			1.88		

(90 and 59, respectively) and diversity (3.07 and 2.49, respectively) were higher than for bendway communities (ESI, 1997b and 1997c), suggesting either greater habitat heterogeneity or less stressful conditions at upper Mississippi River structures. However, some of this difference may be due to sample method, as chevron dikes and I-wall rubble were sampled with rock baskets. Differences between taxa richness and diversity between Carl Baer Bendway and Price's Bendway weirs may be due to the age of the rock structures, as the weir field at Carl Baer Bendway was constructed in April 1996 and Price's Bendway weirs were constructed before 1989. Habitat complexity and species richness should increase with time, as weir rocks settle and stabilize and debris accumulates between rocks. Increased habitat complexity increases competition among invertebrate species (Peckarsky, 1986), potentially increasing species diversity. Differences could also be due to different stress levels due to water quality and/or hydrological conditions between the two areas.

If the weir field is influencing invertebrate colonization, taxonomic richness, dominant taxa, and diversity should differ between bendway substrate and weir rocks. Unlike the sand substrate of the downstream non-weir bendway, the large boulder substrate in the weir field provides irregular surfaces for a variety of invertebrate species (DeMarch, 1976), and spaces between rocks provide protection from the current and areas for debris accumulation (invertebrate food and shelter). Taxonomic richness was substantially higher within the weir field, with 34 taxa collected, compared to only seven taxa collected from the bendway without weirs (see Table 3-1). Macroinvertebrate community composition differed considerably between the downstream non-weir bendway and the weir field, with only four of the 34 species collected from the weir field also being collected at the downstream non-weir bendway; only a 12% similarity.

Both areas were dominated by a single species, and diversity was moderate to low (which is reflective of a stressed community), but diversity was higher within the weir field bendway (1.88) than in the non-weir bendway (0.68) (see Table 3-1). *Barbidrilus paucisetus*, a species typical of large river sand habitat (Seagle and Wetzel, 1982), comprised 89% of the non-weir bendway community. Hydrosychid caddisflies (*H. orris*), which are clinger/filterers typical of hard substrates, comprised 67% of the weir rock community. Most other taxa in both areas were rare, with only nine of the 34 taxa collected from the weirs and two of the seven from the non-weirs comprising more than 1% of the community. Other abundant species within the weir field included midges (*Polypedilum convictum* 3%) which cling to rocks (Merritt & Cummins, 1996), zebra mussels (*Dreissena polymorpha* 8%) which need a stable substrate for attachment, and flatworms (*Dugesia tigrina* 4%) which need organic matter accumulation and shelter found within the weir structure (Pennak, 1989). Conspicuously absent from all samples, both in the weir field and non-weir sites, were taxonomic groups intolerant of poor water quality, such as Odonata and Plecoptera. However, these groups have been reported from this river reach (Lesly Conaway, LTRMP, personal communication). The more complex community found within the weir field suggests that weir fields provide more complex habitat than the sand substrate found in bendways without weirs.

3.3 Correspondence Analysis

Correspondence analysis of sample groups and species further illustrates the differences between invertebrate assemblages with habitat type. Macroinvertebrate communities grouped by bendway, emphasizing the difference in communities on weirs and in substrate (Figure 3-1). Weir rock scrape samples plotted on axis 3 along with species representing the macroinvertebrate community of the area, such as zebra mussels (*D. polymorpha*), midges (*Rheotanytarsus sp.*), and caddisflies (*H. orris*). Substrate samples plotted horizontally on axis 2 along with species preferring sand substrate, such as oligochaetes (*B. paucisetus*).

Correspondence analysis also suggests variation in community composition within both bends. Substrate samples from the non-weir bend separated by transect number along axis 2, with the upstream transect samples (Transect 1) plotting furthest left, the middle transect samples (Transect 2) plotting furthest right, and the downstream transect samples (Transect 3) plotting near the zero point. Pearson Correlation, however, showed no significant relationship between CA axis 2 scores and transect location (Table 3-2). Given that the transects are spread over a distance of a mile, the ordination separation is likely a reflection of longitudinal variation in substrate and flow, and the natural variance in community composition expected across a river bend. Weir samples also separated according to weir location, with the downstream weir samples plotting along the top of axis 3. However, Pearson Correlation also showed no significant relationship between CA axis 3 and weir location (Table 3-3).

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The published 1997 A & M Report did not include pages 14 - 16 of this report

5.0 Conclusion

Bendway weirs provide benefits for navigation channel maintenance, while at the same time provide complex habitat for macroinvertebrate communities. The weir field provides a more heterogeneous environment than the surrounding homogenous sand substrate, resulting in a greater species richness and diversity.

Water Level Manipulation/Vegetation Project
Mississippi Pools 24, 25 and 26

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INTRODUCTION

Water levels in Pools 24, 25, and 26 of the Mississippi River are currently being lowered during the summer in an attempt to enhance growth of vegetation on the river bank, islands and mud bars. Water levels are raised in the fall in order to flood these areas. The purpose of this study is to determine the degree to which fish, especially young-of-the-year, utilizes these newly created vegetated areas.

METHODS

In late September and the first week of October of 1997, after the vegetative areas were inundated, we sampled in the vegetation and in open water areas by seining with a 30' x 6' x 1/8" bar-mesh-bag net. Each seine haul in the vegetation covered approximately 200 square feet. The vegetation was dominated by smart weed and millet. Seine hauls in vegetated areas were parallel and vertical to the shore, with one brail pulled about 20 feet from the other. The open water was sampled by hauling the seine parallel to the shore, with one brail pulled along the offshore margin of the vegetation and the other about 20 feet farther offshore. Each seine haul in the open water covered approximately 400 square feet. When sampling in the vegetation, the seine was pulled up onto the gentle sloping bank. In the open water the seine was spread out approximately 20 feet, moved through the water approximately 20 feet and the weighted end lifted. This procedure was effective in the capture of small fish but adults of larger species probably were able to avoid the net. In addition, in order to obtain a conservative indication of whether or not the fish were utilizing the vegetative area more than the open area, all calculations were made on the raw seine capture data. We did not adjust the number of fish captured per 400 square feet open water seine hauls to the 200 square feet of the vegetative seine hauls. Thus we are assuming that the open water seine hauls are only fifty percent as efficient as the seine hauls in the vegetation. A hand-held GPS unit was used to determine coordinates of latitude and longitude of each sampling site. Sampling locations are shown in Figures 1-4.

RESULTS AND DISCUSSION

A total of 83 seine hauls were taken in Pool 24, 80 hauls in Pool 25, and 70 hauls in Pool 26 (Table 1). A total of 27,640 individuals representing 31 species (33 taxa) was collected (Table 2 and 3). In each pool a t statistic (0.05 level) was used to test for significant differences between the number of individual fishes collected per seine haul during the day in the vegetation versus the number collected during the day outside of the vegetation as well as between the number of fishes collected in the vegetation during the day as compared to those collected in the vegetation at night. Similarly a t-test was used to compare the number of grass shrimp (Palaemonetes kadiakensis) caught per seine haul in Pool 26. During the day in all three pools there were significantly more fish collected in the vegetation than outside of the vegetation (Table 4). Also in all three pools there was no significant difference between the mean number of individuals collected in the vegetation at night and the mean number of individuals collected in the vegetation during the day. In Pool 26, which was the only pool where large numbers of grass shrimp were collected, significantly more grass shrimp were collected per seine haul in the vegetation than from outside of the vegetation (Table 5). Significantly more grass shrimp were collected in the vegetation at night than in the vegetation during the day.

More than 97 percent of the fish collected by seining were young-of-the-year. The most numerous species collected was the emerald shiner. Our study demonstrated that many species of fishes and at least one species of invertebrate, the grass shrimp, are heavily utilizing the inundated vegetated areas.

Clearly, the moist-soil vegetated areas are providing nursery sites for young-of-the-year and probably spawning sites as well. Because sampling was conducted during the fall, long after the spawning seasons of all Mississippi River fishes have ceased, we can only speculate that shoreline vegetation communities benefit spawning, or at least recruitment, for forage and sport fishes alike.

There is a need to compare vegetated and open water areas in the spring and early summer to empirically determine if the vegetation is providing spawning and nursery-area benefits to the fish community. There is also a need to determine if the greater abundance of fish we detected in the vegetated areas may have been linked to other habitat factors, and not to the vegetation. This is necessary because fish abundance may have been greater in the vegetated areas than in the open water areas (which were farther offshore) due to differences in depth, water velocity, or other factors. A follow-up study is needed where portions of the shoreline are denuded of vegetation. Thus, the effects of the vegetation can be isolated from other factors, and relationships between the vegetation and fish spawning, nursery area utilization, abundance, and diversity can be isolated and interpreted. The benefits of the vegetation to invertebrates and nutrient cycling could also be examined using this methodology.

Dominant species such as emerald shiner, bullhead minnow, channel shiner, western mosquitofish, and small Lepomis, are all relatively small and would provide suitable forage for larger sportfish species. A food habits study of major predatory fish species in the pools should be conducted to determine whether their production is linked to prey species which may benefit from the water level management regime and the accompanying growth of vegetation.

An added advantage of the vegetated shorelines and the manipulation of water levels is the outstanding habitat that is now provided for various species of waterfowl. The numerous duck blinds interfaced among the moist-soil vegetation is evidence of the interest and success of the Corps' program to promote this plant community in one of North America's most prized ecosystems.

Table 1. Type, location and number of seine hauls taken on three pools of the Mississippi River in 1997.

				GPS location		No. hauls in vegetation		No. open water hauls
Sample Date	River stages ft	Temperature °C	Station Code	Lat.	Long.	Day	Night	Day
				Pool 24				
9/20	27.1	23	A	39°23'33.3"N	90°56'22.3W	11	---	10
9/20	27.1	23	B	39°22'38.2"N	90°55'36.2W	10	10	10
9/21	27.1	22	C	39°24'20.5"N	90°57'09.2W	16	---	16
				Pool 25				
9/27	27.0	22	A	39°05'35.1"N	90°41'27.5"W	10	---	10
9/27	27.0	22	B	39°05'30.1"N	90°41'23.2"W	10	10	10
9/28	27.0	22	C	39°02'57.1"N	90°42'16.9"W	15	---	15
				Pool 26				
10/4	19.0	26	A	38°54'10.0"N	90°13'41.0"W	10	10	10
10/4	19.0	24	B	38°53'9.4"N	90°12'23.6"W	10	---	10
10/5	19.0	22	C	38°52'59.2"N	90°12'26.4"W	10	---	10

Table 2. Fish collected by seining in three Mississippi River pools in the fall of 1997.

Taxon	Day - Vegetated						Day - Open						Night - Vegetated					
	Pool 24		Pool 25		Pool 26		Pool 24		Pool 25		Pool 26		Pool 24		Pool 25		Pool 26	
	M[a]	%	M	%	M	%	M	%	M	%	M	%	M	%	M	%	M	%
Skipjack herring	<1	<1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gizzard shad	1	<1	<1	<1	--	--	<1	<1	<1	1	<1	4	<1	<1	--	--	1	2
Grass carp	--	--	--	--	--	--	<1	<1	--	--			--	--	--	--	--	--
Red shiner	<1	<1	<1	<1	--	--	--	--	<1	<1			--	--	--	--	--	--
Spotfin shiner	8	3	9	4	1	3	<1	<1	5	5	<1	<1	2	1	13	12	<1	1
Common carp	<1	<1	--	--	2	6	--	--	<1	<1			--	--	<1	<1	1	3
Striped shiner	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<1	<1	--	--
Speckled chub	--	--	--	--	--	--	--	--	--	--	<1	<1	--	--			--	--
Silver chub	--	--	--	--	--	--	<1	<1	--	--	--	--	--	--	--	--	--	--
Emerald shiner	190	70	188	80	1	4	46	85	48	46	1	15	112	90	63	57	8	27
Miss. silver minnow	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<1	<1	--	--
River shiner	<1	<1	<1	<1	<1	<1	--	--	<1	1	<1	<1	<1	<1	<1	<1	<1	<1
Ghost shiner	--	--	--	--	<1	<1	<1	<1	--	--	<1	1	--	--	--	--	--	--
Silverband shiner	--	--	--	--	<1	<1	--	--	--	--	<1	1	--	--	--	--	<1	1
Channel shiner	5	2	6	3	<1	1	1	2	16	16	1	16	1	<1	24	22	--	--
Bluntnose minnow	<1	<1	--	--	--	--	--	--	<1	<1	<1	<1	<1	<1	<1	<1	1	2
Bullhead minnow	42	15	1	<1	<1	2	4	6	3	3	3	34	2	1	1	1	--	--
Cyprinid	--	--	--	--	--	--	--	--	<1	<1	--	--	<1	<1	<1	<1	--	--
River carpsucker	--	--	--	--	--	--	--	--	<1	<1	<1	<1	--	--	--	--	--	--
Smallmouth buffalo	--	--	<1	<1	<1	<1	--	--	<1	<1			--	--	--	--	--	--

Table 2 (contd.). Fish collected by seining in three Mississippi River pools in the fall of 1997.

Taxon	Day - Vegetated						Day - Open						Night - Vegetated					
	Pool 24		Pool 25		Pool 26		Pool 24		Pool 25		Pool 26		Pool 24		Pool 25		Pool 26	
	M[a]	%	M	%	M	%	M	%	M	%	M	%	M	%	M	%	M	%
Quillback	--	--	--	--			--	--	<1	<1			--	--	--	--	--	--
Channel catfish	<1	<1	--	--	1	1	<1	<1	<1	<1	--	--	<1	<1	<1	<1	--	--
Flathead catfish	--	--	--	--	--	--	--	--	<1	<1	--	--	--	--	--	--	--	--
Mosquito fish	12	4	13	6	19	72	<1	<1	<1	1	<1	2	4	3	7	7	16	51
Shortnose gar	<1	--	--	--	--	--	<1	<1	--	--	--	--	--	--	--	--	<1	<1
White bass	<1	<1	<1	<1	<1	1	--	--	<1	<1	<1	<1	--	--	--	1	<1	<1
Bluegill	7	3	<1	<1	<1	1	<1	1	--	--	--	--	1	1	--	--	--	--
Green sunfish	--	--	<1	<1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Orange spotted sunfish	5	2	4	1	2	6	2	4	7	6	4	5	2	2	<1	<1	2	6
White crappie	<1	<1	--	--	--	--	--	--	--	--	--	--	--	--				
Black crappie	<1	<1	<1	<1	--	--	<1	<1	--	--	--	--	--	--	--	--	--	--
Lepomis	1	<1	11	5	--	--	<1	<1	22	22	--	--	<1	<1	<1	<1	--	--
Freshwater drum	<1	<1	<1	<1	--	--	1	1	<1	<1	2	18	<1	<1	<1	<1	2	5
TOTAL	10,086	99	8,225	99	800	97	1,964	99	3,634	101	247	96	1,247	98	1,126	100	311	98

[a] M = mean number of fish per seine haul.

Table 3. Common and scientific names of species collected by seining from Pool 24, 25, and 26 of the Mississippi River in the fall of 1997.

Common Name	Scientific Name
Shortnose gar	*Lepisosteus platostomus*
Skipjack herring	*Alosa chrysochloris*
Gizzard shad	*Dorosoma cepedianum*
Grass carp	*Ctenopharyngodon idella*
Miss. silvery minnow	*Hybognathus nuchalis*
Red shiner	*Cyprinella lutrensis*
Spotfin shiner	*Cyprinella spiloptera*
Common carp	*Cyprinus carpio*
Striped shiner	*Luxilus chrysocephalus*
Silver chub	*Macrhybopsis storeriana*
Speckled chub	*Macrhybopsis aestivalis*
Emerald shiner	*Notropis atherinoides*
River shiner	*Notropis blennius*
Ghost shiner	*Notropis buchanani*
Silverband shiner	*Notropis shumardi*
Channel shiner	*Notropis wickliffi*
Bluntnose minnow	*Pimephales notatus*
Bullhead minnow	*Pimephales vigilax*
River carpsucker	*Carpiodes carpio*
Quillback	*Carpiodes cyprinus*
Smallmouth buffalo	*Ictiobus bubalus*
Channel catfish	*Ictalurus punctatus*
Flathead catfish	*Pylodictis olivaris*
Western mosquitofish	*Gambusia affinis*
Freshwater drum	*Aplodinotus grunniens*
White bass	*Morone chrysops*
Bluegill	*Lepomis macrochirus*
Green sunfish	*Lepomis cyanellus*
Orangespotted sunfish	*Lepomis humilis*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*

Table 4. Catch of fish per seine haul in three pools of the Mississippi River in the fall of 1997.

Day-Vegetated			Day-Open			Night-Vegetated		
No.[a]	Mean[b]	SD	No.	Mean	SD	No.	Mean	SD
				Pool 24				
37	953	1,824	36	54	142	10	125	76
				Pool 25				
35	229	213	35	100	157	10	113	92
				Pool 26				
30	27	44	30	8	6	10	31	11

[a] No. = Number of seine hauls.
[b] Mean = Mean catch per seine haul.

Table 5. Mean catch of grass shrimp per seine haul in Pool 26 of the Mississippi River in the fall of 1997.

Day-Vegetated			Day-Open			Night-Vegetated		
No.	Mean	SD	No.	Mean	SD	No.	Mean	SD
59	43	61	58	2	3	10	90	28

[a] No. = Number of seine hauls.

Figure 1. Sampling locations on the Mississippi River Pool 24

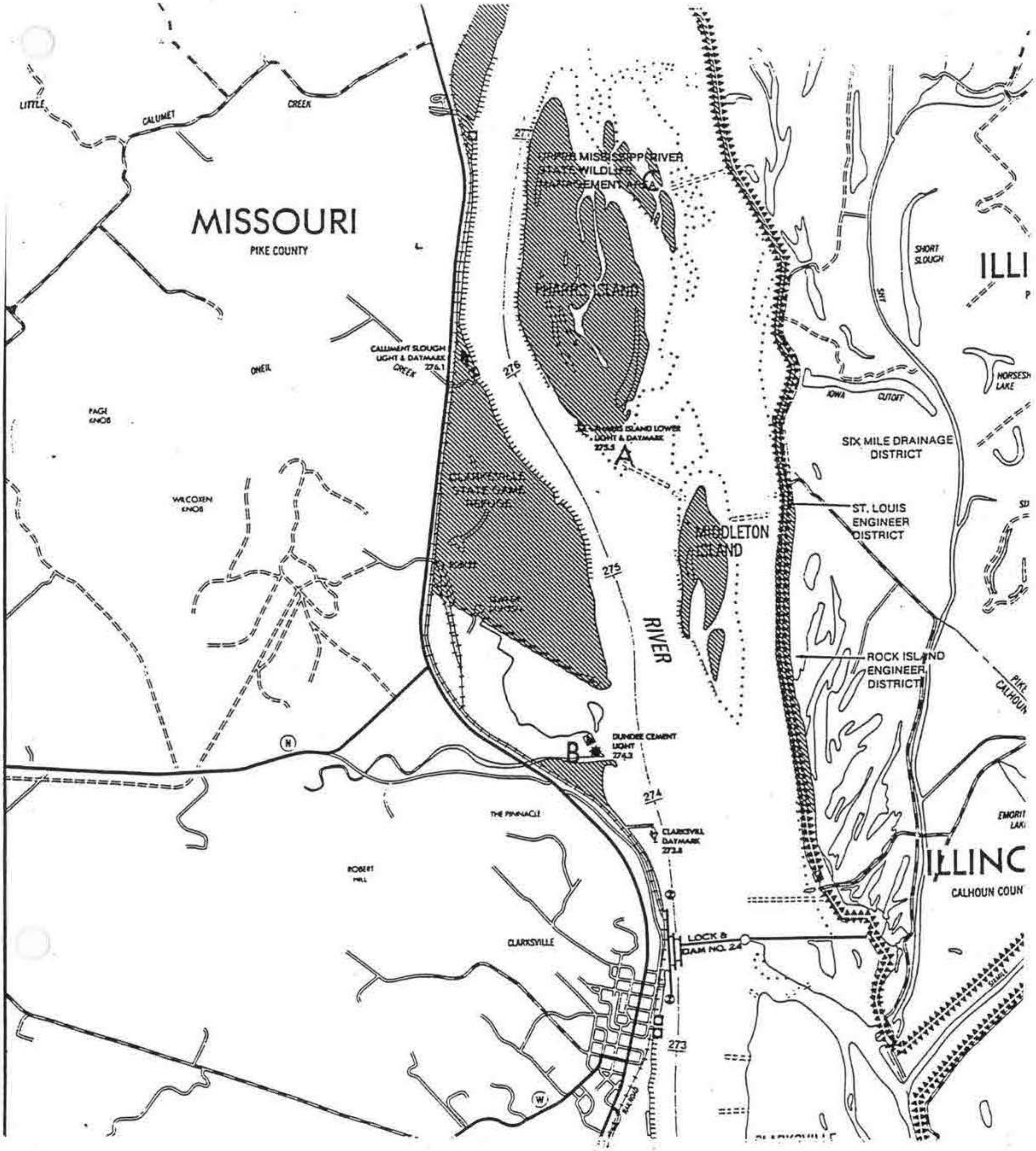


Figure 2. Sampling locations on the Mississippi River Pool 25

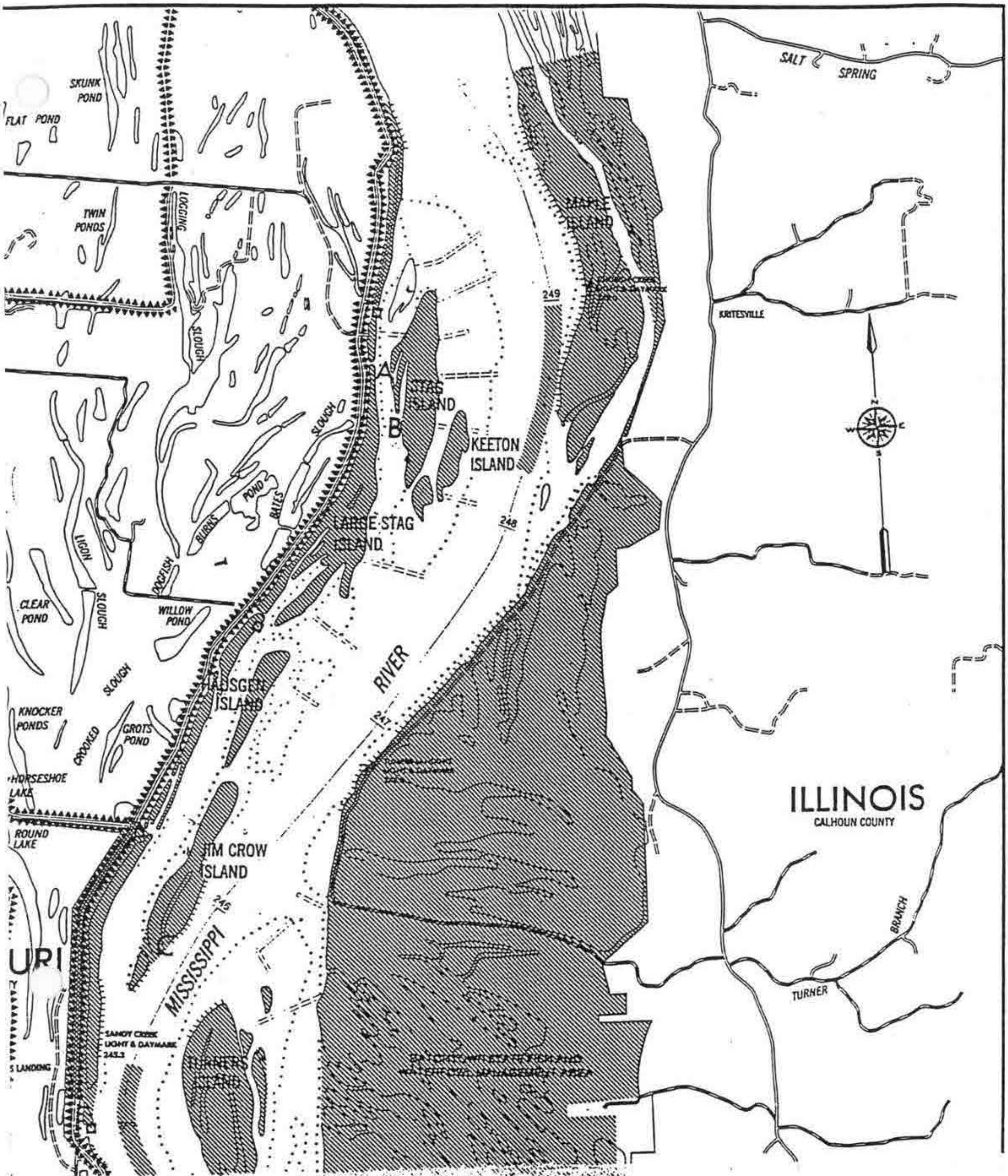


Figure 3. Sampling locations on the Mississippi River Pool 26

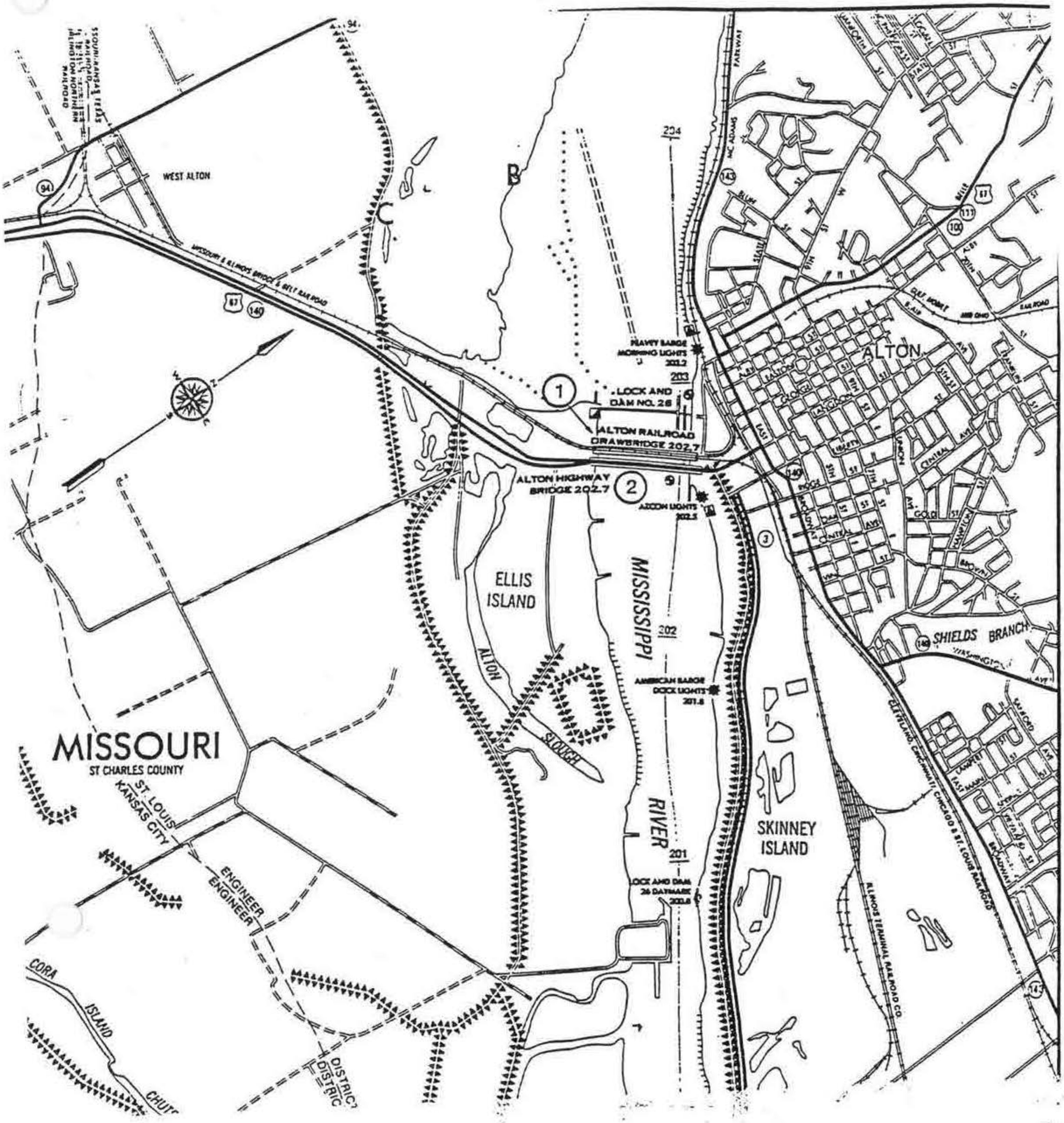
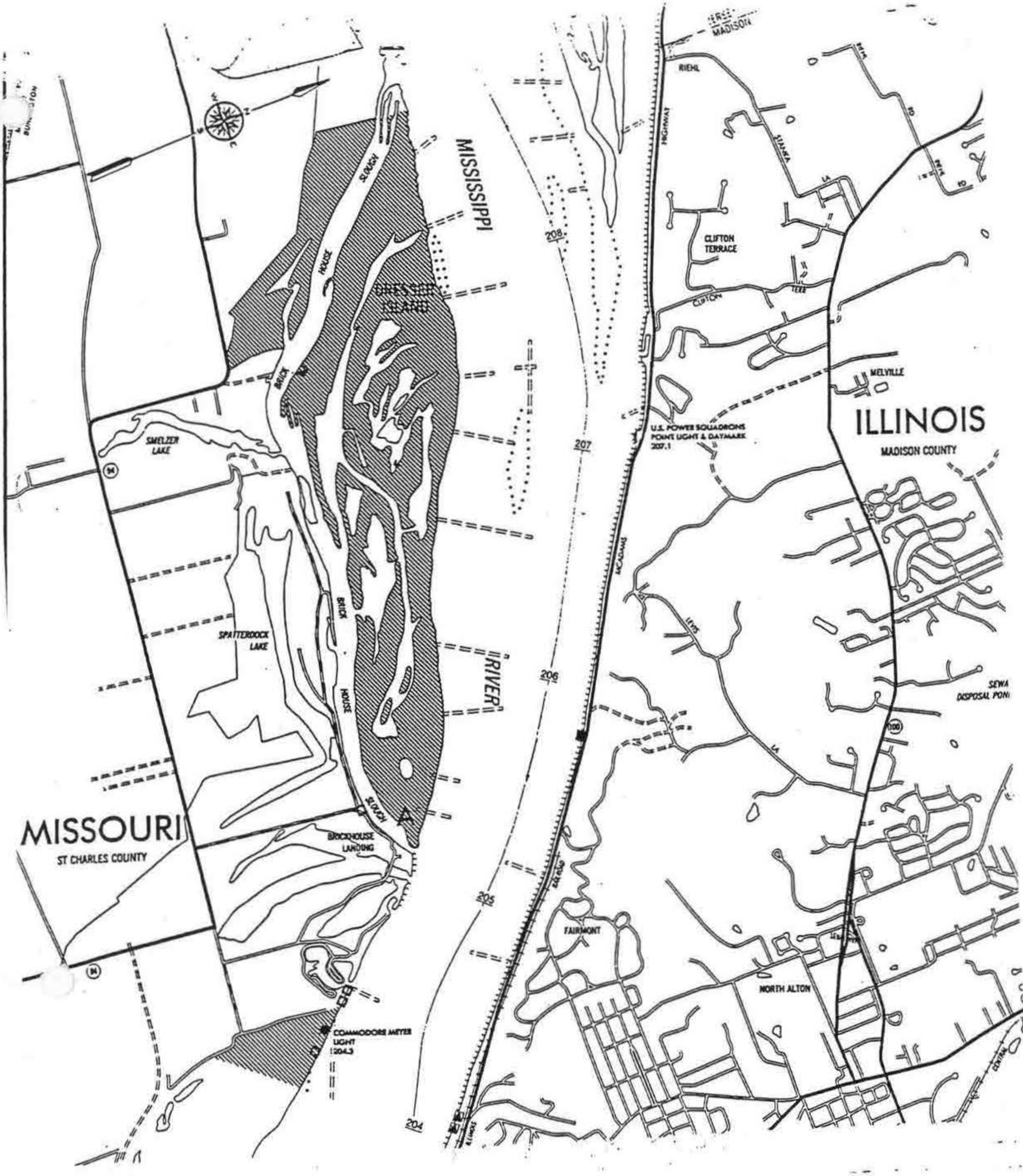


Figure 4. Sampling locations on the Mississippi River Pool 26



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