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Technical Bulletin No. 139
Wisconsin Department of Natural Resources
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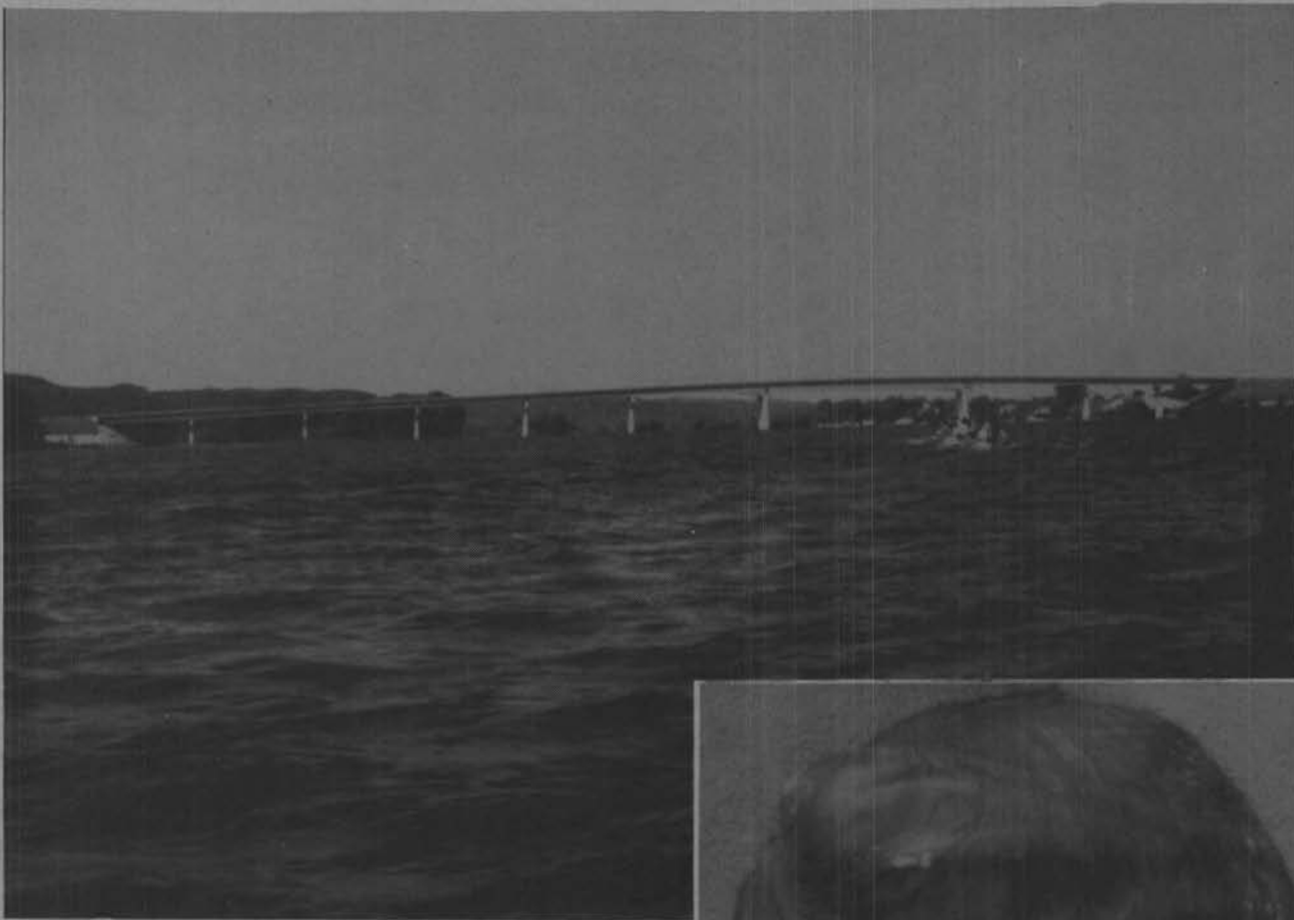

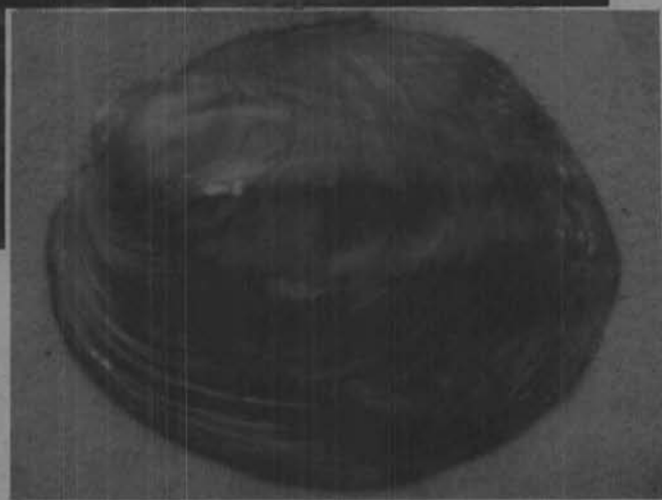

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COVER: East Channel at Prairie du Chien. Threeridge was the most abundant species collected in Pool 10 during the 1980 study.

ABSTRACT

Freshwater mussels were collected by diving during the summer of 1980 from Pool 10 of the Upper Mississippi River. The entire pool was divided into four different regions (upper end, lower end, East Channel, and West Channel) and three habitat types (main channel, main channel border, and backwater) so comparisons of mussel densities (no./ft²) could be made. Of the 309 sites sampled, mussels were found at 224 sites (72%). The East Channel near Prairie du Chien, Wisconsin had the richest mussel fauna with an average density of 2.964 mussels/ft² and only 6% of the sites nonproductive. The lower end of Pool 10 had the lowest mussel density (0.655/ft²) and the highest percentage of nonproductive sites (38%). The mussel density in the main channel border was 2 times greater than in the main channel and backwater.

A total of 12,150 live specimens representing 31 species of freshwater mussels was collected from Pool 10; an additional 7 species were represented only by dead specimens. Threeridge (*Amblema plicata*) was by far the most abundant mussel species, comprising 52.9% of the catch and having an average density of 0.832/ft². Thirty-eight live Higgins' Eye (*Lampsilis higginsi*), a state and federal endangered species, were found during the survey and 20 of these were collected in the East and West Channels.

INTRODUCTION

The Upper Mississippi River is a dynamic alluvial river system. Since early Pleistocene times the river has continually undergone changes as a consequence of hydraulic forces acting on its bed and banks, and related biological forces interacting with these physical forces (Simons et al. 1975). These changes have resulted from both natural and anthropogenic alterations.

The completion of the lock and dam system and the artificial maintenance of a navigation channel to accommodate 9-ft draft vessels has caused major man-induced changes to occur on the Upper Mississippi River in the last 50 years. What was once a free-flowing, braided river is now a series of river lakes or pools. The impoundment of the river has created a more stable and less turbid environment but has started an aging process in which no new backwaters are being created and the pools are gradually filling with sediments (Rasmussen 1979).

Impoundment, water quality, and other factors have had an impact on the mussel fauna of the Upper Mississippi River (Fuller 1978, 1980*a*). The decline of mussel species diversity and a decrease in relative abundance since the inception of the 9-ft channel have been well documented (Coon et al. 1977, Havlik and Stansbery 1978, Fuller 1980*a*, Thiel 1981). Studies on the Tennessee River after impoundment have also shown a decrease in the variety of mussels (Scruggs 1960, Bates 1962, Isom 1969). However, freshwater mussels are still a major component of the benthic community in some areas of the Upper Mississippi River (Fuller 1978, 1980*a*, Thiel 1981).

Previous mussel surveys on the Upper Mississippi River have been primarily qualitative, providing estimates of diversity and relative abundance of mussels (Baker 1905, Shimek 1921, van der Schalie and van der Schalie 1950, Havlik and Stansbery 1978, Fuller 1980*a*, Thiel 1981). However, quantitative estimates of mussel densities provide better baseline data for future environmental impact studies. Therefore, the primary objective of this survey was to quantitatively define the diversity and relative density of the mussel community in Pool 10 of the Upper Mississippi River.

STUDY AREA

Pool 10 of the Upper Mississippi River was selected for this mussel density survey due to its rich mussel fauna. Havlik and Stansbery (1978) stated that the Prairie du Chien, Wisconsin area has the greatest diversity of mussels known from any site on the Mississippi River. Fuller (1980*a*) considered the mussel fauna in Pool 10 to be the most diverse and abundant in the St. Paul District of the U.S. Army Corps of Engineers (includes Pools 1-10). In the study by Thiel (1981) more species and greater numbers of mussels were collected in Pool 10 than in any of the other areas surveyed (Pools 3-11).

Another reason for selecting Pool 10 was the numerous collection records of the state and federal endangered species, Higgins' Eye (*Lampsilis higginsi*), that have been documented in this area. There have been more live Higgins' Eye found in Pool 10 than in any other pool of the Upper Mississippi River (Havlik and Stansbery 1978, Mathiak 1979, Fuller 1980*a*, Havlik 1981*a*, Thiel 1981). The East Channel at Prairie du Chien is thought to have the largest known aggregation of this species (Havlik and Stansbery 1978, Havlik 1981*a*, Havlik and Marking 1981).

Pool 10 extends from Lock and Dam No. 9 near Lynxville, Wisconsin to Lock and Dam No. 10 at Guttenberg, Iowa, a total of 32.8 river miles (Fig. 1). It is the second largest pool in the St. Paul District and has the second longest shoreline, about 110 miles (GREAT I 1980*a*). However, this pool has less water area (17,070 acres) than other shorter-length pools in the St. Paul District because the valley and floodplain area between the high bluffs become increasingly narrow at the lower end of the pool (GREAT I 1980*a*).

The major tributary entering the Upper Mississippi River in Pool 10 is the Wisconsin River. It converges with the main stem of the river about midway between Lock and Dam No. 9 and Lock and Dam No. 10 on the Wisconsin side. In addition to the Wisconsin River, a smaller tributary, the Yellow River, enters the pool from Iowa, about 3 miles upstream from McGregor, Iowa.

The upper end of Pool 10 (i.e., the area above the confluence of the Wisconsin River) has physical characteristics that are similar to preimpoundment days. There are large side channels (e.g., Harper's Slough) off the main channel, and islands are still prominent. Toward the lower end of the pool (i.e., area below the Wisconsin River), the river

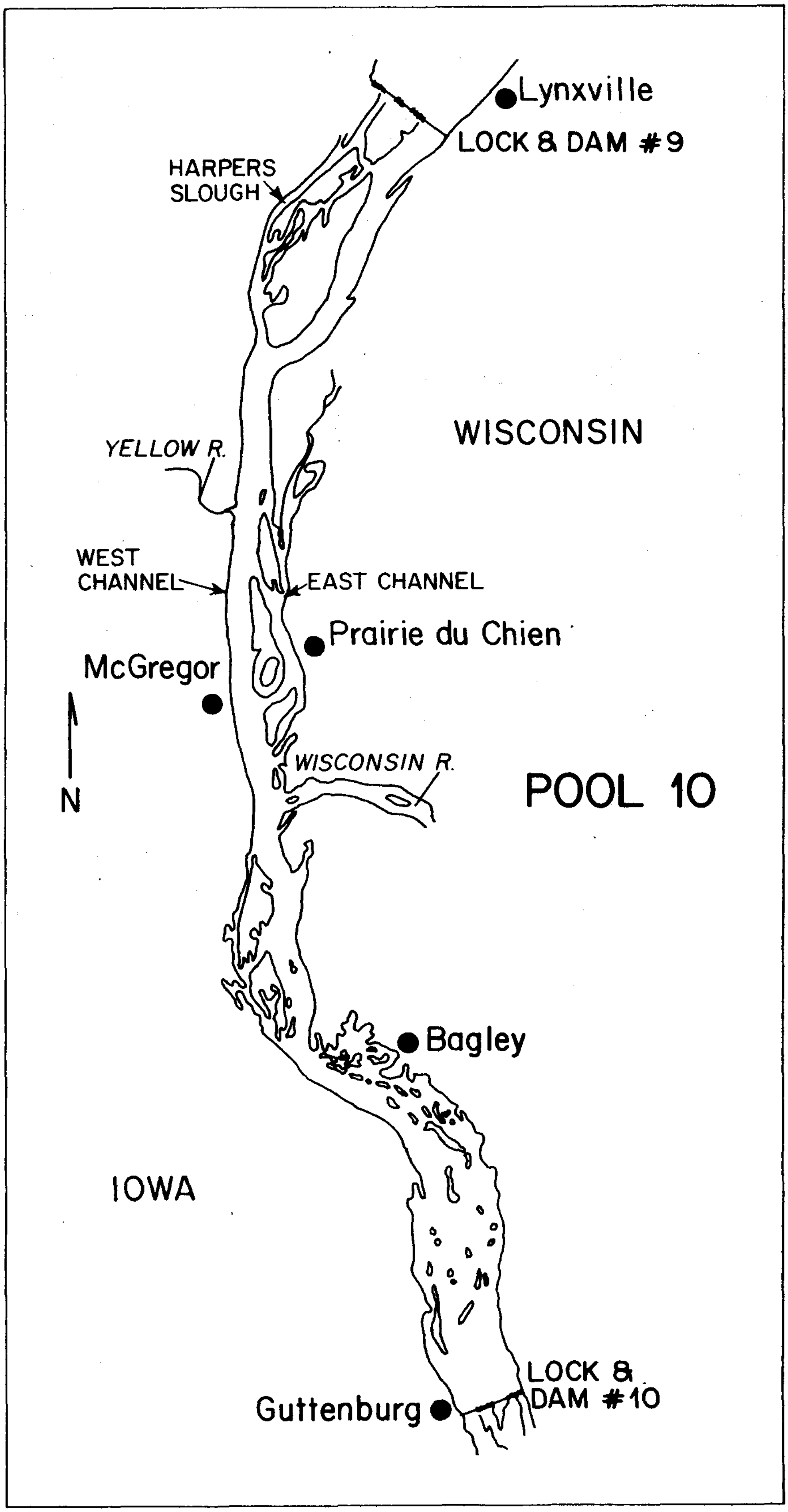


FIGURE 1. *Pool 10 of the Upper Mississippi River.*

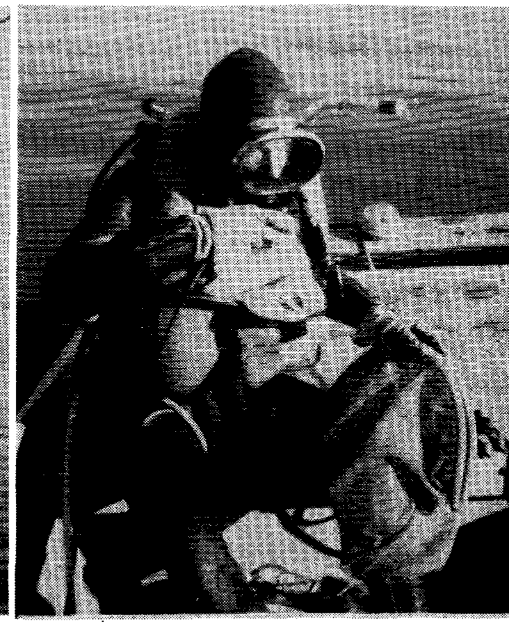
changes from an actively flowing river environment to one more lake-like in nature due to the effect of the dam (Rasmussen 1979). The backwater areas and islands immediately upstream from the dam were submerged by the closure of Lock and Dam No. 10.

For this study, the pool was divided into four different regions (upper end, lower end, West Channel, and East Channel) and three habitat types (main channel, main channel border, and backwater) so comparisons of mussel densities could be made. The area designated upper end extended from Lock and Dam No. 9 to the confluence of the Wisconsin River, approximately 15 miles in length. The lower end of Pool 10 was defined as the stretch of river from the confluence of the Wisconsin River to Lock and Dam No. 10, approximately 17 miles in length.

Within the upper end of Pool 10 are two areas of special interest, the East and West Channels. The West Channel, near McGregor and Marquette, Iowa, is part of the main navigational channel and is approximately 3 miles long. Directly to the east next to Prairie du Chien, Wisconsin is the East Channel, which is slightly longer than the West Channel. Tugboats and barges also enter the East Channel to load and unload their cargoes as well as for fleeting. Commercial clammers have worked the mussel beds in these areas intermittently since the late 1800's (Havlik and Stansbery 1978).

The main channel habitat includes only that portion of the river through which large commercial vessels can operate and is delineated by combinations of river regulating structures (i.e., wing dams), buoys, and other markers. The main channel border is the zone between the 9-ft navigation channel and the main river bank, islands, or submerged definitions of the old main river bank. Buoys often mark the outer edge of this zone and it includes all areas in which wing dams occur along the main channel (Sternberg 1971). For the purpose of this study, side channels, river lakes and ponds, and sloughs were combined into the backwater category. These are all areas outside the main channel and main channel borders.

The metal frame (5 ft²) that was placed on the substrate during SCUBA sampling.



Mussels were collected by SCUBA divers.

METHODS

Freshwater mussels were collected from Pool 10 of the Upper Mississippi River during the period 6 June 1980 to 7 October 1980. SCUBA and hookah diving were the only sampling techniques used during the survey. Four different regions of the pool (upper end, lower end, East Channel, and West Channel) and three habitat types (main channel, main channel border, and backwater) were examined for mussel densities (no./ft^2).

The sampling sites were randomly selected from U.S. Army Corps of Engineers navigation charts and aerial photographs. Transects were established across the river throughout the entire length of the pool. With the exception of the East and West Channel areas, at least one transect was made in each river mile. Each transect consisted of 5 sampling sites: one in the main channel; at least one within the main channel border on each side of the river; and if possible, one or two sites in the backwater areas. If no backwater areas were located in the vicinity of the transect, then additional main channel border sites were sampled. The 1977-79 mussel survey by the Wisconsin Department of Natural Resources (Thiel 1981) showed a larger number of mussels in the upper end of Pool 10 compared with the lower end; therefore, more sampling sites were chosen in the upper region of the pool. Twenty-nine transects were made in the upper end and 20 transects in the lower end of the pool for a total of 49 transects; originally 61 transects were constructed across the river, but due to a lack of time, 12 of the transects were not sampled.

In the East and West Channels, a more intensive sampling was done. With the aid of a grid, a random numbers table, and aerial photographs, 33 sites were selected in the East Channel and 32 sites in the West Channel. The locations of all sites were recorded on U.S. Army Corps of Engineers navigation charts and aerial photographs.

During each collection, a 25-ft^2 (5 x 5 ft) metal frame was placed on the substrate and a diver collected all live and dead mussels within the frame to a depth of at least 2 inches. The length of diving time to clear the mussels from the frame ranged from 2-125 min. The live mussels were identified and measured for length as defined by Ortmann (1920) and Ball (1922), then all but the Higgins' Eye were returned to the river. The dead specimens were identified and any unusual or rare specimens were retained. All live Higgins' Eye were transported to the National Fishery Research Laboratory in La Crosse, Wisconsin. Until verification photographs could be taken, they were housed in continuous flow-through fiberglass rearing tanks that contained 53 F well water and a sand substrate. An identification number was etched on the shell with a pocket knife. The Higgins' Eye were then returned to their collection site and manually positioned into the substrate in a natural orientation.

A cluster analysis was performed on the data (Dixon and Brown 1977). The sites that had no mussels were excluded from this analysis.

RESULTS

A total of 309 sites was sampled in Pool 10 of the Upper Mississippi River and 12,150 live mussels were collected. Thirty-one live species and 7 species represented only by empty shells were found during this survey (Table 1).

The mussel densities derived in this survey are the average number of mussels/ft^2 for the sampling sites. The sample size was not statistically adequate so these data reflect relative densities and not absolute densities. Therefore, the densities given should be used only for comparison purposes and should not be considered actual mussel densities for the particular areas.

Threeridge was the most abundant species collected in the study area, representing 52.9% of the total catch (Table 2). This species was widely distributed throughout the pool, being found at 57.9% of the sampling sites. All three habitat types and the four different regions of Pool 10 showed the Threeridge as the most dense mussel species present. The overall density of 0.832 Threeridge/ft^2 was eight times greater than the next most abundant species, Washboard (Table 2, Fig. 2).

The next three species in abundance, Washboard, Fawnfoot, and Deertoe, occurred about half as frequently as Threeridge at the sampling sites. These species were found in all the regions and habitat types, but had overall densities of only around 0.1/ft^2.

Some species of mussels showed more aggregated or clumped dispersions than others. For example, the Pink Heelsplitter, Spike, and Threehorn had very similar densities (0.037, 0.034, and 0.033, respectively) but the Spike was found at only 14.6% of the sampling sites compared with 29.1% for the Pink Heelsplitter and 27.8% for the Threehorn (Table 2). This suggests that the Spike is found in larger aggregations at fewer sites. The Paper Floater is another example of a mussel species with a slightly more clumped distribution.

Three species were represented only by single living specimens: Mucket, Buckhorn, and Flat Floater. The Ohio River Pigtoe and Yellow Sandshell were represented by 2 and 3 live specimens, respectively. Seven of these eight rare mussels were found in the upper end of Pool 10 and the East Channel.

A total of 38 live Higgins' Eye were collected during this survey. Fifteen were females, 22 were males, and 1 was a young specimen of undetermined sex. Fifty-three percent were found in the East and West Channels. Only 2 Higgins' Eye were collected in the lower end of the pool (both from backwaters). The preferred habitat type was the main channel borders with 21 of 38 being found in these areas.

Length-frequency distributions for those species with more than 100 individuals are illustrated by bar graphs. (Fig. 3). All of the distributions except Fawnfoot and Deertoe were somewhat skewed to the right. There was some sampling bias due to the inability of the diver to pick up mussels less than 1 cm in length. Since numerous Fawnfoot between the lengths of 1 and 4 cm were collected, it was assumed that if small mussels (<1 cm) were present at the sampling sites the diver should have been able to find them. Many of the population structures show low frequencies in the smaller size classes, which probably indicates low recruitment for these mussel species.

The results of the cluster analysis are depicted by a dendogram (Fig. 4). The lengths of the dendogram branches (horizontal lines) indicate the degree of association between the mussel species based on occurrence at the sampling sites. The shorter the horizontal distance from the baseline, the greater the degree of species pair or species group association. As one proceeds from the top of the dendogram to the bottom, the number of species in association increases (i.e., the size of the "cluster" increases), while the degree of association decreases. However, there are smaller clusters within the larger clusters with

TABLE 1. *Species list of mussels collected in Pool 10.*

Scientific Name	Common Name	
Cumberlandia monodonta	Spectable Case	D
Quadrula metanevra	Monkeyface	L
Q. quadrula	Mapleleaf	L
Q. nodulata	Wartyback	L
Q. pustulosa	Pimpleback	L
Tritogonia verrucosa	Buckhorn	L
Cyclonaias tuberculata	Purple Wartyback	D
Fusconaia flava	Pigtoe	L
F. ebena	Ebony Shell	D
Megalonaias gigantea	Washboard	L
Amblema plicata	Threeridge	L
Plethobasus cyphyus	Bullhead	D
Pleurobema cordatum	Ohio River Pigtoe	L
Elliptio crassidens	Elephant Ear	D
E. dilatata	Spike	L
Obliquaria reflexa	Threehorn	L
Proptera alata	Pink Heelsplitter	L
P. laevissima	Pink Papershell	L
Leptodea fragilis	Fragile Papershell	L
Ellipsaria lineolata	Butterfly	L
Truncilla truncata	Deertoe	L
T. donaciformis	Fawnfoot	L
Obovaria olivaria	Hickorynut	L
Actinonaias carinata	Mucket	L
Ligumia recta	Black Sandshell	L
Carunculina parva	Lilliput	L
Lampsilis teres	Yellow Sandshell	L
L. higginsi	Higgins' Eye	L
L. radiata siliquoidea	Fat Mucket	L
L. ovata ventricosa	Pocketbook	L
Arcidens confragosus	Rockshell	L
Lasmigona complanata	White Heelsplitter	L
L. costata	Fluted Shell	D
Alasmidonta marginata	Elktoe	D
Anodonta imbecillis	Paper Floater	L
A. grandis	Giant Floater	L
A. suborbiculata	Flat Floater	L*
Strophitus undulatus	Strange Floater	L

L = collected live and dead
D = only collected dead
L* = only collected live

TABLE 2. *Density of mussels in all habitats in Pool 10 of the Upper Mississippi River.*

Species	Geographic Regions (no/ft.²) Lower End Pool 10	Upper End Pool 10	East Channel	West Channel	Habitat Type (no./ft²) Main Channel	Main Channel Border	Backwater	All of Pool 10 Density (no./ft²)	Relative Abundance (%)	Frequency of Occurrence (%)	Total No.
Threeridge	0.298	0.885	1.691	1.374	0.481	1.122	0.533	0.832	52.9	57.9	6,425
Washboard	0.044	0.124	0.166	0.163	0.068	0.132	0.086	0.107	6.8	28.2	823
Fawnfoot	0.051	0.110	0.192	0.161	0.040	0.144	0.077	0.105	6.7	33.3	810
Deertoe	0.024	0.094	0.132	0.179	0.037	0.116	0.057	0.084	5.3	28.8	649
Fragile Papershell	0.029	0.088	0.148	0.084	0.050	0.101	0.043	0.075	4.8	32.0	579
Pimpleback	0.021	0.061	0.132	0.059	0.043	0.065	0.046	0.055	3.5	34.6	428
Pigtoe	0.030	0.057	0.121	0.060	0.034	0.066	0.050	0.055	3.5	33.3	428
Pink Heelsplitter	0.028	0.039	0.061	0.033	0.025	0.049	0.023	0.037	2.4	29.1	288
Spike	0.016	0.044	0.023	0.055	0.018	0.054	0.008	0.034	2.2	14.6	262
Threehorn	0.030	0.031	0.036	0.049	0.010	0.039	0.037	0.033	2.1	27.8	255
Mapleleaf	0.015	0.027	0.059	0.038	0.018	0.033	0.024	0.028	1.8	26.2	213
Paper Floater	0.011	0.040	0.011	0.014	0.007	0.032	0.023	0.025	1.6	16.5	192
Pocketbook	0.008	0.028	0.039	0.043	0.026	0.033	0.007	0.024	1.6	25.9	189
Wartyback	0.013	0.010	0.022	0.025	0.008	0.019	0.009	0.014	0.9	23.3	108
Hickory Nut	0.002	0.014	0.050	0.009	0.017	0.018	0.003	0.013	0.9	14.6	104
Giant Floater	0.008	0.016	0.010	0.014	0.003	0.015	0.014	0.012	0.8	16.8	95
Black Sandshell	0.002	0.012	0.016	0.011	0.009	0.013	0.003	0.009	0.6	12.9	72
Fat Mucket	0.013	0.001	0.005	0.006	0.001	0.010	0.001	0.006	0.4	7.1	46
Strange Floater	0.002	0.008	0.002	0.008	0.003	0.008	0.003	0.006	0.4	8.7	43
Rockshell	0.002	0.006	0.010	0.008	0.003	0.008	0.001	0.005	0.3	8.4	41
Higgins' Eye	0.001	0.005	0.016	0.008	0.009	0.005	0.002	0.005	0.3	8.7	38
Monkeyface	0	0.003	0.008	0	0.003	0.003	0	0.002	0.1	2.9	16
White Heelsplitter	0.001	0.002	0.006	0.003	0.001	0.002	0.002	0.002	0.1	4.5	15
Pink Papershell	0.003	< 0.001	0.001	0.001	0	0.002	0.001	0.001	0.1	3.6	11
Butterfly	0.001	0.001	0.001	0.001	0.001	0.001	0	0.001	0.1	2.3	7
Lilliput	0.001	0	0.002	0	0	0.001	< 0.001	0.001	< 0.1	1.6	5
Yellow Sandshell	< 0.001	< 0.001	0.001	0	0	0.001	0	< 0.001	< 0.1	1.0	3
Ohio River Pigtoe	0	< 0.001	0.001	0	0.001	< 0.001	0	< 0.001	< 0.1	0.6	2
Flat Floater	0	< 0.001	0	0	0	0	< 0.001	< 0.001	< 0.1	0.3	1
Buckhorn	0	0	0.001	0	0	< 0.001	0	< 0.001	< 0.1	0.3	1
Mucket	0	< 0.001	0	0	0	< 0.001	0	< 0.001	< 0.1	0.3	1
Total	0.655	1.707	2.964	2.401	0.916	2.095	1.055	1.573			12,150

greater degrees of similarity. Thus, the mussel species pair most commonly found at the same sampling sites (i.e., greatest degree of similarity) was Deertoe and Fawnfoot. Other species pairs with high degrees of similarity include Threeridge-Pigtoe, Washboard-Fragile Papershell, Spike-Strange Floater, Pocketbook-Black Sandshell, Pink Heelsplitter-Paper Floater, and Hickorynut-Monkeyface. The top three species on the dendogram (Threeridge, Pigtoe, and Pimpleback) and the next four species (Washboard, Fragile Papershell, Fawnfoot, and Deertoe) form respective clusters with high degrees of association with each other. This means that the species in each of these clusters were more commonly found at the same sampling sites.

Of the 309 sites sampled, mussels were collected at 224 sites (72.5%), and 85 of the sampling sites (27.5%)

TABLE 3. *The percentage of nonproductive sites in the different regions and habitat types in Pool 10 (number of sampling sites in parentheses).*

	Lower End of Pool 10	Upper End of Pool 10	East Channel	West Channel
Main Channel	75.0% (20)	57.1% (28)	0% (7)	33.0% (6)
Main Channel Border	31.1% (45)	13.8% (65)	7.7% (26)	15.4% (26)
Backwater	25.7% (35)	37.3% (51)	-	-
Total	38.0% (100)	30.6% (144)	6.1% (33)	18.8% (32)

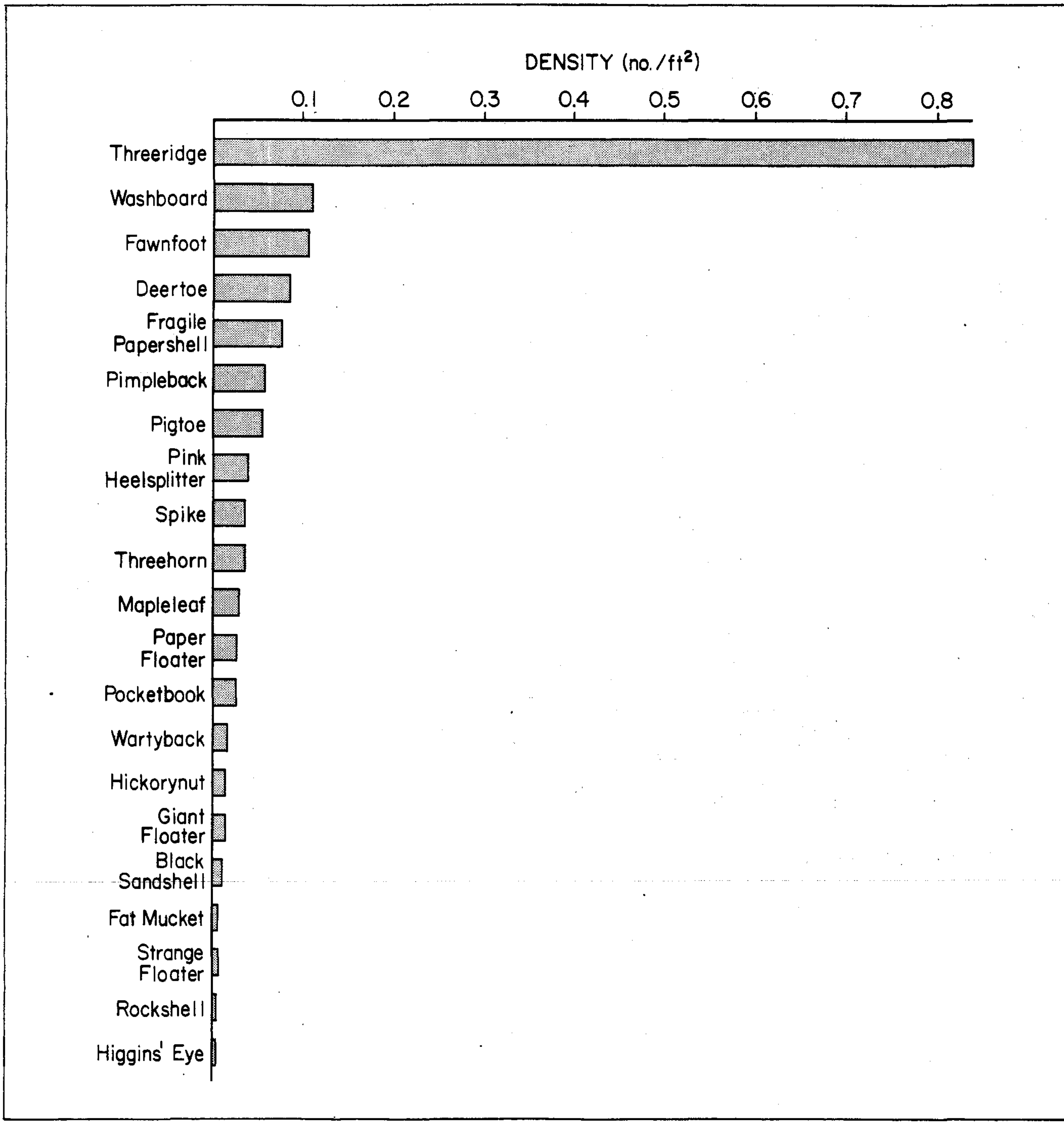


FIGURE 2. *The densities of the 21 most abundant mussel species in Pool 10.*

were nonproductive (i.e., yielded no mussels). The East Channel had the overall lowest percentage (6.1%) of nonproductive sites and all of the sites in the main channel of the East Channel yielded mussels (Table 3). The highest percentage of nonproductive sites (38.0%) was in the lower end of Pool 10. No mussels were collected at 75% of the main channel sites in this region. However, the backwater in the lower end of the pool had a lower percentage of nonproductive sites (25.7%) than the backwater sites in the upper end (37.3%).

The region with the highest density of mussels, 2.964 mussels/ft^2, was the East Channel, followed by the density of 2.401 mussels/ft^2 in the West Channel (Table 2 and Fig. 5). The lower end of Pool 10 was found to have a density of 0.655 mussels/ft^2, which was significantly lower ($P<0.05$) than the density of 1.707 mussels/ft^2 in the upper end (Table 2 and Fig. 6). Mussels in the main channel borders (2.095 mussels/ft^2) were twice as abundant as in the main channel (0.916 mussels/ft^2) and backwaters (1.055 mussels/ft^2) (Table 2 and Fig. 7), a significant difference ($P<0.05$).

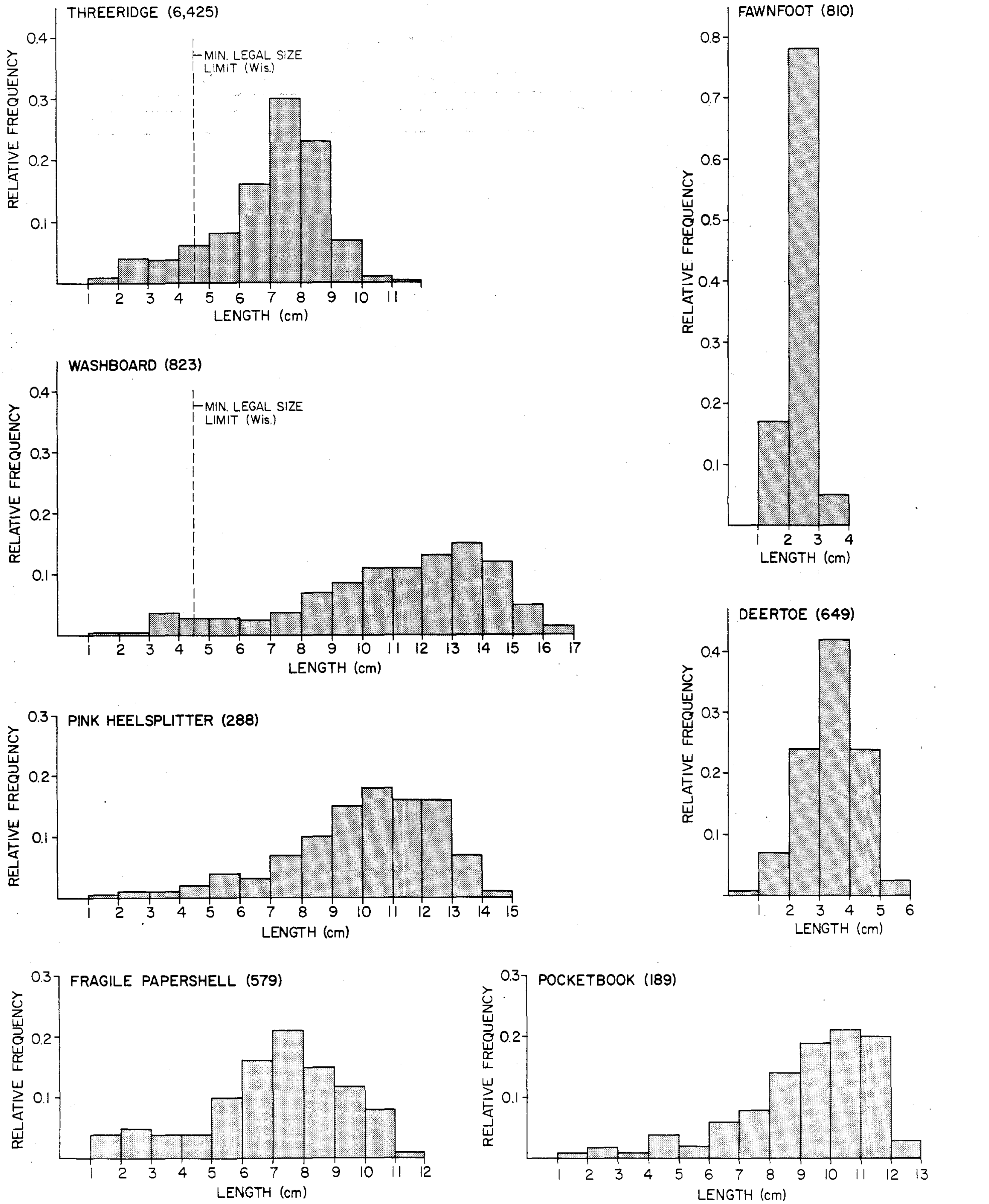
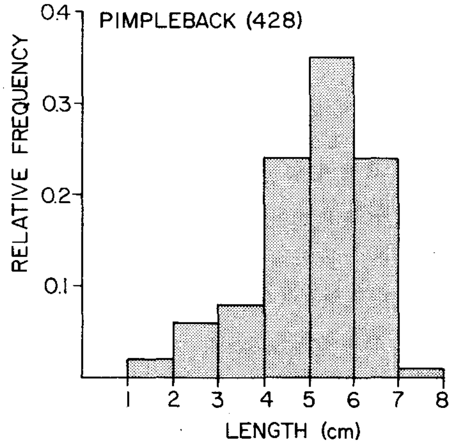
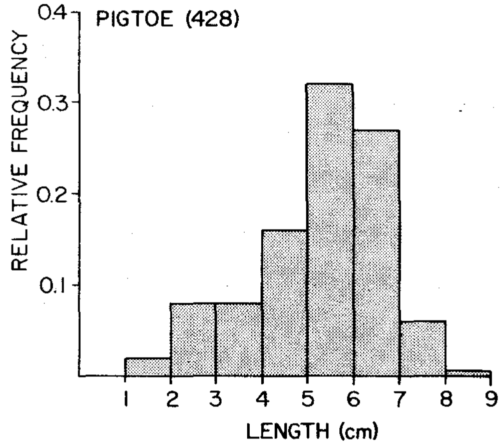
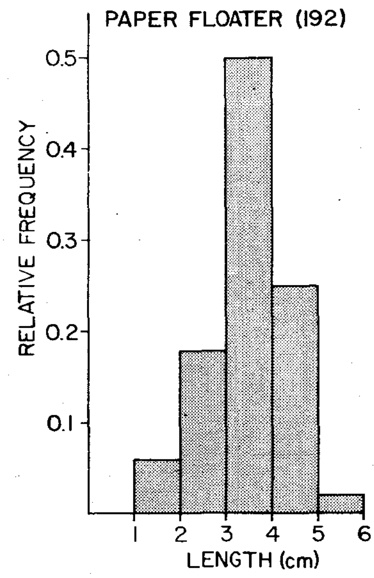


FIGURE 3. *Length-frequency distributions for mussels taken in Pool 10 with more than 100 individuals. (Number collected shown in parentheses.)*


PIMPLEBACK (428)
RELATIVE FREQUENCY
LENGTH (cm)


PIGTOE (428)
RELATIVE FREQUENCY
LENGTH (cm)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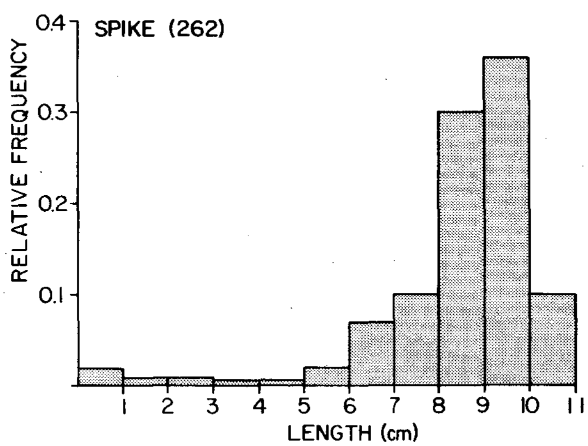
RELATIVE FREQUENCY
LENGTH (cm)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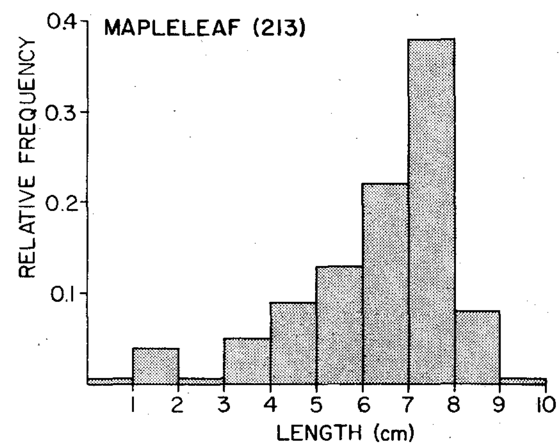
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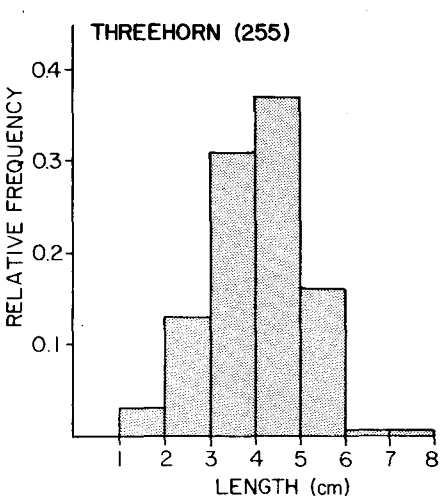
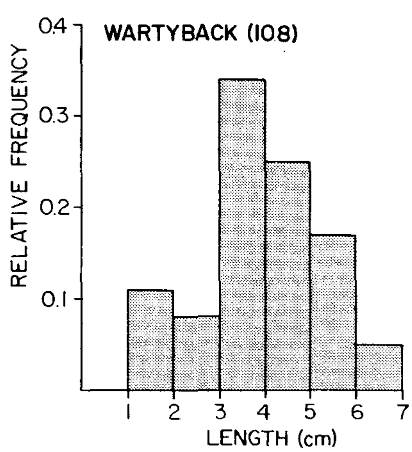
RELATIVE FREQUENCY
LENGTH (cm)


THREEHORN (255)
RELATIVE FREQUENCY
LENGTH (cm)


WARTYBACK (108)
RELATIVE FREQUENCY
LENGTH (cm)

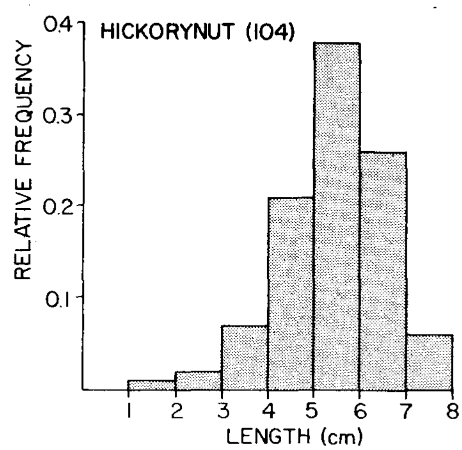
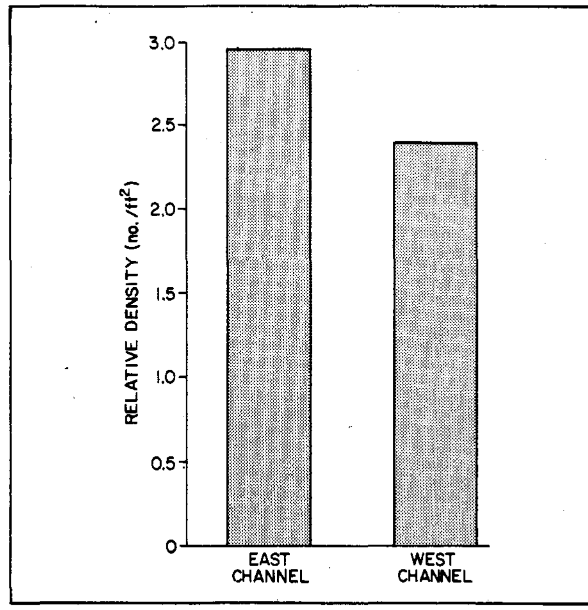
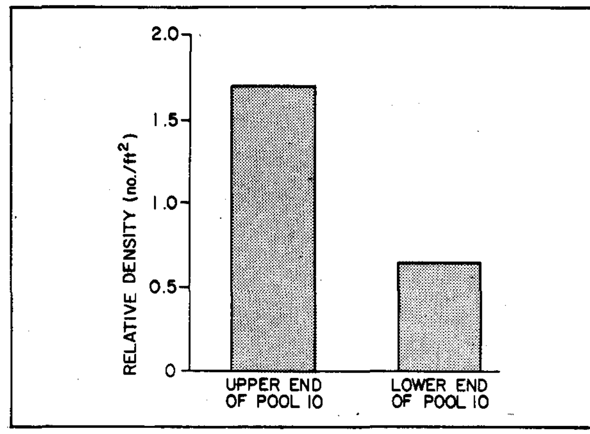

HICKORYNUT (104)
RELATIVE FREQUENCY
LENGTH (cm)

FIGURE 5. *Mussel densities in the East and West Channels. (Right)*

FIGURE 6. *Mussel densities in the upper and lower ends of Pool 10. (Middle)*





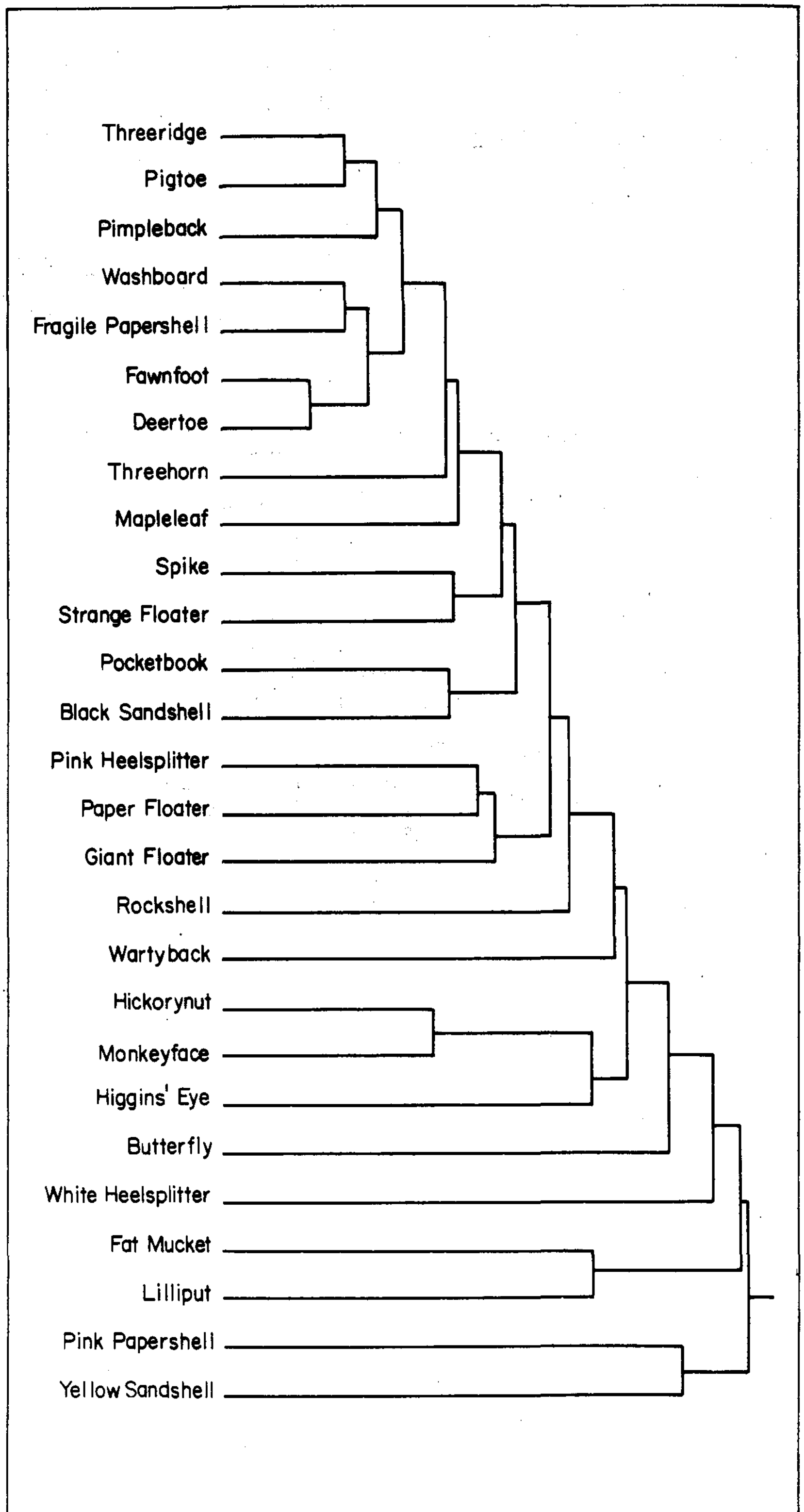


FIGURE 4. *The dendogram resulting from cluster analysis showing the association of mussel species based on occurrence at sampling sites.*

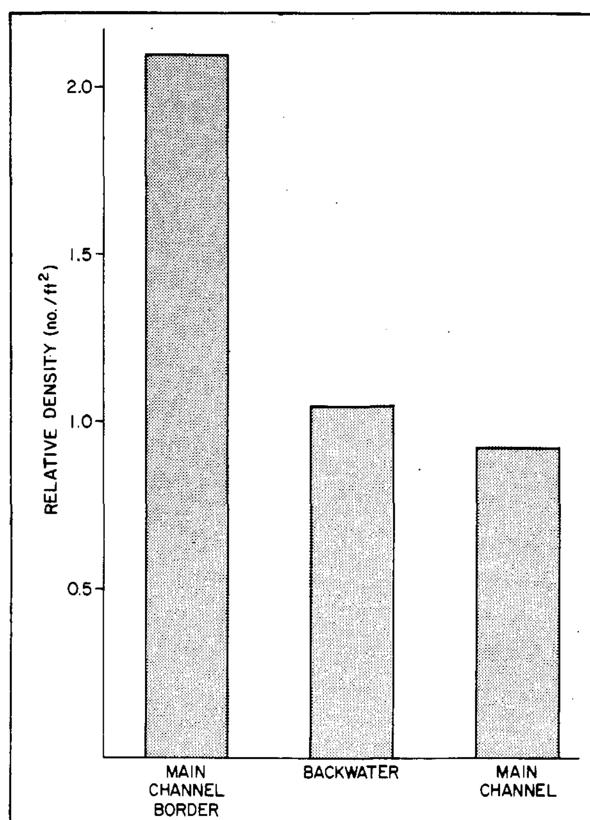


FIGURE 7. *Mussel densities in three habitat types in Pool 10.*

DISCUSSION

The results of this survey support previous studies indicating that Pool 10 has one of the richest mussel faunas in the Upper Mississippi River (Havlik and Stansbery 1978, Fuller 1980*a*, Thiel 1981). The 7 species represented only by empty shells (Spectacle Case, Purple Wartyback, Ebony Shell, Bullhead, Elephant Ear, Fluted Shell, and Elktoe) are evidence of the decline in species diversity. However, the mussel fauna in this pool appears to be less damaged than in the other pools and also less damaged than the mussel fauna of many other large rivers (Havlik and Stansbery 1978, Fuller 1980*a*, Thiel 1981).

All recent mussel surveys have shown the Threeridge to be the most abundant mussel species in the Upper Mississippi River (Finke 1966, Coon et al. 1977, Havlik and Stansbery 1978, Fuller 1978, 1980*a*, Perry 1979, Thiel 1981). Likewise, in this survey, Threeridge was the most abundant species, with a relative abundance of 52.9%. However, the 1930-31 pre-impoundment survey by Ellis (van der Schalie and van der Schalie 1950) found Threeridge to comprise only 7.4% of the total catch in this area. Fuller (1978) attributes the success of Threeridge to the following factors: (1) a long and varied list of glochidial hosts; (2) tolerance of inferior water quality; and (3) indifference to substrate type. The ability to exploit all the habitat types (main channel, main channel border, and backwater) in the Upper Mississippi River has given the Threeridge a significant advantage.

Threeridge and Washboard are the two most important commercial species in the Upper Mississippi River. Even though Washboard is much less dense than Threeridge, the commercial harvest is comprised of about equal numbers of each species. However, Washboard is more massive and accounts for a larger proportion of the tonnage (Thiel 1981). This relatively intensive harvesting of Washboard may be contributing to its decline (Fuller 1980*b*). The population structure of the Washboard shows very few individuals in the lower size classes, probably indicating low levels of recruitment. Currently, the harvesting of Threeridge may not be adversely affecting its population. However, if the acceptable commercial size limit is decreased and/or harvesting pressure increases, the Threeridge population may be negatively affected.

Fawnfoot and Deertoe are probably the most overlooked species in the Upper Mississippi River mainly due to their small size. Previous investigators (Finke 1966, Coon et al. 1977, Fuller 1978, 1980*a*) have used brailing with a crowfoot bar as their only collecting technique which is generally inadequate in sampling for smaller mussels. Since diving was the sole collecting technique for this survey, a more representative sample was obtained and showed Fawnfoot and Deertoe to be the third and fourth most abundant mussel species, respectively. This species pair was most commonly collected at the same sampling site, suggesting that they may have similar habitat requirements.

According to their population structures, some of the mussel species do not appear to be in a healthy condition. The Spike and Mapleleaf are examples of marginal species having extremely skewed length-frequency distributions and showing very little recruitment. Fuller (1980*a*) also found no evidence of recent recruitment for the Spike and considered it as a species in jeopardy. Mapleleaf is a mud-loving species that has been successful in the Tennessee River both before impoundment (Ortmann 1925) and after (Bates 1962). Fuller (1980*a*) labeled the Mapleleaf as healthy and tolerant of impoundment conditions in the Upper Mississippi River. However, this may not continue to be the case even in productive Pool 10 if the Mapleleaf is unable to maintain a higher recruitment level. Length-frequency distributions of other species (e.g., Washboard, Fragile Papershell, Pink Heelsplitter, and Pocketbook) are not as skewed, but they also show very little evidence of recruitment.

The only living specimen of the Flat Floater collected during this survey was found in a backwater area near Harper's Slough in the upper end of the pool. This record is apparently the first time this species has been collected live in Pool 10 and represents a northern extension of the Iowa range of Flat Floater, since it has previously not been collected live in Iowa waters north of Fairport, Iowa (Coker 1919, Havlik 1981*b*).

The preferred habitat of the Flat Floater seems to be the backwater areas, making it difficult to collect since it is often associated with waters that are too shallow to brail. However, there have been several other recent collections of Flat Floater in Upper Mississippi River backwaters. Two specimens of Flat Floater were collected live in Wisconsin backwaters of Pool 8 during 1977 (Havlik 1981*b*). Sixteen live specimens of Flat Floater were collected in the Big Lake area north of Prairie du Chien and empty shells were found in the vicinity of Wyalusing and Bagley in Pool 10 during 1981 (H. Mathiak pers. comm.). Fresh dead specimens of Flat Floater were also found in the Big Lake area during both 1978 and 1980 (Havlik 1981*b*). Apparently this species is more common in the Upper Mississippi River than formerly believed but the favored habitat makes collection difficult (Fuller 1980*a*, Havlik 1981*b*).

Mucket and Buckhorn are the other two species represented by single live specimens. Only four specimens of Mucket and no Buckhorn were collected during the 1977-79 Wisconsin DNR mussel survey (Thiel 1981). These two species appear to be in jeopardy in the Upper Mississippi River and, like other rare species, their decreased abundance may be caused by declining water quality (Fuller 1978, 1980*a*). The mucket was an important commercial species in the early days of clamming activity, and this may be another contributing factor to its decreased abundance (Fuller 1978).

The more favorable habitat conditions for mussels occur in that portion of the pool above the confluence of the Wisconsin River including the East and West Channels. This is evidenced by the greater diversity and higher density of mussels in the upper end of Pool 10. The majority of the Upper Mississippi River mussels are species which prefer flowing rather than standing water (Fuller 1980*a*). After impoundment, the conditions did not change as much in the upper end as the lower end. Therefore, these "flowing water" species were better able to survive the ecological conditions in the upper end of this pool.

This study confirms that some of the remaining great mussel beds of Pool 10 still exist in the East and West Channels. There is no clear-cut explanation as to why these areas are such prime mussel habitats. It is possibly due to a combination of very stable substrate and little dredging activity in the East and West Channels. However, very little is known concerning the habitat requirements of the mussel species in the Upper Mississippi River.

The impounded waters immediately behind dams do not provide good mussel habitat (Fuller 1974) nor do shifting sand bottoms (Murray and Leonard 1962). The mussel populations in the lower end of Pool 10 appear to be suffering from both the adverse impoundment effects behind the dam and the increase in bedload from the Wisconsin River. The Wisconsin River has been estimated to contribute 267,800 tons of sediment/year to Pool 10 (McHenry et al. 1976). The result of this increased bedload is a shifting sand bottom downstream from the Wisconsin River. Stern (1978) found that mussels were least abundant or entirely absent from shifting sand bottoms in the Wisconsin River. Such shifting substrates have probably limited or prevented the establishment of mussel beds in at least part of the lower end of Pool 10. This is indicated in the study by a higher percentage of nonproductive sites in the main channel and main channel borders downstream from the confluence of the Wisconsin River than in the upper end.

The main channel had the lowest density of the three habitat types and several factors have been implicated as causative agents for the sparsity of mussels in the main channel. Increased bedload from tributaries, such as the Wisconsin River, can cause unsuitable conditions for mussels in the main channel downstream from their confluence. Barge traffic is another element that may contribute to the lower density of mussels in the main channel. Heavy barge traffic powered by towboats seriously disrupts the substrate with undertow (Starrett 1971, Coon et al. 1977). However, when water depths exceed 20 ft, the benthic fauna may be protected from mechanical damage caused by large and small crafts (Fuller 1978). In water this deep, there is also no need for maintenance dredging.

Hydraulic dredging is another factor that can have a detrimental effect on mussel populations. Wilson and Clark (1912) noted that dredging destroys the mussel fauna in the immediate vicinity and it may be at least 20 years before the population is restored. Stansbery (1970) reported that a dredged section of a stream will not regain a mussel fauna for as long as a decade or more. Yokley (1977) similarly suggested that it may be years before a mussel population returns to a dredged area. According to a study done on Pools 8, 9, and 10 of the Upper Mississippi River, areas of recent dredging produced few live mussels, even though the dredge spoils from these areas contained many shells (Coon et al. 1977). Havlik and Marking (1981) analyzed the mussel shells from a dredge spoil from the East Channel near Prairie du Chien and found evidence suggesting that numerous mussel species had been alive at the time of dredging but had been killed in the process. In Pool 10, the average annual dredging volume during the period 1956-74 was the smallest of any pool in the St. Paul District of the Army Corps of Engineers (GREAT I 1980*b*). Despite this fact, dredging has adversely affected the main channel and main channel border mussel populations in selected areas throughout Pool 10.

The main channel border, the zone between the 9-ft navigation channel and the main river bank, includes all areas in which wing dams occur (Sternberg 1971). Most of the wing dams are submerged and some, along with submerged riprap, provide good rocky habitat for the rock-loving species of mussels (Fuller 1978). When first constructed, the wing dams caused a shift in the erosion and sedimentation patterns in the main channel border areas which resulted in the destruction of many mussel beds (Grier 1922, Ellis 1931). In subsequent years, many of the wing dams have either completely filled in with sediment or the sediment relocation has reached an equilibrium. The result appears to be creation of a more stable substrate in the main channel borders which is capable of supporting a higher density of mussels. In this study, the density of mussels in the main channel border was found to be twice that of mussel population densities in either the main channel or backwater areas.

Impoundment has increased the surface area of backwaters in the Upper Mississippi River and has created water levels in these backwater areas that are more stable than they were before inundation (Rasmussen 1979). Backwaters are important habitat for certain species of mussels (Fuller 1980*a*), such as the Flat Floater (Havlik 1981*b*). However, fine silts have been accumulating in these shallow water areas, creating unfavorable habitat conditions for many of the mussel species. Since the backwaters are continually filling in (Simons et al. 1975), the mussel populations in these areas will probably decrease in both abundance and diversity.

Pool 10 contains one of the few known viable populations of the Higgins' Eye, a state and federal endangered species. Higgins' Eye was much more common in the East and West Channels and main channel borders, areas of relatively higher mussel diversity and density. Due to the greater number of Higgins' Eye found in the East and West Channels, the rich mussel beds in these areas should be protected against degrading or destructive factors.

If the mussel fauna is going to remain an integral part of the Upper Mississippi River ecosystem, then some precautionary steps need to be taken immediately. The quality of the water needs to be improved or at the very least maintained at the present level. Commercial harvesting of mussels should be carefully monitored and necessary regulations need to be implemented. All potential dredge sites and disposal areas should be examined to prevent any accidental burial or removal of mussel beds. Since the main channel borders support such a rich mussel fauna, these areas need to be protected from disposal of dredge material and any other development activities. The existing mussel beds in the East and West Channels which are inhabited by numerous Higgins' Eye must be protected and managed properly. A recovery program for the Higgins' Eye will be effective only if the beds in which they live are preserved. Through appropriate conservation measures, the freshwater mussels of the Upper Mississippi River can continue to be an important natural resource.

SUMMARY AND CONCLUSIONS

The Upper Mississippi River is changing and so is its mussel community in terms of both density and diversity. Impoundment, a man-induced change, has significantly altered the ecological conditions to which the mussel fauna is subjected and has had a negative impact on most of the mussel species. There are a few species (e.g., Threeridge, Fawnfoot, Deertoe) that have survived well in this largely pooled river environment and dominated the mussel harvest. A mussel community dominated by a few species, however, with the remainder being marginal or near extinction, is a sign of a community under stress (Fuller 1980*b*).

Pool 10 is one of the last strongholds for freshwater mussels in the Upper Mississippi River and supports a greater diversity and higher density of mussels than most any of the other pools. The upper end of Pool 10 including the East and West Channels has the more favorable habitat conditions for mussels as evidenced by the higher density. The preferred habitat type for the majority of the mussel species was the main channel borders which had a mussel density twice that of the main channel and backwaters. The highest density of mussels and over half of the live Higgins' Eye, a state and federal endangered species, were found in the East and West Channels.

Precautionary steps, including maintaining water quality, monitoring the commercial harvest, examining potential dredge sites, and protecting the main channel borders and the East and West channels are necessary to ensure the future of the diverse mussel populations in the Upper Mississippi River.

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