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Effects of Increased Commercial Navigation Traffic on Freshwater Mussels in the Upper Mississippi River: 1993 Studies

by Andrew C. Miller, Barry S. Payne

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Prepared for U.S. Army Engineer District, St. Louis

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U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
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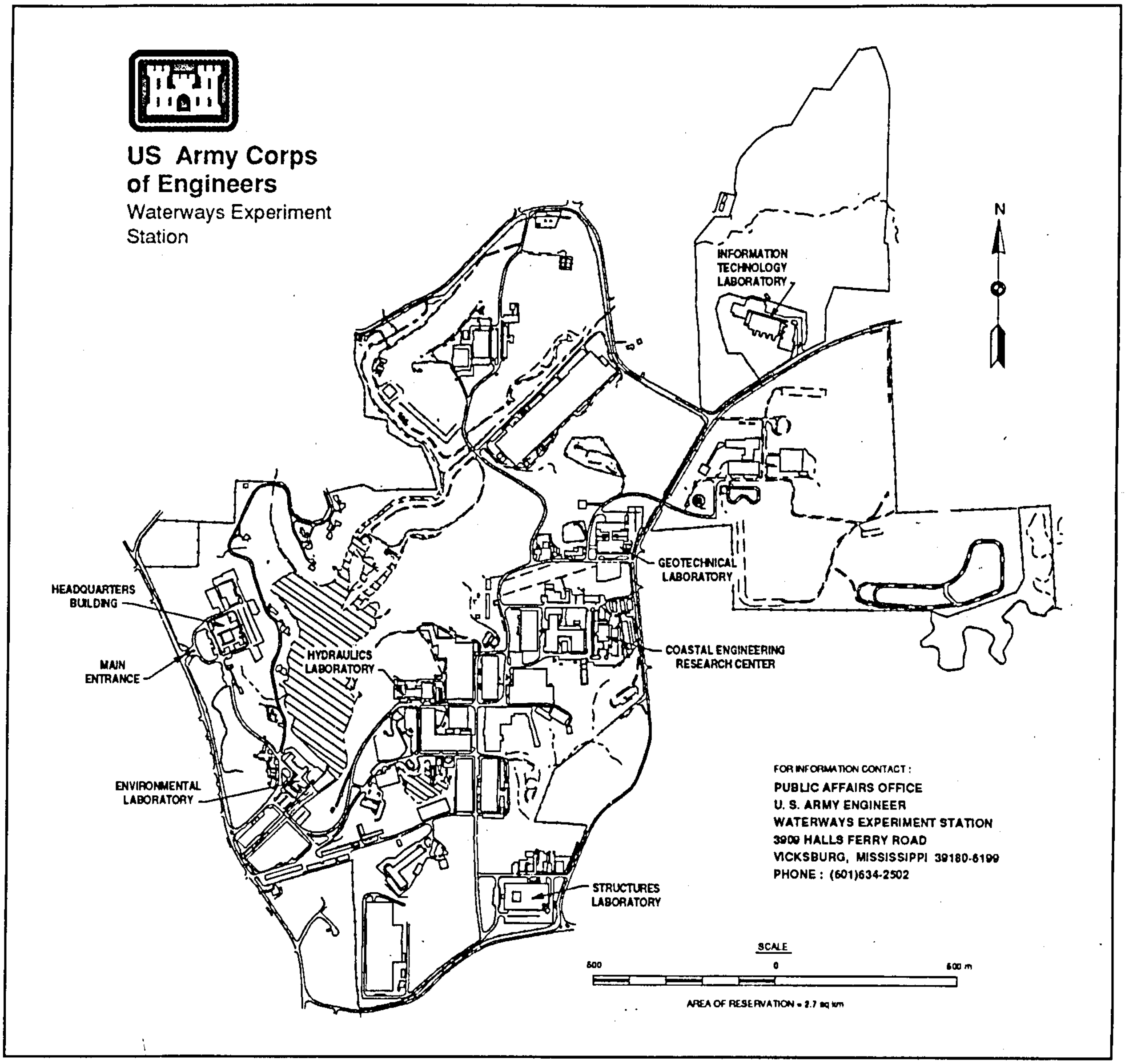

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Preface

In accordance with the Endangered Species Act, Section 7, Consultation, personnel from the U.S. Army Engineer District, St. Louis, and the U.S. Fish and Wildlife Service (USFWS) determined that a monitoring program should be initiated in the upper Mississippi River to assess the effects of existing and projected future increased traffic levels on freshwater mussels including the endangered Higgins' eye mussel, *Lampsilis higginsi*. Concern had been expressed by the USFWS and other agencies that projected increases in commercial traffic resulting from completion of the Melvin Price Locks and Dam, Second Lock Project (formerly known as Locks and Dam 26) at Alton, IL, could negatively affect freshwater mussels. In 1988, the St. Louis District contracted with the U.S. Army Engineer Waterways Experiment Station (WES) to initiate these studies. The purpose of the 1988 studies was to identify sample sites for future work. This report describes results of the fifth full study year, which took place in 1993.

Divers for this study were Messrs. Larry Neill, Kevin Chalk, Pat Hjelm, Rob James, and Jeff Montgomery from the Tennessee Valley Authority (TVA). Mr. B. Will Green, Ms. Gabrielle Meyer, and Dr. David Beckett, University of Southern Mississippi, Hattiesburg, MS, assisted in the field. Ms. Deborah Shafer, WES, was the U.S. Army Corps of Engineers diving inspector. Ms. Sarah Wilkerson, Jackson State University, Jackson, MS, prepared all figures except maps, and Ms. Erica Hubertz, University of West Florida, FL, and Mr. David Felder, Millsaps College, Jackson, MS, identified and measured mussels. Comments on an early draft of this report were provided by Mr. Dan Ragland, St. Louis District. Mr. Robert Read of the Wisconsin Department of Natural Resources, recently deceased, first introduced the authors to the molluscan resources of the east channel and donated his time to assist at this location every year. Foul weather and safety gear was provided by TVA.

During the conduct of these studies, Dr. John W. Keeley was Director, Environmental Laboratory (EL), WES; Dr. Conrad J. Kirby was Chief, Ecological Research Division (ERD), EL; and Dr. Edwin A. Theriot was Chief of the Aquatic Ecology Branch (AEB), ERD. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, AEB.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To obtain
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers

1 Introduction

Background

Operation of the second lock at the Melvin Price Locks and Dam (formerly the Locks and Dam 26 (Replacement) project) will increase the capacity for commercial navigation traffic in the upper Mississippi River (UMR). Changes in water velocity at the substratum-water interface and sediment scour as a result of propeller wash from commercial navigation traffic could detrimentally affect freshwater mussels (Mollusca: Unionidae), including *Lampsilis higginsi*, listed as endangered by the U.S. Fish and Wildlife Service (USFWS) (1993). In accordance with the Endangered Species Act, Section 7, Consultation, personnel from the U.S. Army Engineer District, St. Louis, and the USFWS determined that a monitoring program should be initiated to assess the effects of projected traffic levels on freshwater mussels including *L. higginsi*. Other agencies that participated in the development of this monitoring program included the U.S. Army Engineer Divisions, Lower Mississippi Valley and North Central; U.S. Army Engineer Districts, St. Paul and Rock Island; and selected State conservation agencies.

A reconnaissance survey to choose sample sites and to conduct preliminary sampling was conducted in 1988 (Miller et al. 1990) and also in 1989 (Miller and Payne 1991). Detailed quantitative and qualitative studies at selected mussel beds were initiated in 1989 and will continue through 1994. This report contains an analysis of data collected in August-September 1993, the fifth full year of the monitoring program.

Study Design

This research was designed to obtain information on changes in water velocity and suspended solids near the substrate-water interface when vessels pass dense and diverse mussel beds in the UMR. As part of these physical studies, important biotic parameters (species richness, species diversity, density, growth rate, and population structure of dominant mussel species) are being monitored. Physical and biological data are collected at a farshore (experimental) and nearshore (reference) site within each mussel bed. Experimental sites are located close to th. navigation channel (affected by vessel passage), and reference sites are located as far as possible from the channel (affected to a lesser extent by vessel passage). This research will couple empirical data from physical and biological studies to make predictions of the effects of vessel passage on freshwater mussels.

The objective is to determine whether commercial navigation traffic is negatively affecting *L. higginsi*. This is being accomplished by collecting information on all species of bivalves. As appropriate, results will be applied to *L. higginsi*. This surrogate species concept is being used since it is extremely difficult to obtain information on density, recruitment, etc., for uncommon species such as *L. higginsi*. In addition, intensive collecting could be detrimental to the continued existence of this species. The following six parameters, considered to be indicative of the health of a mussel bed, are being used to determine if movement of commercial navigation vessels is negatively affecting freshwater mussels.

a. Decrease in density of five common-to-abundant species.

b. Presence of *L. higginsi* (if within its range).

c. Live-to-recently-dead ratios for dominant species.

d. Loss of more than 25 percent of the species.

e. Evidence of recent recruitment.

f. A significant change in growth rates or mortality of dominant species.

Selected studies are being done at each bed each year of this monitoring program. Quantitative techniques are being used to collect mussels at each bed every second year. Each year qualitative methods are being used to collect mussels and search for endangered species. In addition, assessments of growth of dominant species have been conducted.

These data are being collected yearly during a period when traffic levels are not expected to increase. After 1994, biological and physical data will be collected at each bed once every 5 years. Based upon this plan, quantitative and qualitative sampling should be done at all five beds in the summer of 1999. This will be done until traffic levels have increased as a result of completion of the Melvin Price Locks and Dam by an average of one tow per day above 1990 levels in the pool where monitoring takes place. Studies will then resume at the original rate (annually) and continue until 2040, the economic life of the project. Results of studies from each year are being reviewed annually to determine the need for altering sampling protocol. A schedule of studies to be conducted at each mussel bed appears in Table 1. Information from the previous years are available: 1988 (Miller et al. 1990), 1989 (Miller and Payne 1991), 1990 (Miller and Payne 1992), 1991 (Miller and Payne 1993), and 1992 (Miller and Payne 1994).

Purpose and Scope

The purpose of this monitoring program (1988-94) is to obtain baseline data on physical (water velocity and suspended solids) and biological conditions (density, species richness, relative species abundance, population demography of dominant species, etc.) at five mussel beds between River Miles (RMs) 299 and 635 in the UMR. This report presents results of sampling conducted in Pool 10 during 1993. Because of high water, no data were collected in Pools 24 and 14 as planned (Table 1).

2 Study Area and Methods

Study Area

The UMR was once a free-flowing, braided, pool-riffle habitat with side channels, sloughs, and abandoned channels. This riverine habitat was altered as a result of passage of the Rivers and Harbors Act of 3 July 1930, which authorized the U.S. Army Corps of Engineers to construct a navigation channel with a minimum depth of 9 ft[1] and a minimum width of 300 ft. Development of this navigation channel, which included construction of locks, dams, dikes, wing dams, and levees, converted the river to a series of run-of-the-river reservoirs characterized by relatively slow-moving water and extensive adjacent lentic habitats. Typically, the upper reaches of pools in the UMR have comparatively high water velocity and coarse substratum, whereas the lower reaches are more lake-like with deep, low-velocity water and fine-grained sediments (Eckblad 1986).

Study Sites

In 1988, preliminary data on physical and biological conditions were collected at mussel beds in Pools 26, 25, 24, 19, 18, 17, 14, 10, and 7. In 1989, additional preliminary studies were conducted in Pools 12 and 13. Both qualitative and quantitative sampling techniques were employed to determine if mussel beds identified from resource maps (Peterson 1984) were suitable for detailed study. Based on information from these surveys, a list of mussel beds suitable for more detailed study was prepared.

Personnel of the St. Louis District, the U.S. Army Engineer Waterways Experiment Station (WES), and the USFWS participated in the final selection process. Beds chosen for detailed study are located at the following river miles (Figure 1):

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page viii.

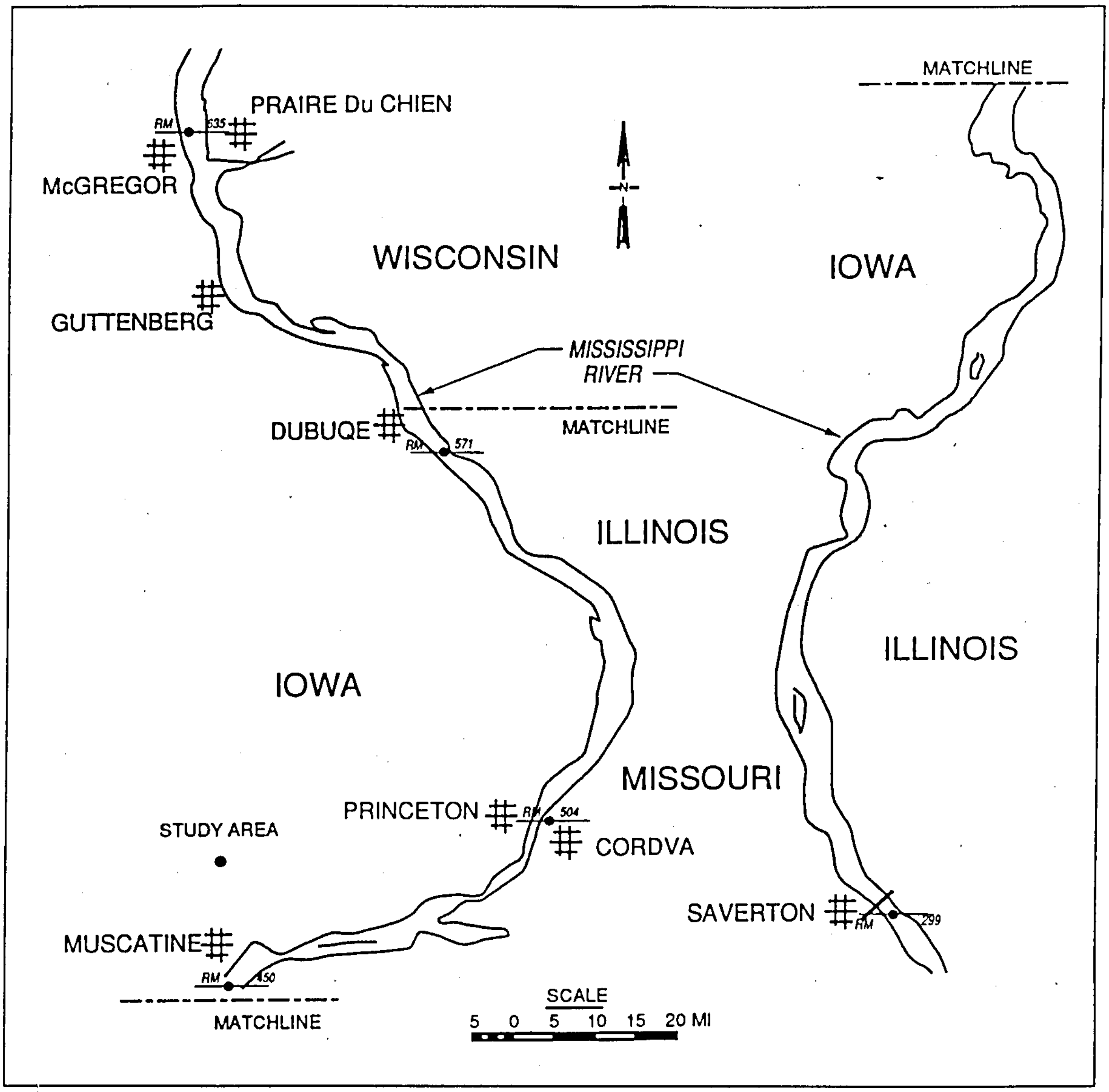

Figure 1. Location of five mussel beds chosen for detailed study in UMR, 1989-1994

Each bed is 1 to 3 km long; exact location of sampling sites on beds often varies slightly from year to year. A brief description of sites sampled for this program appear below:

Pool	RM
24	299.6 RDB
17	450.4 RDB
14	504.8 LDB
12	571.5 RDB
10	635.2 RDB (Main Channel)
Note: RDB = right descending bank; LDB = left descending bank.	

Near Prairie du Chien, WI, the UMR splits into an east and west or main channel (Figure 2). The east channel is slightly less deep and not as wide as the main channel, although it is navigable. Sediments in both the east and main channel consist of sand and silt with less than 5-percent gravel by weight. Numerous sloughs, aquatic plant beds, and islands characterize much of Pool 10.

The study site for this monitoring program is in the west or main channel of the UMR. During this year, samples were also collected in the turning basin of the east channel and a reference site located about 0.5 km downriver. Samples have been collected in previous years at the turning basin and reference site. Although the east channel sites are not in this monitoring plan, they were sampled in 1993 since samples could not be taken downriver because of high water.

Grain size distribution of each substratum sample was evaluated as the mussels were removed (Figures 3 and 4). In the main channel at both nearshore and farshore sites, sediments were dominated by particles less than 6.35 mm in diameter. Typically, this size of particle comprised 40 to 60 percent of the bottom material. Large-diameter particles, greater than 34 mm, consisted mainly of dead shells or shell material and were usually less common than fine-grained particles.

Sediments in the turning basin consisted almost entirely of small-diameter sediments, less than 6.35 mm (Figure 4, top). The reference site sediments were dominated with small-diameter particles, although some larger sized material was also present (Figure 4, bottom). As with the main channel, the majority of the larger sized material consisted of shells and shell fragments with very little gravel.

Methods

Preliminary reconnaissance

A diver equipped with surface air supply and communication equipment made a preliminary survey of each sample site before detailed studies began. He obtained information on substrate type, water velocity, and presence of mussels. A fathometer was used to measure water depth, and distance to shore was determined with an optical range finder.

Qualitative collections

Qualitative samples were obtained by two divers working simultaneously. The pair of divers was given a total of 12 nylon bags and instructed to place about 5 mussels in 3 bags and about 20 mussels in the remaining 9 bags.

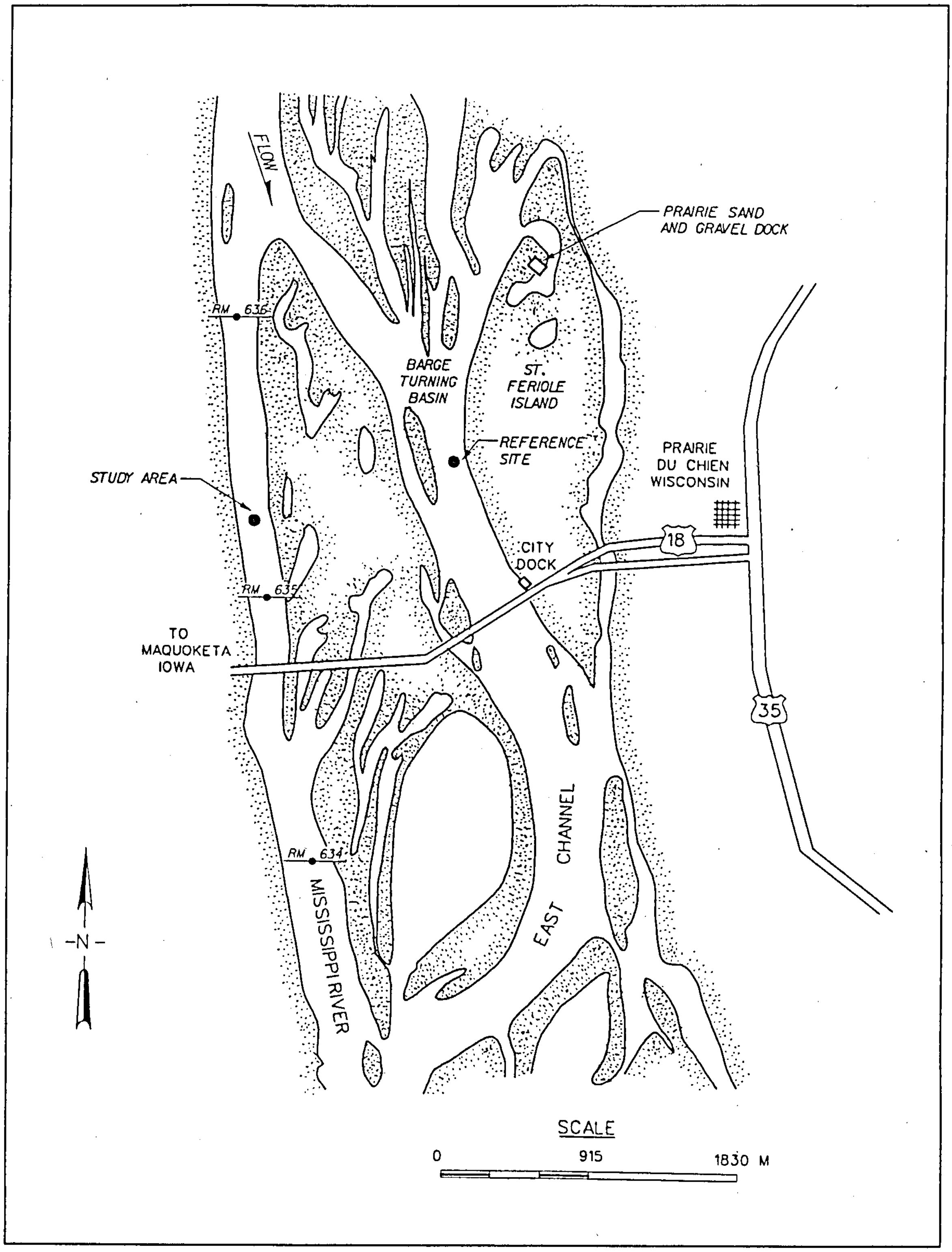

Figure 2. Samples collected in main channel and at turning basin and reference site in east channel

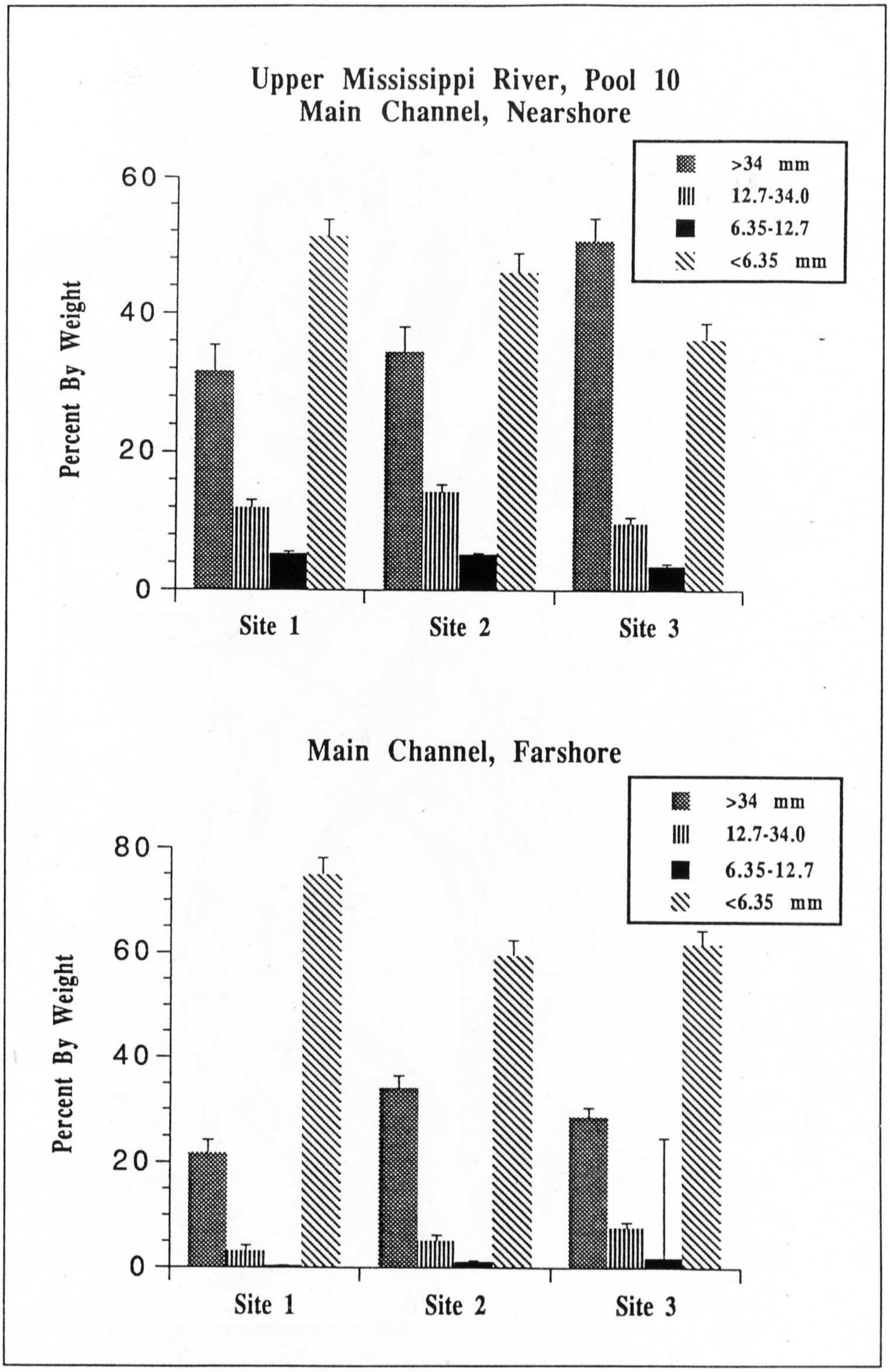

Figure 3. Sediment characteristics at a nearshore and farshore site in main channel

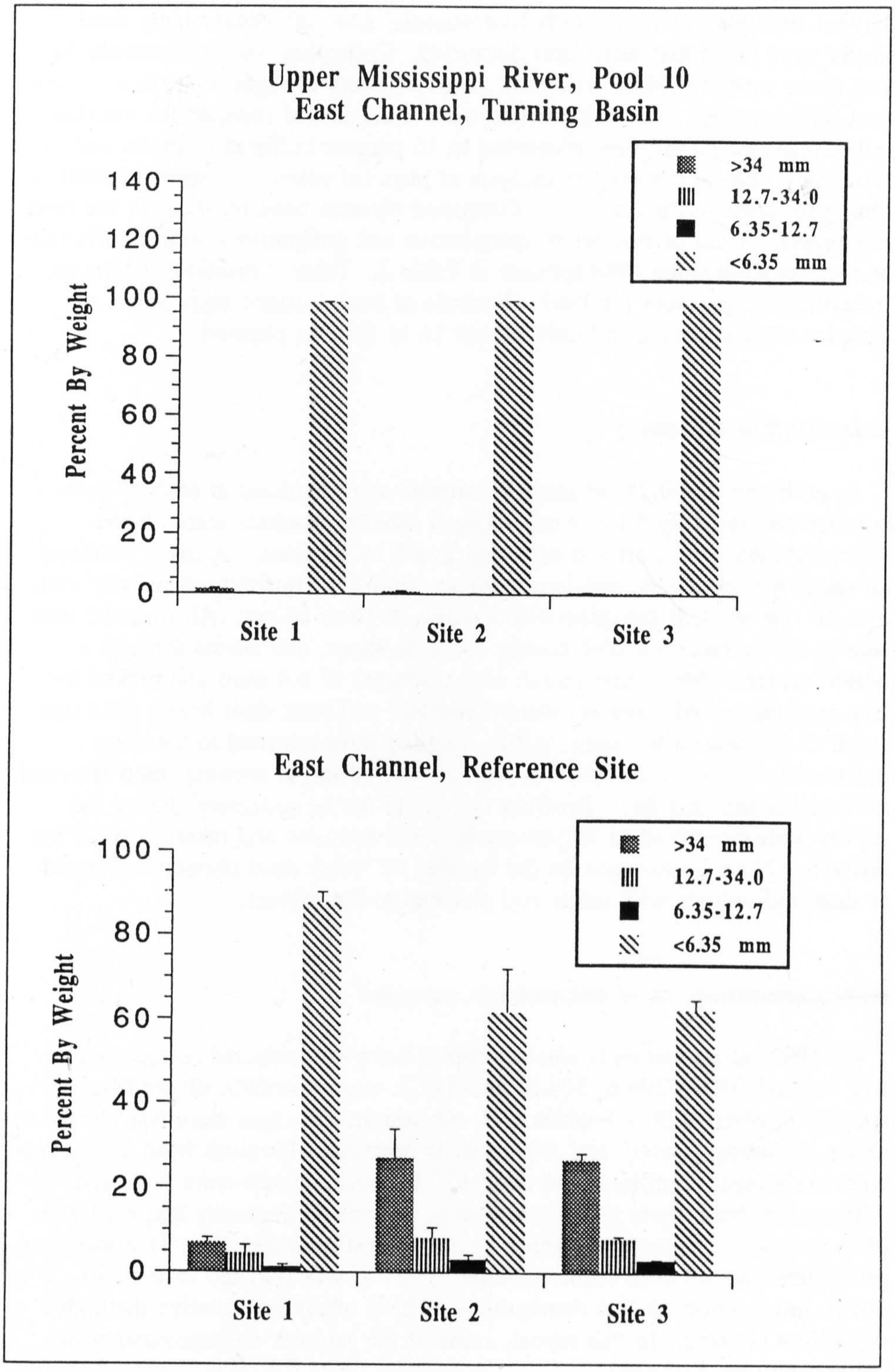

Figure 4. Sediment characteristics at turning basin and reference site in east channel

Divers attempted to collect only live mussels, although occasionally dead shells were taken that were later discarded. Collecting was done mainly by feel since water visibility was poor. Mussels were brought to surface, identified, and counted. Selected mussels were shucked and retained for voucher. Additional specimens were preserved in 10-percent buffered formalin and returned to the laboratory for analysis of physical condition (ratios of shell length to tissue dry mass, etc.). Unneeded mussels were returned to the river unharmed. A list of number of quantitative and qualitative samples collected at each location since 1988 appears in Table 2. Table 3 provides details on the collection protocol for 1993. Because of exceptionally high water, no samples were collected in Pools 24 and 14 in 1993 as planned.

Quantitative sampling

At each site, ten 0.25-m^2 quadrat samples were obtained at each of three subsites separated by 5 to 10 m. At each subsite, quadrats were placed approximately 1 m apart and arranged in a 2 by 5 matrix. A diver removed all sand, gravel, shells, and live molluscs within the quadrat. It usually took 5 to 10 min to clear the quadrat to a depth of 10 to 15 cm. All material was sent to the surface in a 20-ℓ bucket, taken to shore, and sieved through a nested screen series (finest screen with apertures of 6.4 mm) and picked for live organisms. All bivalves were identified, and total shell length (SL) measured to the nearest 0.1 mm. All *L. higginsi* were returned to the river unharmed. Some of the bivalves were measured in the evening, then returned to the river the next day. Bivalves that could not be processed during the survey were preserved in 10-percent buffered formalin and taken to WES for analysis. Notes were made on the number of "fresh dead mussels" (defined as dead individuals with tissue still attached to the valves).

Nonquantitative, total substratum samples

In 1992, at mussel beds where samples were not collected using quantitative methods (RMs 299.6, 504.8, and 635.2, main channel), divers filled a specific number of 20-ℓ buckets with substratum. Buckets were transported to shore, sediments sieved, and live mussels removed. Bivalves from all buckets were combined, identified, and counted. Because mussels were collected without size bias, these data were used to analyze demography and evidence of recruitment. These data cannot be used to estimate density. This sampling procedure was not used before or after 1992. It was initiated in 1992 to obtain information on size demography at beds where quantitative methods would not be used. In this report, some of the samples collected using this method will be discussed.

Data analysis

All bivalve data (lengths, weights, etc.) were entered on a spreadsheet and stored in ASCII files. Summary statistics were calculated using functions in the spreadsheets or with programs written in BASIC or SAS (Statistical Analysis System). All computations were accomplished with an IBM or compatible personal computer. Biological and physical data were plotted directly from ASCII files using a Macintosh SE computer and laser printer.

3 Results

Community Composition

Using qualitative methods, a total of 25 species and 1,360 native mussels were collected in 84 samples taken from the east and main channel of Pool 10, UMR (Table 4). Using quantitative methods, 25 species and 1,176 bivalves were obtained in 160 samples. The bivalves collected using quantitative methods contain native Unionidae as well as the nonindigenous zebra mussel, *Dreissena polymorpha*. In 1993, zebra mussels were still uncommon at this location. *Lampsilis higginsi*, listed as endangered by the USFWS (1993), was collected using quantitative and qualitative methods.

Community Characteristics

Twenty-four qualitative samples were collected in the main channel of the UMR in September 1993 (see Appendix A - Table A1). The fauna was dominated by the commercially valuable threeridge, *Amblema plicata plicata*, which comprised 62.1 percent of the fauna and was found in 23 of 24 of the samples (95.8 percent). Ten species each comprised 1 to 8 percent of the fauna, and 11 species were less than 1 percent of the fauna. The high dominance of *A. p. plicata* at both nearshore and farshore sites of the main channel is illustrated graphically in Figure 5. The molluscan fauna has evenness values of approximately 0.5 (on a scale of near 0.0 to near 1.0) and spans two orders of magnitude (see Tables A2 and A4).

Using quantitative methods, a total of 19 and 20 species were collected at nearshore and farshore sites in the main channel (Table A2-A5). Community composition was similar at both locations and did not differ greatly from samples collected using qualitative methods. For example, *A. p. plicata* comprised 53 and 60 percent of the nearshore and farshore samples, respectively. Quantitative sampling retrieved more of the diminutive *Truncilla truncata* (between 12 and 16 percent) than qualitative methods (7.4 percent) (Table A1). Overall species diversity (H') was similar at both sites, 1.70 and 1.58 at the nearshore and farshore sites, respectively. The greater evenness of this fauna, in comparison to the main channel sites, is illustrated in Figure 6.

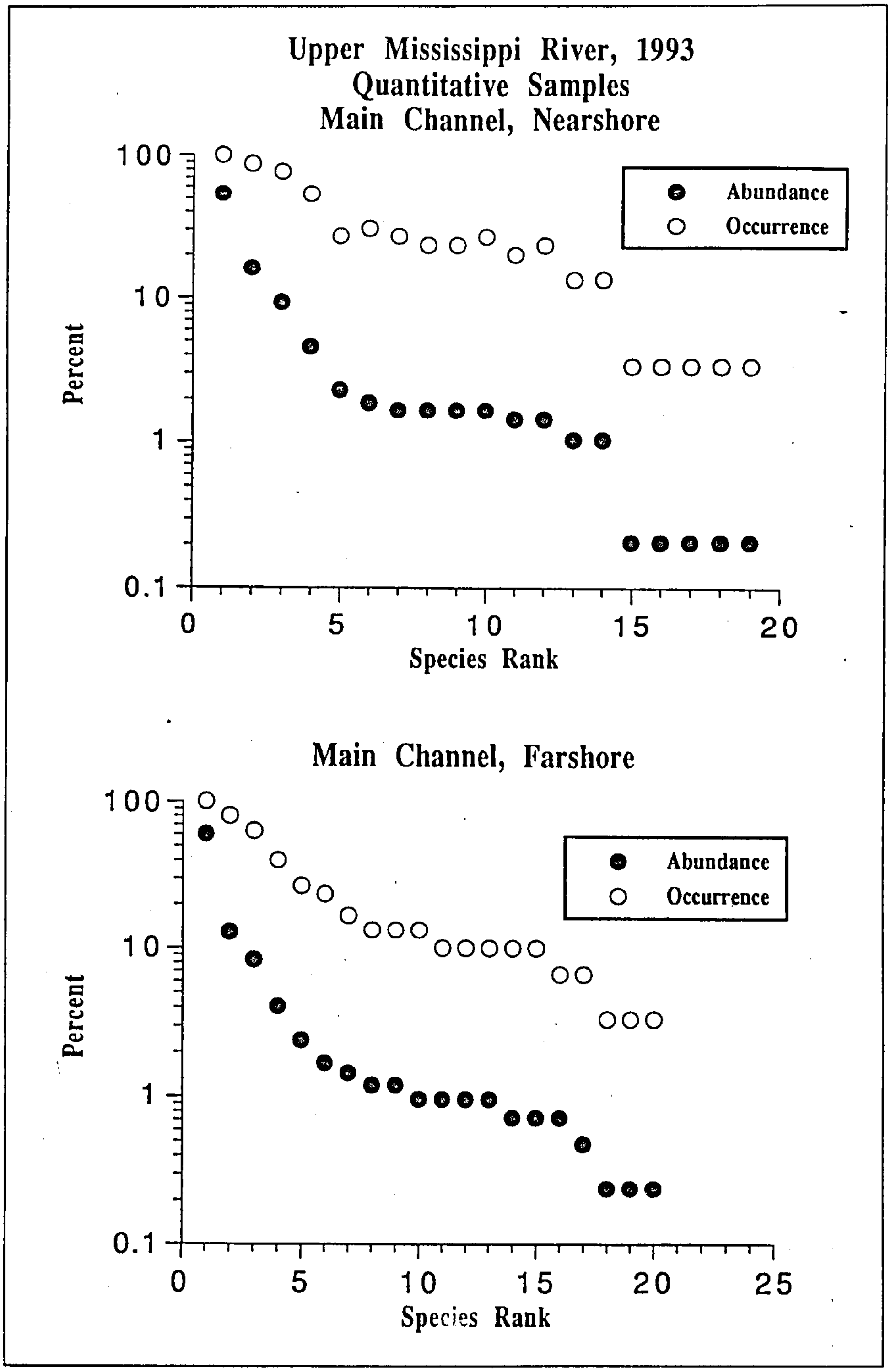

Figure 5. Percentage abundance and occurrence versus species rank for all mussels collected using quantitative methods in main channel of UMR, 1993

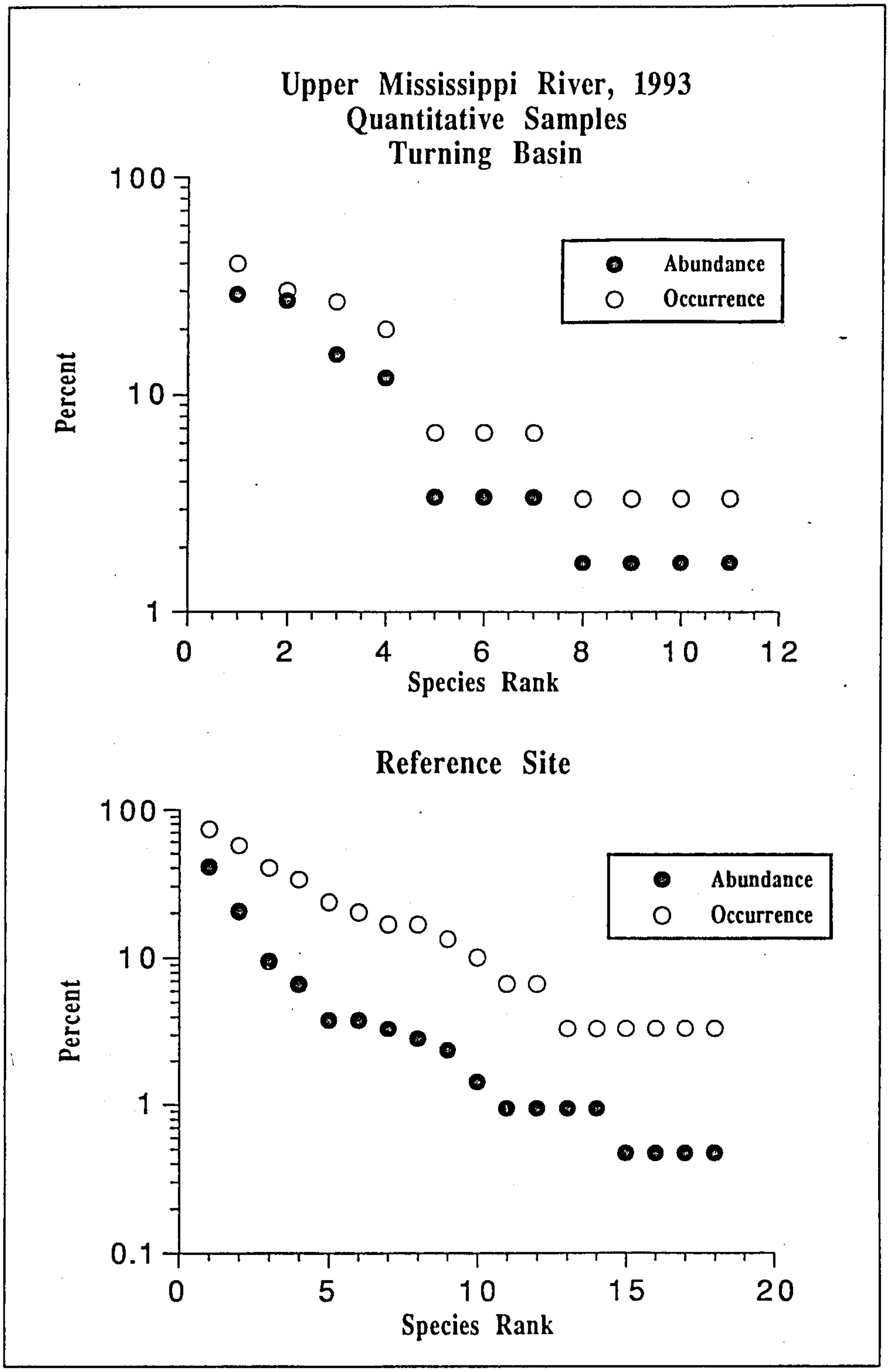

Figure 6. Percentage abundance and occurrence versus species rank for all mussels collected using quantitative methods in east channel of UMR, 1993

In the turning basin, evenness was 0.8 (for three subsites, see Appendix B - Table B2); at the reference site, it was 0.56 (Table B4).

Sixty qualitative samples were obtained from the east channel of the UMR in September 1993 (Table B1). Twenty-four species were identified from the nearly 1,000 individuals collected. As in the main channel, *A. p. plicata* comprised more than 50 percent of the fauna. Ten species each comprised 10 to 1 percent, and 13 species each comprised less than 1 percent of the mussel assemblage. Using quantitative methods, 59 individuals and 11 species were collected in the turning basin of the east channel (Table B2). This assemblage was more evenly distributed than the fauna of the main channel evaluated using quantitative methods. In the turning basin, two species comprised more than 25 percent of the mussels, and two other species each comprised 10 to 15 percent of the fauna. Species diversity was 1.87, which was higher than in the main channel.

Eighteen species and 212 mussels were collected at the reference site, located downriver of the turning basin (Figure 2, Table B4). This fauna was evenly distributed, overall species diversity was 1.98 (higher than in the main channel), and *A. p. plicata* and *Obliquaria reflexa* comprised 41 and 20 percent of the fauna, respectively. Eight species comprised between 3 and 10 percent, and eight species each comprised less than 1 percent of the fauna. Species diversity was 1.98, slightly greater than in the turning basin and the main channel.

The relationship between cumulative number of individuals and species collected provides an indication of the difficulty of obtaining uncommon species. In the main channel, species were collected at a slightly greater rate at the nearshore as compared with the farshore sites (Figure 7). However, after approximately 360 individuals were collected, both sites supported about the same number of species. Species were collected at the same rate at the turning basin and reference site in the east channel (Figure 8). Had more individuals been collected at the turning basin, it would be possible to compare these two sites with respect to difficulty of obtaining additional species. However, previous sampling has indicated that species composition at both sites is approximately equal.

Evidence of Recent Recruitment

Evidence of recent recruitment (successful reproduction) is quantified by determining the percentage of individuals and species less than 30 mm total SL. Typically, there is successful community-wide recruitment at this location each year. In the main channel, 15.66 and 11.54 percent of the fauna showed evidence of recent recruitment at nearshore and farshore sites, respectively (Tables A2 and A4). Approximately half of the species showed evidence of at least some recent recruitment. In the east channel, 8.5 and 41.5 percent (in the turning basin and reference site, respectively) of the fauna exhibited evidence of recent recruitment (Tables B2 and B4). Some species are so

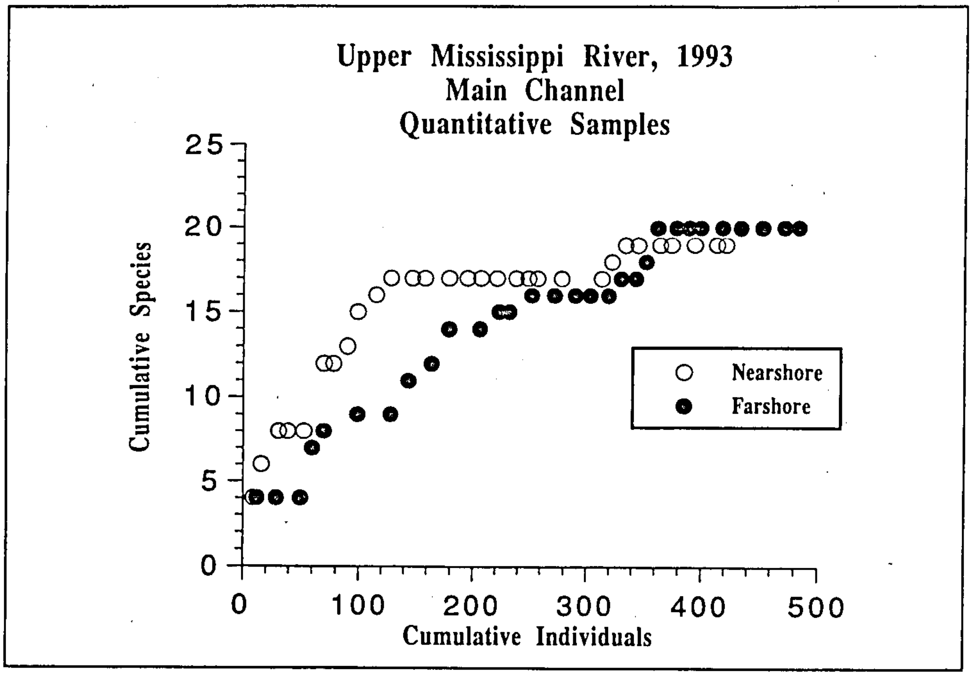

Figure 7. Cumulative number of species versus cumulative number of individuals collected using quantitative methods at a nearshore and farshore site in main channel, 1993

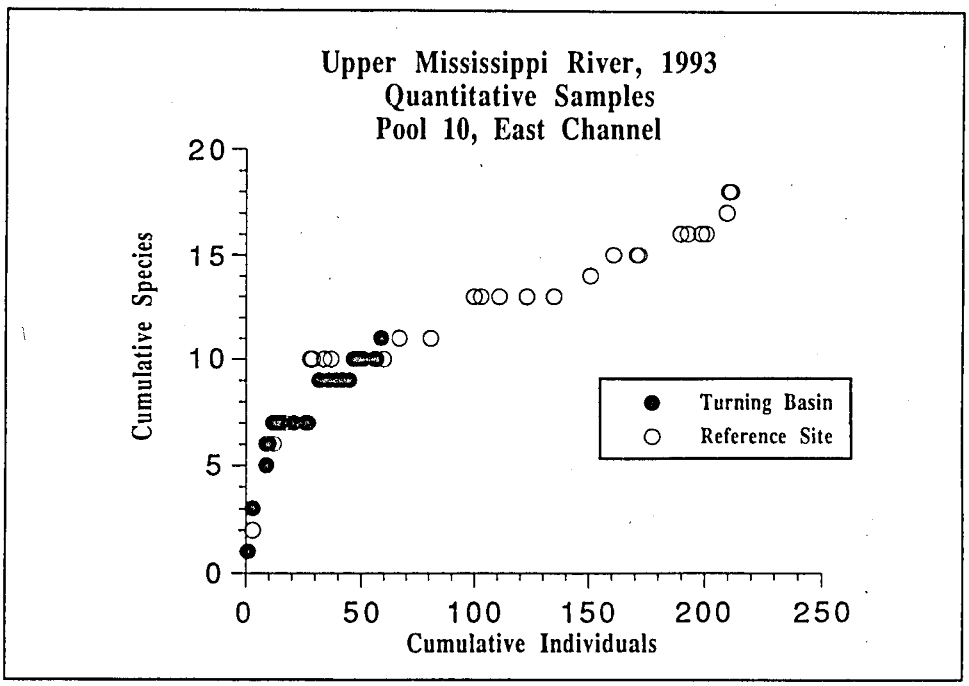

Figure 8. Cumulative number of species versus cumulative number of individuals collected using quantitative methods at barge turning basin and reference site of east channel, 1993

uncommon that only one or two individuals were found; it is possible that juveniles were present but not collected.

Density

Density (individuals/square meter) at the nearshore (64.5) and farshore sites (56.1) were not significantly different ($F = 2.01$, $P > 0.05$, Table 5). Likewise, mean biomass (grams/square meter) at the nearshore and farshore sites was not significantly different ($F = 0.07$, $P > 0.05$). In the east channel, density and biomass were significantly greater at the reference site than in the turning basin ($P < 0.05$, Table 6). A graphical depiction of these density and biomass values is in Figures 9 and 10.

Evidence of Recent Mortality

As the quantitative samples were processed, the number of fresh dead bivalves (individuals that were obviously dead but still had tissue attached to the valves) were counted (Table 7). No fresh dead mussels were found in the main channel, although one individual was found in the barge turning basin in the east channel. Considering all quantitative samples collected in Pool 10, 0.09 percent were considered fresh dead.

Presence of *Lampsilis higginsi*

Based on qualitative sampling methods, *L. higginsi*, listed as endangered by the USFWS (1993), comprised 0.25 percent (one individual collected) in the main channel (Table 8). Using quantitative methods, four individuals (0.11 percent of the collection) were found. Occurrence of the Higgins' eye mussel in the east channel was similar to that in the main channel. Using qualitative methods, 2 of 956 mussels (0.21 percent) were *L. higginsi*. No *L. higginsi* were collected in the east channel using quantitative methods in 1993.

Demographic Analysis

Amblema plicata plicata

In the main channel, *A. p. plicata* ranged from approximately 10 to 100 mm long (Figure 11). Large mussels (greater than 70 mm long) dominated the population. The sawtoothed nature of the length frequency distribution of mussels greater than 70 mm suggested multiple year classes; there was evidence of cohorts centered at 71, 75, 79, 83, and 93 mm. The four minor peaks from 71 to 83 mm were regularly spaced at a 4-mm interval, possibly

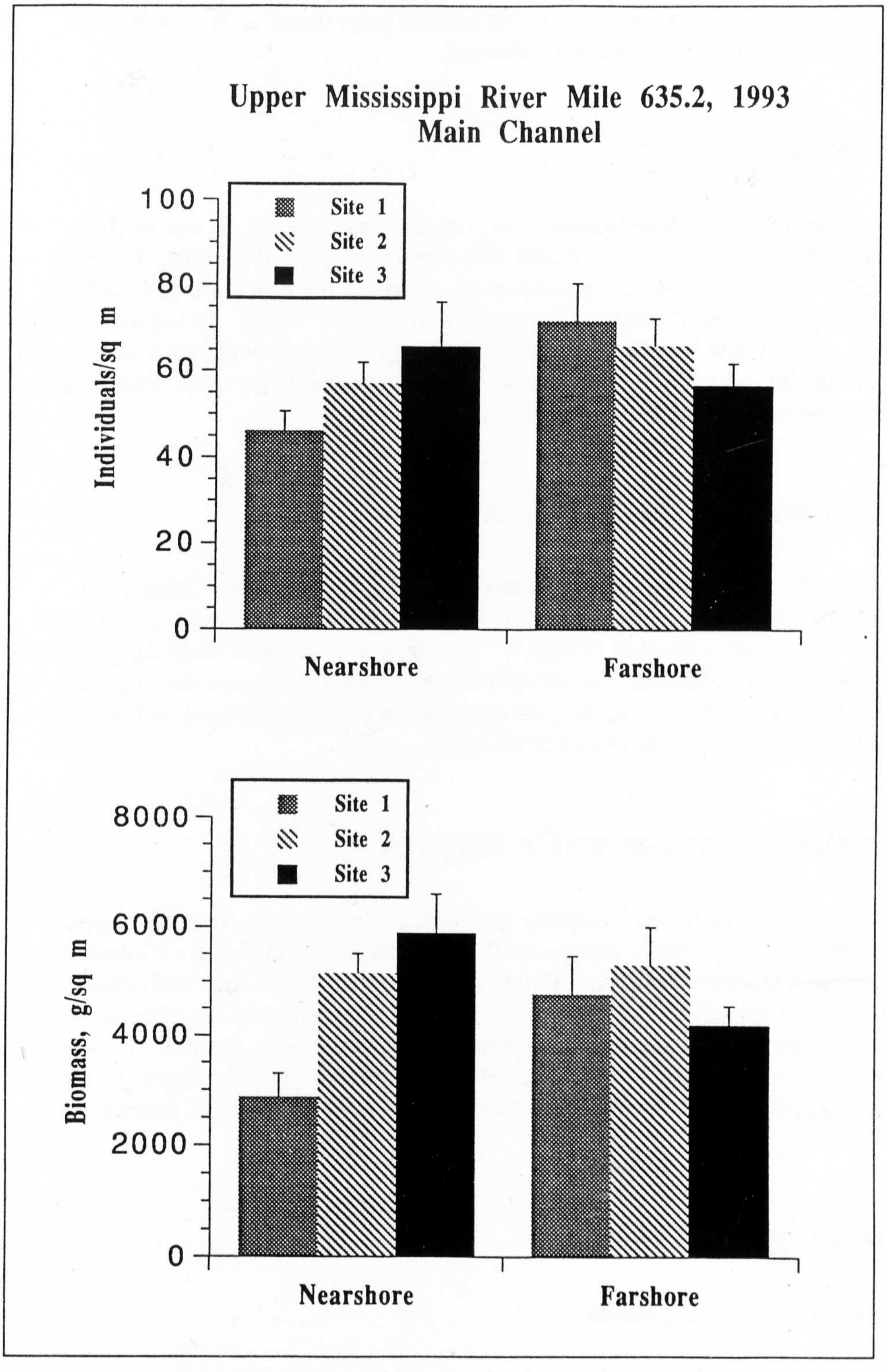

Figure 9. Mean density (individuals/sq m) and standard error of mean for freshwater mussels collected at a nearshore and farshore site in main channel, 1993

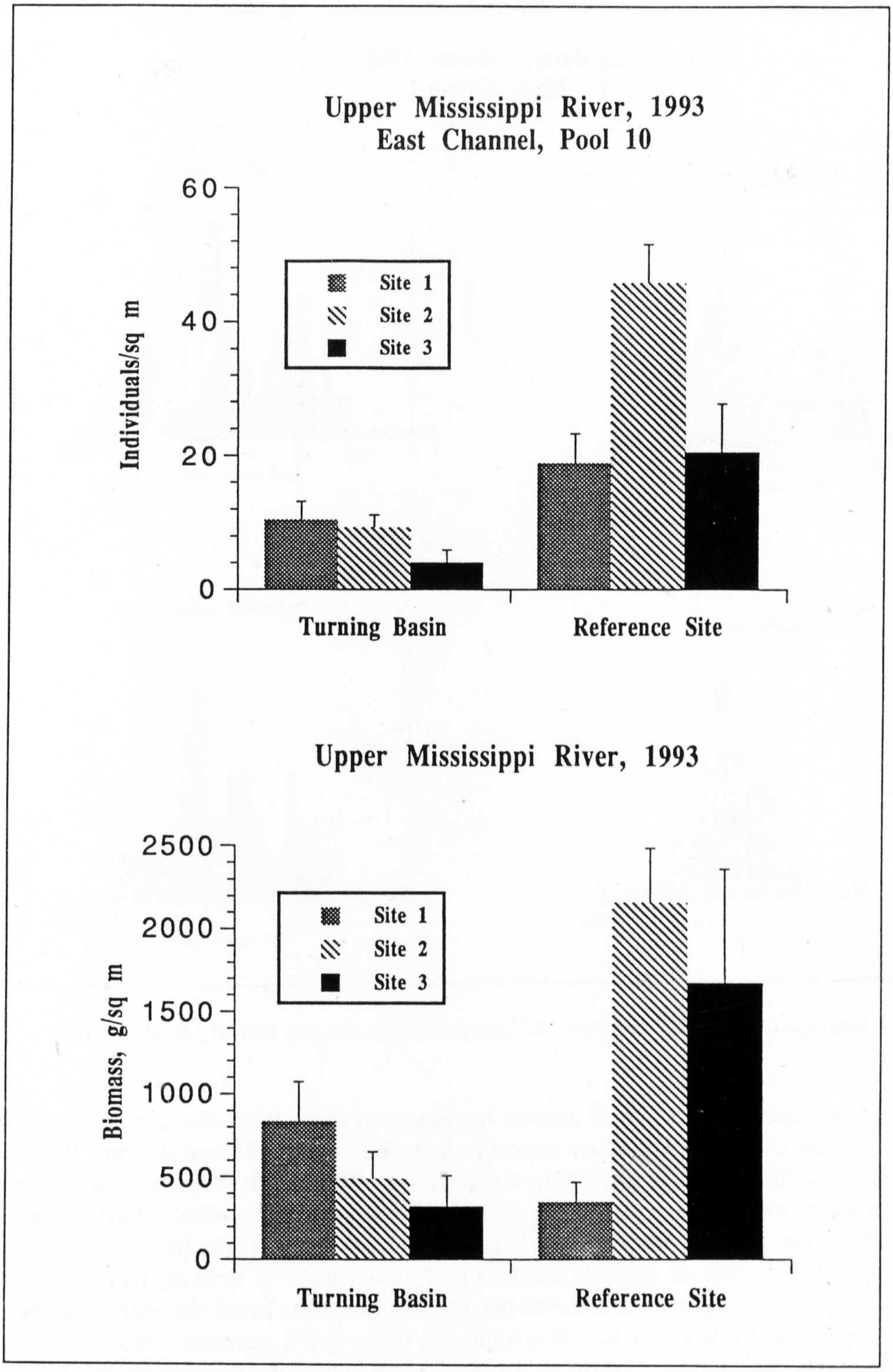

Figure 10. Mean density (individuals/sq m) and standard error of mean for freshwater mussels collected at barge turning zone and reference site located downriver, 1993

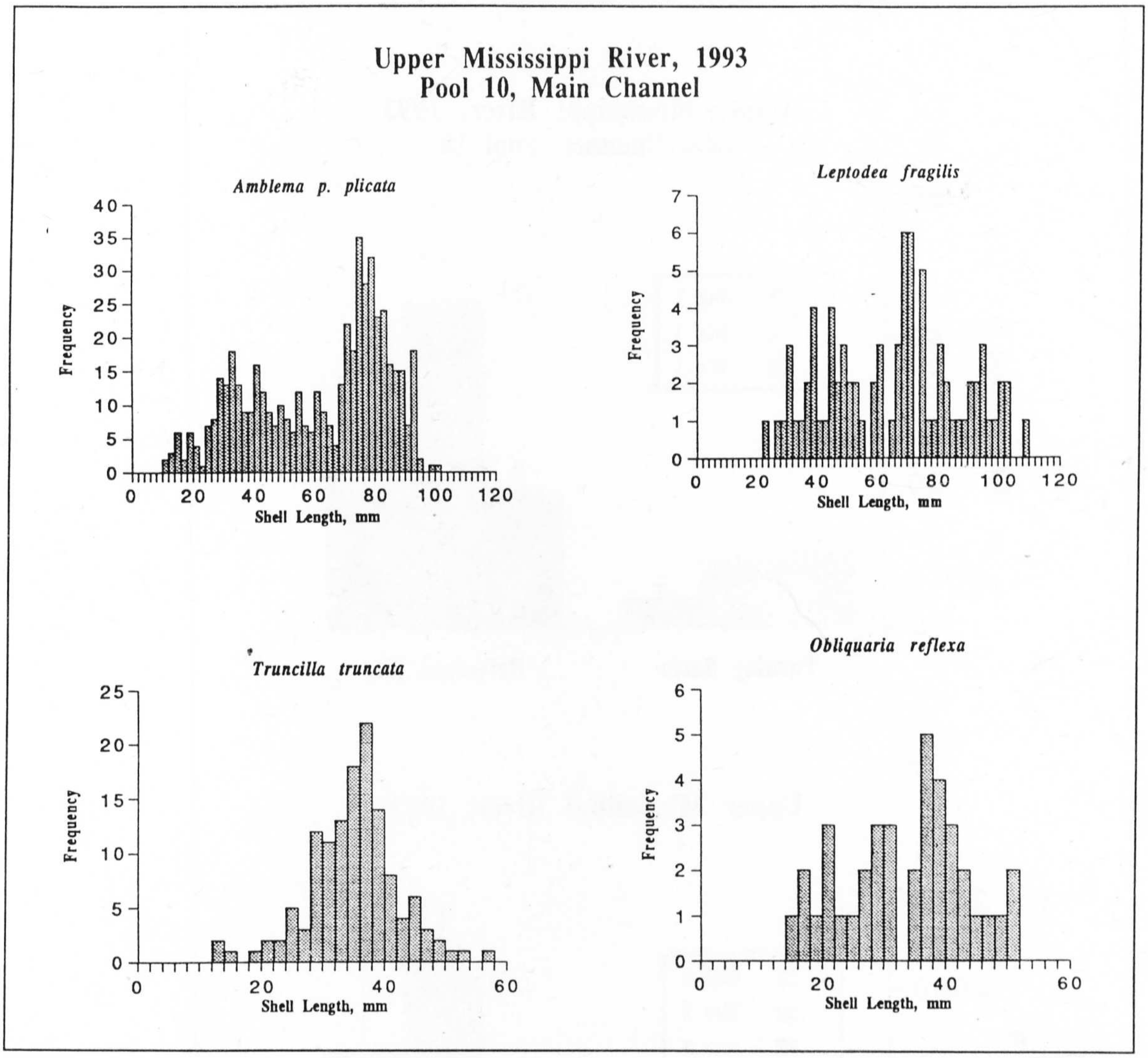

Figure 11. Size demography of four species of Unionidae, main channel of UMR, 1994

an indication of the annual growth increment of mussels of this size and age. One- or two-year classes are probably included between 83 and 93 mm, but are obscured by their low relative abundance. The length frequency histogram of mussels less than 70 mm long was similarly sawtoothed. Peaks (possible year classes) occurred at 61, 55, 49, 41, 33, and 17 mm (the 17-mm cohort including all mussels from 10 to 22 mm long). It is likely that a cohort of low relative abundance occurs between those more abundant cohorts centered at 61 and 71 mm. It is similarly likely that a year class occurs between the cohorts centered at 33 and 17 mm, but it is obscured by the high relative abundance of the cohort with average length of approximately 33-mm. Overall, approximately 11 cohorts are apparent in the size structure of this population, with approximately three to four additional cohorts probably being present but obscured by their low abundance relative to adjacent cohorts.

In the east channel reference sites, *A. p. plicata* was collected in lesser numbers such that size structure of the population was more difficult to analyze (Figure 13). Young, small mussels were dominant at this location. The two most abundant cohorts were centered at 19 and 27 mm. Mussels greater than 35 mm long were not present in sufficient abundance to allow detailed analysis. The total size range at this location was similar to that in the main channel, despite there being lower abundance of large mussels in the east channel.

Very few individuals were collected in the turning basin (Figure 12), and hardly any analysis of size structure was warranted. The size range here suggested a similar range as observed at the other locations.

Obliquaria reflexa

Although not enough individuals were collected in either the main channel (Figure 11) or the east channel (Figure 12) to warrant detailed analysis, there was some obvious similarity to intersite differences noted for *A. p. plicata*. The east channel population of *O. reflexa* was dominated by small, young mussels more so than the main channel population.

Leptodea fragilis

This species ranged from approximately 15 to 115 mm long in both the main channel (Figure 11) and the east channel (Figure 12). Too few individuals were obtained to support detailed analysis.

Truncilla truncata

The *T. truncata* population in the main channel included individuals ranging from 12 to 58 mm long (Figure 11). The dominant cohort was centered at 37 mm, with less abundant cohorts indicated at 45, 29, and 13 mm.

Fusconaia flava

Individuals of this species ranged from 36 to 64 mm long in the turning basin (Figure 12). Too few were collected to support detailed analysis.

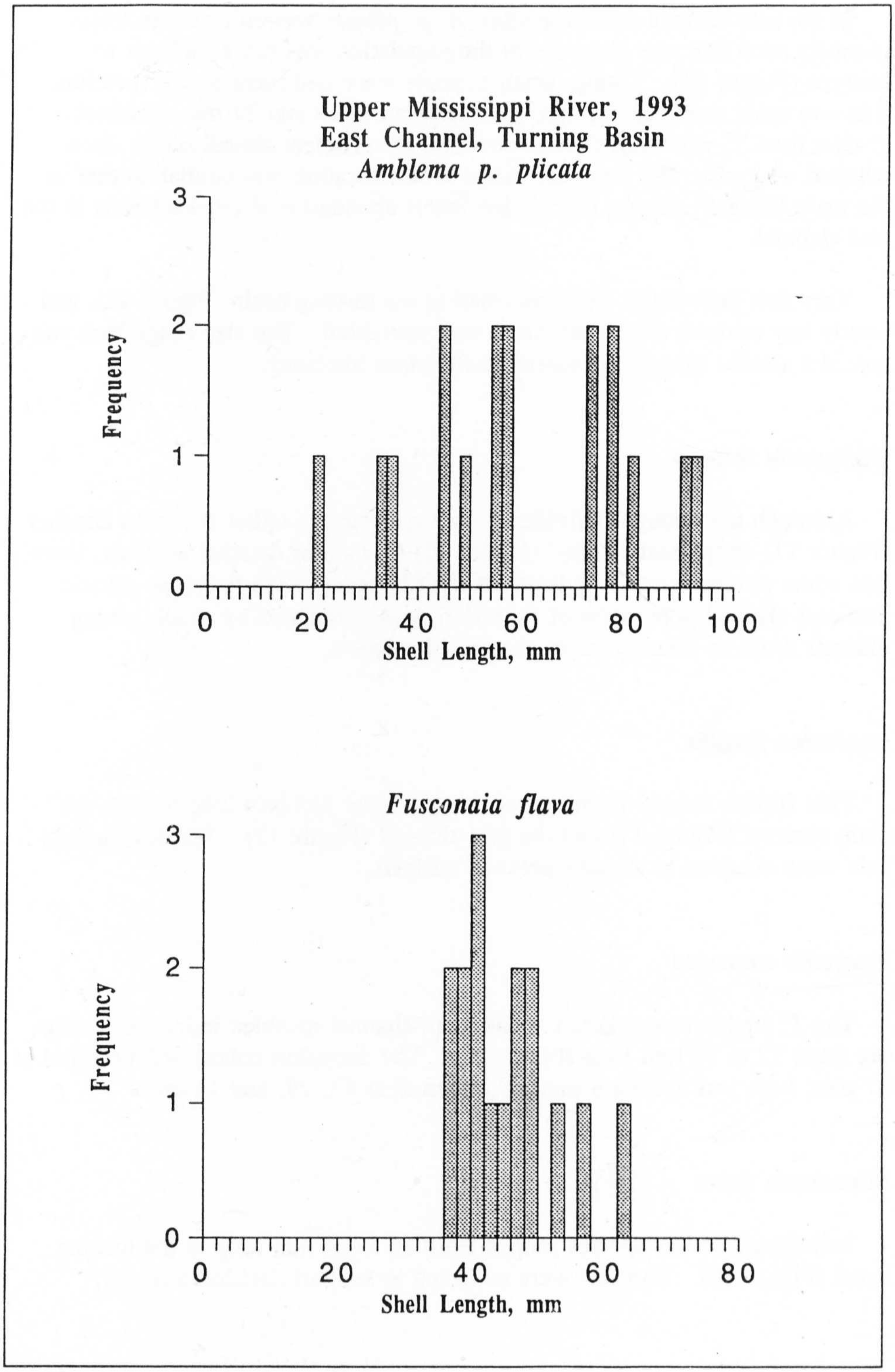

Figure 12. Size demography of two species of Unionidae, turning basin of east channel of UMR, 1994

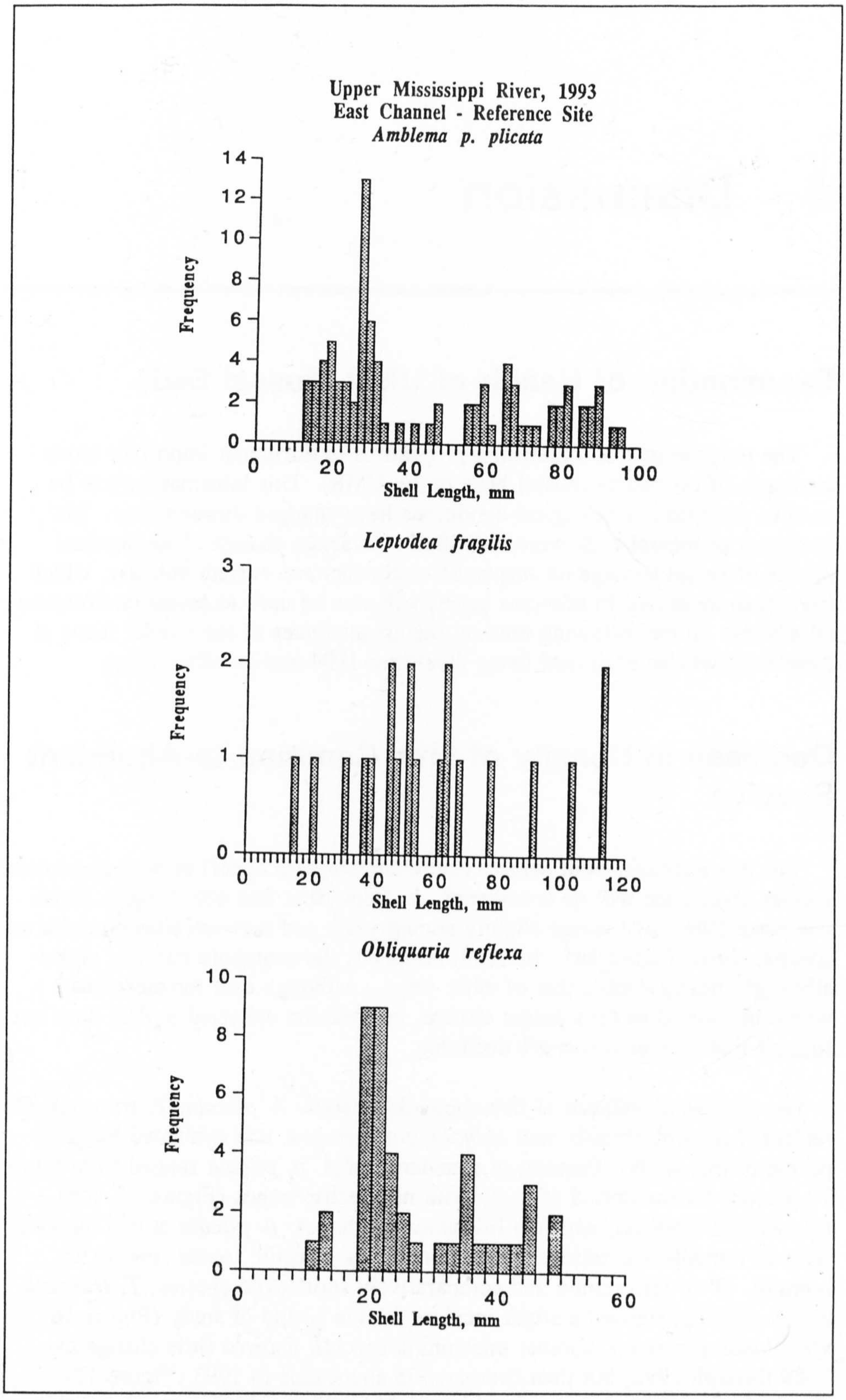

Figure 13. Size demography of three species of Unionidae, turning basin of east channel of UMR, 1994

4 Discussion

Examination of Health of UMR Mussel Beds

The purpose of this monitoring program is to document important biotic attributes of prominent mussel beds in the UMR. This information will be used to determine if biological conditions have changed through time. Six attributes of mussel beds were identified to evaluate change. The physical effects of vessel passage on suspended sediments and current velocity, which have been measured in previous years, will also be used to assess environmental effects. In the following section, the six attributes of the mussel fauna at these beds will be examined using data from 1994 and previous years.

Decrease in Density of Five Common-to-Abundant Species

For this attribute, both density (individuals/square meter) as well as percent species abundance will be considered. In Pool 10 at RM 635.2, mean densities since 1989 have varied slightly among years and between sites but with no specific trend (Figure 14). In 1989, density at the nearshore site was unusually high, nearly double that of other years. Although data for more years would be needed to fully assess change, information collected to date does not suggest that mussel stocks are declining.

The relative abundance of five common mussels, *A. plicata, T. truncata, O. reflexa, Leptodea fragilis*, and *Megalonaias nervosa*, was evaluated for the period of this study. Percentage abundance of *A. p. plicata* ranged from 50 to 70 percent for the period of study with no specific trends (Figure 15, top). Likewise, *O. reflexa*, which is less common than *A. p. plicata* at this location, showed intrasite and intrayear variation, but no specific trends (Figure 15, bottom). Two uncommon and comparatively short-lived species, *T. truncata* and *L. fragilis*, showed a slight increase for the period of study (Figure 16). *Megalonaias nervosa*, another uncommon species, showed little change for 1989 through 1992, but then decreased in abundance in 1993 (Figure 17). These changes, although measurable, could be the result of sampling slightly different areas of the bed each year or slight interyear variation brought about

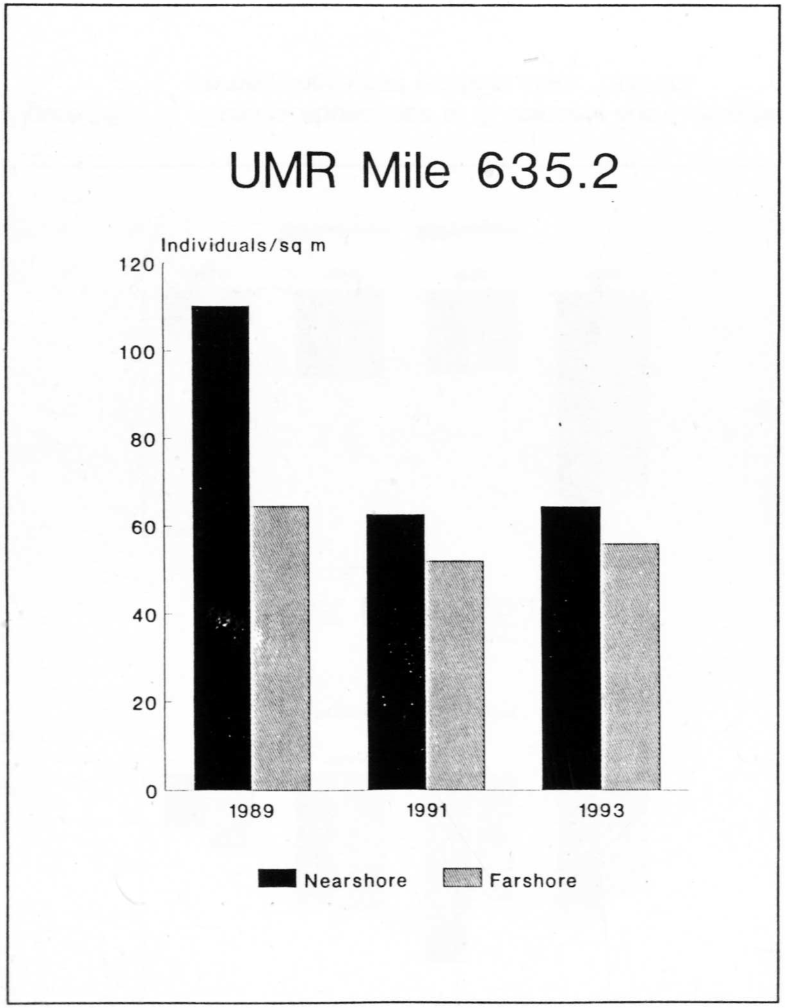

Figure 14. Mean unionid density at nearshore and farshore sites, 1989-93

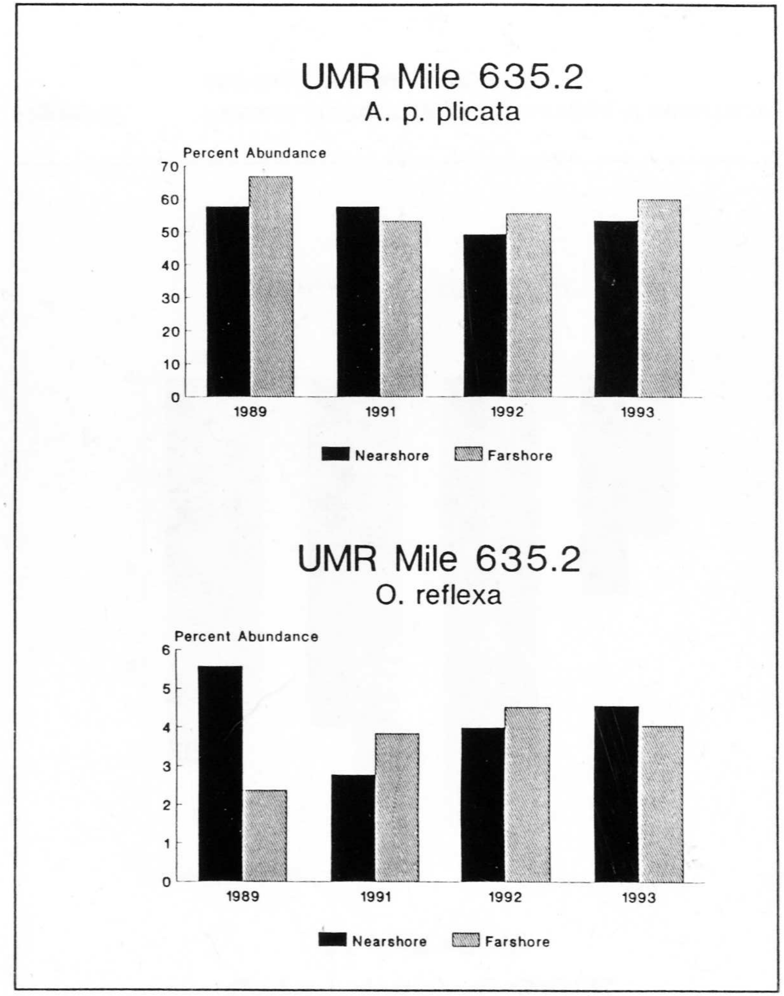

Figure 15. Percent abundance of *A. p. plicata* and *O. reflexa* at nearshore and farshore sites, 1989-93

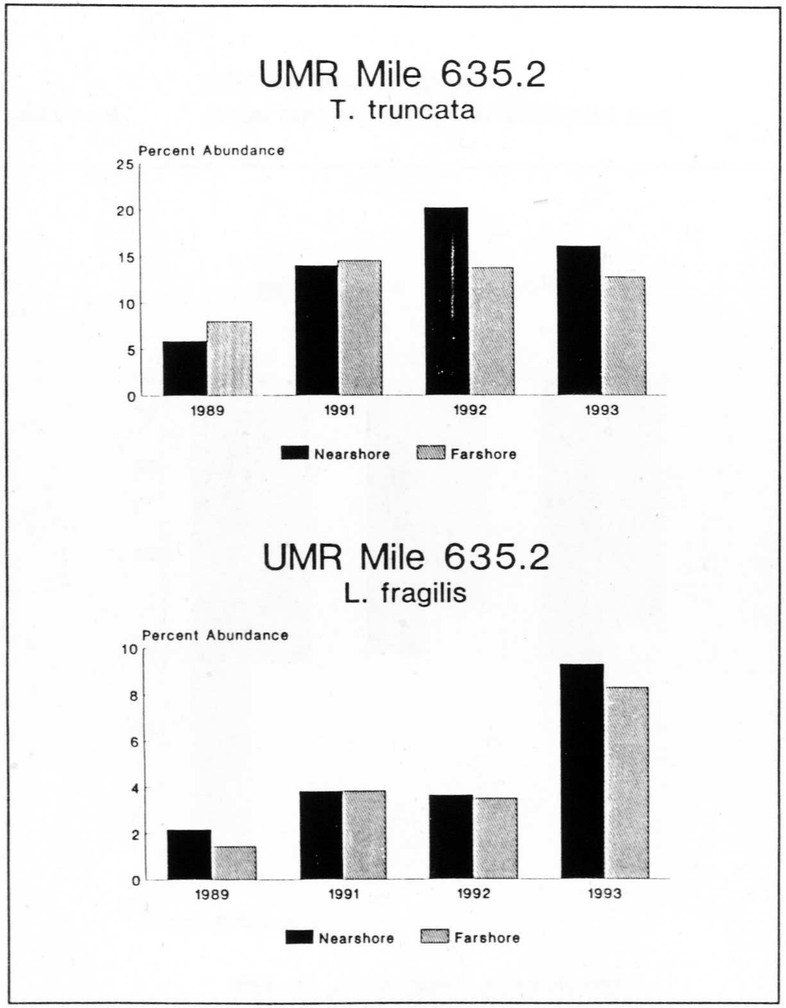

Figure 16. Percent abundance of *T. truncata* and *L. fragilis* at nearshore and farshore sites, 1989-93

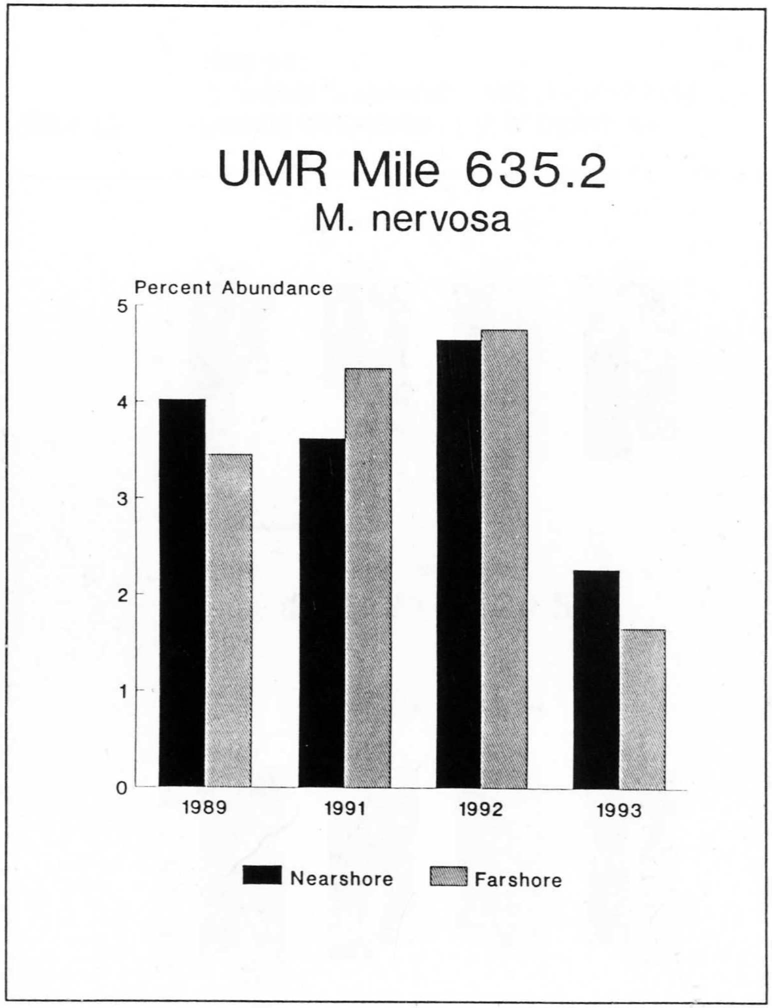

Figure 17. Percent abundance of *M. nervosa* at nearshore and farshore sites, 1989-93

by natural recruitment or mortality. It is reasonable to expect abundances of short-lived species such as *L. fragilis* or *T. truncata* to fluctuate more than the longer lived, thick-shelled species.

Presence of *L. higginsi*

In the main channel, *L. higginsi* ranged from 0.11 percent in 1993 to 0.68 percent in 1989 (Table 8). Although numbers vary from year to year, there does not appear to be a specific trend either toward increased or decreased numbers of this species. This species has never been abundant in large rivers (Higgins' Eye Recovery Team 1982), and its numbers do not appear to be changing at these beds.

Live-to-Recently-Dead Ratios for Dominant Species

In quantitative samples taken in the UMR, often more than 50 percent of the shells can be considered "relics" and may have been dead for many years. One objective of this study is to quantify the number of "fresh dead" mussels taken in quantitative samples. These are defined as mussels that are dead but still have tissue attached to the shells. Only a single fresh dead mussel was found in all of the quantitative samples collected in Pool 10 in 1993 (Table 7). Although commercial shell fisherman have reported high numbers of fresh dead mussels at certain locations in the UMR, none of the sampling for this monitoring program has indicated high recent mortality.

Loss of More than 25 Percent of the Mussel Species

The number of species identified is related to the number of individuals collected; hence, this attribute has to be evaluated with caution. Between 1989 and 1993, the number of species and individuals collected using qualitative methods at RM 635.2 has changed little (Figure 18). In 1993, *Dreissena polymorpha* was collected in quantitative samples at both locations, so the total number of individuals and species collected in 1993 includes a nonindigenous species.

Species diversity (H'), which depends upon the number of species (richness) and the distribution of species within the community (evenness), is being used as a measure of the overall health of a mussel bed. At the bed in the main channel of Pool 10, species diversity ranged from slightly less than 1.5 to nearly 2.0 between 1989 and 1993 (Figure 19). No specific increases or decreases through time have been noted.

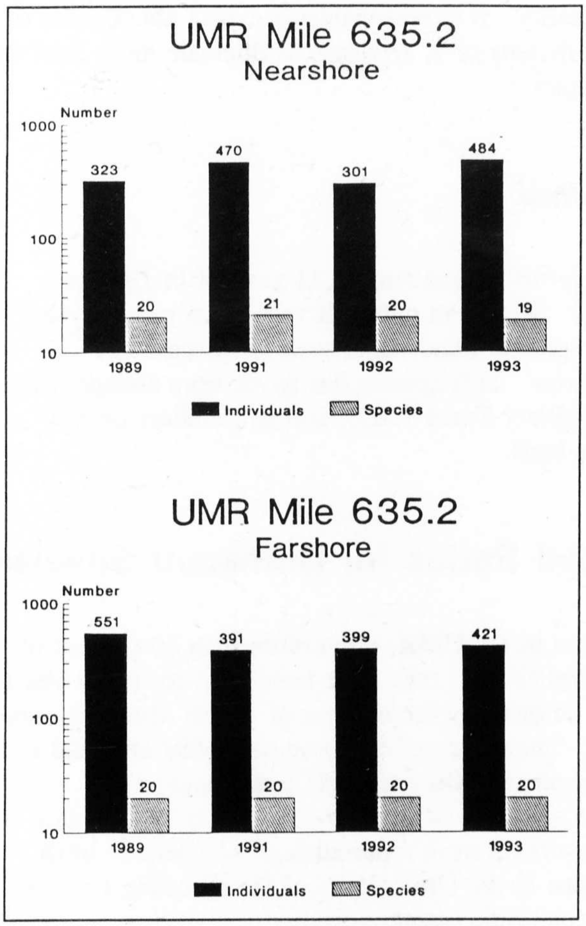

Figure 18. Number of individuals and species collected at nearshore and farshore sites, 1989-93

Evidence of Recent Recruitment

The percentage of individuals and species less than 30 mm total SL is being used as evidence of recent recruitment. Small (*Truncilla* spp.) or thin-shelled species (*L. fragilis*) will often show recruitment pulses more often than thick-shelled species such as *A. p. plicata* or *M. nervosa*. Since 1989, the percentage of individuals less than 30 mm total SL has ranged from approximately 12 to 28 percent (Figure 20, top). The percentage of species with at least one individual less than 30 mm has ranged from approximately 30 to 50 percent (Figure 20, bottom). Both figures show year-to-year variation with little notable trends.

Demography

The detailed analysis of the size demography of the large population sample of *A. p. plicata* from the main channel can be used to estimate age-to-size relationships. If it assumed that the smallest cohort collected represents 1992 recruits (i.e., assumes that 1993 recruits were too small to be retained on the smallest sieve used), then age-to-average length estimates can be made as follows:

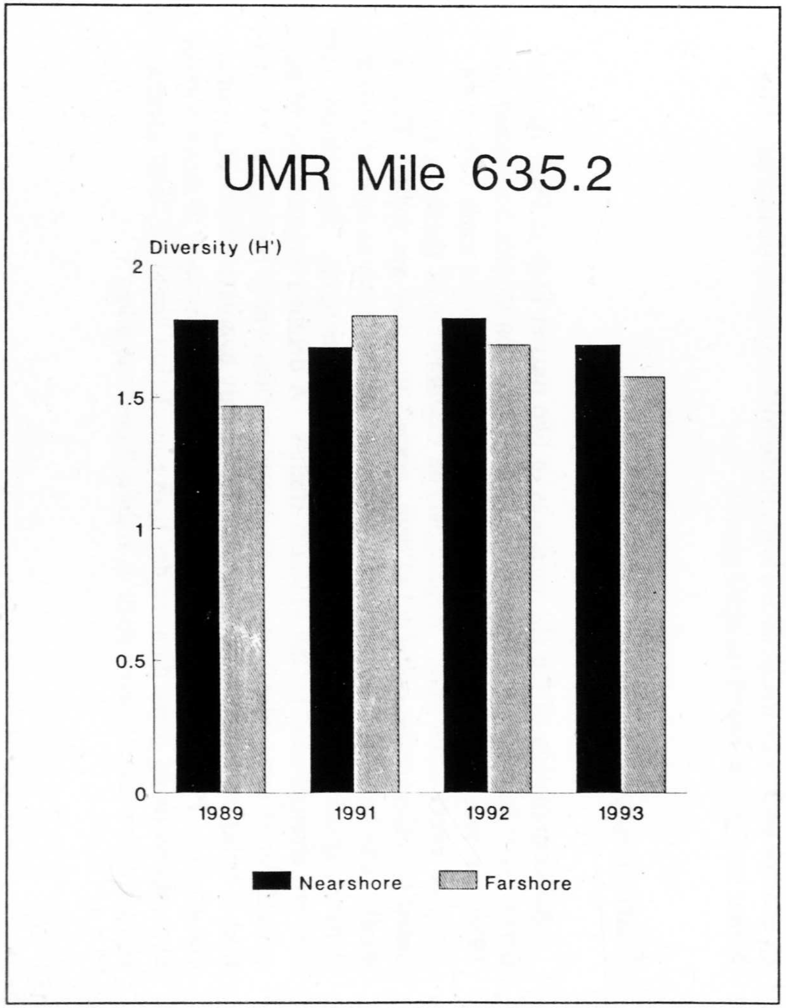

Figure 19. Species diversity (H′) at nearshore and farshore sites, 1989-93

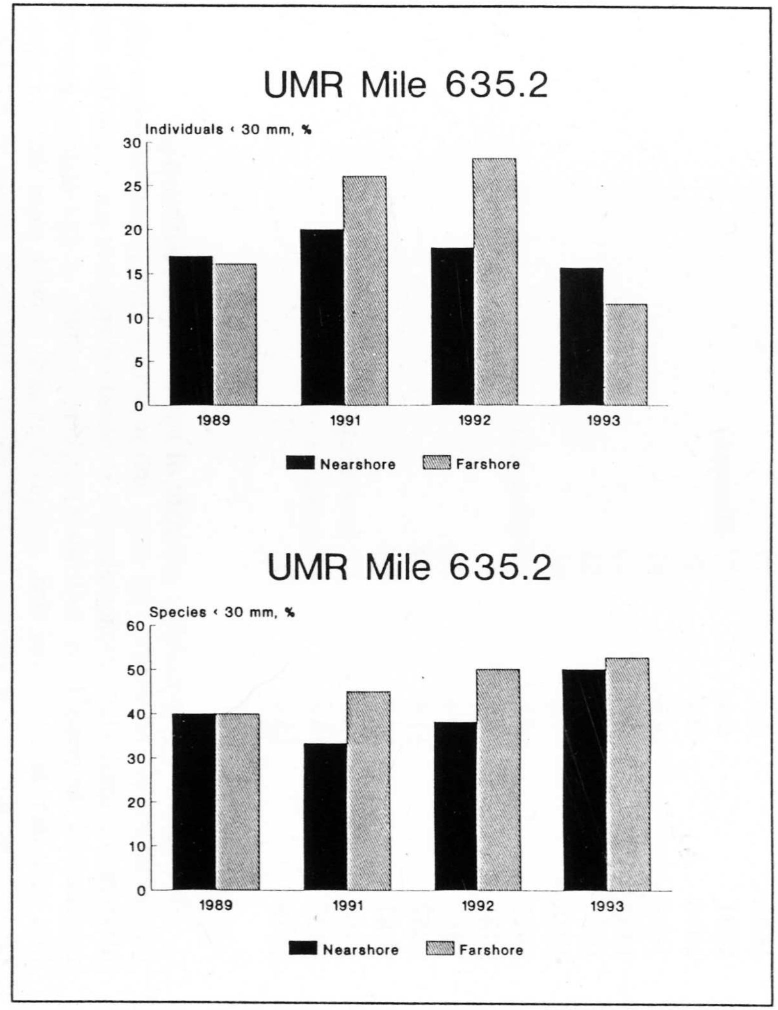

Figure 20. Evidence of recent recruitment at nearshore and farshore sites, 1989-93

Year Recruited	Appropriate Age, years	SL, mm
1992	1+	17
1991	2+	27 (obscure)
1990	3+	33
1989	4+	41
1988	5+	49
1987	6+	55
1986	7+	61
1985	8+	66 (obscure)
1984	9+	71
1983	10+	75
1982	11+	79
1981	12+	83
1980	13+	87 (obscure)
1979	14+	90 (obscure)
1978	15+	93

This admittedly speculative estimate of age-to-length relationships should ultimately be verified by mark and recapture growth studies (especially of large, old mussels). Nonetheless, it is based on apparent pattern in the size structure of the population, follows an expected pattern of diminishing growth rate with increased age and size, and predicts early growth rates that are similar to those that can be verified by shell annuli. Figure 21 compares the age-to-growth estimates made above with those for early growth suggested by Miller and Payne based on shell annuli.

Summary

An examination of the six attributes of two mussel beds in Pool 10 that define their health or well-being were made based on studies conducted since 1989. In most cases, only 3 years can be compared since most beds were sampled every other year. Regardless, an examination of these six attributes, based on information collected to date, reveals that they are stable. Future studies can be used to determine if important indices such as rate of growth, density, species richness and diversity, etc., are changing. These biotic data sets are strengthened by the physical studies. A detailed examination of physical effects of commercial vessel movement at sites where biological information is being collected is necessary to thoroughly evaluate effects of commercial traffic. Planners and resource managers are encouraged to make careful evaluations using these data, rather than speculation based on "best estimates" or qualitative assessments such as habitat-based methods.

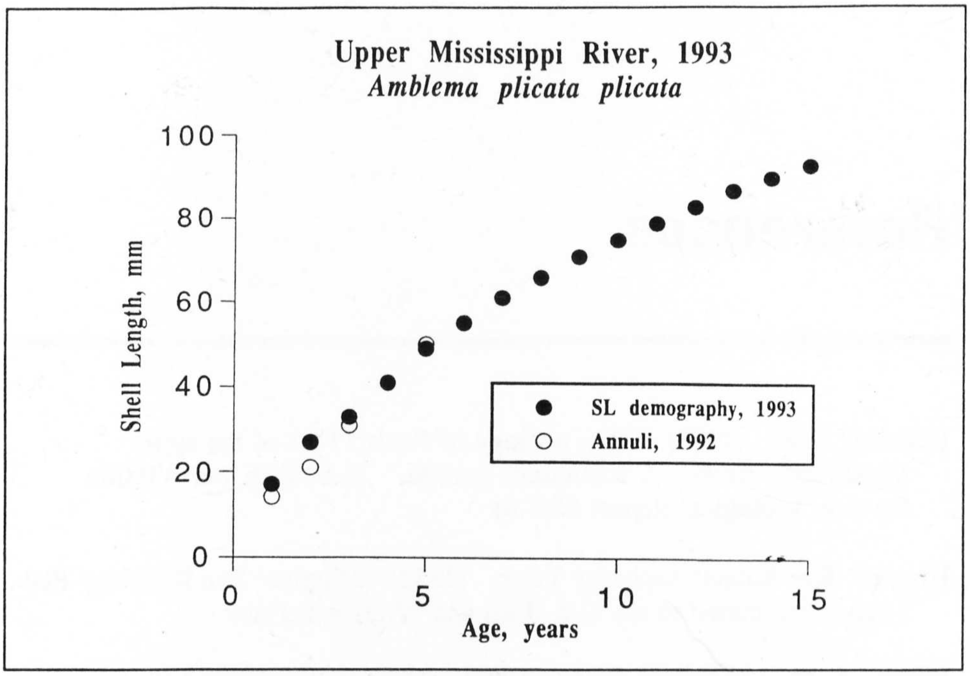

Figure 21. Age and SL measurements based on SL demography and counts of annuli

References

Eckblad, J. W. (1986). "The ecology of Pools 11-13 of the upper Mississippi River: A community profile," U.S. Fish and Wildlife Service, Biological Report 85(7.8).

Higgins' Eye Mussel Recovery Team. (1982). Higgins' Eye Recovery Plan, a report submitted to the U.S. Fish and Wildlife Service.

Miller, A. C., and Payne, B. S. (1991). "Effects of increased commercial navigation traffic on freshwater mussels in the upper Mississippi River: 1989 studies," Technical Report EL-91-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. (1992). "Effects of commercial navigation traffic on freshwater mussels in the upper Mississippi River: 1990 studies," Technical Report EL-92-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. (1993). "Effects of commercial navigation traffic on freshwater mussels in the upper Mississippi River: 1991 studies," Technical Report EL-93-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. (1994). "Effects of commercial navigation traffic on freshwater mussels in the upper Mississippi River: 1992 studies," Technical Report EL-94-14, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Miller, A. C., Payne, B. S., Hornbach, D. J., and Ragland, D. V. (1990). "Physical effects of increased commercial navigation traffic on freshwater mussels in the upper Mississippi River: Phase I studies," Technical Report EL-90-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Peterson, G. A. (1984). "Resources inventory for the upper Mississippi River (Guttenber, Iowa to Saverton, Missouri)," Prepared for U.S. Army Engineer District, Rock Island, Rock Island, IL.

U.S. Fish and Wildlife Service. (1993). "Endangered and threatened wildlife and plants," 50 CFR 17.11 and 17.12 (August 23, 1993), Office of Endangered Species, U.S. Fish and Wildlife Service, Washington, DC.

Table 1
Summary of Biological and Physical Studies Conducted in Navigation Traffic Effects Study, UMR, 1988-94

Pool	RM	Year 88	89	90	91	92	93	94
24	299.6	Qual	Qual		Qual		ND	Qual
		Quant	Quant		Quant		ND	Quant
					Growth			
					Phys			
17	450.4	Qual		Qual		Qual		Qual
		Quant		Quant		Quant		Quant
				Growth				
				Phys				
14	504.8	Qual	Qual		Qual		ND	Qual
		Quant	Quant		Quant		ND	Quant
			Growth					
			Phys		Phys			
12	571.5		Qual	Qual		Qual		Qual
				Quant		Quant		Quant
				Growth				
				Phys				
10	635.2-MC	Qual	Qual		Qual		Qual	Qual
			Quant		Quant		Quant	Quant
			Growth					
			Phys		Phys			

Notes: This report describes studies conducted in 1993.
Precise river miles can differ in previous reports since exact location can vary slightly (0.1 to 0.4 miles) each year. Quant = Quantitative samples; Qual = Qualitative samples; Growth = Marked mussels were placed for analysis of rate of growth; Phys = Physical studies such as measures of water velocity and total suspended solids following passage of a commercial vessel; MC = Main channel; ND = No data because of high water.

Table 2
Summary of Bivalve Collections Using Qualitative and Quantitative Methods, UMR, 1988-93

Pool	RM	Year	No. of Quantitative Samples	No. of Qualitative Samples	No. of Bucket Samples
24	299.6	1988	10	18	--
		1989	60	42	--
		1990	--	--	--
		1991	60	24	--
		1992	--	12	10
17	450.4	1988	20	27	--
		1989	--	--	--
		1990	60	32	--
		1991	--	--	--
		1992	60	24	--
14	504.8	1988	20	27	--
		1989	60	59	--
		1990	--	--	--
		1991	60	48	--
		1992	--	24	40
12	571.5	1988	--	--	--
		1989	--	33	--
		1990	60	36	--
		1991	--	--	--
		1992	60	36	--
10	635.2	1988	--	43	--
		1989	40	14	--
		1990	--	--	--
		1991	60	48	--
		1992	--	24	40
		1993-MC	60	24	--
		1993-EC	60	60	--

Note: In 1992, bucket samples were collected at selected locations; see text for details. EC = East channel; MC = Main channel.

Table 3
Location of Sites Where Quantitative and Qualitative Samples Were Collected, UMR, 1993

RM	Subsite	Distance to Shore, ft	Depth ft	Qualitative Samples	Quantitative Samples	Buckets
3 September 1993, Pool 10						
635.2	EC-BTB	500L	10	--	30	--
635.2	EC	200L	12	12	--	
635.2	EC	200L	12	12	--	
635.2	EC	200R	20	12	--	5
4 September 1993, Pool 10						
635.2	EC-REF	100L	14	--	30	--
635.2	EC	100L	14	12	--	--
635.2	EC	100L	14	12	--	--
5 September 1993, Pool 10						
635.2	MC-FS	100	16	--	30	--
635.2	MC-NS	75	12	--	20	20
6 September 1993, Pool 10						
635.2	MC-NS	75	12	--	10	--
635.2	MC-NS	75	12	12	--	--
635.2	MC-FS	100	16	12	--	--

Note: EC = East channel; MC = Main channel; BTB = Barge turning basin; REF = Reference site; FS = Farshore; NS = Nearshore; L = Left descending bank; R = Right descending bank.

Table 4
Freshwater Mussels Collected Using Qualitative (Qual) and Quantitative (Quant) Techniques, Main and East Channels, UMR, September 1993

Species	Qual	Quant
Amblema plicata plicata (Say, 1817)	X	X
Actinonaias ligamentina (Larmack, 1819)	X	X
Anodonta grandis (Say, 1829)	X	X
Anodonta imbecillis (Say, 1829)	X	X
Arcidens confragosus (Say, 1829)	X	X
Dreissena polymorpha (Pallas, 1771)		X
Ellipsaria lineolata (Rafinesque, 1820)	X	X
Elliptio dilatata (Rafinesque, 1820)	X	X
Fusconaia flava (Rafinesque, 1820)	X	X
Lasmigona complanata (Barnes, 1823)	X	X
Lampsilis higginsi (Lea, 1857)	X	X
Lampsilis ovata (Say, 1817)	X	X
Leptodea fragilis (Rafinesque, 1820)	X	X
Ligumia recta (Lamarck, 1819)	X	X
Megalonaias nervosa (Rafinesque, 1820)	X	X
Obliquaria reflexa (Rafinesque, 1820)	X	X
Obovaria olivaria (Rafinesque, 1820)	X	X
Pleurobema coccineum (Conrad, 1834)	X	X
Potamilus alatus (Say, 1817)	X	X
Quadrula metanevra (Rafinesque, 1820)	X	X
Quadrula nodulata (Rafinesque, 1817)	X	
Quadrula pustulosa pustulosa (Lea, 1831)	X	X
Quadrula quadrula (Rafinesque, 1820)	X	X
Strophitus undulatus (Say, 1817)	X	X
Truncilla donaciformis (I. Lea, 1828)	X	X
Truncilla truncata (Lea, 1860)	X	X
Total individuals	1,360	1,176
Total species	25	25
Total samples	84	160

Table 5
Mean Density (individuals/sq m), Mean Biomass (g/sq m), and Standard Error of Mean (SE) of Unionidae at Two Locations, Main Channel, UMR near Prairie du Chien, WI, September 1993

		Density		Biomass	
Location	N	Mean	SE	Mean	SE
Nearshore Site					
Subsite 1	10	46.0[a]	4.7	2,859.7[b]	442.2
Subsite 2	10	56.8[a]	5.1	5,139.9[a]	378.3
Subsite 3	10	65.6[a]	10.4	5,844.8[a]	718.7
F		1.85		8.71	
Pr > F		0.177		0.0012	
Farshore Site					
Subsite 1	10	71.6[a]	8.8	4,771.7[a]	715.9
Subsite 2	10	65.6[a]	6.6	5,312.4[a]	712.6
Subsite 3	10	56.4[a]	5.2	4,203.8[a]	364.5
F		1.19		0.80	
Pr > F		0.321		0.46	
Grand Totals					
Nearshore Site	30	64.55[a]	4.1	4,762.63[a]	355.5
Farshore Site	30	56.1[a]	4.3	4,628.1[a]	381.5
F		2.01		0.07	
Pr > F		0.16		0.80	

Note: Means with the same superscript are not significantly different, $P < 0.05$. F = F statistic; Pr = Probability.

Table 6

Mean Density (individuals/sq m), Mean Biomass (g/sq m), and Standard Error of Mean (SE) of Unionidae, Two Locations in East Channel, UMR near Prairie du Chien, WI, September 1993

		Density		Biomass	
Location	**N**	**Mean**	**SE**	**Mean**	**SE**
Turning Basin					
Subsite 1	10	10.4^{a}	2.8	832.6^{a}	239.7
Subsite 2	10	9.2^{a}	2.0	484.4^{a}	167.3
Subsite 3	10	4.0^{a}	2.0	321.7^{a}	187.7
F		2.21		1.69	
Pr > F		0.1295		0.2027	
Reference Site					
Subsite 1	10	18.8^{b}	4.5	348.6^{b}	119.4
Subsite 2	10	45.6^{a}	5.8	$2,159.9^{a}$	328.8
Subsite 3	10	20.4^{b}	7.3	$1,675.4^{a}$	687.3
F		6.32		4.44	
Pr > F		0.0056		0.0216	
Grand Totals					
Turning Basin	30	7.9^{a}	1.4	546.3^{b}	118.5
Reference Site	30	28.3^{b}	4.0	$1,394.6^{a}$	285.9
F		22.88		7.51	
Pr > F		0.0001		0.0081	

Note: Means with the same superscript are not significantly different, $P < 0.05$. F = F statistic; Pr = Probability.

Table 7
Number of Fresh Dead Unionidae (tissue present) in Quantitative Samples Collected, Pool 10, September 1993

Location	Subsite 1	Subsite 2	Subsite 3
Main Channel			
Nearshore	0	0	0
Farshore	0	0	0
East Channel			
Turning Basin	0	0	1
Reference Site	0	0	0

Table 8
Numbers of *Lampsilis higginsi* Taken in Qualitative and Quantitative Samples, UMR, 1988-93

Year	Quantitative			Qualitative		
	Total Mussels	*L. higginsi*		Total Mussels	*L. higginsi*	
		Total	%		Total	%
Pool 24 (RM 299.6)						
1988	78	0	0.00	326	0	0.00
1989	1,143	0	0.00	648	0	0.00
1991	301	0	0.00	465	0	0.00
1992	107	0	0.00	184	0	0.00
Pool 17 (RM 450.4)						
1988	1,176	0	0.0	567	1	0.18
1989	651	0	0.00	506	0	0.00
1990	954	0	0.00	402	0	0.00
Pool 14 (RM 504.8)						
1988	253	1	0.4	734	8	1.09
1989	1,131	1	0.09	961	5	0.52
1991	1,247	6	0.49	815	6	0.74
1992	800	2	0.25	386	3	0.78
Pool 12 (RM 571.5)						
1989	--	--	--	98	0	0.00
1990	408	5	1.22	518	5	0.98
1992	558	1	0.18	376	0	0.00
Pool 10 (RM 635.2 - Main Channel)						
1988	845	2	0.24	699	12	1.72
1989	1,616	11	0.68	212	0	0.00
1991	861	2	0.23	690	4	0.58
1992	700	3	0.43	376	1	0.27
1993	905	4	0.11	404	1	0.25
Pool 10 (RM 635.2 - East Channel)						
1993	59	0	0.0	956	2	0.21

Appendix A
Freshwater Mussels Collected in the Main Channel of Upper Mississippi River (UMR), Pool 10, September 1993

Table A1
Percent Abundance and Percent Occurrence of Freshwater Mussels at Two Sites, Main Channel, UMR, Using Qualitative Methods, September 1993

Species	Total Individuals	% Abundance	Total Sample	% Occurrence
A. plicata plicata	251	62.13	23	95.83
L. fragilis	33	8.17	18	75.00
T. truncata	30	7.43	14	58.33
M. nervosa	21	5.20	14	58.33
Q. quadrula	11	2.72	9	37.50
S. undulatus	9	2.23	8	33.33
F. flava	6	1.49	5	20.83
L. ovata	6	1.49	4	16.67
L. recta	6	1.49	6	25.00
P. alatus	6	1.49	6	25.00
O. reflexa	5	1.24	4	16.67
A. confragosus	4	0.99	4	16.67
Q. p. pustulosa	4	0.99	3	12.50
Q. nodulata	3	0.74	3	12.50
E. dilatata	2	0.50	2	8.33
A. ligamentina	1	0.25	1	4.17
E. lineolata	1	0.25	1	4.17
L. complanata	1	0.25	1	4.17
L. higginsi	1	0.25	1	4.17
L. radiata radiata	1	0.25	1	4.17
O. olivaria	1	0.25	1	4.17
Q. metanevra	1	0.25	1	4.17
Total individuals	404			
Total species	22			
Total samples	24			

Table A2
Percent Abundance of Freshwater Mussels Collected at a Nearshore Site, Main Channel, UMR near Prairie du Chien, WI, 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	51.96	52.44	56.03	53.31
T. truncata	18.44	10.98	19.15	16.12
L. fragilis	8.94	12.20	6.38	9.30
O. reflexa	5.59	4.27	3.55	4.55
M. nervosa	1.68	3.66	1.42	2.27
E. dilatata	1.68	1.83	2.13	1.86
Q. p. pustulosa	1.12	2.44	1.42	1.65
P. alatus	2.79	1.22	0.71	1.65
F. flava	2.23	1.83	0.71	1.65
T. donaciformis	1.68	0.61	2.84	1.65
L. recta	0.56	2.44	1.42	1.45
L. ovata	1.12	2.44	0.71	1.45
D. polymorpha	0.56	1.83	0.71	1.03
Q. quadrula	0.00	1.83	1.42	1.03
L. higginsi	0.00	0.00	0.71	0.21
A. grandis	0.00	0.00	0.71	0.21
L. complanata	0.56	0.00	0.00	0.21
E. lineolata	0.56	0.00	0.00	0.21
A. confragosus	0.56	0.00	0.00	0.21
Total individuals	179	164	141	484
Total species	16	14	16	19
Species diversity	1.66	1.74	1.57	1.70
Evenness	0.51	0.48	0.48	0.47
Menhinick's index	1.20	1.09	1.35	0.86
Simpson's dominance	0.31	0.30	0.35	0.32
% Individuals <30 mm	21.35	8.69	16.43	15.66
Species <30 mm	46.67	42.86	33.33	50.00

Note: With the exception of total individuals and total species, all community indices exclude *D. polymorpha*.

Table A3
Percent Occurrence of Freshwater Mussels Collected at a Nearshore Site, Main Channel, UMR near Prairie du Chien, WI, 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	100.00	100.00	100.00	100.00
T. truncata	100.00	70.00	90.00	86.67
L. fragilis	80.00	90.00	60.00	76.67
O. reflexa	70.00	50.00	40.00	53.33
M. nervosa	20.00	40.00	20.00	26.67
E. dilatata	30.00	30.00	30.00	30.00
Q. p. pustulosa	20.00	40.00	20.00	26.67
P. alatus	40.00	20.00	10.00	23.33
F. flava	40.00	20.00	10.00	23.33
T. donaciformis	30.00	10.00	40.00	26.67
L. recta	10.00	30.00	20.00	20.00
L. ovata	20.00	40.00	10.00	23.33
D. polymorpha	10.00	20.00	10.00	13.33
Q. quadrula	0.00	30.00	10.00	13.33
L. higginsi	0.00	0.00	10.00	3.33
A. grandis	0.00	0.00	10.00	3.33
L. complanata	10.00	0.00	0.00	3.33
E. lineolata	10.00	0.00	0.00	3.33
A. confragosus	10.00	0.00	0.00	3.33
Total samples	10	10	10	30

Table A4
Percent Abundance of Freshwater Mussels Collected at a Farshore Site, Main Channel, UMR near Prairie du Chien, WI, September 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	61.74	61.27	57.32	59.86
T. truncata	11.30	12.68	14.02	12.83
L. fragilis	9.57	4.23	10.98	8.31
O. reflexa	4.35	6.34	1.83	4.04
Q. quadrula	1.74	2.11	3.05	2.38
M. nervosa	1.74	2.11	1.22	1.66
P. alatus	0.00	0.00	3.66	1.43
T. donaciformis	0.87	0.70	1.83	1.19
D. polymorpha	0.00	2.11	1.22	1.19
S. undulatus	0.87	1.41	0.61	0.95
E. lineolata	0.87	0.70	1.22	0.95
Q. pustulosa	1.74	0.70	0.61	0.95
F. flava	0.00	2.11	0.61	0.95
L. higginsi	0.87	1.41	0.00	0.71
L. ovata	0.87	0.70	0.61	0.71
P. coccineum	2.61	0.00	0.00	0.71
A. confragosus	0.87	0.70	0.00	0.48
O. olivaria	0.00	0.00	0.61	0.24
L. recta	0.00	0.00	0.61	0.24
Q. metanevra	0.00	0.70	0.00	0.24
Total individuals	115	142	164	421
Total species	14	16	16	20
Species diversity	1.45	1.52	1.56	1.58
Evenness	0.45	0.42	0.47	0.42
Menhinick's index	1.31	1.34	1.25	0.97
Simpson's dominance	0.40	0.40	0.36	0.38
% Individuals <30 mm	17.39	8.63	9.88	11.54
% Species <30 mm	50.00	40.00	40.00	52.63

Note: With the exception of total individuals and total species, all community indices exclude *D. polymorpha*.

Table A5
Frequency of Occurrence of Freshwater Mussels Collected at a Farshore Site, Main Channel, UMR near Prairie du Chien, WI, September 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	100.00	100.00	100.00	100.00
T. truncata	80.00	80.00	80.00	80.00
L. fragilis	40.00	60.00	90.00	63.33
O. reflexa	40.00	50.00	30.00	40.00
Q. quadrula	10.00	30.00	40.00	26.67
M. nervosa	20.00	30.00	20.00	23.33
P. alatus	0.00	0.00	30.00	10.00
T. donaciformis	10.00	10.00	20.00	13.33
D. polymorpha	0.00	30.00	20.00	16.67
S. undulatus	10.00	20.00	10.00	13.33
E. lineolata	10.00	10.00	20.00	13.33
Q. pustulosa	10.00	10.00	10.00	10.00
F. flava	0.00	10.00	10.00	6.67
L. higginsi	10.00	20.00	0.00	10.00
L. ovata	10.00	10.00	10.00	10.00
P. coccineum	30.00	0.00	0.00	10.00
A. confragosus	10.00	10.00	0.00	6.67
O. olivaria	0.00	0.00	10.00	3.33
L. recta	0.00	0.00	10.00	3.33
Q. metanevra	0.00	10.00	0.00	3.33
Total samples	10	10	10	30

Appendix B
Freshwater Mussels Collected in the East Channel of Upper Mississippi River (UMR), Pool 10, September 1993

Table B1
Percent Abundance and Frequency of Occurrence for Freshwater Mussels Collected at Five Sites in the East Channel, UMR, September 1993, Using Qualitative Methods

Species	Total Indices	% Abundance	Total Sample	% Occurrence
A. p. plicata	529	55.33	56	93.33
L. fragilis	89	9.31	25	41.67
T. truncata	53	5.54	29	48.33
F. flava	46	4.81	28	46.67
Q. p. pustulosa	33	3.45	24	40.00
L. ovata	30	3.14	18	30.00
M. nervosa	30	3.14	18	30.00
L. recta	29	3.03	22	36.67
P. alatus	28	2.93	18	30.00
Q. quadrula	26	2.72	21	35.00
O. olivaria	23	2.41	15	25.00
O. reflexa	7	0.73	7	11.67
A. grandis	6	0.63	4	6.67
Q. metanevra	6	0.63	6	10.00
A. confragosus	4	0.42	4	6.67
E. dilatata	3	0.31	3	5.00
L. complanata	3	0.31	2	3.33
E. lineolata	2	0.21	2	3.33
L. higginsi	2	0.21	2	3.33
Q. nodulata	2	0.21	2	3.33
S. undulatus	2	0.21	2	3.33
A. imbecillis	1	0.10	1	1.67
P. coccineum	1	0.10	1	1.67
T. donaciformis	1	0.10	1	1.67
Total individuals	956			
Total species	24			
Total samples	60			

Table B2
Percent Abundance of Freshwater Mussels Collected in the Turning Basin, East Channel, UMR near Prairie du Chien, September 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	34.62	31.82	9.09	28.81
F. flava	30.77	22.73	27.27	27.12
O. reflexa	7.69	31.82	0.00	15.25
P. alatus	15.38	0.00	27.27	11.86
Q. quadrula	3.85	0.00	9.09	3.39
T. truncata	0.00	4.55	9.09	3.39
A. imbecillis	0.00	9.09	0.00	3.39
L. fragilis	3.85	0.00	0.00	1.69
D. polymorpha	3.85	0.00	0.00	1.69
A. grandis	0.00	0.00	9.09	1.69
M. nervosa	0.00	0.00	9.09	1.69
Total individuals	26	22	11	59
Total species	7	5	7	11
Species diversity (H')	1.59	1.42	1.80	1.87
Evenness	0.92	1.06	1.62	0.80
Menhinick's index	1.37	1.07	2.11	1.43
Simpson's dominance	0.22	0.23	0.11	0.18
Total individuals <30 mm	3.85	13.04	10.00	8.47
Total species <30 mm	14.29	50.00	16.67	45.45

Note: With the exception of total individuals and total species, all community indices exclude *D. polymorpha*.

Table B3
Frequency of Occurrence of Freshwater Mussels Collected in the Turning Basin, East Channel, UMR near Prairie du Chien, September 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	50.00	60.00	10.00	40.00
F. flava	30.00	40.00	20.00	30.00
O. reflexa	20.00	60.00	0.00	26.67
P. alatus	40.00	0.00	20.00	20.00
Q. quadrula	10.00	0.00	10.00	6.67
T. truncata	0.00	10.00	10.00	6.67
A. imbecillis	0.00	20.00	0.00	6.67
L. fragilis	10.00	0.00	0.00	3.33
D. polymorpha	10.00	0.00	0.00	3.33
A. grandis	0.00	0.00	10.00	3.33
M. nervosa	0.00	0.00	10.00	3.33
Total samples	10	10	10	30

Table B4
Percent Abundance of Freshwater Mussels Collected in the Reference Site in East Channel, UMR, September 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	44.68	36.84	45.10	40.57
O. reflexa	19.15	23.68	13.73	20.28
L. fragilis	2.13	11.40	11.76	9.43
T. truncata	8.51	7.02	3.92	6.60
F. flava	4.26	2.63	5.88	3.77
P. alatus	4.26	2.63	5.88	3.77
M. nervosa	2.13	3.51	1.96	2.83
T. donaciformis	0.00	1.75	1.96	1.42
Q. pustulosa	4.26	0.88	3.92	2.36
Q. quadrula	8.51	2.63	0.00	3.30
L. higginsi	0.00	1.75	0.00	0.94
A. ligamentina	0.00	1.75	0.00	0.94
E. dilatata	0.00	1.75	0.00	0.94
A. imbecillis	0.00	0.00	1.96	0.47
L. ovata	0.00	0.00	1.96	0.47
S. undulatus	2.13	0.88	0.00	0.94
L. recta	0.00	0.00	1.96	0.47
O. olivaria	0.00	0.88	0.00	0.47
Total individuals	47	114	51	212
Total species	10	15	12	18
Species diversity	1.74	1.96	1.86	1.98
Evenness	0.66	0.63	0.61	0.56
Menhinick's index	1.46	1.40	1.68	1.24
Simpson's dominance	0.24	0.21	0.23	0.22
% Individuals <30 mm	61.70	40.35	25.49	41.51
% Species <30 mm	60.00	46.67	50.00	44.44

Note: With the exception of total individuals and total species, all community indices exclude *D. polymorpha*.

Table B5
Frequency of Occurrence of Freshwater Mussels Collected in the Reference Site in East Channel, UMR, September 1993, Using Quantitative Methods

Species	Subsite 1	Subsite 2	Subsite 3	Total
A. p. plicata	70.00	100.00	50.00	70.00
O. reflexa	40.00	90.00	40.00	63.33
L. fragilis	10.00	60.00	50.00	56.67
T. truncata	30.00	60.00	10.00	43.33
F. flava	10.00	20.00	20.00	33.33
P. alatus	20.00	30.00	20.00	36.67
M. nervosa	10.00	40.00	10.00	36.67
T. donaciformis	0.00	20.00	10.00	30.00
Q. pustulosa	20.00	10.00	20.00	30.00
Q. quadrula	30.00	10.00	0.00	23.33
L. higginsi	0.00	10.00	0.00	23.33
A. ligamentina	0.00	10.00	0.00	23.33
E. dilatata	0.00	20.00	0.00	26.67
A. imbecillis	0.00	0.00	10.00	23.33
L. ovata	0.00	0.00	10.00	23.33
S. undulatus	10.00	10.00	0.00	23.33
L. recta	0.00	0.00	10.00	23.33
O. olivaria	0.00	10.00	0.00	23.33
Total samples	10	10	10	30

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13. ABSTRACT *(Maximum 200 words)*

In 1988, the U.S. Army Engineer District, St. Louis, initiated a monitoring program to analyze the effect of commercial navigation traffic on freshwater mussels (Mollusca: Unionidae), especially the endangered *Lampsilis higginsi*, in the upper Mississippi River (UMR). Preliminary studies were conducted in 1988, and detailed studies were initiated in 1989 and will continue until 1994. In August-September 1993, freshwater mussels were collected using qualitative and quantitative (0.25 sq m total substrate) methods in the main and east channel of Pool 10 near River Mile (RM) 635.2. The sampling program was reduced in 1993 because of high water throughout most of the UMR.

Using quantitative methods, a total of 19 and 20 bivalve species were collected at nearshore and farshore sites in the main channel. Overall species diversity (H') was similar at both sites, 1.70 and 1.58 at the nearshore and farshore sites, respectively. In the main channel, 15.66 and 11.54 of the fauna showed evidence of recent recruitment at nearshore and farshore sites, respectively. Density (individuals/square meter) at the nearshore (64.5) and farshore site (56.1) was not significantly different ($F = 1.85$, $P > 0.05$). The endangered *L. higginsi* comprised 0.25 percent (one individual collected) and 0.11 percent (four individuals collected) using qualitative and quantitative methods, respectively, in the main channel.

(Continued)

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Six attributes of mussel beds were examined to judge their health: (a) decrease in density of five common-to-abundant species, (b) presence of *L. higginsi* (if within its range); (c) live-to-recently-dead ratios for dominant species, (d) loss of more than 25 percent of the mussel species, (e) evidence of recent recruitment, and (f) a significant change in growth rates or mortality of dominant species. An examination of these six attributes, based on information collected to date, reveals that biotic conditions are stable at these beds.