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August 1996

US Army Corps of Engineers
Waterways Experiment Station

Importance of a Mussel Bed Near McMillan Island, Pool 10 of the Upper Mississippi River, for *Lampsilis higginsi*

by Andrew C. Miller, Barry S. Payne

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

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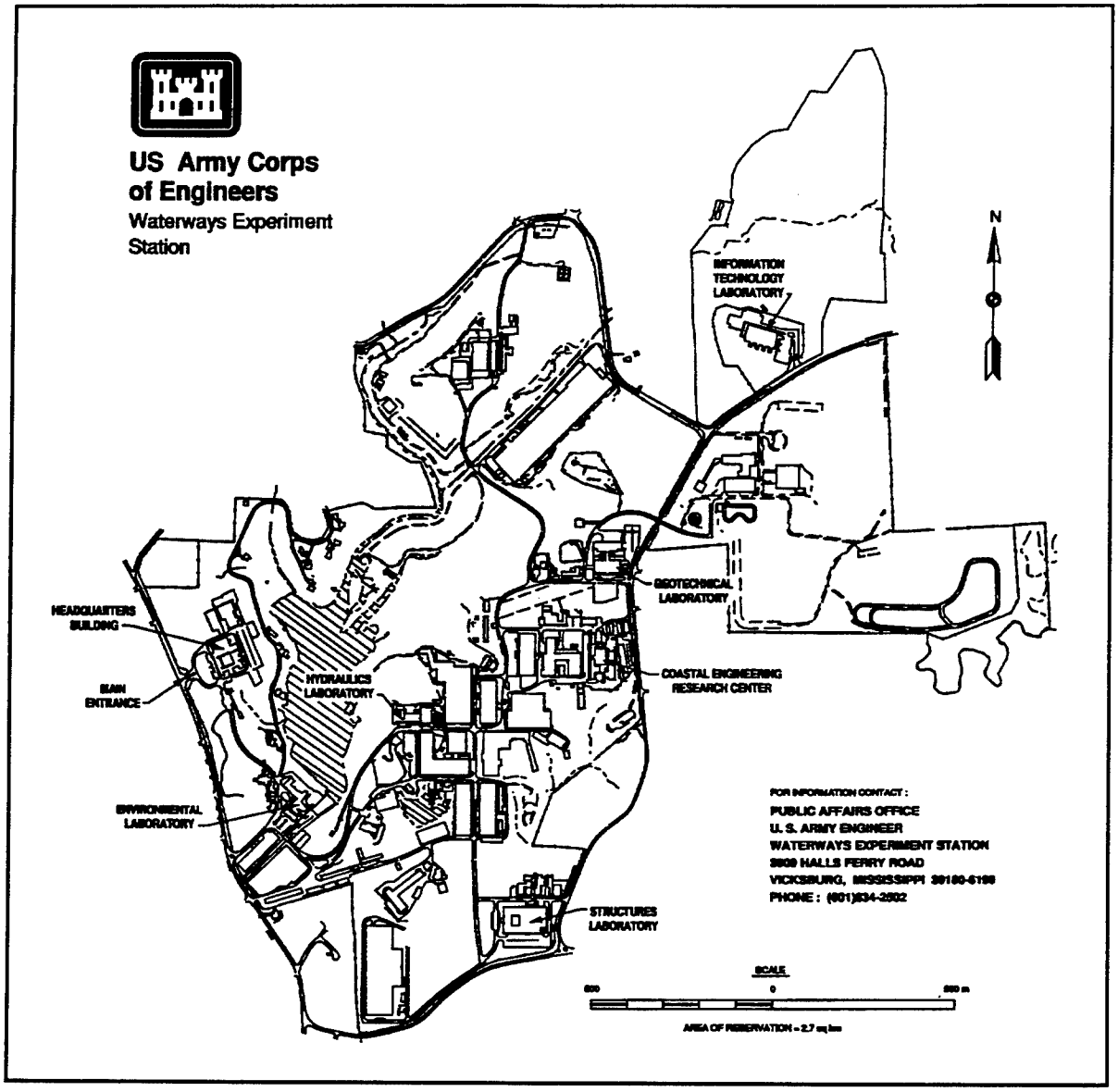

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Preface

Research described in this report was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) in August 1994 for the U.S. Army Engineer District, St. Paul, St. Paul, MN. The purpose was to characterize native and non-native bivalves in a reach of the upper Mississippi River near McMillan Island, considered to be one of seven essential locations for *Lampsilis higginsi* (Lea). Information will be used by the District for environmental impact evaluation and planning purposes.

Divers for this study were Messrs. Larry Neill, Kevin Chalk, Robert T. James, Jeff Montgomery, and Robert Warden from the Tennessee Valley Authority. Assistance in the field was provided by Messrs. Travis Whiting, University of Southern Mississippi, and David Rogillio, diving inspector from WES. Figures were prepared by Ms. Geralline Wilkerson, Jackson State University. The assistance of Mr. Bob Whiting, St. Paul District, is acknowledged.

During the conduct of this study, Dr. John W. Keeley was Director, Environmental Laboratory (EL), WES; Dr. Conrad J. Kirby was Chief, Ecological Research Division (ERD), EL; and Dr. Alfred F. Cofrancesco was Chief, 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, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

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1 Introduction

Background

The Higgins' Eye Recovery Team (1982) evaluated 16 localities in the upper Mississippi River (UMR) for the Higgins' eye mussel, *Lampsilis higginsi* (Lea, 1857). The team determined that sufficient information was available to list seven as essential habitat. An additional nine locations were considered to be of secondary importance, mainly because of a lack of available information. Since the Higgins' Eye Recovery Plan was published in the early 1980s, many Government and private organizations have funded additional research on freshwater mussels in the UMR. These studies, conducted to obtain information for environmental impact statements, assessments, and permit actions, have provided information not only on *L. higginsi* but other species as well. The purpose of this study was to obtain information on density, community composition, species diversity, and richness at a mussel bed near McMillan Island, an area considered to be essential for *L. higginsi*. The McMillan Island area was evaluated by the St. Paul District as a potential site for construction of channel control structures as part of the long-term channel maintenance plan for the District. A section of the main channel near McMillan Island has required dredging in the past (Whiting 1981).

Freshwater mussels are long lived (30 or more years in some species), rely on particulate organic matter for nutrition, and because they are relatively nonmotile, are unable to move if conditions become unsuitable. Their habitat is affected by local and upriver changes in climate, season, land use, edaphic conditions, and water level. In addition, they can be affected by source and nonsource pollution and modification of waterways for commercial traffic. The biological consequences of man-made and natural disturbances can be measured on organisms held in the laboratory. However, caution must be used when extrapolating results of laboratory experiments to the field (Payne and Miller 1987). Alternatively, repetitive field studies can be designed to measure physical effects of water resource development on recruitment, rate of growth, density, species richness, and diversity. These parameters provide the most useful measures of the overall health and ultimate survival of a mussel community. It is particularly important to investigate biological attributes of a community that includes an endangered species. Long-term studies of freshwater mussels provide baseline data that can be used to evaluate the

effects of man's activities on a resource with ecological, economic, and cultural value.

Purpose and Scope

The purpose was to conduct a survey for freshwater mussels near McMillan Island, River Mile (RM) 617-619 in the UMR. The research was designed to address four objectives:

a. Determine the percent abundance and make a numerical density estimate of *L. higginsi* in the project area.

b. Determine the spatial distribution patterns of *L. higginsi* in the project area.

c. Relate physical parameters (depth, water velocity, and sediment type) to presence of *L. higginsi*.

d. Determine if other species of native bivalves are found in association with *L. higginsi*.

This study was funded by the St. Paul District for environmental impact evaluation and planning purposes.

2 Study Area and Methods

Study Area

McMillan Island is near Guttenburg, IA, in Pool 10 of the UMR (Figure 1). The island is approximately 3 river miles[1] upriver of Lock and Dam 10, RM 615. Thirty miles upriver of McMillan Island, at RM 648, is Lock and Dam 9. McMillan Island is actually a group of small islands separated by shallow water less than 1 to 2 m deep at normal stage. Substratum consists of gravelly sand. Aquatic plants are located in shallow areas west of the island along much of shore. During the survey, in August 1994, current velocities ranged from 5 to 30 cm/sec.

Mussels were collected by divers at 12 locations (Figure 1). Sites 1-8 were west and Sites 9-12 were east of the island and the main river channel. Site 9 was between two wing dams, and Sites 10-12 were located on or immediately downriver of a wing dam. Water depth ranged from approximately 1 to more than 4 m at survey sites.

Methods

All underwater work was accomplished by a dive crew equipped with surface-supplied air and communication equipment. Before intensive sampling was initiated, a diver conducted a preliminary reconnaissance of each sample site. He obtained qualitative information on substratum composition (i.e., relative percentages of sand and gravel), water velocity, and presence of mussels. Qualitative sampling was initiated if substratum appeared stable and if there was moderate to high mussel density (i.e., greater than 3 to 5 individuals/square meter).

Qualitative samples were obtained by two divers working simultaneously. Each diver worked for a specific length of time (Table 1) and retrieved live mussels by touch. Two divers working together placed 5 mussels in each of three nylon bags and 20 mussels in each of nine nylon bags. They were

[1] To convert miles (U.S. statute) to kilometers, multiply by 1.609347.

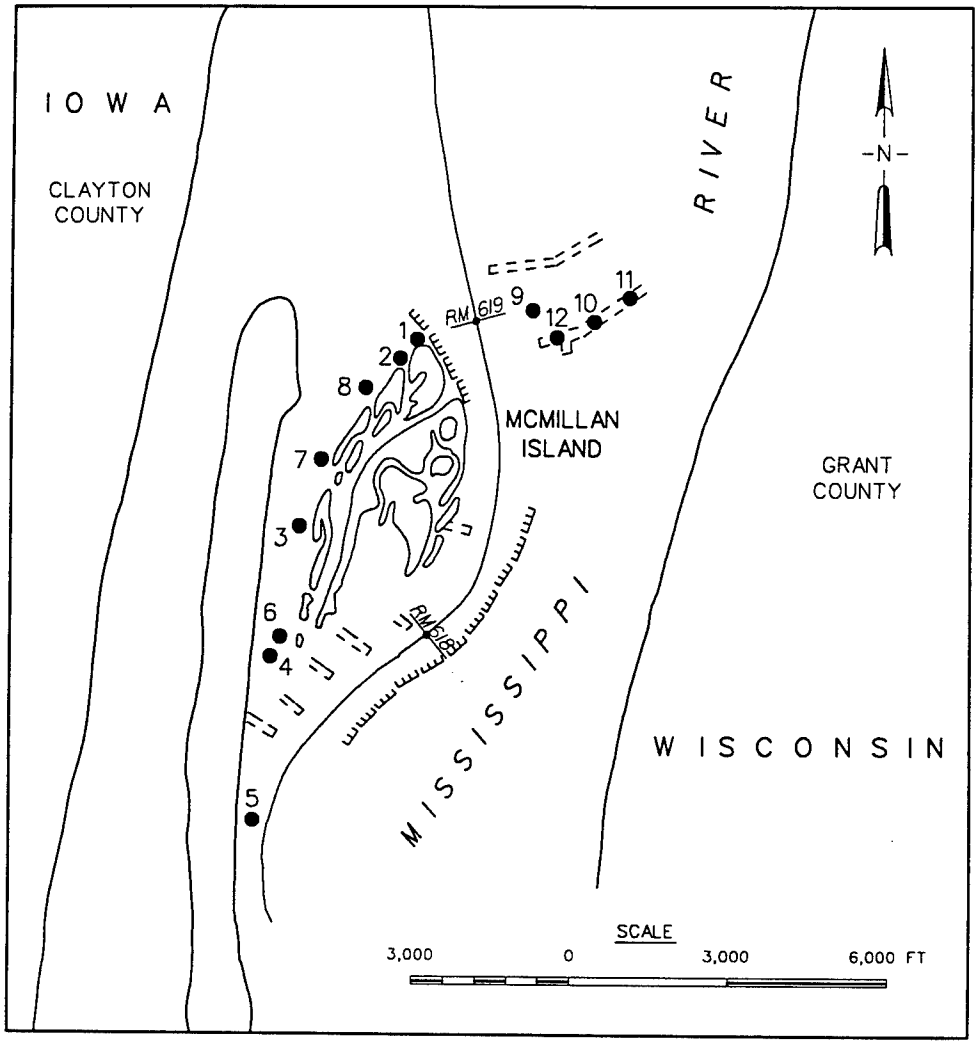

Figure 1. Study area (Qualitative methods were used at all 12 sites; quantitive methods were used at Site 5 and near Sites 1 and 2)

instructed to obtain native mussels without bias to size or type and to exclude two small nonindigenous species, *Corbicula fluminea* and *Dreissena polymorpha*. Differentiation of these species was based upon touch; however, if these species were collected, they were later excluded from data analysis.

The above method for qualitative samples was not used on wing dams. At three sites on a wing dam, a 20-min collection was made on and immediately downriver of the dam. Incremental collections (a specific number of mussels per bag) were not obtained at wing dam sites.

Quantitative samples were obtained at two sites (Table 2). The quantitative methods provided information on *C. fluminea* and *D. polymorpha*. At RM 617.2, near a daymark at Site 5, 10 samples were taken at each of three closely placed subsites (30 samples total). At the second location (RM 619.0,

Table 1
Description Information on Qualitative Samples Collected Near McMillan Island, Pool 10, UMR, August 1994

Site No.	No. of Reps	Description	Depth, m	Time, min
1	5	Upper end of island	1	50
2	5	Upper end of island	1	25
3	2	Part way down island	2	24
4	2	Southern tip of island	3-4	20
5	2	Daymark	2-4	20
6	12	Southern tip of island	1-2	55
7	4	Part way down slough	2	20
8	2	Upper end of island	1.5	20
9	2	Between dikes	3-4	20
10	4	Wing dam (on and just downriver)	2-4	40
11	4	Wing dam (on and just downriver)	2-4	40
12	4	Wing dam (on and just downriver)		40
Total	48			374

Note: See Figure 1 for location of sites.

Table 2
Description Information on Quantitative Samples Collected Near McMillan Island, Pool 10, UMR, August 1994

Site No.	Sample No.	No. of Reps	Location	Sample Type	Depth, m
1	4	10	North end of island - RM 619.0	Total Substratum	< 0.5
1	5	10	North end of island - RM 619.0	Total Substratum	< 0.5
1	6	10	North end of island - RM 619.0	Suction	1.0
1	7	10	North end of island - RM 619.0	Suction	1.0
1	8	10	North end of island - RM 619.0	Suction	1.5
5	1	10	Daymark - RM 617.2	Suction	4.0
5	2	10	Daymark - RM 617.2	Suction	4.0
5	3	10	Daymark - RM 617.2	Suction	4.0

Note: River Mile 617.2 was at Site 5, and RM 619.0 was near Site 1 (See Figure 1). Sample 4 was taken from a plant bed with very low density. Bucket samples are total substratum collected by divers and sieved on shore.

at the upper end of the island, near Site 1), 10 samples were taken at each of each of five closely placed subsites (50 samples total).

Two methods for collecting quantitative samples were used. Twenty samples were obtained by having a diver excavate all sand, gravel, and shells from within a 0.25-m^2 aluminum quadrat. Substratum was transferred to a 20-ℓ bucket, taken to shore, and sieved through a screen series with the finest apertures 6.4 mm on a side. All live mussels removed from samples were placed in 4-ℓ zipper-lock bags. Each bivalve was identified and total shell length measured to the nearest 0.1 mm with calipers.

Sixty samples were obtained with a suction pump. The suction pump was used to remove substratum from the 0.25-m^2 quadrat (Table 2). This technique was used because it was fast and efficient, and previous sampling revealed that it provided the same results as total substratum methods. Sand and gravel were pumped to the boat and screened and picked for live mussels. Once collected, sediments from the total substratum and suction pump were treated in an identical manner. All live mussels were bagged for later processing.

U.S. Army Engineer Waterways Experiment Station personnel had appropriate State and local permits. All live *Lampsilis higginsi* were aged and total shell length measured. They were then placed back in the substratum by hand.

Data from qualitative and quantitative collections were recorded on standard data sheets and returned to the laboratory for analysis and plotting. Shells of voucher specimens for each species were placed in plastic zipper-lock bags. Mussels not needed for voucher were returned to the river. Methods for sampling mussels are based on techniques described in Miller and Nelson (1983); Isom and Gooch (1986); Kovalak, Dennis, and Bates (1986); Miller and Payne (1988); and Miller et al. (1994). Mussel identification was based on taxonomic keys and descriptive information in Murray and Leonard (1962); Parmalee (1967); Starrett (1971); and Burch (1975). Taxonomy is consistent with Williams et al. (1992).

Species diversity was determined with the following formula:

$$H' = -p_j \log p_j$$

where p_j is the proportion of the population that is of the jth species (Shannon and Weaver 1949). All calculations were done with programs written in BASIC or SAS (Statistical Analytical System) on a personal computer.

3 Results

Community Analysis

Twenty-four species of bivalves were collected using quantitative (22 species) and qualitative (20 species) methods (Table 3 and Appendix A). The fauna included species typically found in the UMR and the endangered *Lampsilis higginsi* (U.S. Fish and Wildlife Service 1991) often collected in Pool 10. The nonindigenous *C. fluminea*, restricted to warmer waters (McMahon 1983), was uncommon. The zebra mussel, *D. polymorpha*, first collected in North America in 1988, was also found. Information on mussels previously collected by personnel of the U.S. Army Engineer District, St. Paul, appears in Appendix B.

Using qualitative methods, 19 species of Unionidae were collected on or immediately downriver of a wing dam, and 20 species were collected at Sites 1-9 in gravelly sand substratum (Table 4). The fauna obtained with quantitative collecting was dominated by *Amblema plicata plicata*, *Obliquaria reflexa*, and *Lampsilis cardium*. The endangered *L. higginsi* comprised 0.40 percent of the community on the wing dams and 0.61 percent in gravelly sand. Sites where *L. higginsi* were found and numbers taken are as follows: Site 1 (1), Site 2 (1), Site 4 (1), Site 5 (2), Site 10 (1), and Site 11 (1).

Wing dams provided stable substratum for unionids. Species diversity (the Shannon Index, H') was greater than 2.1 on or immediately downriver of the wing dams but less than 1.8 in gravelly sand west of the island (Table 4). Lower species diversity values in gravelly sand was the result of higher relative abundance of the ubiquitous *A. p. plicata*. This species was approximately twice as abundant in gravelly sand as it was on or immediately downriver of the wing dam.

Mussels were more difficult for divers to obtain on the wing dam. Native species were collected at a rate of 2.2 individuals/minute on the wing dam versus 4.1 individuals/minute downriver of the wing dam and 3.2 individuals/minutes in gravelly sand substratum some distance from wing dams (Sites 1-8.) The ability to obtain new species per number of individuals collected was greater on or immediately downriver of the wing dam than in gravelly sand (Figure 2). After 200 individuals were obtained from the wing dam,

Table 3
Species of Freshwater Bivalves Collected Using Quantitative (Quant) and Qualitative (Qual) Methods Near McMillan Island, Pool 10, UMR, August 1994

Species	Quant	Qual
Arcidens confragosus	X	
Pyganodon grandis	X	X
Amblema p. plicata	X	X
Corbicula fluminea	X	
Dreissena polymorpha	X	
Elliptio dilatata	X	X
Fusconaia flava	X	X
Lasmigonia complanata	X	X
Lasmigonia costata		X
Leptodea fragilis	X	X
Lampsilis higginsi	X	X
Lampsilis cardium	X	X
Lampsilis siliquoidea	X	X
Ligumia recta	X	X
Megalonaias nervosa	X	X
Obovaria olivaria	X	X
Obliquaria reflexa	X	X
Potamilus alatus	X	X
Quadrula nodulata	X	X
Quadrula p. pustulosa	X	X
Quadrula quadrula	X	X
Strophitus undulatus		X
Truncilla donaciformis	X	
Truncilla truncata	X	X
Total species	22	20

18 species were identified. After 200 individuals were collected from gravelly sand, only 11 had been identified. The ability to find new species more quickly on or near the wing dam was due in part to fewer numbers of *A. p. plicata* in this habitat type.

Density

Mean density of all bivalves (including *C. fluminea* and *D. polymorpha*) was 10.5 and 16.2 individuals/square meter at RM 619.0 and 617.2, respectively (Table 5 and Appendix A). Unionids density (excluding *C. fluminea*

Table 4
Percent Species Abundance and Summary Statistics for Mussel Data Collected Using Qualitative Methods on or Immediately Downriver of Wing Dams and in Gravelly Sand Near McMillan Island, Pool 10, UMR, August 1994

Species	Wing Dams (Sites 10-12)			Gravelly Sand (Sites 1-9)
	On Wing Dams	Downriver of Wing Dams	Total	
Percent Species Abundance				
A. p. plicata	28.00	25.50	26.33	47.75
O. reflexa	8.00	23.51	18.35	17.17
L. cardium	16.80	11.95	13.56	6.58
F. flava	7.20	8.76	8.24	5.12
Q. quadrula	2.40	8.76	6.65	4.87
L. recta	6.40	4.38	5.05	0.37
L. fragilis	8.80	1.20	3.72	0.12
Q. p. pustulosa	2.40	4.38	3.72	5.36
M. nervosa	8.00	0.80	3.19	0.49
T. truncata	4.00	1.99	2.66	0.97
Q. nodulata	0.00	3.59	2.39	6.70
O. olivaria	2.40	1.99	2.13	1.10
L. complanata	0.00	0.40	0.27	0.37
P. alatus	1.60	0.80	1.06	1.10
S. undulatus	1.60	0.80	1.06	0.00
L. siliquoidea	0.80	0.80	0.80	0.85
P. grandis	0.80	0.00	0.27	0.24
L. higginsi	0.00	0.40	0.27	0.61
E. dilatata	0.00	0.00	0.00	0.12
L. costata	0.00	0.00	0.00	0.12
Summary Statistics				
Total individuals	125	251	376	821
Total species	16	18	19	20
Total time (min)	60	60	120	254
Collection rate (/min)	2.2	4.1	3.1	3.23
Species diversity	2.34	2.15	2.32	1.79
Evenness	0.73	0.72	0.69	0.53
Menhinick's Index	1.41	1.14	0.98	0.66

Note: Sites 10-12 included areas on and immediately downriver of wing dams, and Sites 1-9 were at areas with gravelly sand (See Figure 1).

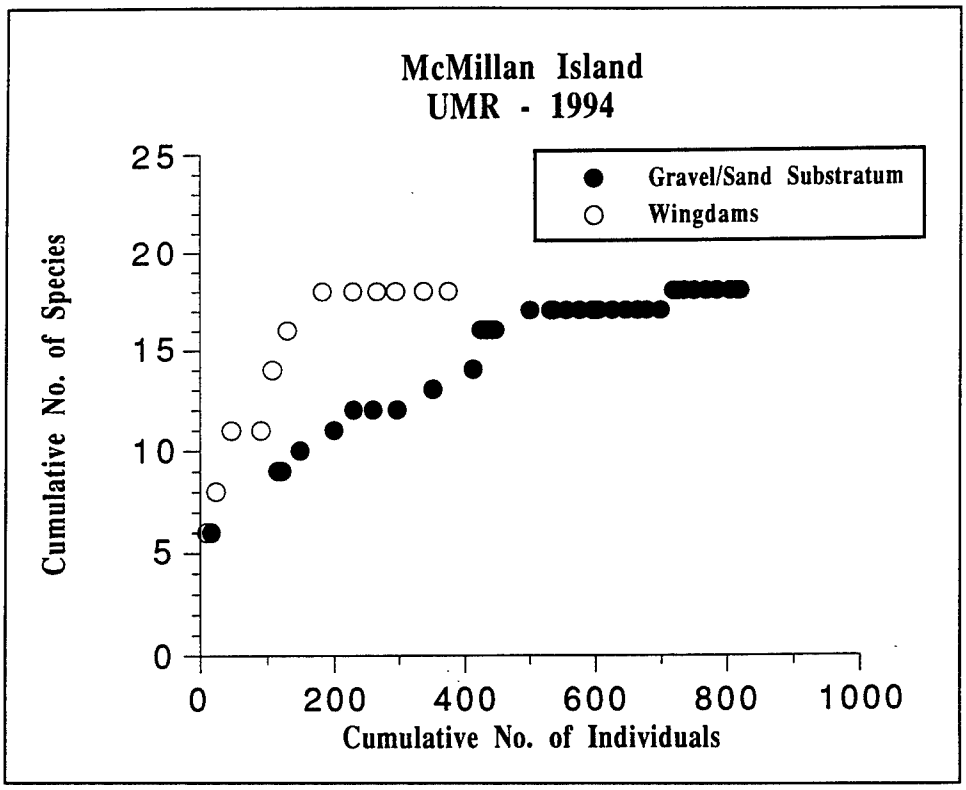

Figure 2. Relationship between cumulative species and cumulative individuals collected using qualitative methods at two habitat types

and *D. polymorpha*) at these two sites was 9.2 and 15.1 individuals/square meter. *Amblema p. plicata* was dominant at both locations, although less than half as abundant in the shallow water at the northern end of the island than in the deeper water at RM 617.2. Overall, the zebra mussel comprised approximately 8 percent and the Asian clam only 0.41 percent of the collection. Based on quantitative sampling during this survey, *L. higginsi* was more common in shallow than deep water near RM 617.2 (depth from 2 to 4 m). In shallow water at RM 619.0, this species comprised 1.3 percent of the fauna. At RM 617.2 (depth 2 to 4 m), *L. higginsi* was not taken in quantitative samples.

There was ample evidence of community-wide recruitment for indigenous and nonindigenous species. Approximately 23 percent of all individuals and 41 percent of all bivalves were less than 30 mm total shell length. Organisms of this size are 1 to 2 years old and provide evidence of recent recruitment. Excluding *D. polymorpha* and *C. fluminea*, 15 percent of the indigenous individuals and 35 percent of all indigenous species showed evidence of recent recruitment.

Table 5
Percent Species Abundance and Other Summary Statistics for Bivalve Data Collected at Two Locations Near McMillan Island, Pool 10, UMR, August 1994, Using Quantitative Methods

Species	RM 619.0 Samples 1-3	RM 617.2 Samples 5-8	Total
Percent Species Abundance			
A. p. plicata	18.99	54.94	43.15
F. flava	6.33	14.20	11.62
D. polymorpha	11.39	6.79	8.30
O. reflexa	13.92	4.94	7.88
L. fragilis	13.92	3.09	6.64
T. truncata	8.86	1.85	4.15
L. cardium	6.33	2.47	3.73
Q. quadrula	5.06	2.47	3.32
Q. pustulosa	1.27	3.09	2.49
L. siliquidea	0.00	1.85	1.24
O. olivaria	2.53	0.62	1.24
L. complanata	0.00	1.23	0.83
L. recta	1.27	0.62	0.83
M. nervosa	2.53	0.00	0.83
P. alatus	1.27	0.62	0.83
T. donaciformis	0.00	0.62	0.41
Q. nodulata	1.27	0.00	0.41
L. higginsi	1.27	0.00	0.41
P. grandis	0.00	0.62	0.41
E. dilatata	1.27	0.00	0.41
C. fluminea	1.27	0.00	0.41
A. confragosus	1.27	0.00	0.41
Total individuals	79	162	241
Total subsites	3	4	6
Total samples	30	40	70
Bivalve density (Includes *D. polymorpha* and *C. fluminea*)	10.53	16.20	13.58
Standard deviation	9.82	16.02	13.99
Unionid density (Excludes *D. polymorpha* and *C. fluminea*)	9.20	15.10	12.39
Standard Deviation	7.34	14.24	12.16
Total species	18	16	22
Species diversity	2.46	1.69	2.09
Evenness	0.87	0.46	0.50
Menhinick's Index	2.02	1.26	1.42
Percent Individuals < 30 mm	34.18	17.28	22.82
Percent Species < 30 mm	38.89	50.00	40.91

Note: Sample 4 was not included since it was from an aquatic plant bed that was much different from the other sites.

Size Demography of Common Species

Amblema plicata plicata

The size demography of *A. p. plicata*, the most abundant indigenous species at McMillan Island, indicated reasonably strong and consistent annual recruitment. Individual mussels ranged in length from 18 to 104 mm (Figure 3). The size structure of the population was generally bimodal. Mussels averaging 45 and 83 mm long represented the most abundant cohorts in the population; no mussels were obtained that measured from 64 to 68 mm long. Mussels ranging from 18 to 64 mm long undoubtedly represent multiple year classes. Sample size was not sufficiently large to clearly discern detailed aspects of cohort structure. However, three cohorts appear to comprise most of the smaller mussels in the population. These three cohorts are centered at 26 to 30 mm, 40 to 46 mm, and 52 to 58 mm and occur approximately in the ratio of 1:3:2, respectively. Larger mussels, ranging from 68 to 104 mm, also include multiple-year classes that could not be clearly discerned. Cohorts appear to be centered at 68 to 72 mm, 80 to 84 mm, 88 to 92 mm, and 98 to 100 mm, occurring approximately in the ratio of 16:4:2:1.

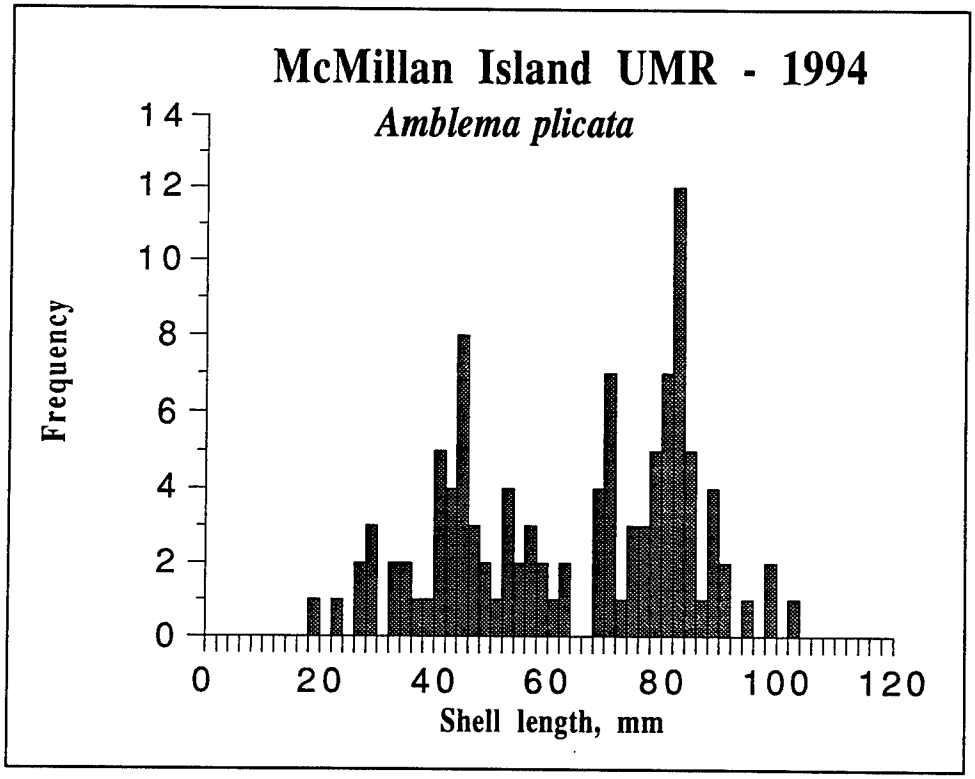

Figure 3. Length-frequency histogram for *Amblema plicata plicata* near McMillan Island, 1994

Dreissena polymorpha

Although only 20 individuals of *D. polymorpha* were obtained of this recently introduced species, the size structure of the population clearly reflected that only relatively recent recruits were present (Figure 4). All individuals ranged from 5 to 13 mm long and probably represented recruits during their first season of growth (i.e., spring 1994 settlement). Individuals of this species typically attain a maximum size of 30 to 40 mm over three seasons of growth.

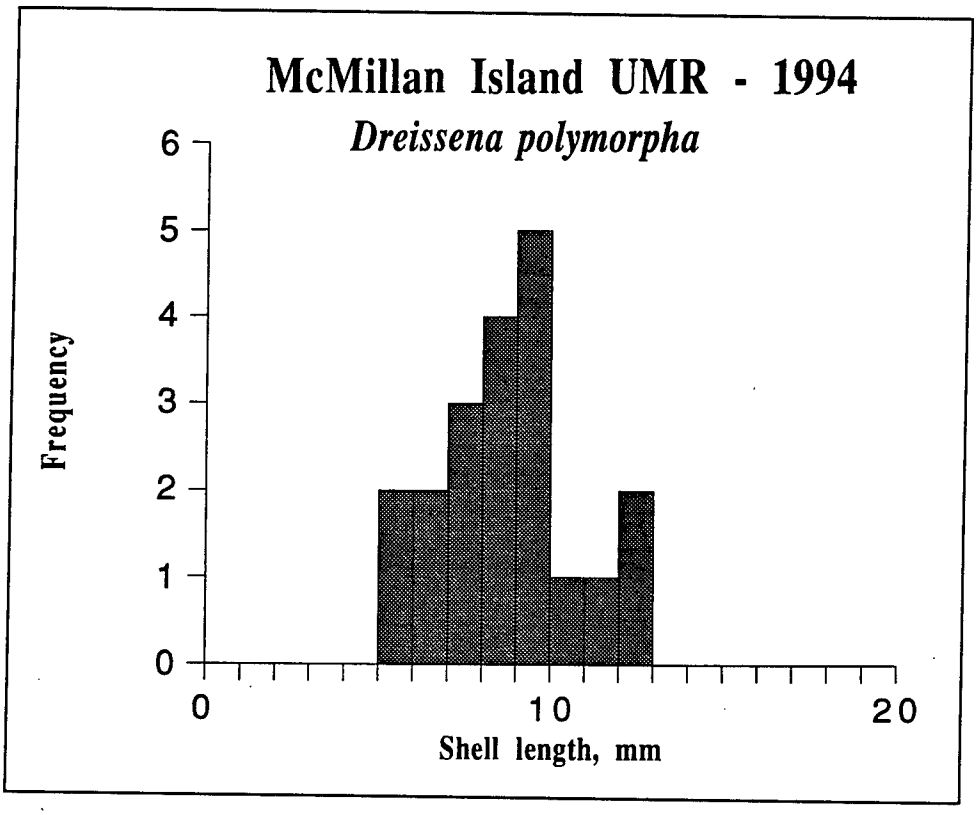

Figure 4. Length-frequency histogram for *Dreissena polymorpha* near McMillan Island, 1994

Truncilla truncata

Only 11 individuals of *T. truncata* were collected in quantitative samples, precluding detailed analysis of size demography. Individuals obtained ranged from 18 to 48 mm (Figure 5). The full-size range of this species was reasonably well represented, indicating consistent recruitment of this relatively small, short-lived, native unionid.

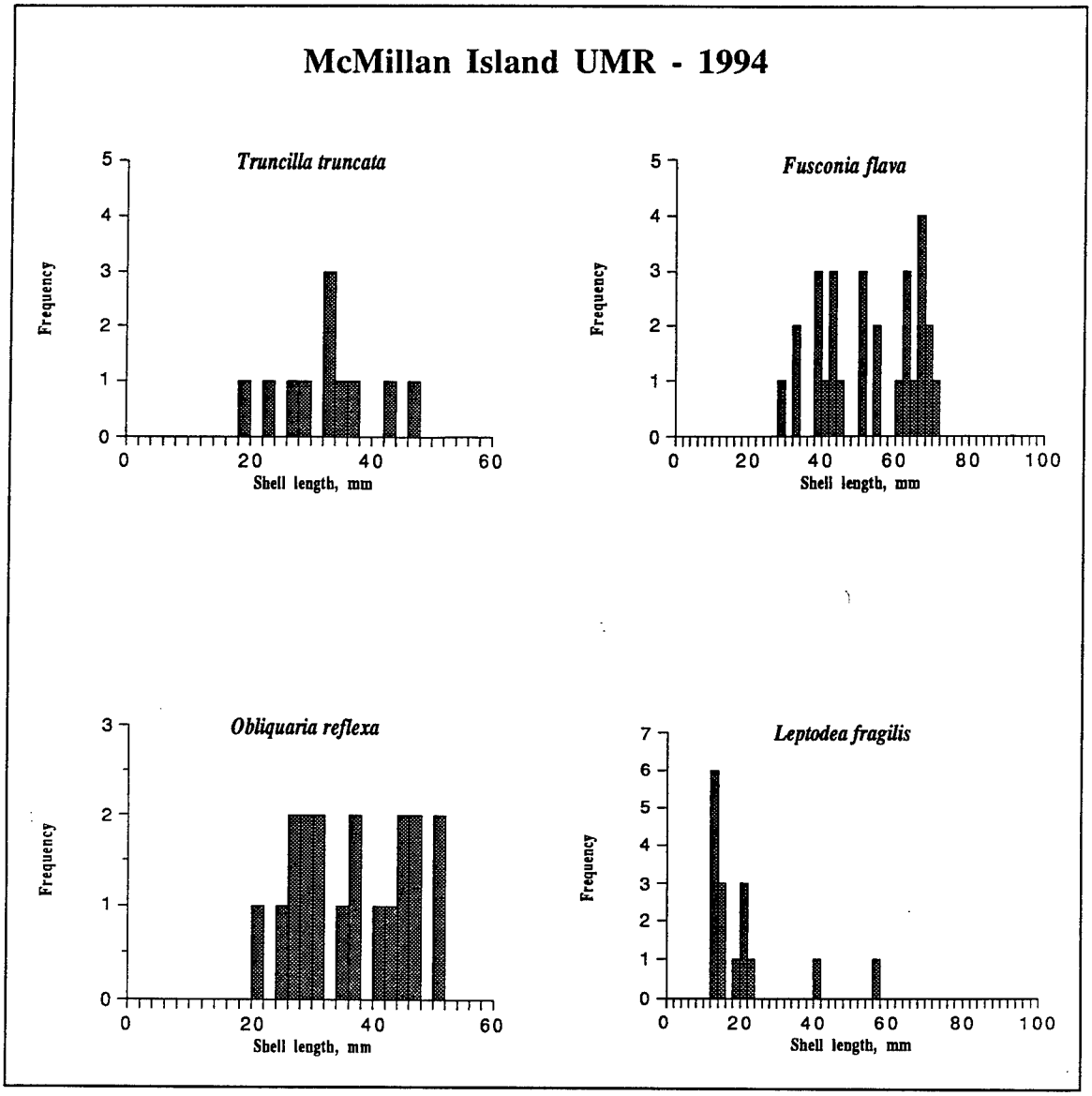

Figure 5. Length-frequency histograms for four species of freshwater mussels near McMillan Island, 1994

Fusconaia flava

A total of 28 individuals of *F. flava* were obtained in quantitative samples. Much like *T. truncata*, the small sample nonetheless represented a relatively complete size range (Figure 5). Individuals ranged from 28 to 72 mm, with abundance being relatively equally shared among size classes within that range. Thus, annual recruitment to this population appears to be relatively consistent.

Obliquaria reflexa

Once again, a small sample (n = 19) of *O. reflexa* nonetheless represented a size range (20 to 52 mm) that is typical of this species. Within the total size range, abundance was equally shared among size classes, indicating consistent annual recruitment of this medium-sized and moderately long-lived species (Figure 5).

Leptodea fragilis

Size structure of *L. fragilis* differed from the other native unionids. This species was represented almost entirely by very small, recent recruits. Fourteen of sixteen individuals collected were less than 24 mm long (Figure 5). Fully grown adults of this species typically range in length from 125 to 150 mm.

4 Discussion

Community and Population Characteristics

Total species richness near McMillan Island (24 species including *C. fluminea* and *D. polymorpha*), based on quantitative and qualitative sampling methods (Table 2), is slightly greater than that at other mussel beds in large rivers. At a bed in the lower Ohio River near Olmsted, IL, 23 species of freshwater mussels were identified during a single survey. In a survey of the lower Tennessee River, Miller, Payne, and Tippit (1992) collected 4,768 individuals and identified 23 species. In the east channel of the UMR, there are approximately 30 species (Miller and Payne 1993a).

The unionid fauna of most large-river mussel beds is dominated by two or three species. At a bed in the middle Ohio River near Cincinnati, OH, the fauna was dominated by *Pleurobema cordatum* and *Quadrula p. pustulosa*, which together comprised 39.9 percent of the assemblage (Miller and Payne 1993b). At a bed in the lower Tennessee River, the fauna was dominated by *A. p. plicata* (39.4 percent) and *Fusconaia ebena* (39.4 percent) (Miller, Payne, and Tippit 1992). Community composition at McMillan Island, although dominated by a single species (*A. p. plicata*), is similar to that at other large-river mussel beds.

Extreme dominance by a single species reduces species diversity values (H′). At RM 617.2, *A. p. plicata* comprised more than 50 percent of the community, and H′ was equal to 1.7. At RM 619.0, *A. p. plicata* comprised 19 percent of the community, and diversity was equal to 2.5. Total number of species at the two sites was only slightly different, 18 at RM 619.0 and 16 at RM 617.2.

In comparison with other large-river mussel beds, the range in total unionid density (9.2 and 15.1 individuals/square meter) at the two sites can be considered low. In a survey of the UMR in 1988, Miller et al. (1990) reported that total mussel density ranged from 5.2 to 333.2 individuals/square meter at 16 sites (10 quantitative samples were taken at each). At half of the sites, total density was greater than 50 individuals/square meter, and at four sites it was greater than 100 individuals/square meter. At an inshore and offshore site in the lower Tennessee River sampled in 1986 (32 quantitative

samples were collected at each), total mussel density was 187.7 and 79.7 individuals/square meter, respectively (Way, Miller, and Payne 1989). In the middle Ohio River near Cincinnati, mussel density ranged from 4.4 to 52.4 individuals/square meter (Miller and Payne 1993b).

The number of individuals less than 30 mm total shell length provides an estimate of recent recruitment. Individuals of this size are approximately 2 to 3 years old, and their presence indicates that conditions were appropriate for successful recent reproduction. The overall percentage of indigenous individuals and species (excluding *C. fluminea* and *D. polymorpha)* was 15 and 35 percent, respectively. Unionidae at McMillan Island exhibit evidence of fairly consistent recent recruitment.

Occasionally, mussel beds are surveyed that exhibit evidence of very strong recent recruitment. At a mussel bed in the lower Ohio River, a single cohort of *F. ebena* with an average shell length of 15.8 mm represented 71 percent of the population in 1983 (Payne and Miller 1989). However, several years passed before strong recruitment for this species was noted. Successful stocks of freshwater mussels (and other long-lived species) can be sustained without annual recruitment.

Presence of *Dreissena polymorpha*

The first report of *Dreissena polymorpha* in North America was from Lake St. Clair in June 1988 (Hebert, Muncaster, and Mackie 1989). By late summer 1989, zebra mussels had spread downstream into the Detroit River, Lake Erie, the Niagara River, and western Lake Ontario (Griffiths, Kovalak, and Schloesser 1989). By late September 1990, zebra mussels had spread through Lake Ontario and down the St. Lawrence River to Massena, NY. In June 1991, biologists from the Illinois Natural History Survey found adult zebra mussels at Illinois River Miles 50, 60, and 110 (Moore 1991; Sparks and Marsden 1991).

By early January 1993, zebra mussels had spread throughout most of the inland waterway system. They probably reached upriver sites on hulls of commercial navigation vessels (Keevin, Yarbrough, and Miller 1992). They were found in the lower Mississippi River as far south as Vicksburg, MS, and in the upper Mississippi River near St. Paul, MN (*Dreissena polymorpha* Information Review 1992). There is every reason to believe that this species will continue to spread throughout North America where suitable habitat exists (Strayer 1990).

Based on quantitative sampling, *D. polymorpha* comprised slightly less than 10 percent of the bivalve assemblage near McMillan Island (Table 5). Zebra mussels were found on native unionids, although usually less than five individuals per native mussel. Less than 25 percent of the native mussels had one or more attached zebra mussels. Although present in low numbers at this location, based on information from other water bodies of North America,

high densities of *D. polymorpha* were found in the UMR in 1995. A nonindigenous species usually achieves high densities after initial introduction, then numbers decline rapidly as resources diminish and parasites and predators become more abundant. Unlike the case of *C. fluminea*-unionid interactions, which are not always adverse (Miller and Payne 1994a), zebra mussels are likely to have negative localized effects on native mussels. There is every reason to believe that numbers of *D. polymorpha* will increase in this reach of the UMR and will ultimately have adverse effect on native mussels including *L. higginsi*. Future success of mussel stocks in this reach of the UMR will depend on how well native mussels survive the infestation of high-density populations of zebra mussels.

Value of Wing Dams for *L. higginsi*

Results of qualitative sampling on and immediately downriver of a wing dam east of McMillan Island demonstrated the value of this habitat for freshwater mussels. New species were found at a more rapid rate on the wing dam than in gravelly sand (Figure 2). Species diversity was higher on and immediately downriver of wing dams, mainly because of a more equitable distribution of species within the community (i.e., gravelly sand supported comparatively more *A. p. plicata*). Thin-shelled species such as *L. fragilis*, *L. cardium*, and *P. grandis* were more abundant on wing dams than in gravelly sand some distance from wing dams (Figure 6). *Lampsilis higginsi* was found immediately below the wing dam (Table 4) and has been collected on wing dams near Prairie du Chien, Pool 10) (Miller and Payne, unpublished information).

Suitability of Aquatic Habitat Near McMillan Island for *L. higginsi*

Research on the suitability of aquatic habitat near McMillan Island for *L. higginsi* was designed to specifically investigate the following topics:

Relation of physical parameters (depth, water velocity, and sediment type) to presence of *L. higginsi*

Multiple factors are responsible for determining the exact location where a unionid species will be found. A suitably infected fish must be immediately over a habitat with appropriate water velocity, depth, and substratum conditions when the glochidia is released. A specific microhabitat will not necessarily be suitable during all hydrologic conditions. A mussel community, comprised of multiple species and cohorts, exists because suitable hydrologic conditions are present over many seasons and years. Coupled with the fact that some mussels can be transported large distances by high water, predictive models relating species presence with habitat variables have low confidence

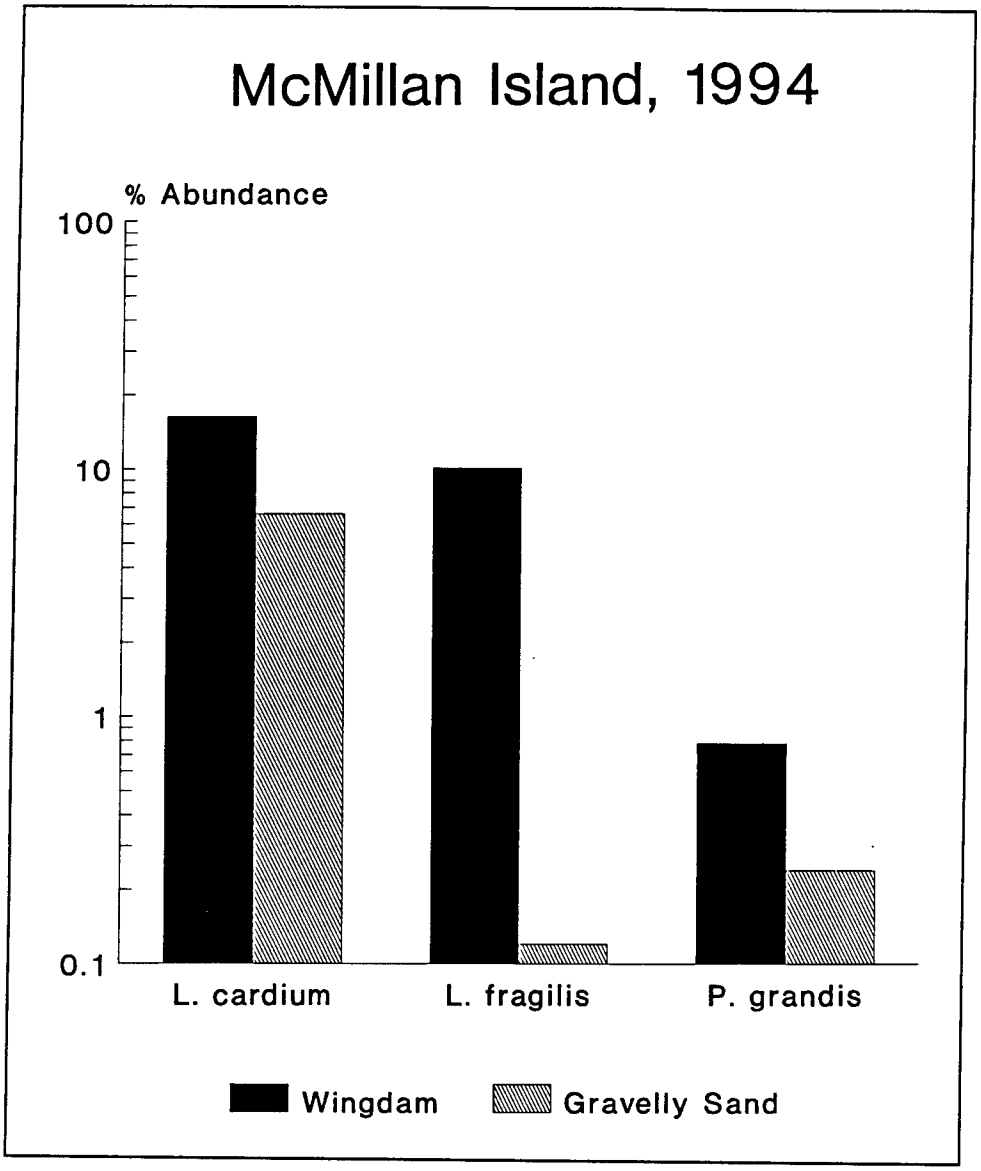

Figure 6. Percent abundance for three species of freshwater mussels at two habitat types, McMillan Island, 1994

(See Holland-Bartels (1990) and Strayer (1993)). Based upon results of this survey, relationships between this species and physical variables are not strong.

Spatial distribution of *L. higginsi*

Habitat was considered suitable for *L. higginsi* in the project area if water was greater than 1.0 m deep at low flow and substratum was free of plants and consisted of stable, gravelly sand. Based upon grain-size analysis, suitable sediments at McMillan Island consisted of small-to-medium-sized

particles, <6.35 mm (90 percent), small gravel, 6.35 to 12.7 mm (2 percent), medium gravel, 12.7 to 34.0 mm (5 percent), and large gravel, >34.0 mm (2 percent). During this survey, at least one *L. higginsi* was collected by hand in water slightly less than 1.0 m deep. This species, and other unionids, were not found in plant beds or in sediments consisting entirely of sand. Based upon an analysis of conditions at McMillan Island, it was estimated that 40,000 m^2 was suitable for *L. higginsi*.

Percent abundance and numerical density estimate for *L. higginsi* in project area

Compared with other Unionidae, *L. higginsi* was uncommon near McMillan Island. However, its overall percent abundance was actually slightly higher than at other nearby mussel beds. This comparatively high abundance is more striking when it is considered that this river reach supported relatively low mussel density. For example, at RM 619.0 this species comprised 1.3 percent of the fauna, and total unionid density was 9.2 individuals/square meter. In the east channel of the UMR near Prairie du Chien, where total unionid density ranges between 50 and 80 individuals/square meter, the percent composition of *L. higginsi* was 0.24 (1988), 0.68 (1989), 0.23 (1991), and 0.43 (1992) (Miller and Payne 1994b).

Using quantitative methods at sites east of McMillan Island (Figure 1), *L. higginsi* was collected at RM 619, where density was 9.2 individuals/square meter, but not at RM 617.2 where total density was slightly higher, 15.1 individuals/square meter. Using qualitative methods, this species was found at Sites 1, 2, 5, 6. *Lampsilis higginsi* was not collected at Sites 3, 4, 7, and 8. Sites where *L. higginsi* was not collected were characterized by low unionid density; collection rate ranged from 0.65 to 2.45 individuals/minute. At sites where *L. higginsi* was found, collection rate ranged from 3.4 to 8.52 individuals/minute. Substratum at low-density sites consisted of unstable sand or supported macrophytes, as compared with sites suitable for *L. higginsi*, where substratum consisted of stable sand and gravel.

Accurate estimates of standing crop at habitats with low-density populations require many quantitative samples. The total number of samples required to estimate the mean (plus or minus a certain acceptable error) with 95-percent confidence limits can be estimated (Green 1979). An estimate of the total standing crop of *L. higginsi* in the channel east of McMillan Island has been made. This was done by multiplying the estimated density of this species near RM 619, 0.133 $\pm$ 0.131 (standard error) individuals/square meter by the total area of available habitat (see above). Therefore, the total standing crop of *L. higginsi* in suitable habitat near McMillan Island was 5,320 $\pm$ 5,243 individuals.

Relationship of other species of native bivalves to *L. higginsi*

Jaccard's Association Index (Ludwig and Reynolds 1988) was calculated for all mussels collected using qualitative methods at sites near McMillan Island. This index considers each pair of species in the total collection and considers four possibilities: both species present, both species absent, only species "A" present, and only species "B" present. Since the index ignores the case when both species are absent, there are no spurious correlations between zero values that can occur with a Pearson Product-Moment Correlation. Jaccard's Index for each species-by-species comparison was tested for significance using the chi square frequency test and appears in Table 6.

Because it is ubiquitous, *A. p. plicata* was positively associated with nearly every other species (15 out of 19 species). Positive associations occurred between *L. higginsi* and the following species: *Potamilus alatus*, *Lasmigonia complanata*, *P. grandis*, *Strophitus undulatus*, and *Elliptio dilatata*. These relationships have to be viewed with caution since all species are uncommon, each representing approximately 1 percent or less of the qualitative collection (Table 4). However, with the exception of *E. dilatata*, all had thin or medium-thick shells. No significant positive relationships were found between *L. higginsi* and *Quadrula* spp., *M. nervosa*, or *A. p. plicata*. Regardless of the appeal of these indices, it must be remembered that mussel species are relatively nonmotile, and their location is governed to a large extent by local hydrologic conditions and fish behavior at the time glochidia are released from the host. This species is most likely to be found in an area with water 1 m deep or more throughout the season, with stable, gravelly sand substratum, in a bed with high density and species richness.

Recommendation on the Value of Habitat Near McMillan Island for *L. higginsi*

Based on the results of this survey and criteria stated by members of the original Higginsi Recovery Team (Higgins' Eye Mussel Recovery Team 1982), the authors recommend that the area near McMillan Island is essential for *L. higginsi*. This recommendation applies to shallow-to-moderately deep areas with firm gravelly sand substratum immediately east, north, and south of the island. The recommendation applies to wing dams that are not buried in sand and silt, and stable areas immediately downriver of wing dams. The recommendation would not apply to deep water associated with the main navigation channel, although it is likely that few *L. higginsi* could be found in these areas.

This decision was based on the comparatively high numbers of *L. higginsi* collected using qualitative methods during this survey. As described above, total numbers of *L. higginsi* at this location are greater than those typically found in the east channel of the Mississippi River near RM 635, Pool 10, a well-known valuable habitat for this species. Results of this survey suggest

Table 6
Jaccard's Association Index for Native Mussels Collected Using Qualitative Methods at 12 Sites Near McMillan Island, 1994 (Underlined numbers are significant (an association between species exists) based on a chi square frequency test)

	AP	OR	LV	FF	QQ	QN	QP	LR	TT	OO	MN	LF	PA	LS	LH	LC	PG	SU	LK	ED
AP	1.00	0.53	0.67	0.60	0.40	0.35	0.39	0.44	0.30	0.42	0.26	0.40	0.38	0.41	0.20	0.29	0.19	0.39	0.40	0.40
OR		1.00	0.53	0.47	0.32	0.41	0.45	0.35	0.43	0.41	0.27	0.39	0.38	0.40	0.21	0.29	0.21	0.30	0.33	0.28
LV			1.00	0.69	0.41	0.30	0.47	0.53	0.38	0.58	0.29	0.55	0.60	0.50	0.27	0.30	0.27	0.38	0.48	0.41
FF				1.00	0.28	0.32	0.42	0.39	0.27	0.45	0.24	0.36	0.48	0.39	0.23	0.21	0.23	0.33	0.43	0.30
QQ					1.00	0.37	0.33	0.38	0.32	0.44	0.28	0.42	0.33	0.35	0.26	0.24	0.14	0.32	0.23	0.35
QN						1.00	0.30	0.40	0.41	0.39	0.21	0.32	0.31	0.45	0.25	0.19	0.25	0.35	0.38	0.44
QP							1.00	0.53	0.26	0.36	0.23	0.35	0.39	0.29	0.27	0.30	0.33	0.38	0.29	0.24
LR								1.00	0.29	0.40	0.14	0.38	0.43	0.47	0.29	0.22	0.37	0.35	0.38	0.32
TT									1.00	0.35	0.12	0.28	0.27	0.33	0.31	0.24	0.21	0.25	0.33	0.39
OO										1.00	0.32	0.44	0.42	0.45	0.35	0.28	0.30	0.35	0.32	0.38
MN											1.00	0.36	0.41	0.24	0.19	0.26	0.17	0.33	0.36	0.25
LF												1.00	0.52	0.43	0.33	0.38	0.19	0.33	0.42	0.36
PA													1.00	0.48	0.48	0.48	0.46	0.74	0.59	0.52
LS														1.00	0.33	0.21	0.29	0.33	0.43	0.43
LH															1.00	0.46	0.44	0.48	0.39	0.50
LC																1.00	0.30	0.55	0.32	0.38
PG																	1.00	0.53	0.41	0.41
SU																		1.00	0.52	0.52
LK																			1.00	0.55
ED																				1.00

Note: AP = *A. p. plicata*; OR = *O. reflexa*; LV = *L. cardium*; FF = *F. flava*; QQ = *Q. quadrula*; QN = *Q. nodulata*; QP = *Q. p. pustulosa*; LR = *L. recta*; TT = *T. truncata*; OO = *O. olivaria*; MN = *M. nervosa*; LF = *L. fragilis*; PA = *P. alatus*; LS = *L. siliquoidea*; LH = *L. higginsi*; LC = *L. complanata*; PG = *P. grandis*; SU = *S. undulatus*; LK = *L. costata*; ED = *E. dilatata*.

that McMillan Island has a value for *L. higginsi* equal to or greater than that of the east channel in Pool 10. Much of the area near McMillan Island has stable, high-quality substratum. Densities of other native mussels, species diversity, and richness are moderate to high.

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Appendix A
Summary of Qualitative and Quantitative Data on Freshwater Bivalves Collected Near McMillan Island, Pool 10, Upper Mississippi River (UMR), August 1994

Table A1
Percent Abundance of Freshwater Mussels Collected Using Qualitative Methods at 12 Sites Near McMillan Island, Pool 10, UMR, August 1994 (See Figure 1 (main text) for location of sample sites)

Species	Site Number												Total Percent
	1	2	3	4	5	6	7	8	9	10	11	12	
A. p. plicata	67.93	81.22	9.52	15.38	18.82	30.48	8.16	5.41	6.67	31.87	24.46	24.66	41.02
O. reflexa	4.98	1.41	61.90	23.08	12.94	20.86	65.31	62.16	46.67	23.08	15.83	17.81	17.54
L. cardium	8.96	3.76	0.00	23.08	17.65	3.21	2.04	2.70	13.33	12.09	10.79	16.44	8.77
F. flava	5.47	7.04	0.00	0.00	15.29	1.60	0.00	0.00	0.00	8.79	12.95	3.42	6.10
Q. quadrula	1.99	0.94	0.00	0.00	12.94	11.76	0.00	2.70	0.00	2.20	8.63	7.53	5.43
Q. nodulata	0.00	0.00	4.76	30.77	3.53	19.79	8.16	13.51	6.67	0.00	0.72	5.48	5.35
Q. p. pustulosa	4.48	2.35	14.29	7.69	3.53	5.88	12.24	8.11	20.00	4.40	2.16	4.79	4.85
L. recta	0.00	0.47	0.00	0.00	1.18	0.00	0.00	0.00	6.67	3.30	2.88	8.22	1.84
T. truncata	1.00	0.00	0.00	0.00	4.71	1.07	0.00	0.00	0.00	0.00	6.47	0.68	1.50
O. olivaria	0.00	0.00	9.52	0.00	0.00	2.67	0.00	5.41	0.00	2.20	1.44	2.74	1.42
M. nervosa	0.00	0.00	0.00	0.00	4.71	0.00	0.00	0.00	0.00	0.00	5.76	2.74	1.34
L. fragilis	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.00	0.00	7.69	2.88	2.05	1.25
P. alatus	1.99	0.47	0.00	0.00	2.35	0.53	2.04	0.00	0.00	1.10	0.72	1.37	1.09
L. siliquoidea	2.99	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.16	1.37	0.84
L. higginsi	0.50	0.47	0.00	0.00	1.18	1.07	0.00	0.00	0.00	1.10	0.72	0.00	0.67
L. complanata	0.50	0.47	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.33
P. grandis	0.00	0.47	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.72	0.00	0.25
S. undulatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.22	0.72	0.00	0.25
E. dilatata	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.08
L. costata	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Total individuals	201	213	21	13	85	187	49	37	15	91	139	146	1,197
Total species	11	13	5	5	13	13	7	7	6	12	17	15	20
Rate (mussels/min)	4.02	8.52	0.87	0.65	4.25	3.40	2.45	1.85	0.75	2.27	3.47	3.65	3.20

Table A2
Percent Occurrence of Freshwater Mussels Collected Using Qualitative Methods at 12 Sites Near McMillan Island, Pool 10, UMR, August 1994

Species	Site Number												Total Percent
	1	2	3	4	5	6	7	8	9	10	11	12	
A. p. plicata	100.0	100.0	50.0	100.0	100.0	83.3	75.0	100.0	50.0	100.0	100.0	100.0	89.6
O. reflexa	60.0	60.0	100.0	100.0	100.0	75.0	100.0	100.0	100.0	50.0	75.0	100.0	79.2
L. cardium	80.0	80.0	0.0	100.0	100.0	50.0	25.0	50.0	50.0	100.0	100.0	100.0	68.8
Q. p. pustulosa	60.0	60.0	100.0	50.0	100.0	41.7	75.0	100.0	50.0	75.0	75.0	50.0	62.5
F. flava	80.0	100.0	0.0	0.0	100.0	25.0	0.0	0.0	0.0	75.0	75.0	50.0	45.8
Q. nodulata	0.0	0.0	50.0	50.0	100.0	75.0	75.0	100.0	50.0	0.0	25.0	25.0	43.8
Q. quadrula	40.0	40.0	0.0	0.0	100.0	50.0	0.0	50.0	0.0	25.0	75.0	75.0	41.7
O. olivaria	0.0	0.0	100.0	0.0	0.0	33.3	0.0	100.0	0.0	50.0	50.0	50.0	29.2
L. recta	0.0	20.0	0.0	0.0	50.0	0.0	0.0	0.0	50.0	75.0	75.0	100.0	27.1
P. alatus	60.0	20.0	0.0	0.0	100.0	8.3	25.0	0.0	0.0	25.0	25.0	25.0	22.9
T. truncata	20.0	0.0	0.0	0.0	100.0	16.7	0.0	0.0	0.0	0.0	100.0	25.0	20.8
L. siliquoidea	60.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.0	16.7
L. fragilis	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	0.0	50.0	50.0	50.0	14.6
L. higginsi	20.0	20.0	0.0	0.0	50.0	16.7	0.0	0.0	0.0	25.0	25.0	0.0	14.6
M. nervosa	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	75.0	25.0	12.5
L. complanata	20.0	20.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	8.3
P. grandis	0.0	20.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	25.0	0.0	6.3
S. undulatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	25.0	0.0	6.3
E. dilatata	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	2.1
L. costata	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
Total samples	5	5	2	2	2	12	4	2	2	4	4	4	48

Table A3
Percent Abundance and Summary Statistics for Freshwater Bivalves Collected Using Quantitative Methods Near McMillan Island, Pool 10, UMR, August 1994 (Samples 1-4 were collected at RM 619, Site 5, and Samples 5-8 were collected at RM 617.2, Station 1. See Figure 1 of main text)

Species	Sample Number								Total Percent
	1	2	3	4	5	6	7	8	
A. p. plicata	23.81	12.90	22.22	100.00	44.44	83.33	73.33	46.67	44.08
F. flava	0.00	3.23	14.81	0.00	13.89	0.00	8.89	18.67	11.43
D. polymorpha	4.76	12.90	14.81	0.00	11.11	0.00	0.00	9.33	8.16
O. reflexa	19.05	16.13	7.41	0.00	2.78	0.00	2.22	8.00	7.76
L. fragilis	4.76	16.13	18.52	0.00	8.33	0.00	2.22	1.33	6.53
T. truncata	14.29	6.45	7.41	0.00	2.78	0.00	4.44	0.00	4.08
L. cardium	4.76	9.68	3.70	0.00	8.33	0.00	0.00	1.33	3.67
Q. quadrula	9.52	6.45	0.00	0.00	0.00	0.00	4.44	2.67	3.27
Q. pustulosa	4.76	0.00	0.00	0.00	0.00	0.00	2.22	5.33	2.45
L. siliquoidea	0.00	0.00	0.00	0.00	2.78	0.00	2.22	1.33	1.22
O. olivaria	4.76	0.00	3.70	0.00	2.78	0.00	0.00	0.00	1.22
L. complanata	0.00	0.00	0.00	0.00	0.00	16.67	0.00	1.33	0.82
L. recta	4.76	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.82
M. nervosa	4.76	0.00	3.70	0.00	0.00	0.00	0.00	0.00	0.82
P. alatus	0.00	3.23	0.00	0.00	2.78	0.00	0.00	0.00	0.82
E. dilatata	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.41
L. higginsi	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.41
T. donaciformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.41
P. grandis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.41
Q. nodulata	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.41
C. fluminea	0.00	3.23	0.00	0.00	0.00	0.00	0.00	0.00	0.41
A. confragosus	0.00	0.00	3.70	0.00	0.00	0.00	0.00	0.00	0.41
Total individuals	21	31	27	4	36	6	45	75	245
Total species	11	13	10	1	10	2	8	13	22
Percent Individuals < 30 mm	23.81	32.29	44.44	0.00	22.22	0.00	8.89	21.33	22.45
Percent Species < 30 mm	36.36	23.08	50.00	0.00	30.00	0.00	37.50	46.15	40.91

Table A4
Percent Occurrence of Freshwater Bivalves Collected Using Quantitative Methods Near McMillan Island, Pool 10, UMR, August 1994

Species	Sample Number								Total Percent
	1	2	3	4	5	6	7	8	
A. p. plicata	40.0	40.0	60.0	30.0	80.0	40.0	100.0	90.0	60.00
F. flava	0.0	10.0	30.0	0.0	40.0	0.0	30.0	80.0	23.75
D. polymorpha	10.0	20.0	30.0	0.0	30.0	0.0	0.0	30.0	15.00
O. reflexa	40.0	40.0	20.0	0.0	10.0	0.0	10.0	50.0	21.25
L. fragilis	10.0	30.0	30.0	0.0	20.0	0.0	10.0	10.0	13.75
T. truncata	30.0	20.0	10.0	0.0	10.0	0.0	20.0	0.0	11.25
L. cardium	10.0	20.0	10.0	0.0	20.0	0.0	0.0	10.0	8.75
Q. quadrula	20.0	20.0	0.0	0.0	0.0	0.0	20.0	20.0	10.00
Q. p. pustulosa	10.0	0.0	0.0	0.0	0.0	0.0	10.0	40.0	7.50
L. siliquoidea	0.0	0.0	0.0	0.0	10.0	0.0	10.0	10.0	3.75
O. olivaria	10.0	0.0	10.0	0.0	10.0	0.0	0.0	0.0	3.75
L. complanata	0.0	0.0	0.0	0.0	0.0	10.0	0.0	10.0	2.50
L. recta	10.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	2.50
M. nervosa	10.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	2.50
P. alatus	0.0	10.0	0.0	0.0	10.0	0.0	0.0	0.0	2.50
E. dilatata	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.25
L. higginsi	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.25
T. donaciformis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	1.25
P. grandis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	1.25
Q. nodulata	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.25
C. fluminea	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0	1.25
A. confragosus	0.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	1.25
Total samples	10	10	10	10	10	10	10	10	80

Appendix B
Mussel Survey of Willow and McMillan Islands, July and September 1994

Introduction

Background

This report presents the results from mussel surveys conducted by the U.S. Army Engineer District, St. Paul, in the McMillan Island area of Pool 10 of the upper Mississippi River (UMR) near River Mile (RM) 625.6. Data from Locations 1, 2, and 6 were used to assess the disposal potential for dredging activities as part of the Bussey Lake Disposal Project. Data from all locations were used to determine whether the area was an essential habitat for the Federally endangered *Lampsilis Higginsi*. For reference, data from the six locations were compared with data from the east channel of the UMR, near Prairie du chien, WI, a prominent mussel bed also in Pool 10.

Study area and methods

Locations 1, 2, and 6 were at Willow Island (Table B1). A diving survey using qualitative methods was conducted at seven sites at Location 1 on 27-28 July 1994. A skimmer dredge supplemented the activity of the divers and was used for two transects. Substrate was analyzed visually when it was brought to the surface with the mussels. A survey using qualitative methods was conducted at Location 2 on 26-28 September, in which 142 0.25-m^2 quadrats were randomly placed. Divers excavated quadrats to a depth of 10 to 15 cm and brought all material to the surface. Organisms were removed and identified. At Location 6, qualitative diving surveys were conducted at eight sites, and the skimmer dredge was used for two transects.

Locations 3, 4, and 5, at McMillan Island were surveyed on 26-28 July. Hand collecting (polywogging) was used at 26 sites at Location 3. Workers

Table B1
Percent Species Abundance at Six Locations Near McMillan Island, Pool 10, UMR, July and September, 1994

Species	Location						Total
	1	2	3	4	5	6	
Amblema p. plicata	60.86	50.43	71.51	39.17	37.14	61.93	57.45
Obliquaria reflexa	4.89	5.98	10.72	28.92	30.00	4.97	11.22
Fusconaia flava	5.12	2.56	3.53	6.40	1.43	5.21	4.97
Quadrula quadrula	3.36	7.69	0.85	8.75	2.86	3.42	4.31
Lampsilis siliquoidea	6.73	3.42	1.13	0.43	1.43	6.68	4.29
Potamilus alatus	3.13	2.56	1.97	0.00	0.00	3.65	2.38
Pyganodon grandis	7.57	3.85	0.42	0.00	0.00	7.15	4.47
Truncilla truncata	1.83	5.56	0.28	2.67	2.86	1.32	1.83
Quadrula nodulata	0.38	4.70	0.71	4.91	11.43	0.47	1.78
Quadrula p. pustulosa	0.38	2.56	1.13	3.74	1.43	0.47	1.34
Lampsilis cardium	1.30	0.43	2.82	0.85	0.00	1.32	1.39
Leptodea fragillis	1.15	2.14	0.28	0.11	0.00	1.24	0.86
Potamilus ohiensis	0.99	1.71	1.41	0.11	2.86	0.54	0.81
Arcidens confragosus	1.30	1.28	0.85	0.21	0.00	0.78	0.84
Obovaria olivaria	0.00	0.00	0.28	2.77	8.57	0.00	0.75
Megalonaias nervosa	0.31	1.71	1.13	0.43	0.00	0.31	0.53
Lasmigona complanata	0.38	1.71	0.00	0.32	0.00	0.39	0.37
Ligumia recta	0.08	0.43	0.99	0.21	0.00	0.08	0.26
Truncilla donaciformis	0.15	0.43	0.00	0.00	0.00	0.00	0.07
Lampsilis higginsi	0.08	0.00	0.00	0.00	0.00	0.08	0.04
Lampsilis teres	0.00	0.85	0.00	0.00	0.00	0.00	0.04
Total individuals	1,308	234	709	937	70	1,287	4,545
Total species	19	19	17	16	10	18	21

Location, project, number of stations per location, and survey method used:

Location 1: Willow Island; Bussey Lake Disposal; 7 stations—qualitative; 2 stations—skimmer dredge.

Location 2: Willow Island; Bussey Lake Disposal; 142 quadrats; quantitative.

Location 3: McMillan Island; Higgins Eye assessment; 26 stations; polywogging.

Location 4: McMillan Island; Higgins Eye assessment; 32 stations; skimmer dredge.

Location 5: Lower McMillan Island; Higgins Eye assessment; 12 stations; skimmer dredge.

Location 6: Willow Island; 8 stations—Qualitative; 2 stations—skimmer dredge.

visually analyzed the substrate that was brought to the surface, then searched for 30-min intervals, bringing up all mussels found. A skimmer dredge was used at 32 stations at Location 4, near the north end of McMillan Island. Location 5 was situated near lower McMillan Island, where a skimmer dredge was used at 12 stations. The Shannon Species Diversity Index (H′) was used to analyze data.

Results

A total of 1,308 live individuals representing 19 species were collected in the qualitative survey at Location 1 (Table B1). *Amblema p. plicata* was the dominant species, comprising 62.8 percent of the overall catch. One *Lampsilis higginsi* was collected. Five *Quadrula nodulata,* listed as threatened in Wisconsin, were collected.

Two hundred and thirty-four individual mussels representing 19 species were collected in the quantitative survey at Location 2. *Amblema p. plicata* was dominant, comprising 50.43 percent of the total. One *Lampsilis teres,* listed as endangered in Wisconsin and Iowa, was found in addition to 11 *Q. nodulata*. A cumulative species to individuals curve was plotted, showing that a sample of an additional 1,000 individuals would probably only produce an additional one or two more species. Thus, it was concluded that the majority of the species in the area were found.[1] The density at Site 2 was determined to be 6.59 mussels/square meter, which is considerably less than in the east channel of the Mississippi River near Prairie du Chien (located upriver), where densities can exceed 50 individuals/square meter.

Amblema p. plicata, Obliquaria reflexa, and *Pyganodon grandis* each comprised 61.93, 4.97, and 7.15 percent, respectively, of the total at Location 6. One *L. higginsi* and six *Q. nodulata* were also found.

Obliquaria reflexa was comparatively abundant at Locations 3-5 (near McMillan Island). At Location 3, *A. p. plicata* comprised 71.51 percent of the fauna, whereas *O. reflexa* accounted for 10.72 percent. At Locations 4 and 5, *A. p. plicata* contributed to 39.17 and 37.14 percent of the catch, respectively, and *O. reflexa* comprised 28.92 and 30 percent. Also, Location 4 produced a notable amount of *Q. nodulata* (4.91 percent), *Quadrula quadrula* (8.75 percent), and *Fusconaia flava* (6.4 percent). At Location 5, *Q. nodulata* and *Obovaria olivaria* made up 11.43 and 8.57 percent of the fauna, respectively.

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[1] Yager, T. K., and Whiting, R. J. (1994). "Mussel survey, Pool 10, Bussey Lake Disposal—Willow Island," Environmental Resources Section, U.S. Army Engineer District, St. Paul, 190 5th Street East.

Discussion

Despite the relative dominance of *A. p. plicata*, the mussel populations at Willow Island and McMillan Island have moderate to high species diversity. Species diversity for the Willow Island sites was 1.71, which is equal to that at six stations of the east channel. At McMillan Island, species diversity was less, 1.54. The east channel is known to be an essential habitat for *Lampsilis higginsi*. From 1988 to 1992, Miller and Payne determined the percent composition of *Lampsilis higginsi* in the east channel to be 0.24 (1988), 0.68 (1989), 0.23 (1991), and 0.43 (1992).[1] *Lampsilis higginsi* was found at two locations at Willow Island. *Lampsilis higginsi* comprised 0.08 percent of the total mussel population collected at Willow Island and 0.04 percent of the mussels collected at the six locations in this survey. East of McMillan Island, at RM 619, the standing crop of *L. higginsi* was determined to be 5,320 (main text of this report).

[1] Miller, A. C., and Payne, B. S. (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.

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13. ABSTRACT *(Maximum 200 words)*

A bivalve survey was conducted in the upper Mississippi River near McMillan Island (River Mile 618.5, north of Guttenburg, IA), one of seven designated essential habitats for the endangered *Lampsilis higginsi* (Lea). Divers collected mussels at 12 sites using qualitative methods and at 2 sites using quantitative methods. Qualitative samples were taken from areas on and immediately downriver of a wing dam, as well as in gravelly sand substratum near the island. Twenty-four species of bivalves were collected, including *L. higginsi*, and two nonindigenous species, the Asiatic clam, *Corbicula fluminea*, and the zebra mussel, *Dreissena polymorpha*. Overall, *D. polymorpha* comprised slightly less than 10 percent of the bivalves. Typically, less than five zebra mussels were found on a single native unionid, and less than 25 percent of native mussels were infested.

The freshwater mussel (family: Unionidae) fauna was dominated by *Amblema plicata plicata*, *Obliquaria reflexa*, and *Lampsilis cardium*. Mean unionid density (excluding nonindigenous species) at two sites was low, 9.2 and 15.1 individuals/square meter. Evidence of recent recruitment was good; approximately 15 percent of native mussels and 35 percent of native species were less than 30 mm total shell length.

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No significant positive relationships (based upon the Jaccard coefficient) were found between *L. higginsi* and common unionids such as *Quadrula* spp., *Megalonaias nervosa*, or *A. p. plicata*, although a significant relationship was found between *Pyganodon* (= *Anodonta*) *grandis* and *L. higginsi*. Although total density of native species at this location was comparatively low, *L. higginsi* comprised a slightly higher percentage abundance of the community than at other historically prominent, high-density mussel beds in Pool 10. Based on a density of 0.133 ($\pm$ 0.131 (standard error) individuals/square meter) and the total available habitat near McMillan Island for *L. higginsi* (40,000 m^2), the total standing crop of this species was estimated to be 5,320. Based on the results of this survey, the area near McMillan Island is appropriately listed as essential for *L. higginsi*.