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An Analysis of Freshwater Mussels (Unionidae) in the Upper Ohio River Near Huntington, West Virginia: 1992 Studies

by Andrew C. Miller, Barry S. Payne
Environmental Laboratory

WES

Prepared for U.S. Army Engineer District, Huntington

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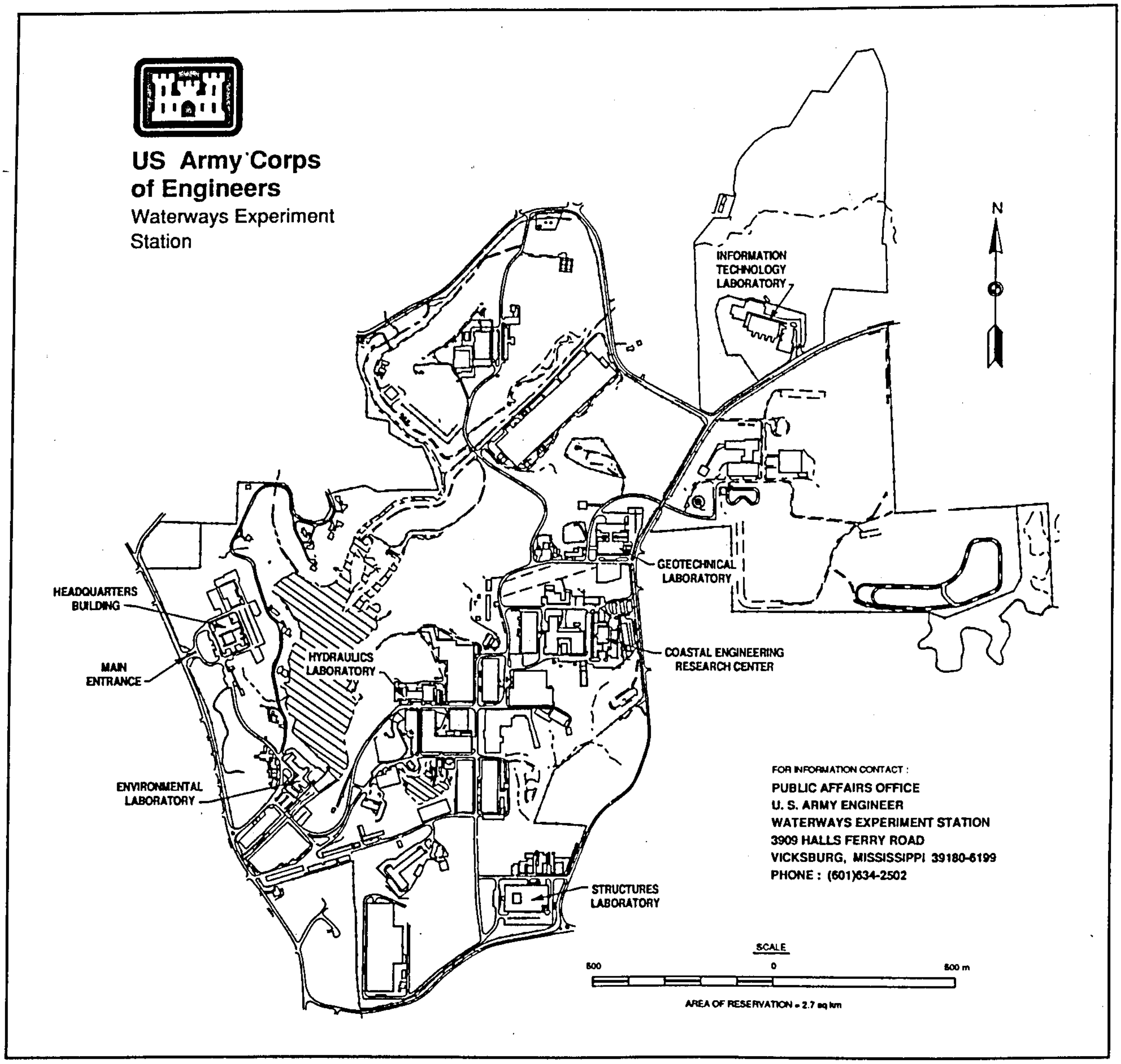

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Contents

Preface

The work reported herein was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) in October 1992 for the U.S. Army Engineer District, Huntington, Huntington, WV. The purpose was to use qualitative and quantitative methods to collect freshwater mussels (Unionidae) from known mussel beds in a reach of the Ohio River near Huntington. Data on density, size demography of dominant populations, species diversity, and community composition will be used to analyze the environmental effects of increased commercial navigation traffic resulting from completion of Gallipolis Lock and Dam.

Divers for this study were Messrs. Larry Neill, Robert Warden, Robert T. James, and Jeff Montgomery from the Tennessee Valley Authority. Assistance in the field and advice on location of sampling sites were provided by Mr. Bill Tolin, U.S. Fish and Wildlife Service, and Mr. Barry Passmore, Huntington District. Messrs. Jim Jones and Chuck Boston, University of Louisville, assisted in the field. Ms. Deborah Shafer, WES, was the Diving Inspector for this work. Mr. Barry Passmore monitored the contract with WES. Ms. Karen Gunnison, Kalamazoo College, weighed and measured all *Corbicula fluminea*. Figures were prepared by Ms. Sarah Wilkerson, Mississippi College, and tables were prepared by Ms. Geralline Wilkerson, Hinds Jr. College.

During the conduct of this study, Dr. John Harrison was Director, Environmental Laboratory (EL), WES, Dr. Conrad J. Kirby was Chief, Ecological Research Division, EL, and Dr. Edwin Theriot, was Chief of the Aquatic Ecology Branch, EL. Authors of this report were Drs. Andrew C. Miller and Barry S. Payne, EL. Design of the study and conduct of all related activities in the field and laboratory were the sole responsibility of Drs. Miller and Payne.

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

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Conversion Factors, Non-SI to SI Units of Measurement

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

Multiply	By	To Obtain
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. nautical)	1.852	kilometers

1 Introduction

Background

Freshwater mussels, a resource with economic, ecological, and cultural value, can be affected by changes in water levels, sediment resuspension caused by dredging and disposal of dredged material, and movement of navigation vessels. Their sedentary lifestyle and reliance on suspended particulate organic material for food makes them particularly susceptible to fluctuating water levels, sediment scour, elevated suspended sediment, and turbulence. The biological consequences of these disturbances can be measured on organisms held in the laboratory (Holland 1986; Aldridge, Payne, and Miller 1987; Killgore, Miller, and Conley 1987; Payne and Miller 1987). However, caution must be used when extrapolating results of laboratory experiments to the field (Payne and Miller 1987). Physiological responses that occur in a laboratory often do not occur under natural conditions.

Planners and biologists should evaluate the effects of physical disturbances such as those caused by dredging and movement of commercial navigation vessels on naturally occurring populations, not on individual organisms held in the laboratory. Field studies are the best means of understanding effects of physical disturbances on naturally occurring populations of mussels. These studies can be designed to evaluate 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. A predetermined set of criteria can be evaluated yearly to determine if man-made disturbances are negatively affecting native mussels.

Purpose and Scope

The purpose is to characterize important biotic variables (mussel density, evidence of recent recruitment, community structure, and spatial distribution) at mussel beds downriver of the Gallipolis Lock and Dam in the Ohio River, West Virginia. Results of this work will be used by personnel of the U.S. Army Engineer District, Huntington, to evaluate the effects of water resource developments on freshwater mussels. In addition, these data will provide a baseline for evaluating the effects of introduction and spread of the exotic zebra mussel *Dreissena polymorpha* on native freshwater mussels.

2 Study Area and Methods

Study Area

The Ohio River originates in Pittsburgh, PA, at the confluence of the Allegheny and Monongahela Rivers. It flows 981 miles[1] to the northwest and then the southwest before it joins the Mississippi River near Cairo, IL. The river drains 203,900 square miles and falls 450 ft before it joins the lower Mississippi River.

For this project, study sites were located in the upper Ohio River (UOR) between River Miles (RM) 292.2 and 283.9 (Table 1, Figure 1). Quantitative methods were used to collect bivalves at RM 292.2, 292.1, 287.0, and 283.9. Qualitative methods were used to collect mussels at RM 292.2, 289.8, 288.7, 287.0, and 284.0 (Figures 2 and 3). The majority of samples were collected about 200 ft from shore in water 12 to 21 ft deep.

At all sites, substratum consisted of stable sand mixed with medium-sized to large gravel. Substratum at the downriver reach of the study area (RM 292.2) had higher percentages of coarse-grained particles greater than 34 mm in diameter (Figure 4). Substratum at the upper reach of the study area (RM 283.9) was characterized by having higher percentages of finer grained material with particle diameter less than 6.35 mm. Intermediate-sized particles (those with diameters between 12.7 and 34.0 mm and between 6.35 and 12.7 mm) tended to become more common moving upriver (Figure 4).

Methods

Preliminary reconnaissance

All underwater work was accomplished by a dive crew equipped with surface-supplied air and communication equipment. Before intensive sampling was initiated, a single diver conducted a preliminary reconnaissance of the

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

immediate area. He obtained information on substrate type, water velocity, and presence of mussels. Qualitative sampling was initiated if the substrate appeared stable and if there was moderate to high mussel density (i.e., greater than 3 to 5 individuals/square meter).

Qualitative mussell samples

The majority of the qualitative samples were obtained by having two divers collect simultaneously. Each diver placed a specific number of live mussels in each of six nylon bags; 5 mussels were placed in three bags and 20 were placed in each of the other nine bags. The divers were instructed to obtain mussels without bias toward size or type. They attempted to exclude the Asiatic clam *Corbicula fluminea*. If *C. fluminea* was inadvertently collected, it was later eliminated. A total of 90 qualitative samples (bags of mussels) were taken from nine locations (Table 1). Typically, 12 samples were taken at each site; however, at RM 288.7 and 287.0, only seven and six samples were taken, respectively. Fewer samples were taken at these latter sites since densities were extremely low; it is inefficient to collect where mussels are very uncommon.

All mussels were brought to the surface, counted, and identified. Data 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 and labeled with high rag content paper. Mussels not needed for voucher were returned to the river. Methods for sampling mussels were based on techniques described in Coker (1919); Brice and Lewis (1979); Miller and Nelson (1983); Isom and Gooch (1986); Kovalak, Dennis, and Bates (1986); and Miller and Payne (1988). 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 Turgeon et al. (1988).

Quantitative mussel samples

Quantitative samples that included unionids as well as *C. fluminea* were obtained at RM 292.2, 287.0, and 283.9. At each location, bivalves were collected at each of four sites that were separated by 5 to 10 m. At each site, 10 quadrats (0.25 sq m) were positioned approximately 1 m apart and arranged in a 2 by 5 matrix. A diver excavated all sand, gravel, shells, and live bivalves to a depth of 10 to 15 cm. Material was sent to the surface in a 20-ℓ bucket and transported to shore. Sediment was screened through a sieve series. All live mussels and *C. fluminea* removed from samples were placed in 4-ℓ zipper lock bags. Each bivalve was then identified and total shell length (SL) measured to the nearest 0.1 mm with a caliper.

Grain size analysis

Sediment samples from the quantitative samples from each wash screen were weighed on a top-loading balance in the field. Mesh sizes of screens were 34.0, 12.7, and 6.35 mm. The sediments on each screen (excluding the mass of bivalves, which were treated separately) were weighed in the field.

Data analysis

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 an IBM XT or AT personal computer. Discussion of statistical procedures that were used can be found in Green (1979) and Hurlbert (1984). Species area curves and dominance-diversity curves were constructed from qualitative and quantitative biological data. More information on methods used for this survey can be found in McNaughton and Wolf (1973), Isom and Gooch (1986), Kovalak, Dennis, and Bates (1986), Hughes (1986), and Miller and Payne (1988).

3 The Bivalve Community

Community Characteristics

Qualitative samples

A total of 1,477 individuals and 20 species of mussels were collected at five locations in the study area using qualitative methods (Table 2). The fauna was dominated by two thick-shelled species (*Elliptio crassidens* and *Quadrula pustulosa*), which together comprised 66.7 percent of the fauna. Seven species comprised 1 to 8 percent of the fauna, and 11 species each comprised less than 1 percent of the fauna. The majority of these mussels were thick or moderately thick species; thin-shelled species (*Leptodea fragilis* and *Lampsilis ovata*) were uncommon and comprised 0.07 and 0.74 percent of the fauna, respectively. *Elliptio crassidens* was taken in all qualitative samples at each site except at RM 288.7, where it was found in only 66.7 percent of the samples (Table 3). In addition to *E. crassidens*, three species occurred in more than 55 percent of all qualitative samples (*Q. p. pustulosa, Quadrula metanevra,* and *Pleurobema cordatum*). Nine species were found in 10 to 41 percent of the samples, and seven species were found in less than 10 percent of the samples (Table 4).

A plot of percent species abundance versus percent occurrence of each species in all 90 qualitative samples appears in Figure 5. The 20 species spanned 3 orders of magnitude (from 34 to 0.07 percent) and depict a community that is evenly distributed (i.e., with no clear dominants). Frequency of occurrence data spanned 1 order of magnitude (from 98 to 1.11 percent).

The relationship between the cumulative number of individuals and the cumulative number of species collected depicts the effort required to collect uncommon species (Figure 6). Sixteen species (80 percent of the collection) were found after slightly more than 400 individuals had been taken at RM 292.2. After an additional 1,000 individuals had been collected at sites farther upriver, a total of four more species were identified. It is likely that additional species were obtained as a result of obtaining more individuals rather than collecting at new habitats.

There were no specific trends with respect to RM for abundance of common species (Figure 7). The site at RM 288.7 was dominated by *Q. p. pustulosa* and *Q. metanevra* rather than *E. crassidens*. *Pleurobema cordatum* was twice as abundant at RM 289.8 and 287.0 than at RM 292.2, 288.7, and 284.0 (Figure 8). The slight differences in community composition were probably related to minor variations in each of these mussel beds.

Quantitative samples

A total of 328 individuals and 17 species were collected in the 120 quantitative samples taken at three locations in the UOR (Table 5). As with qualitative collections, the fauna was dominated by *E. crassidens* (33.8 percent) and *Q. p. pustulosa* (30.8 percent). When results of qualitative and quantitative sampling methods were compared, the percentage abundance of the two dominate species differed by approximately 10 percent (Figure 9). However, two small and therefore difficult-to-collect species, *Obliquaria reflexa* and *Truncilla truncata*, were several times as abundant in the quantitative samples as in the qualitative samples (see also Tables 3 and 5). *Obliquaria reflexa* and *T. truncata* comprised 0.41 and 0.20 percent, respectively, of the qualitative collection and 3.7 percent of the quantitative collection. Very uncommon species that were usually easy for divers to find (*Lampsilis ovata* and *Plethobasis cyphyus*) each comprised less than 1 percent of the qualitative and quantitative collections. Because these were low-density beds, even the dominant species were not common in quantitative samples. For example, *E. crassidens* and *Q. p. pustulosa* were found in slightly more than 50 percent of the quantitative samples (Table 6). Four species were taken in 10 to 20 percent of the quantitative samples, and eleven species were found in less than 10 percent of the quantitative samples.

Based on results of quantitative sampling, the distribution of species within the community was even, with no clear dominant (Figure 10). Distribution of species within the community was similar regardless of sampling technique (compare Figures 5 and 10). However, as described above, because of low density, the quantitative sampling resulted in a lower frequency of occurrence for species than did the qualitative sampling (compare Figures 5 and 10, and also see Table 6). After approximately 160 individuals had been collected using quantitative methods, 15 species had been identified (Figure 11). Although more individuals were collected using qualitative methods, the species area curves were similar (compare the first part of Figure 6 with Figure 11).

Species diversity, a measure of the number of species in a sample (richness) as well as the distribution of species within the community (evenness), was slightly higher at RM 283.9 than at RM 292.0 or RM 287.0 (Figure 12). Evenness can range from near 0 for communities strongly dominated by one or two species to near 1.0 for communities with no clear dominants. Values greater than 0.5 indicate communities that show no clear dominants.

Individuals less than 30 mm total SL can be considered evidence of fairly recent recruitment (i.e., organisms that developed within the last 2 years). At the three locations sampled using quantitative methods, the total percentage of species that had at least one individual less than 30 mm total SL ranged from 9.1 to 15.4 percent (Table 5 and Figure 13). Number of organisms collected and mean, minimum, and maximum SL for each species at each of the three locations sampled quantitatively are given in Table 7. *Quadrula pustulosa pustulosa* had representatives less than 30 mm total SL at all sites. Other species with some small individuals included *Truncilla truncata* (minimum size 27.2 mm at RM 283.9), *Obliquaria reflexa* (minimum size 32.1 mm at RM 283.9), and *Potamilus alatus* (minimum size 36.2 mm at RM 283.9).

Total density of Unionidae ranged from 6.0 (Site 4, RM 287.0) to a maximum of 16.8 individuals/square meter (Site 4, RM 292.0) (Table 8 and Figure 14). Variation in density among sites for Unionidae at each of the three locations was not significant (P > 0.05). Mean density at RM 292.0 and 283.9 (13.7 and 11.2 individuals/square meter) was significantly greater than at RM 287.8 (7.9 individuals/square meter). Total biomass of Unionidae ranged from 404.9 g/square meter (Site 4, RM 283.9) to 2,485.9 g/square meter (Site 3, RM 292.0). As with density, biomass values were not significantly different among sites at each RM (P > 0.05). Total biomass of Unionidae was significantly greater at RM 292.0 (2,441.6 g/square meter) than at RM 287.0 or 283.9 (1,251.0 and 1,075.9 g/square meter, respectively).

Total density of *C. fluminea* ranged from 140.8 (Site 2, RM 292.0) to 3,381.6 individuals/square meter (Site 4, RM 283.9) (Table 8 and Figure 15). Variation in density among the four sites was significant at RM 287.0 (P = 0.0002), but not at RM 292.0 or 239.0 (P > 0.05). Mean density of *C. fluminea* was significantly different at each of the three RMs (P = 0.0001). Biomass of *C. fluminea* ranged from 271.4 (Site 2, RM 292.2) to 6,073.3 g/square meter (Site 4, RM 283.9). Significant intrasite variation in biomass of *C. fluminea* was found at RM 287.0 and 283.9 (P < 0.05), but not at RM 292.0 (P = 0.3562). As with numerical density, mean biomass density was significantly different among the three RMs (P = 0.0001).

There was a substantial increase in density of medium-sized *C. fluminea* (total SL 14 to 19.99 mm) moving upriver from RM 292.2 to RM 283.9 (Figure 16 and Table 9). Density of small and larger sized *C. fluminea* was similar among the three locations.

Total density and total biomass of Unionidae in each 0.25-square meter quadrat were plotted against four size fractions of particles. Particle size classes were <6.35 mm, 6.35 to 12.7 mm, 12.7 to 34.0 mm, and >34.0 mm. Notable trends for either density or biomass with respect to these size fractions were not observed (Figures 17 and 18). However, when this comparison was made for total density and biomass of *C. fluminea*, notable relationships were observed. Both density and biomass of Asian clams were positively related to three size classes of particles less than 34 mm (Figures 19 and 20). Numerical and biomass density of *C. fluminea* was positively related to increased percentages of small-sized particles. Finer grained sediments were most common at the most upriver location (RM 283.9) and least common at the downriver location (RM 292.2) (see also Figure 4). In both numerical and biomass terms, there was a negative relationship between percentages of particles greater than 34 mm and density of *C. fluminea.*

Correlations among percentages of various size fractions of sediments and total biomass and density of Unionidae and *C. fluminea* are included on Table 10. There was a significant positive correlation between density and biomass of *C. fluminea* and percentage of fine-grained sediments. Conversely, the correlation between biomass and density of Unionidae and the three particle size classes smaller than 34.0 mm were mostly negative. Stated simply, the Unionidae became slightly more common in sediments with large diameter particles, and *C. fluminea* became more common in sediments with small diameter particles. As a result, there was a significant negative relationship between density and biomass of *C. fluminea* and biomass of Unionidae. If grain size distribution had been the same at all collecting sites, then the negative correlation between Unionidae and *C. fluminea* might be considered biologically significant. However, since there was a significant relationship between river mile and percentage of fine-grained sediments, it appears that grain size distribution was the major causative factor affecting distribution of Unionidae and *C. fluminea.*

Demography of Dominant Populations

Only two species of native unionids were collected in sufficient numbers to allow analysis of population-size demography. These two species were *E. crassidens* and *Q. p. pustulosa,* which both have massive shells. *Elliptio crassidens* grows to large adult size (>100 mm long) and is long-lived (approximately 25 years). *Quadrula pustulosa pustulosa* grows to moderate adult size and is moderately long-lived (approximately 12 years). In addition, size demography of the Asian clam *C. fluminea* was also examined. *Corbicula fluminea* is small relative to most native unionids and typically lives for 1 to 3 years, with recruitment occurring in spring and fall of each year.

The two native unionids were approximately equally abundant at all RM locations, and there were no clear intersite differences in size demography. In contrast, density of *C. fluminea* increased greatly from RM 292.0 to RM 283.9, and the size structure of the population at RM 292.0 was slightly different than at RM 283.9 and 287.0. These patterns are discussed in more detail below.

Elliptio crassidens

Elliptio crassiden individuals were large, ranging from 90 to 118 mm long (Figure 21). The model length of mussels in this population was 103 mm.

The lack of small mussels indicates a population that has not had substantial recruitment in several years.

Quadrula pustulosa pustulosa

The population of *Q. p. pustulosa* was dominated by relatively large mussels, although some small individuals were collected (Figure 22). Mussels greater than 48 mm long comprised 60 percent of the population. Twelve percent of the population measured less than 30 mm long. These small *Q. p. pustulosa* are evidence that recent recruitment has been substantial when compared with other native species.

Corbicula fluminea

At all locations (i.e., RM 283.9, 287.0, and 292.0), the *C. fluminea* population was heavily dominated by individuals less than 20 mm long (Figures 23-25). A single cohort of *C. fluminea* centered at 15 to 18 mm (ranging from 12 to 20 mm) was heavily dominant at RM 283.9. This cohort comprised approximately 98 percent of the total population. Total size range of *C. fluminea* at RM 283.9 was 9 to 36 mm. At RM 287.0, a single cohort centered at 13 to 17 mm (ranging from 11 to 18 mm) was heavily dominant. This cohort comprised 94 percent of the *C. fluminea* population at RM 287. Total size range of Asian clams at RM 287.0 was 8 to 32 mm. Small *C. fluminea* at RM 292.0 were clearly divided among two cohorts. A minor cohort centered at 10 to 13 mm (Range 8 to 14 mm) comprised 20 percent of the population. This small cohort could not be distinguished at either RMs 283.9 or 287.0, although size ranged downward to 8 mm at RM 283.9 and 9 mm at RM 287.0. A second cohort of small *C. fluminea* centered at 16 to 18 mm (range 14 to 19 mm) comprised 76.1 percent of the population at RM 292.0. The size of this cohort corresponded relatively closely with the major cohort of small Asian clams at both RMs 283.9 and 287.0. It is possible that overwhelming abundance of this cohort at the latter two locations masked the occurrence of the slightly smaller and less abundant cohort that was clearly evident only at RM 292.0.

Variation in *C. fluminea* mean density among locations was much more striking than variation in size demography. *Corbicula fluminea* occurred at an average density of 3,079 individuals/square meter at RM 283.9. Density at RM 287.0 was approximately half this value, averaging 1,537 individuals per square meter. At RM 292.0, *C. fluminea* mean density averaged only 154 individuals/ square meter.

4 Discussion

The mussel assemblage in the reach of the UOR consisted almost entirely of thick-shelled species (*E. crassidens* and *Q. p. pustulosa*), with lesser numbers of *Q. metanevra* and *P. cordatum*. Thin-shelled species such as *L. fragilis* were uncommon and comprised less than 1 percent of the qualitative collection. Within their range, these thin-shelled species are found in appropriate substratum in large rivers (Murray and Leonard 1962; Parmalee 1967; and Starrett 1971). Each has multiple fish hosts (Fuller 1974) and would be more common in this reach if more suitable substratum and flow existed for them. However, gravel and erosive flows at high discharge stress thin-shelled species. If present, few would reach adult size. There would be more thin-shelled species in this reach of the UOR if substratum consisted of more fine-grained particles and maximum water velocities were reduced.

Lampsilis abrupta, listed as endangered by the U.S. Fish and Wildlife Service (1991), has been reported from this reach of the UOR (Tolin, Schmidt, and Zeto 1987). It is so uncommon that it is likely to be missed even during intensive surveys. It is likely that this species will be collected during future years. *Plethobasus cyphyus*, listed as endangered by the Commonwealth of Kentucky (Branson et al. 1981), was collected using qualitative and quantitative techniques. This species has been found in a dense and diverse bed in the lower Ohio River near Olmsted, IL (Payne and Miller, unpublished information), and comprised 0.19 percent of the fauna at a site stabilized by wing dams in Pool 10 of the upper Mississippi River (Miller 1988).

Total species richness in the study area (20 species) is similar to that at other mussel beds in large rivers. At a mussel bed in the lower Ohio River near Olmsted, IL, 23 species of freshwater mussels were collected (Miller 1988). In a survey of the upper Mississippi River, Miller et al. (1990) collected over 15,000 bivalves in 667 qualitative samples at 58 locations and identified 34 species. However, total species richness at any one location was usually between 15 and 25.

Mean unionid density at the six sites sampled (6.0 to 16.8 individuals/square meter) is slightly less than values often found at large river mussel beds. In a survey of the upper Mississippi River, 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 those sites, total density was greater than 50 individuals/square meter; at four sites it was greater than 100 individuals/square meter. At an inshore and offshore site sampled in 1986 at RM 18.6 in the lower Tennessee River (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).

The only species of Unionidae that exhibited fairly strong evidence of recent recruitment was *Q. p. pustulosa*. About 12 percent of the individuals were judged to be evidence of recent recruitment. This is an indication of stable substrate and suitable water velocity at the time of reproduction for this species. These results can be contrasted with a bed on the lower Ohio River where Payne and Miller (1989) reported that 71 percent of the dominant species *Fusconaia ebena* belonged to a single cohort with an average SL of 15.8 mm.

Estimates of total density, measures of recruitment, and adequate characterization of population demography require quantitative, total substratum samples (Miller and Payne 1988). However, quantitative methods in large rivers are difficult and expensive. Resource agency personnel interested in mainly searching for rare or endangered species or characterizing important community parameters such as diversity and evenness should consider qualitative methods. This assumes that studies are well-designed and adequate numbers of individuals are collected.

The Asian clam *C. fluminea* has been abundant in the lower Ohio River since at least 1957 (Sinclair and Isom 1963). There has been considerable speculation that *C. fluminea* would competitively displace native unionid and sphaeriid bivalves (see McMahon (1983) and references within). In this river reach, unionids have maintained moderate densities and diversities and show some evidence of recent recruitment despite at least 25 years of occurrence with an abundant *C. fluminea* population. Another exotic pest bivalve, the zebra mussel *Dreissena polymorpha*, has now become part of the bivalve fauna in the Ohio River. In the lower Ohio River near Olmsted, IL, a single individual was found byssally attached to a piece of gravel. A second individual was found on a unionid during a qualitative search for mussels. Because *D. polymorpha*, unlike *C. fluminea*, can byssally attach to unionids in high density, there is potentially much more direct competition between the former species and the native mussels.

Catastrophic declines of unionids have been reported in Lake St. Clair and Lake Erie because of intense fouling of live unionids by zebra mussels (Mackie 1993). However, in these instances, unionids may have provided a much more suitable substrate for attachment than sand or mud. Furthermore, *D. polymorpha* produces a true veliger larva via external fertilization (Hopkins and Leach 1993). This mode of reproduction has allowed rapid colonization along the fringes of the Great Lakes.

The continued use of inland waterways to transport bulk commodities (Dietz et al. 1983) has caused planners and biologists in Government agencies to express concern over the possible negative effects of commercial use of waterways on freshwater mussels (Rasmussen 1983). Rather than rely on speculation or questionable predictive methods, quantitative and qualitative techniques should be used to obtain data on mussel density, relative species abundance, community composition, and population demography. The results of future studies at these mussel beds will provide information necessary to evaluate the effects of commercial navigation vessels and other water resource development on freshwater molluscs in this reach of the UOR.

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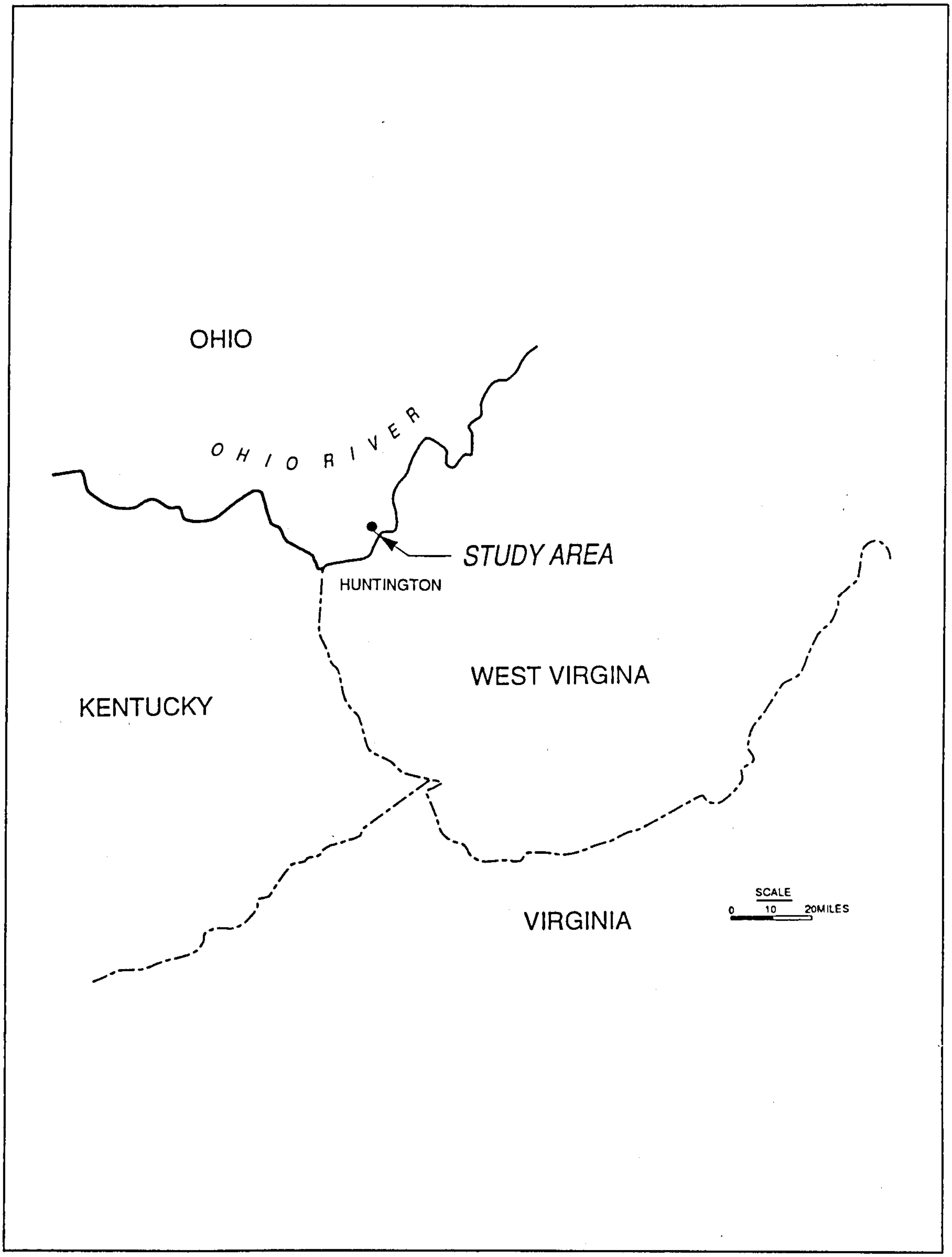

Figure 1. Study area

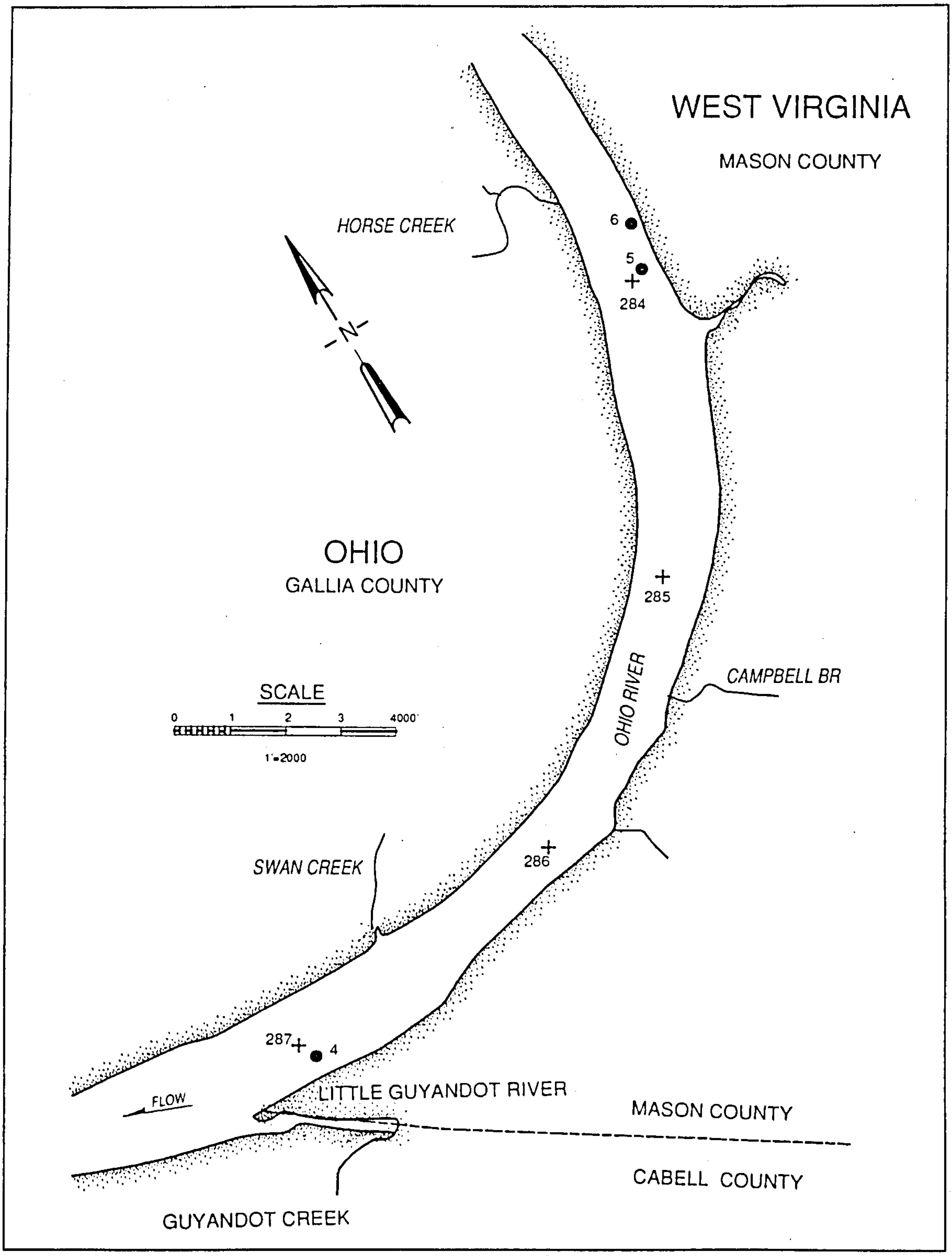

Figure 2. Sites 4-6 in the upper Ohio River

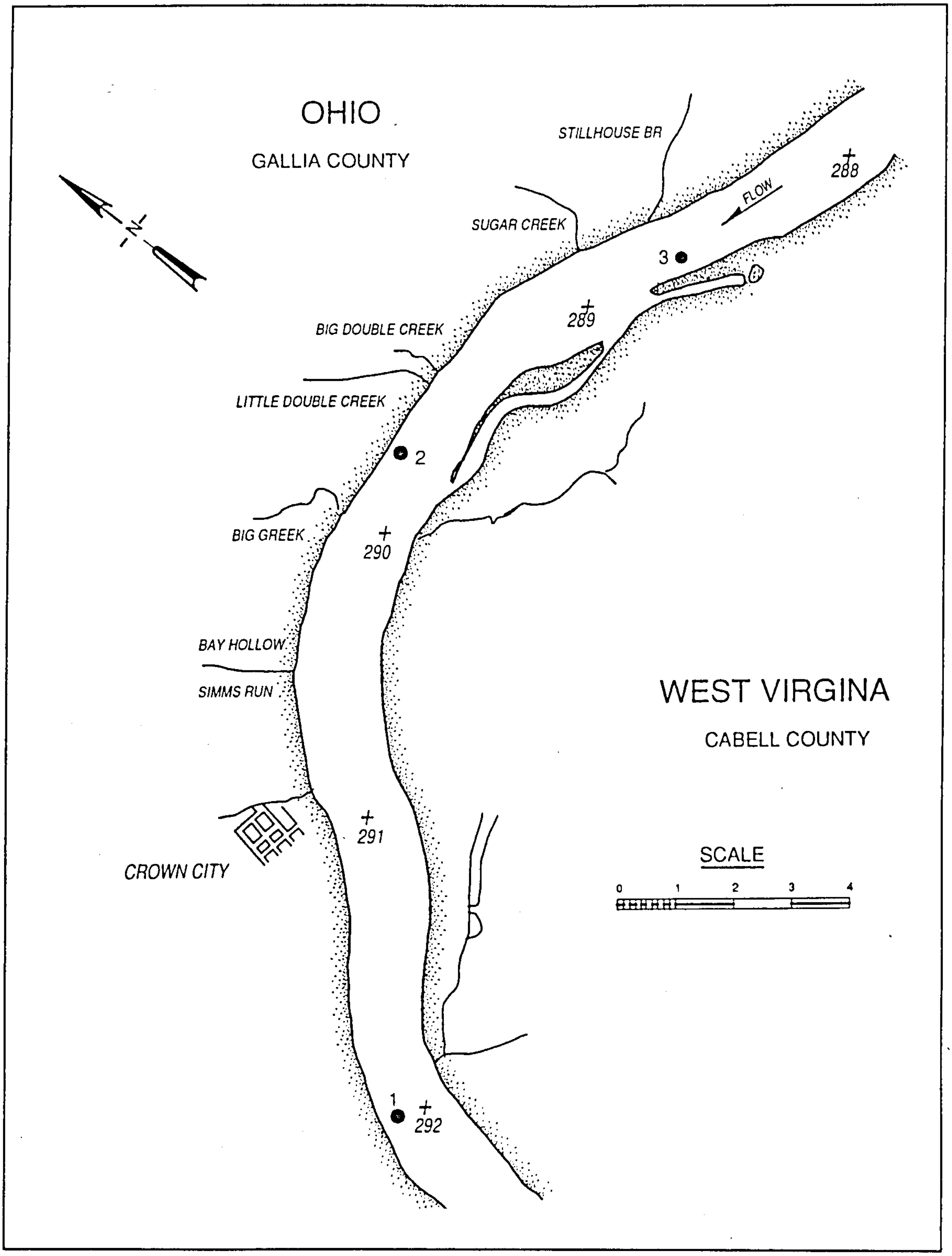

Figure 3. Sites 1-3 in the upper Ohio River

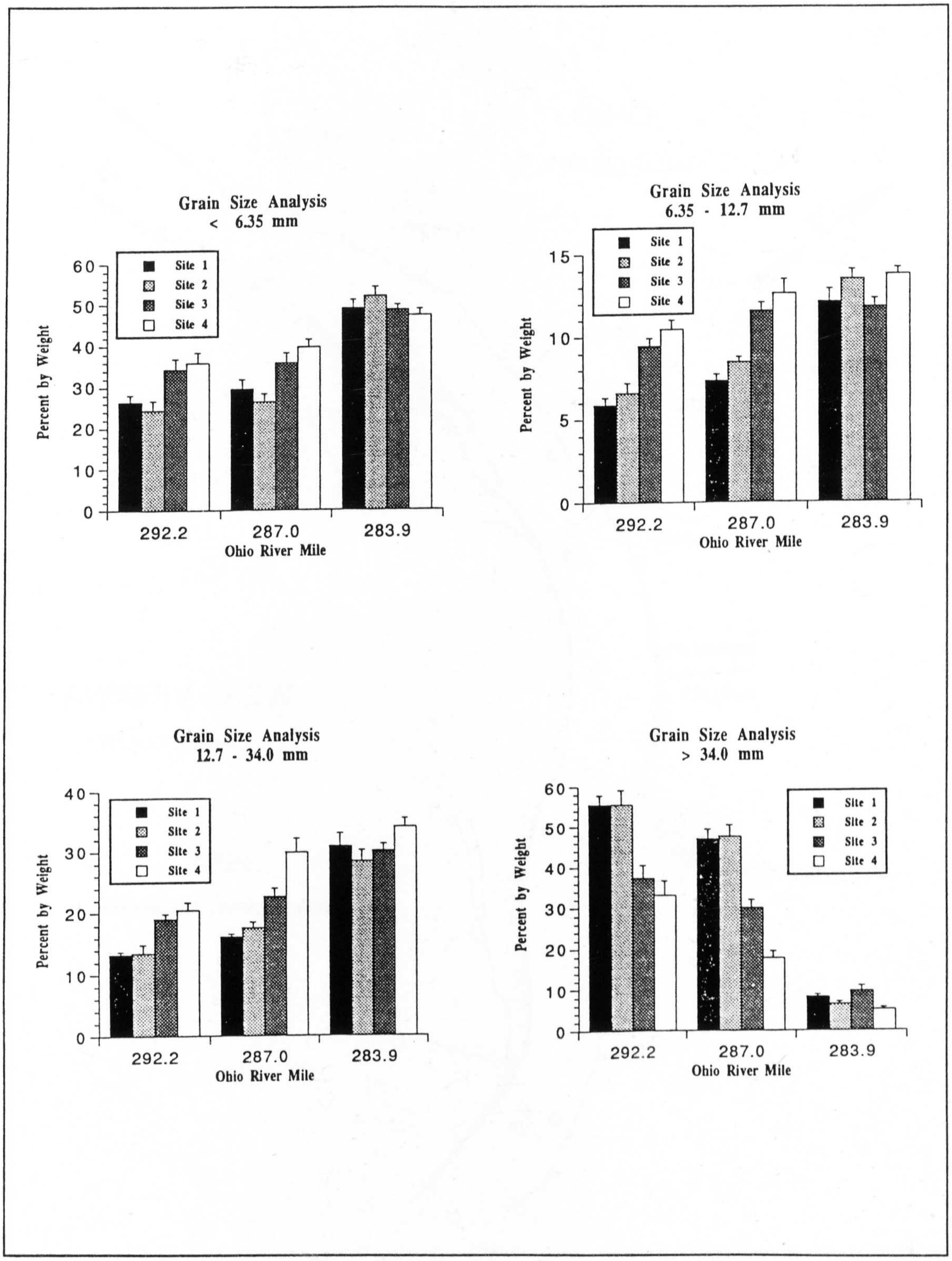

Figure 4. Grain size analysis for three locations on the upper Ohio River where quantitative samples were collected

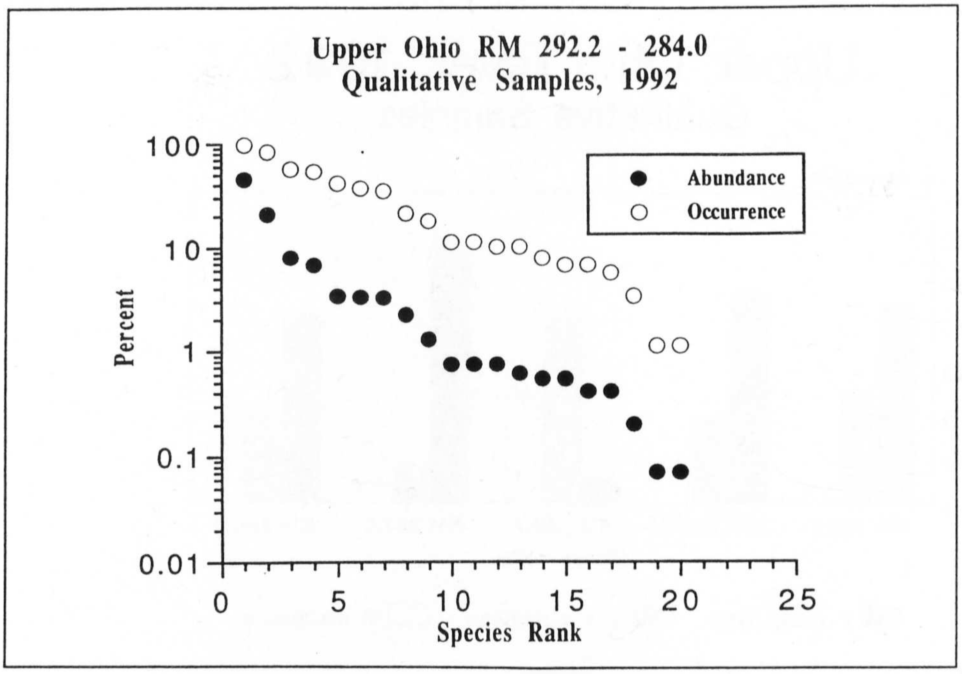

Figure 5. Relationship between percent abundance, percent occurrence, and species rank for mussels collected using qualitative methods, upper Ohio River, 1992

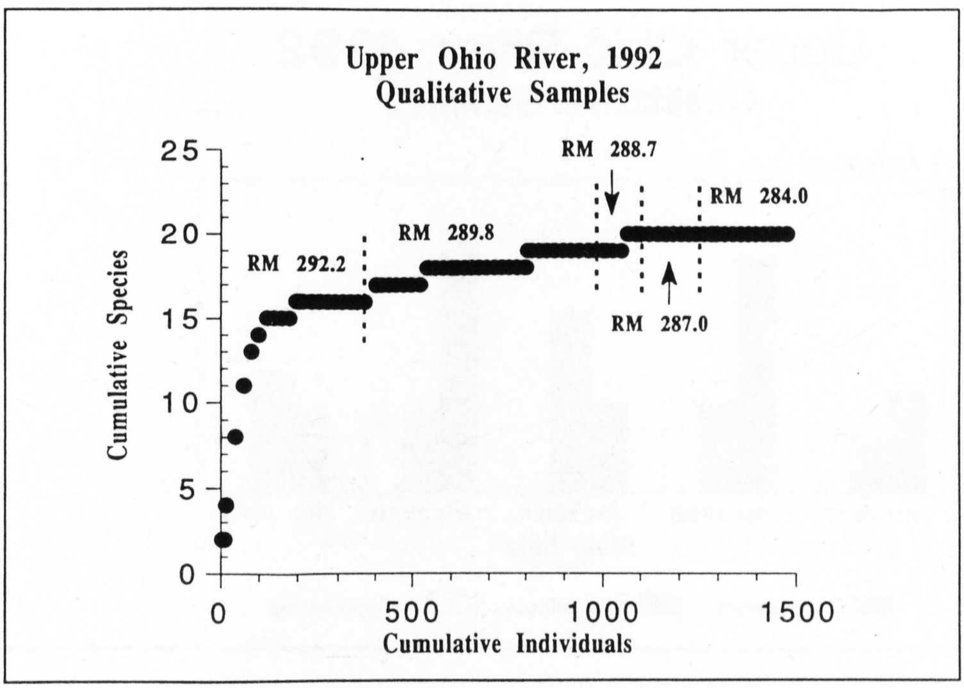

Figure 6. Relationship between cumulative number of individuals and cumulative number of species collected using qualitative methods, upper Ohio River, 1992

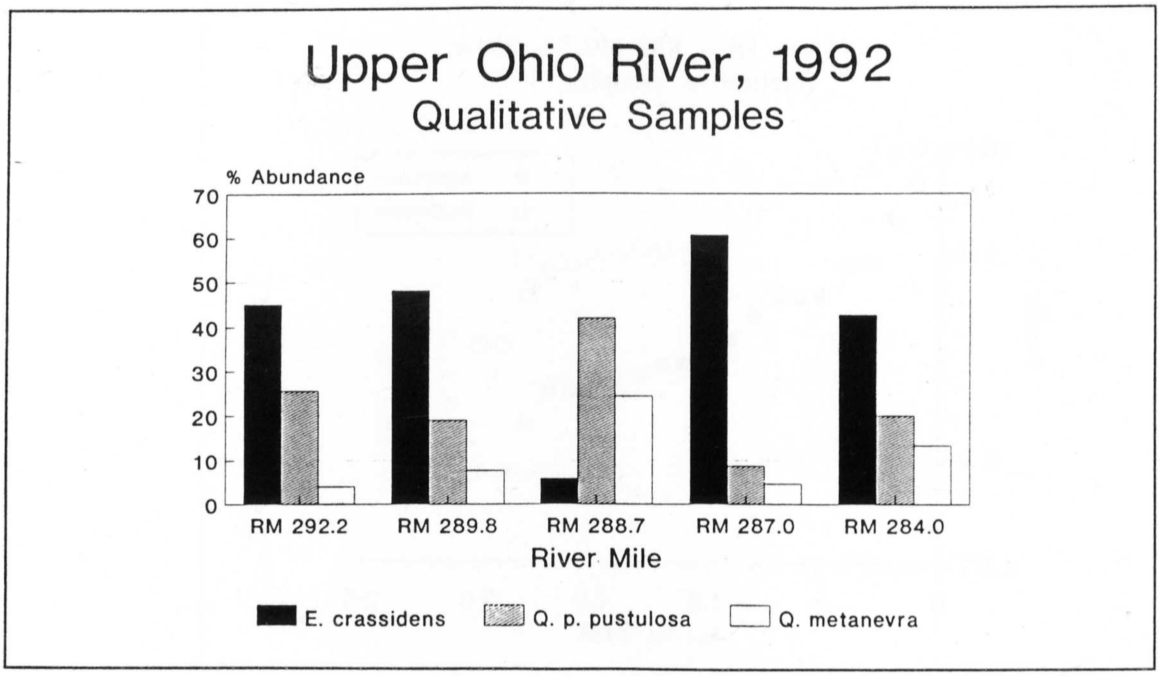

Figure 7. Percent abundance for *Elliptio crassidens*, *Quadrula pustulosa pustulosa*, and *Quadrula metanevra* collected using qualitative methods, upper Ohio River, 1992

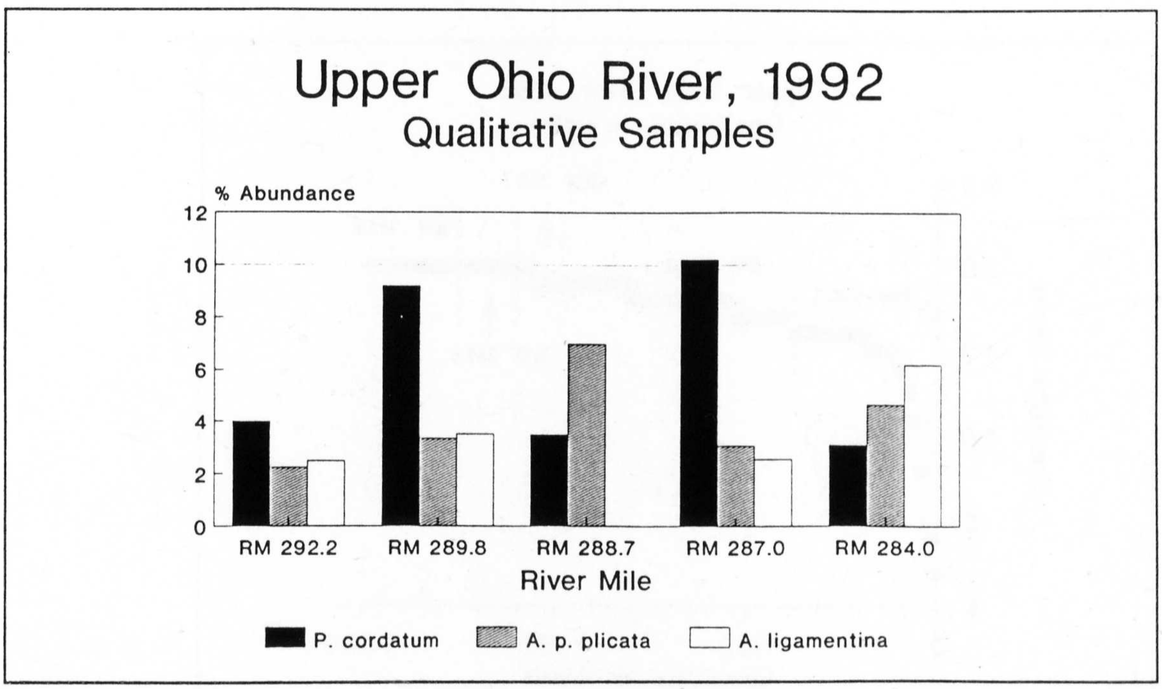

Figure 8. Percent abundance for *Pleurobema cordatum, Amblema plicata plicata*, and *Actinonais ligamentina* collected using qualitative methods, upper Ohio River, 1992

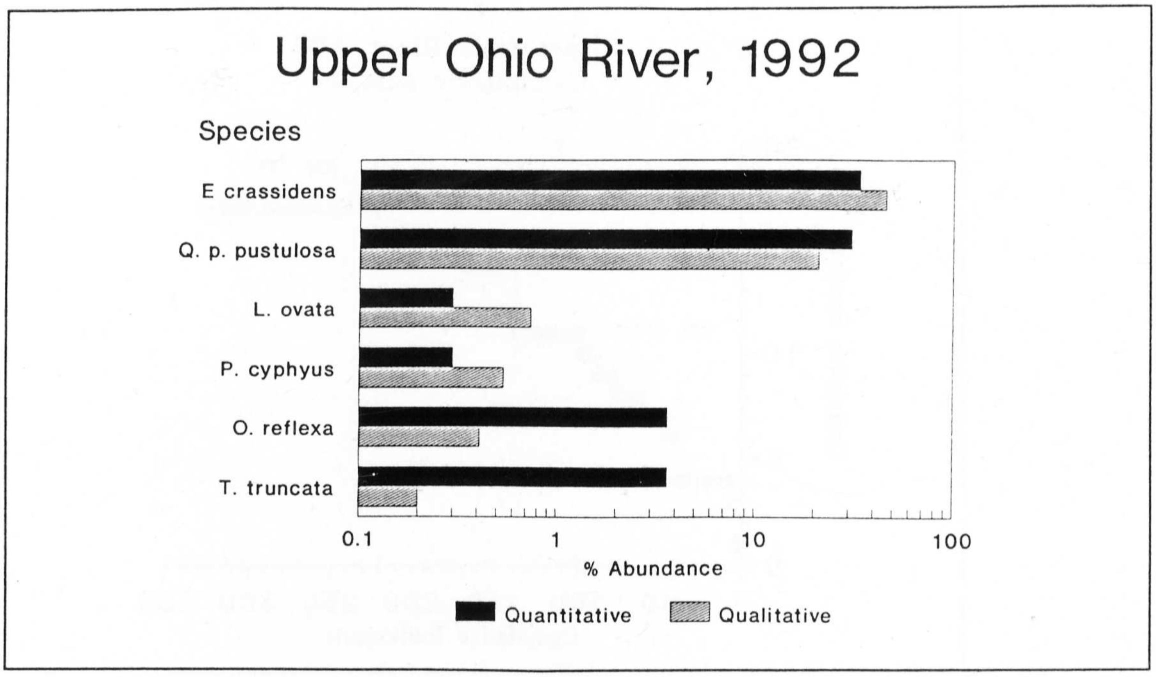

Figure 9. Percent abundance for six species of freshwater mussels collected using qualitative and quantitative methods

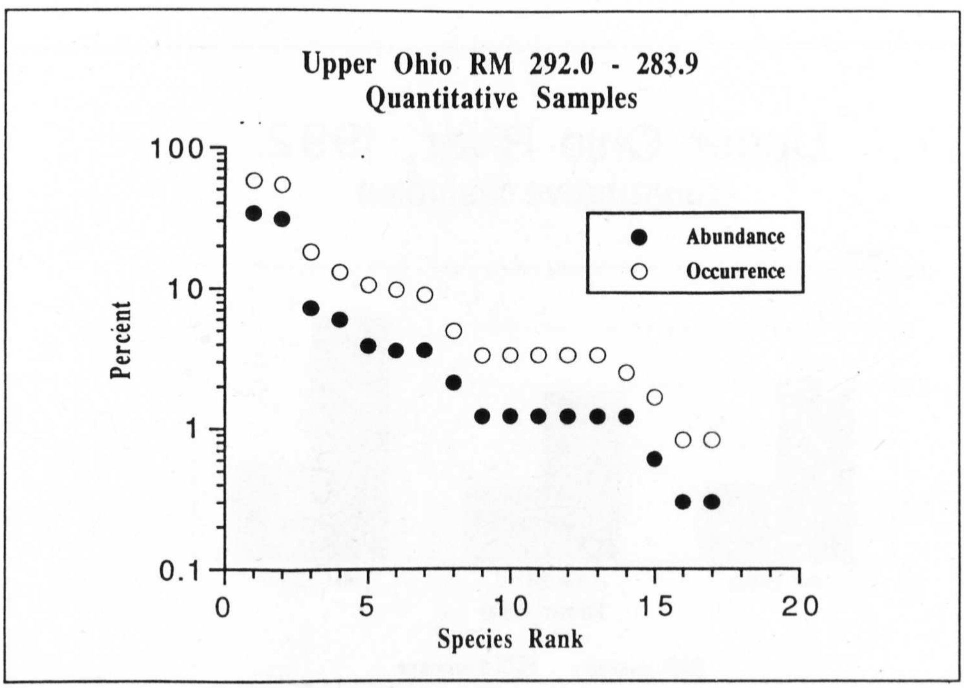

Figure 10. Relationship between percent abundance, percent occurrence, and species rank for mussels collected using quantitative methods, upper Ohio River, 1992

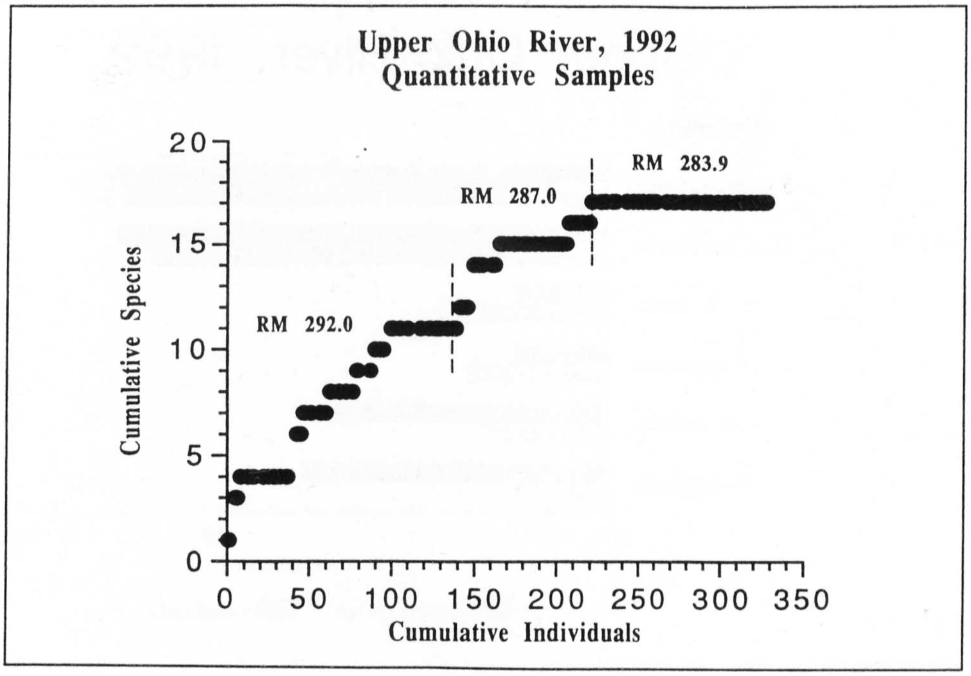

Figure 11. Relationship between cumulative number of individuals and cumulative number of species collected using quantitative methods, upper Ohio River, 1992

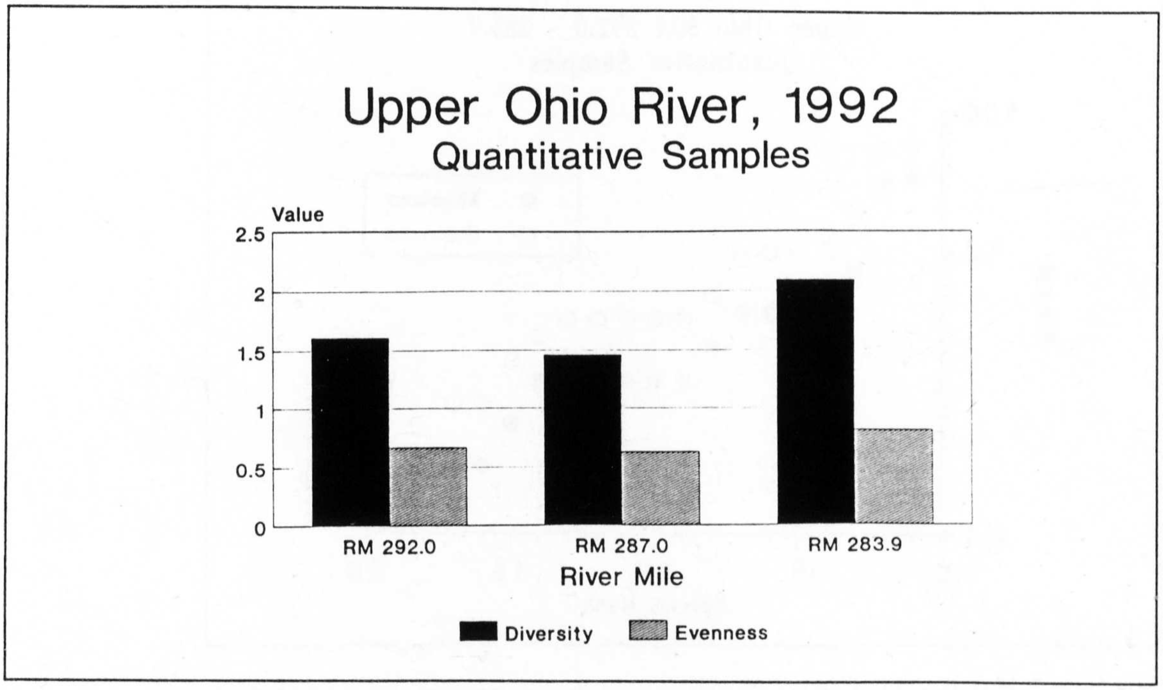

Figure 12. Species diversity and evenness at three locations in the upper Ohio River, 1992

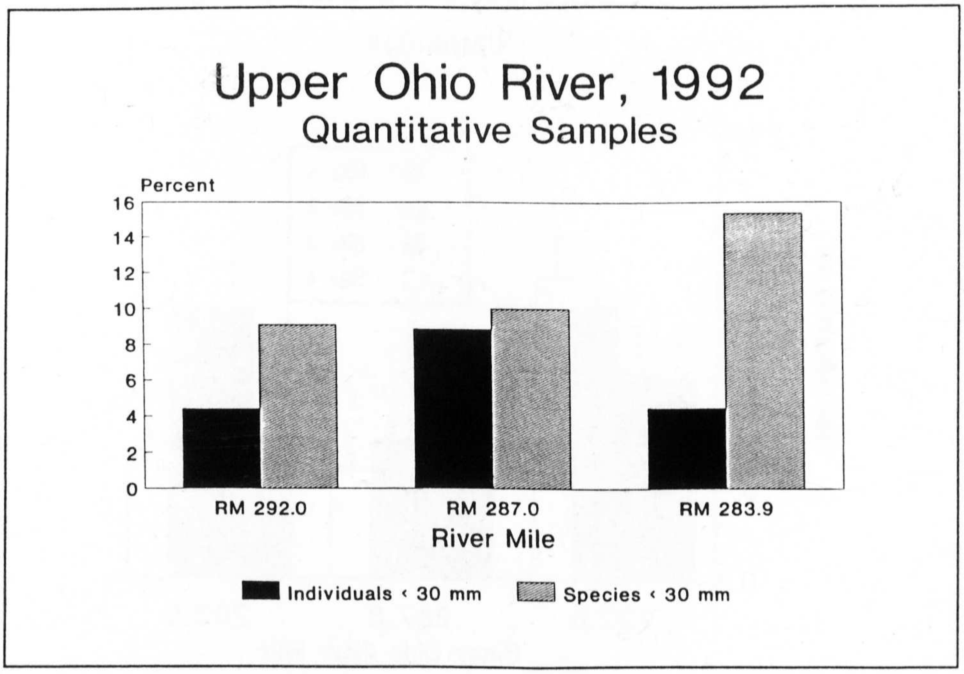

Figure 13. Percent individuals less than 30 mm total shell length and percent species with at least one representative less than 30 mm total shell length at three locations in the upper Ohio River, 1992

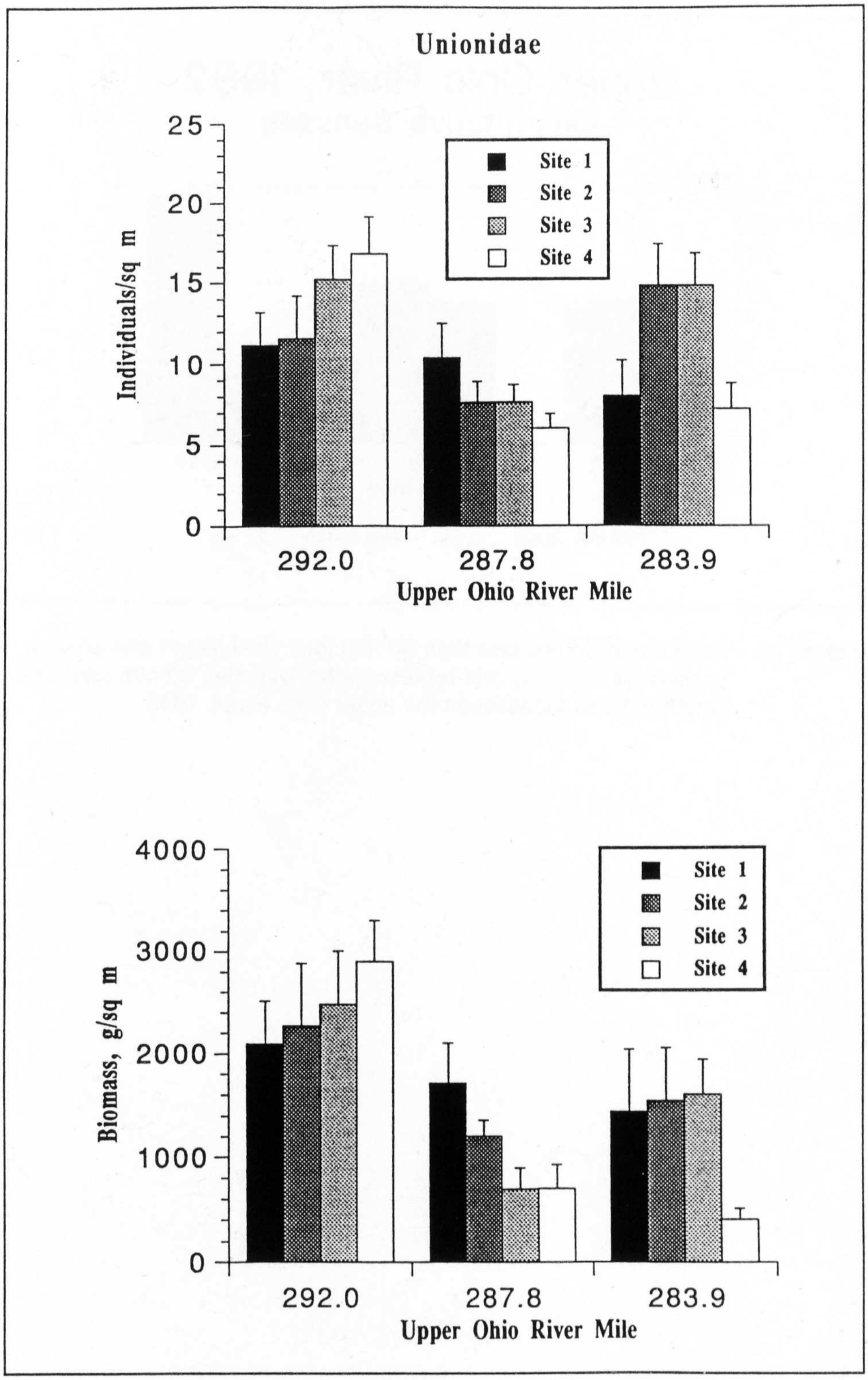

Figure 14. Numerical and biomass density for Unionidae collected at three locations in the upper Ohio River, 1992

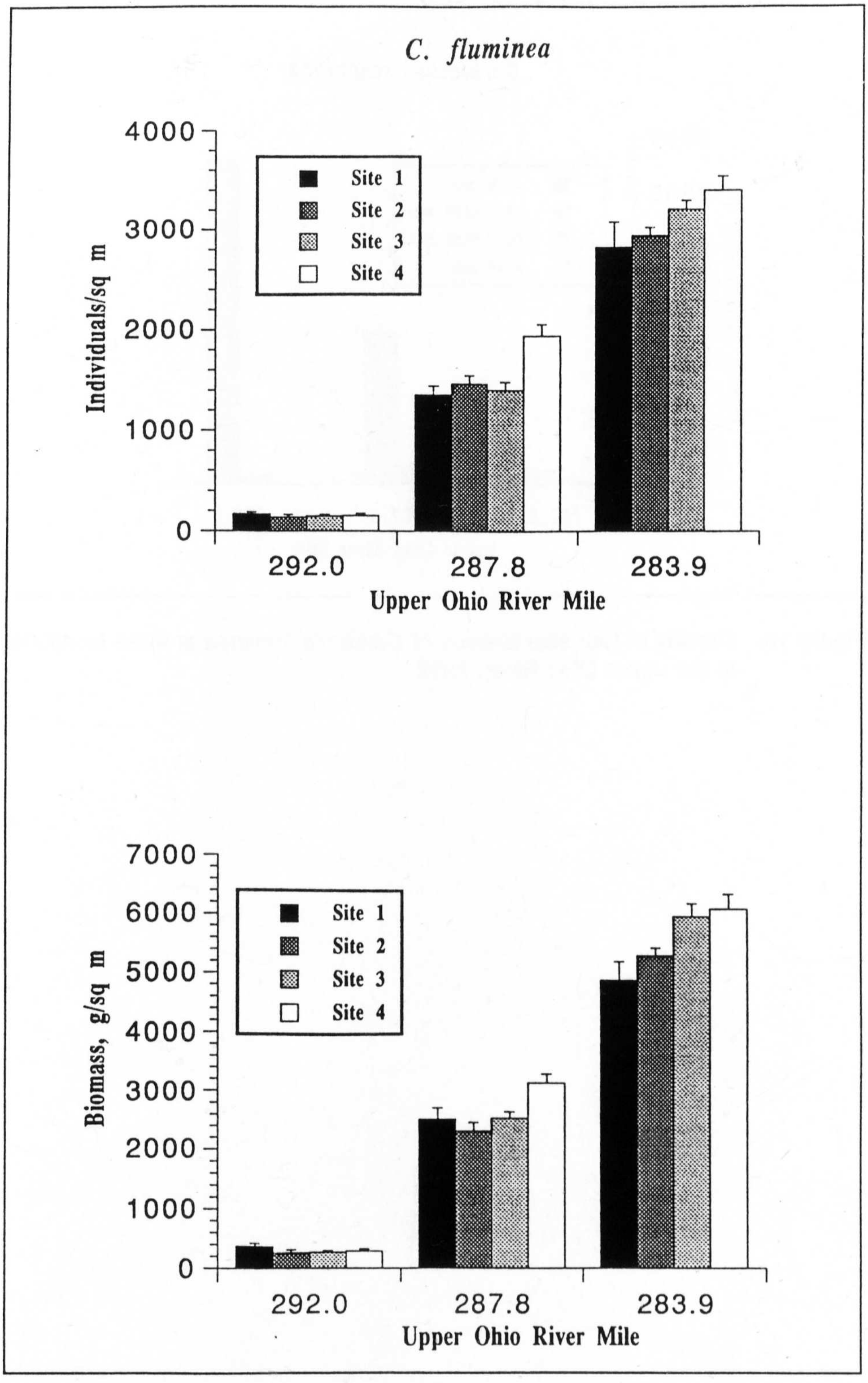

Figure 15. Numerical and biomass density for *Corbicula fluminea* collected at three locations in the upper Ohio River, 1992

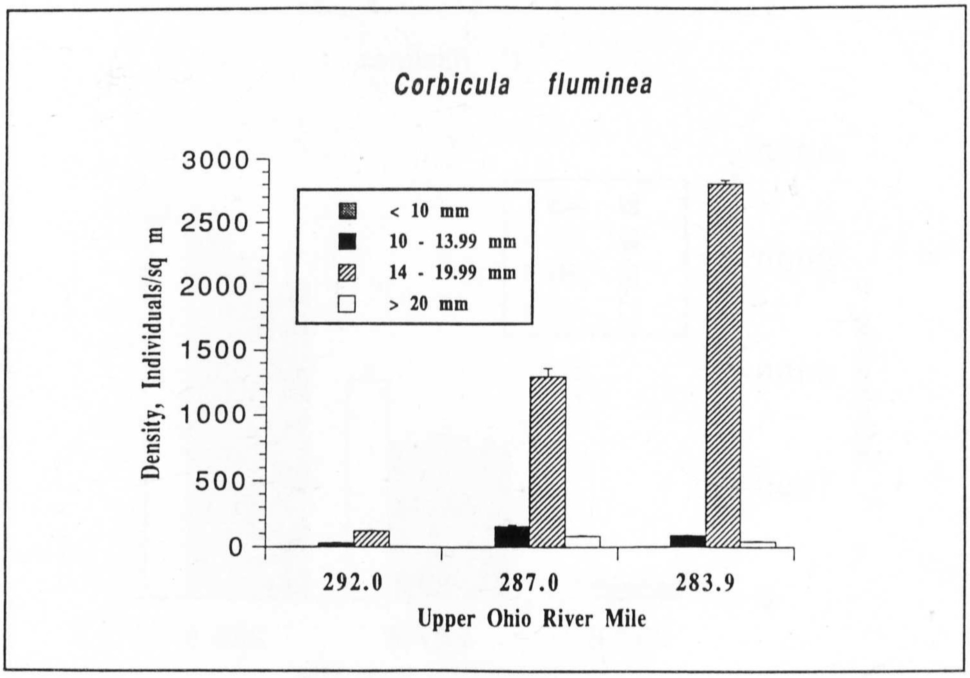

Figure 16. Density of four size classes of *Corbicula fluminea* at three locations in the upper Ohio River, 1992

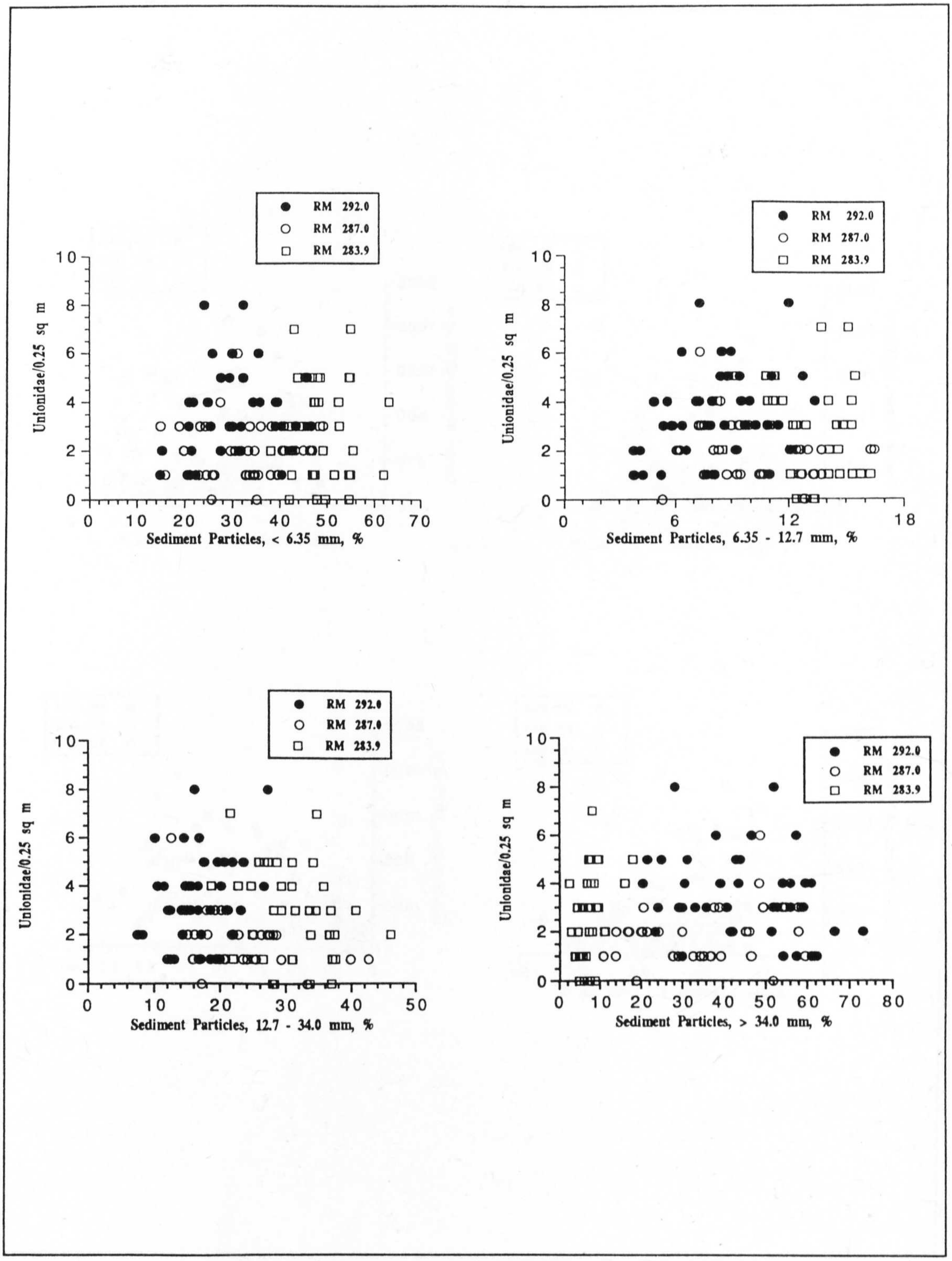

Figure 17. Relationship between four size classes of sediment particles and density of Unionidae, upper Ohio River, 1992

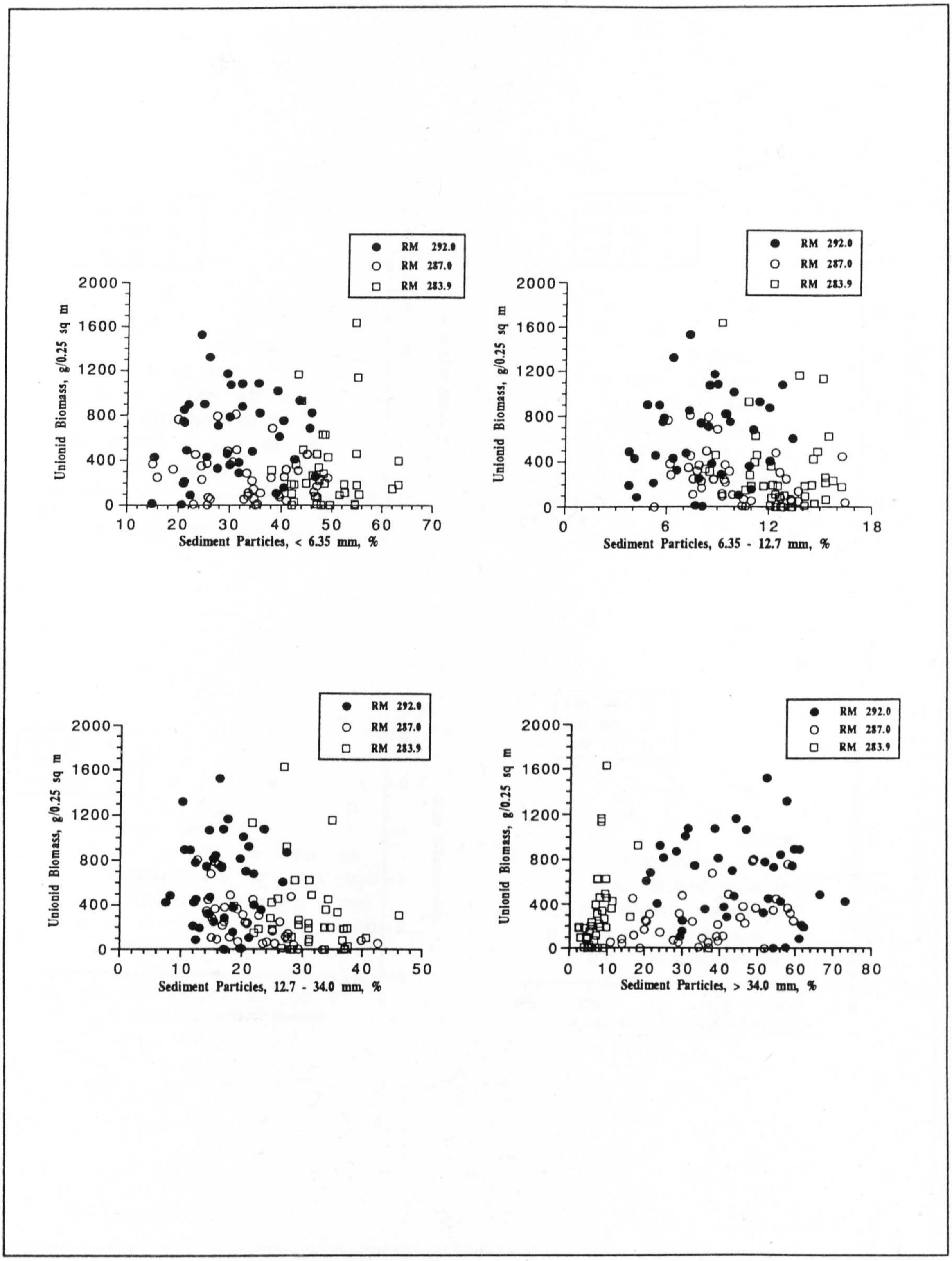

Figure 18. Relationship between four size classes of sediment particles and biomass density of Unionidae, upper Ohio River, 1992

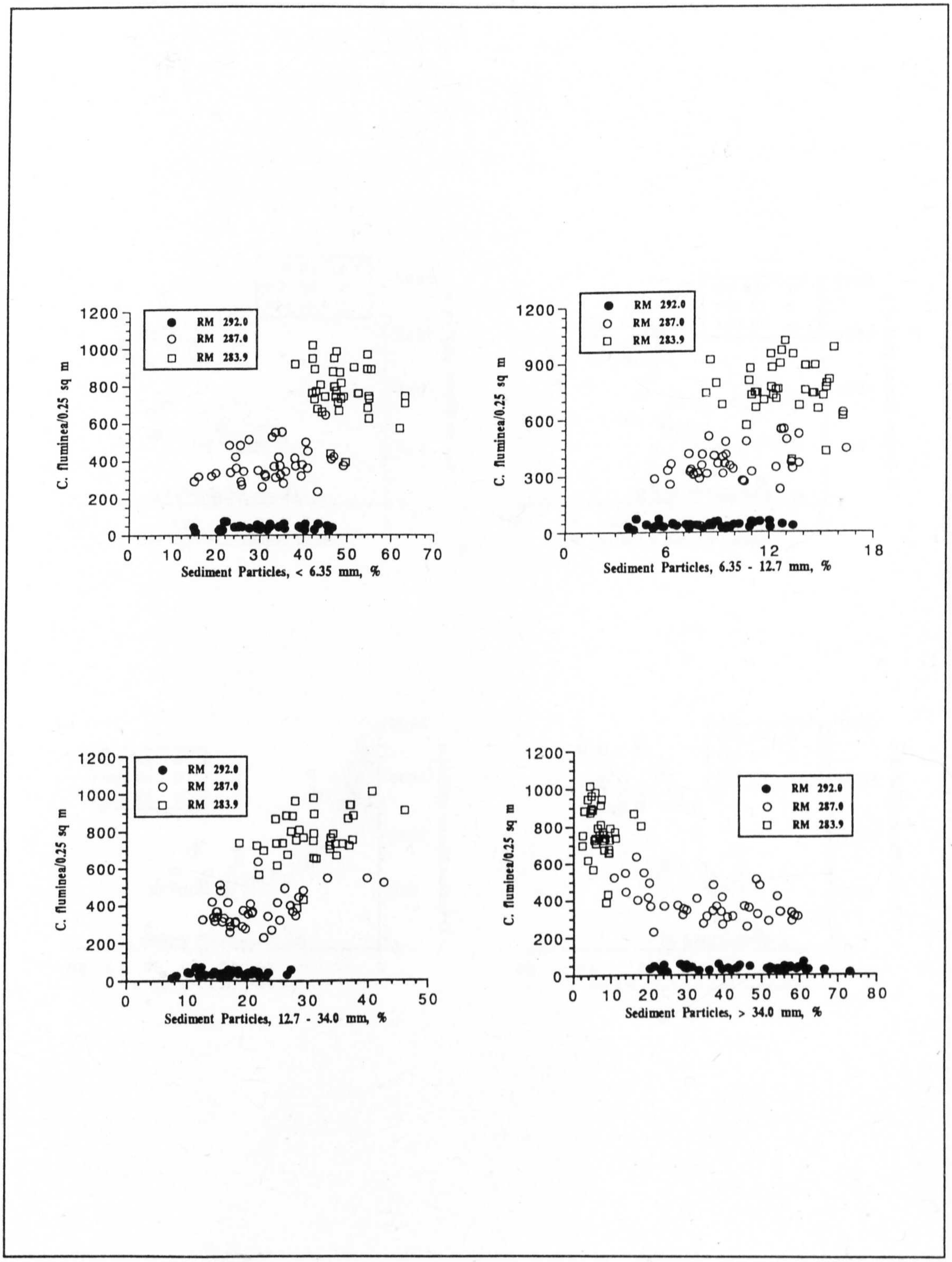

Figure 19. Relationship between four size classes of sediment particles and density of *Corbicula fluminea*, upper Ohio River, 1992

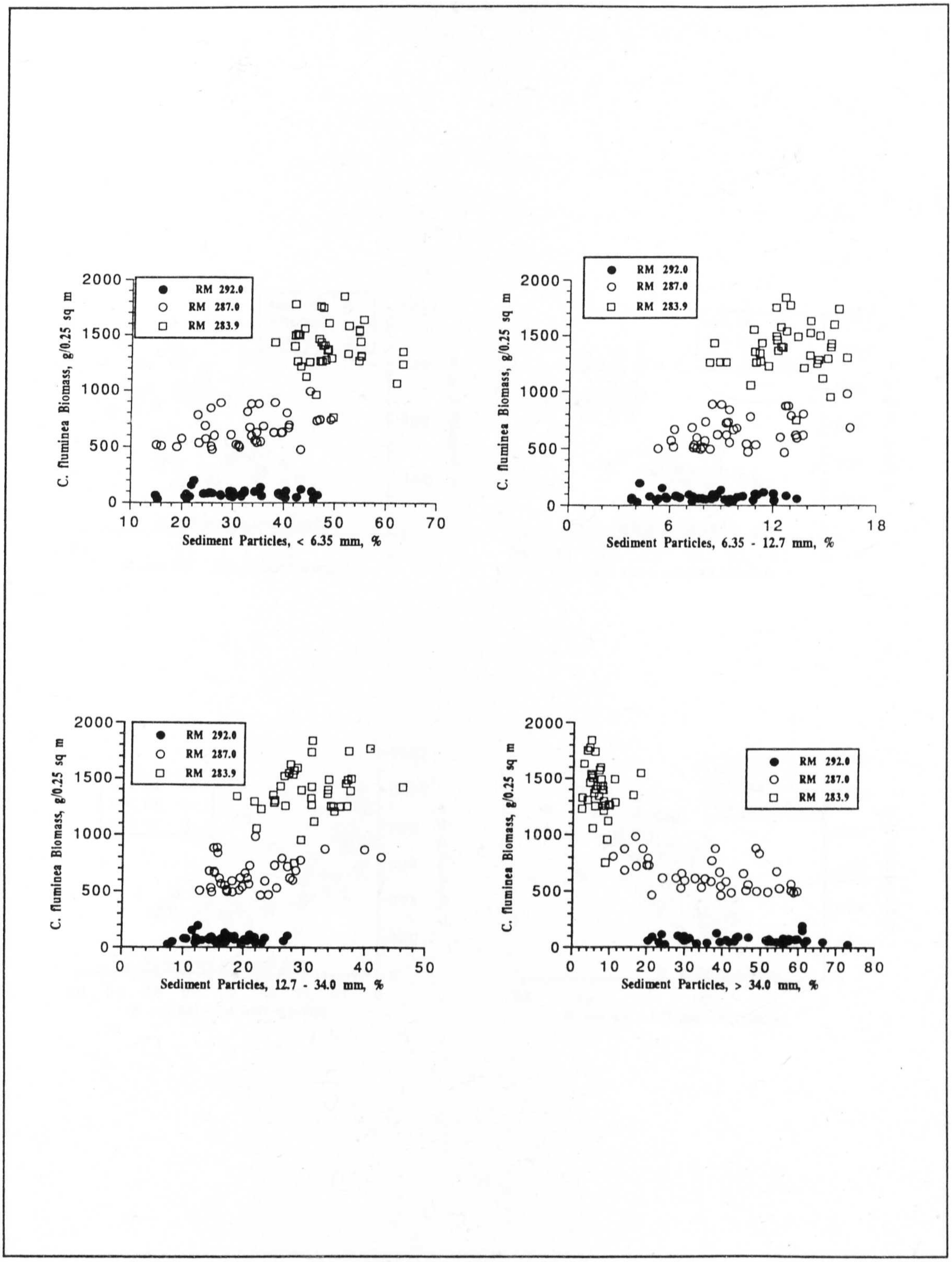

Figure 20. Relationship between four size classes of sediment particles and biomass density of *Corbicula fluminea*, upper Ohio River, 1992

```
SHELLEN                                                                CUM                  CUM
                                                                FREQ   FREQ   PERCENT   PERCENT

   80 |                                                           0      0      0.00      0.00
   82 |                                                           0      0      0.00      0.00
   84 |                                                           0      0      0.00      0.00
   86 |                                                           0      0      0.00      0.00
   88 |                                                           0      0      0.00      0.00
   90 |*********                                                  5      5      4.50      4.50
   92 |*********                                                  5     10      4.50      9.01
   94 |*************                                              7     17      6.31     15.32
   96 |*********                                                  5     22      4.50     19.82
   98 |******************                                        10     32      9.01     28.83
  100 |******************                                        10     42      9.01     37.84
  102 |************************************                      20     62     18.02     55.86
  104 |*************************                                 14     76     12.61     68.47
  106 |****************                                           9     85      8.11     76.58
  108 |****************                                           9     94      8.11     84.68
  110 |*********                                                  5     99      4.50     89.19
  112 |***********                                                6    105      5.41     94.59
  114 |*****                                                      3    108      2.70     97.30
  116 |*****                                                      3    111      2.70    100.00
  118 |                                                           0    111      0.00    100.00
  120 |                                                           0    111      0.00    100.00
  122 |                                                           0    111      0.00    100.00
  124 |                                                           0    111      0.00    100.00
  126 |                                                           0    111      0.00    100.00
  128 |                                                           0    111      0.00    100.00
  130 |                                                           0    111      0.00    100.00
      ----+---+---+---+---+---+---+---+---+
          2   4   6   8  10  12  14  16  18

               PERCENTAGE
```

Figure 21. Length-frequency histogram for *Elliptio crassidens* collected at RM 292.0, 287.0, and 283.9, upper Ohio River, October 1992

```
SHELLEN                                                        CUM                  CUM
                                                     FREQ     FREQ    PERCENT     PERCENT
        |
   0    |                                              0        0       0.00        0.00
   2    |                                              0        0       0.00        0.00
   4    |                                              0        0       0.00        0.00
   6    |                                              0        0       0.00        0.00
   8    |                                              0        0       0.00        0.00
  10    |                                              0        0       0.00        0.00
  12    |                                              0        0       0.00        0.00
  14    |                                              0        0       0.00        0.00
  16    |                                              0        0       0.00        0.00
  18    |                                              0        0       0.00        0.00
  20    |****                                          2        2       1.98        1.98
  22    |**********                                    5        7       4.95        6.93
  24    |                                              0        7       0.00        6.93
  26    |****                                          2        9       1.98        8.91
  28    |******                                        3       12       2.97       11.88
  30    |******                                        3       15       2.97       14.85
  32    |******                                        3       18       2.97       17.82
  34    |**                                            1       19       0.99       18.81
  36    |********                                      4       23       3.96       22.77
  38    |**                                            1       24       0.99       23.76
  40    |**                                            1       25       0.99       24.75
  42    |********                                      4       29       3.96       28.71
  44    |****                                          2       31       1.98       30.69
  46    |****                                          2       33       1.98       32.67
  48    |**************                                7       40       6.93       39.60
  50    |******************************               15       55      14.85       54.46
  52    |************************                     12       67      11.88       66.34
  54    |**************************                   13       80      12.87       79.21
  56    |**************                                7       87       6.93       86.14
  58    |********                                      4       91       3.96       90.10
  60    |************                                  6       97       5.94       96.04
  62    |******                                        3      100       2.97       99.01
  64    |**                                            1      101       0.99      100.00
  66    |                                              0      101       0.00      100.00
  68    |                                              0      101       0.00      100.00
  70    |                                              0      101       0.00      100.00
  72    |                                              0      101       0.00      100.00
  74    |                                              0      101       0.00      100.00
  76    |                                              0      101       0.00      100.00
  78    |                                              0      101       0.00      100.00
        ----+----+----+----+----+----+----+--
            2    4    6    8   10   12   14

                    PERCENTAGE
```

Figure 22. Length-frequency histogram for *Quadrula pustulosa pustulosa* collected at RM 292.0, 287.0, and 283.9, upper Ohio River, October 1992

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
7.0		0	1	0.00	0.06
7.2		0	1	0.00	0.06
7.4		0	1	0.00	0.06
7.6		0	1	0.00	0.06
7.8		0	1	0.00	0.06
8.0		1	2	0.06	0.13
8.2		0	2	0.00	0.13
8.4		0	2	0.00	0.13
8.6	*	2	4	0.13	0.26
8.8	*	4	8	0.26	0.52
9.0		0	8	0.00	0.52
9.2	*	2	10	0.13	0.65
9.4	*	3	13	0.19	0.84
9.6	*	2	15	0.13	0.97
9.8	*	4	19	0.26	1.23
10.0	*	4	23	0.26	1.49
10.2	**	7	30	0.45	1.94
10.4	***	13	43	0.84	2.79
10.6	**	8	51	0.52	3.31
10.8	***	10	61	0.65	3.95
11.0	****	14	75	0.91	4.86
11.2	*****	18	93	1.17	6.03
11.4	***	12	105	0.78	6.80
11.6	***	10	115	0.65	7.45
11.8	*****	19	134	1.23	8.68
12.0	*****	20	154	1.30	9.98
12.2	******	24	178	1.56	11.54
12.4	******	22	200	1.43	12.96
12.6	*****	21	221	1.36	14.32
12.8	*****	21	242	1.36	15.68
13.0	*****	18	260	1.17	16.85
13.2	*****	18	278	1.17	18.02
13.4	***	13	291	0.84	18.86
13.6	**	9	300	0.58	19.44
13.8	***	10	310	0.65	20.09
14.0	**	6	316	0.39	20.48
14.2	*	2	318	0.13	20.61
14.4	**	7	325	0.45	21.06
14.6	*	5	330	0.32	21.39
14.8	****	14	344	0.91	22.29
15.0	**	9	353	0.58	22.88
15.2	****	17	370	1.10	23.98
15.4	*******	26	396	1.69	25.66
15.6	*********	34	430	2.20	27.87
15.8	***********	43	473	2.79	30.65
16.0	***************	56	529	3.63	34.28
16.2	******************	68	597	4.41	38.69
16.4	**********************	83	680	5.38	44.07
16.6	*****************************	110	790	7.13	51.20
16.8	**********************	85	875	5.51	56.71
17.0	*********************************	129	1004	8.36	65.07

Figure 23. Length-frequency histogram for *Corbicula fluminea* collected in the upper Ohio River Mile 292.0, October 1992 (Continued)

17.2	**************************	100	1104	6.48	71.55
17.4	***************************	103	1207	6.68	78.22
17.6	********************	79	1286	5.12	83.34
17.8	*******************	75	1361	4.86	88.20
18.0	***************	59	1420	3.82	92.03
18.2	******	24	1444	1.56	93.58
18.4	*****	20	1464	1.30	94.88
18.6	****	16	1480	1.04	95.92
18.8	**	9	1489	0.58	96.50
19.0	*	2	1491	0.13	96.63
19.2	*	4	1495	0.26	96.89
19.4	*	2	1497	0.13	97.02
19.6	**	8	1505	0.52	97.54
19.8	*	2	1507	0.13	97.67
20.0	*	2	1509	0.13	97.80
20.2		0	1509	0.00	97.80
20.4		1	1510	0.06	97.86
20.6		1	1511	0.06	97.93
20.8		0	1511	0.00	97.93
21.0	*	3	1514	0.19	98.12
21.2		1	1515	0.06	98.19
21.4		1	1516	0.06	98.25
21.6		0	1516	0.00	98.25
21.8	*	2	1518	0.13	98.38
22.0		1	1519	0.06	98.44
22.2	*	3	1522	0.19	98.64
22.4		1	1523	0.06	98.70
22.6	*	2	1525	0.13	98.83
22.8		0	1525	0.00	98.83
23.0		1	1526	0.06	98.90
23.2	*	2	1528	0.13	99.03
23.4		1	1529	0.06	99.09
23.6	*	2	1531	0.13	99.22
23.8		1	1532	0.06	99.29
24.0	*	2	1534	0.13	99.42
24.2		1	1535	0.06	99.48
24.4	*	3	1538	0.19	99.68
24.6	*	3	1541	0.19	99.87
24.8		0	1541	0.00	99.87
25.0		1	1542	0.06	99.94
25.2		0	1542	0.00	99.94
25.4		1	1543	0.06	100.00
25.6		0	1543	0.00	100.00
25.8		0	1543	0.00	100.00
26.0		0	1543	0.00	100.00
	1 2 3 4 5 6 7 8 PERCENTAGE				

Figure 23. (Concluded)

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
8.2		0	0	0.00	0.00
8.4		1	1	0.08	0.08
8.6		0	1	0.00	0.08
8.8		0	1	0.00	0.08
9.0		1	2	0.08	0.15
9.2		0	2	0.00	0.15
9.4		0	2	0.00	0.15
9.6		0	2	0.00	0.15
9.8		1	3	0.08	0.23
10.0		2	5	0.15	0.39
10.2		2	7	0.15	0.54
10.4		0	7	0.00	0.54
10.6		3	10	0.23	0.77
10.8		0	10	0.00	0.77
11.0		1	11	0.08	0.85
11.2		1	12	0.08	0.93
11.4		2	14	0.15	1.08
11.6		1	15	0.08	1.16
11.8		1	16	0.08	1.24
12.0	*	5	21	0.39	1.63
12.2		2	23	0.15	1.78
12.4	*	9	32	0.70	2.48
12.6	*	4	36	0.31	2.79
12.8	*	7	43	0.54	3.33
13.0	***	17	60	1.32	4.64
13.2	*	8	68	0.62	5.26
13.4	****	24	92	1.86	7.12
13.6	****	27	119	2.09	9.21
13.8	*****	35	154	2.71	11.92
14.0	*******	43	197	3.33	15.25
14.2	**********	67	264	5.19	20.43
14.4	*********	57	321	4.41	24.85
14.6	*************	83	404	6.42	31.27
14.8	**************	88	492	6.81	38.08
15.0	*****************	107	599	8.28	46.36
15.2	*****************	110	709	8.51	54.88
15.4	**********************	140	849	10.84	65.71
15.6	****************	106	955	8.20	73.92
15.8	************	80	1035	6.19	80.11
16.0	************	77	1112	5.96	86.07
16.2	******	37	1149	2.86	88.93
16.4	****	25	1174	1.93	90.87
16.6	**	16	1190	1.24	92.11
16.8	**	11	1201	0.85	92.96
17.0	*	7	1208	0.54	93.50
17.2		1	1209	0.08	93.58
17.4		1	1210	0.08	93.65
17.6		0	1210	0.00	93.65
17.8		0	1210	0.00	93.65
18.0		2	1212	0.15	93.81
18.2		1	1213	0.08	93.89

Figure 24. Length-frequency histogram for *Corbicula fluminea* collected at Sites 1 and 2, upper Ohio River Mile 287.0, October 1992 (Sheet 1 of 3)

18.4		1	1214	0.08	93.96
18.6		1	1215	0.08	94.04
18.8		3	1218	0.23	94.27
19.0		0	1218	0.00	94.27
19.2		1	1219	0.08	94.35
19.4		0	1219	0.00	94.35
19.6		1	1220	0.08	94.43
19.8		0	1220	0.00	94.43
20.0		2	1222	0.15	94.58
20.2		1	1223	0.08	94.66
20.4		2	1225	0.15	94.81
20.6		3	1228	0.23	95.05
20.8		2	1230	0.15	95.20
21.0		2	1232	0.15	95.36
21.2	*	4	1236	0.31	95.67
21.4		2	1238	0.15	95.82
21.6		3	1241	0.23	96.05
21.8	*	6	1247	0.46	96.52
22.0	*	5	1252	0.39	96.90
22.2		1	1253	0.08	96.98
22.4		2	1255	0.15	97.14
22.6	*	5	1260	0.39	97.52
22.8		1	1261	0.08	97.60
23.0		1	1262	0.08	97.68
23.2		1	1263	0.08	97.76
23.4		0	1263	0.00	97.76
23.6		1	1264	0.08	97.83
23.8		0	1264	0.00	97.83
24.0		0	1264	0.00	97.83
24.2		0	1264	0.00	97.83
24.4		0	1264	0.00	97.83
24.6		0	1264	0.00	97.83
24.8		0	1264	0.00	97.83
25.0		0	1264	0.00	97.83
25.2		0	1264	0.00	97.83
25.4		0	1264	0.00	97.83
25.6		0	1264	0.00	97.83
25.8		0	1264	0.00	97.83
26.0		0	1264	0.00	97.83
26.2		0	1264	0.00	97.83
26.4		0	1264	0.00	97.83
26.6		1	1265	0.08	97.91
26.8		0	1265	0.00	97.91
27.0		0	1265	0.00	97.91
27.2		0	1265	0.00	97.91
27.4		0	1265	0.00	97.91
27.6		0	1265	0.00	97.91
27.8		0	1265	0.00	97.91
28.0		0	1265	0.00	97.91
28.2		1	1266	0.08	97.99
28.4		0	1266	0.00	97.99
28.6		0	1266	0.00	97.99
28.8		1	1267	0.08	98.07
29.0		0	1267	0.00	98.07

Figure 24. (Sheet 2 of 3)

```
29.2  |                                   2    1269    0.15    98.22
29.4  |                                   0    1269    0.00    98.22
29.6  |                                   0    1269    0.00    98.22
29.8  |                                   1    1270    0.08    98.30
30.0  |                                   1    1271    0.08    98.37
30.2  |                                   0    1271    0.00    98.37
30.4  |*                                  4    1275    0.31    98.68
30.6  |                                   2    1277    0.15    98.84
30.8  |*                                  6    1283    0.46    99.30
31.0  |*                                  4    1287    0.31    99.61
31.2  |                                   3    1290    0.23    99.85
31.4  |                                   1    1291    0.08    99.92
31.6  |                                   0    1291    0.00    99.92
31.8  |                                   0    1291    0.00    99.92
32.0  |                                   0    1291    0.00    99.92
      ----+----+----+----+----+--
          2    4    6    8    10

            PERCENTAGE
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Figure 24. (Sheet 3 of 3)

SHELLEN		FREQ	CUM FREQ	PERCENT	CUM PERCENT
11.0		1	6	0.06	0.37
11.2		0	6	0.00	0.37
11.4		1	7	0.06	0.44
11.6		0	7	0.00	0.44
11.8		1	8	0.06	0.50
12.0		1	9	0.06	0.56
12.2		2	11	0.12	0.69
12.4	*	5	16	0.31	1.00
12.6	*	6	22	0.37	1.37
12.8	*	3	25	0.19	1.56
13.0	*	6	31	0.37	1.93
13.2	*	6	37	0.37	2.31
13.4	**	9	46	0.56	2.87
13.6	****	16	62	1.00	3.87
13.8	*****	20	82	1.25	5.11
14.0	******	24	106	1.50	6.61
14.2	********	31	137	1.93	8.54
14.4	**********	39	176	2.43	10.97
14.6	*************	54	230	3.37	14.34
14.8	*************	52	282	3.24	17.58
15.0	*********************	83	365	5.17	22.76
15.2	*********************	83	448	5.17	27.93
15.4	***********************	91	539	5.67	33.60
15.6	**********************	87	626	5.42	39.03
15.8	********************************	129	755	8.04	47.07
16.0	************************	95	850	5.92	52.99
16.2	***************************	107	957	6.67	59.66
16.4	****************************	114	1071	7.11	66.77
16.6	**********************	90	1161	5.61	72.38
16.8	*********************	83	1244	5.17	77.56
17.0	************************	95	1339	5.92	83.48
17.2	*******************	77	1416	4.80	88.28
17.4	**************	58	1474	3.62	91.90
17.6	********	31	1505	1.93	93.83
17.8	*******	30	1535	1.87	95.70
18.0	****	18	1553	1.12	96.82
18.2	**	9	1562	0.56	97.38
18.4	*	4	1566	0.25	97.63
18.6	**	9	1575	0.56	98.19
18.8		0	1575	0.00	98.19
19.0		2	1577	0.12	98.32
19.2		0	1577	0.00	98.32
19.4		1	1578	0.06	98.38
19.6		1	1579	0.06	98.44
19.8		1	1580	0.06	98.50
20.0		2	1582	0.12	98.63
20.2		2	1584	0.12	98.75
20.4		0	1584	0.00	98.75
20.6		0	1584	0.00	98.75
20.8		0	1584	0.00	98.75
21.0		1	1585	0.06	98.82

Figure 25. Length-frequency histogram for *Corbicula fluminea* collected at Site 1, upper Ohio River Mile 283.9, October 1992 (Sheet 1 of 3)

21.2	1	1586	0.06	98.88
21.4	1	1587	0.06	98.94
21.6	0	1587	0.00	98.94
21.8	1	1588	0.06	99.00
22.0	1	1589	0.06	99.06
22.2	1	1590	0.06	99.13
22.4	0	1590	0.00	99.13
22.6	0	1590	0.00	99.13
22.8	1	1591	0.06	99.19
23.0	0	1591	0.00	99.19
23.2	1	1592	0.06	99.25
23.4	0	1592	0.00	99.25
23.6	0	1592	0.00	99.25
23.8	0	1592	0.00	99.25
24.0	0	1592	0.00	99.25
24.2	0	1592	0.00	99.25
24.4	0	1592	0.00	99.25
24.6	0	1592	0.00	99.25
24.8	0	1592	0.00	99.25
25.0	0	1592	0.00	99.25
25.2	0	1592	0.00	99.25
25.4	0	1592	0.00	99.25
25.6	0	1592	0.00	99.25
25.8	0	1592	0.00	99.25
26.0	0	1592	0.00	99.25
26.2	0	1592	0.00	99.25
26.4	0	1592	0.00	99.25
26.6	0	1592	0.00	99.25
26.8	0	1592	0.00	99.25
27.0	0	1592	0.00	99.25
27.2	0	1592	0.00	99.25
27.4	0	1592	0.00	99.25
27.6	0	1592	0.00	99.25
27.8	1	1593	0.06	99.31
28.0	0	1593	0.00	99.31
28.2	0	1593	0.00	99.31
28.4	0	1593	0.00	99.31
28.6	0	1593	0.00	99.31
28.8	1	1594	0.06	99.38
29.0	1	1595	0.06	99.44
29.2	0	1595	0.00	99.44
29.4	0	1595	0.00	99.44
29.6	0	1595	0.00	99.44
29.8	0	1595	0.00	99.44
30.0	0	1595	0.00	99.44
30.2	0	1595	0.00	99.44
30.4	0	1595	0.00	99.44
30.6	0	1595	0.00	99.44
30.8	0	1595	0.00	99.44
31.0	0	1595	0.00	99.44
31.2	0	1595	0.00	99.44
31.4	0	1595	0.00	99.44
31.6	0	1595	0.00	99.44
31.8	1	1596	0.06	99.50

Figure 25. (Sheet 2 of 3)

32.0	0	1596	0.00	99.50
32.2	0	1596	0.00	99.50
32.4	0	1596	0.00	99.50
32.6	0	1596	0.00	99.50
32.8	0	1596	0.00	99.50
33.0	0	1596	0.00	99.50
33.2	0	1596	0.00	99.50
33.4	2	1598	0.12	99.63
33.6	0	1598	0.00	99.63
33.8	0	1598	0.00	99.63
34.0	1	1599	0.06	99.69
34.2	2	1601	0.12	99.81
34.4	0	1601	0.00	99.81
34.6	0	1601	0.00	99.81
34.8	1	1602	0.06	99.88
35.0	1	1603	0.06	99.94
35.2	0	1603	0.00	99.94
35.4	0	1603	0.00	99.94
35.6	1	1604	0.06	100.00
35.8	0	1604	0.00	100.00
36.0	0	1604	0.00	100.00
36.2	0	1604	0.00	100.00
36.4	0	1604	0.00	100.00
36.6	0	1604	0.00	100.00
36.8	0	1604	0.00	100.00
37.0	0	1604	0.00	100.00

1 2 3 4 5 6 7 8

PERCENTAGE

Figure 25. (Sheet 3 of 3)

Table 1
Location and Number of Samples Collected Using Qualitative (Qual) and Quantitative (Quant) Methods in the Upper Ohio River, October 1992

River Mile	Bank	Distance to shore ft	Water Depth ft	No. of Qual Samples	No. of Quant Samples	Date	Site No.
292.2	RDB	200	17	12	NC	25 Oct 92	1
292.2	RDB	200	18	12	NC	25 Oct 92	1
292.1	RDB	200	17	NC	20	21 Oct 92	1
292.0	RDB	200	21	NC	20	21 Oct 92	1
289.8	RDB	200	18	12	NC	23 Oct 92	2
289.8	RDB	200	14	12	NC	25 Oct 92	2
289.8	RDB	200	18	12	NC	25 Oct 92	2
288.7	LDB	200	14	7	NC	25 Oct 92	3
287.0	LDB	200	14	6	40	24 Oct 92	4
287.0	LDB	200	15	12	NC	22 Oct 92	4
284.0	LDB	200	12	12	NC	23 Oct 92	5
283.9	LDB	200	13	NC	20	23 Oct 92	6
283.9	LDB	175	12	NC	20	22 Oct 92	6

Note: Quantitative samples taken from River Miles 292.1 and 292.0 are listed as having been collected at 292.0.

Table 2
Freshwater Mussels Collected Using Qualitative and Quantitative Methods in the Upper Ohio River, October 1992

Species	Qualitative	Quantitative
Actinonaias ligamentina (Lamarck,1819)	X	X
Amblema p. plicata (Say,1817)	X	X
Ellipsaria lineolata (Rafinesque,1820)	X	X
Elliptio crassidens (Lamarck,1819)	X	X
Fusconaia ebena (I. Lea,1831)	X	X
Fusconaia subrotunda (I. Lea,1839)	X	
Lampsilis ovata (Say,1817)	X	X
Leptodea fragilis (Rafinesque,1820)	X	
Ligumia recta (Lamarck,1819)	X	X
Megalonaias nervosa (Rafinesque,1820)	X	X
Obliquaria reflexa (Rafinesque,1820)	X	X
Plethobasis cyphyus (Rafinesque,1820)	X	X
Pleurobema cordatum (Rafinesque,1820)	X	X
Pleurobema sintoxia (Conrad,1834)	X	X
Potamilus alatus (Say,1817)	X	X
Quadrula p. pustulosa (I. Lea,1831)	X	X
Quadrula quadrula (Rafinesque,1820)	X	X
Quadrula metanevra (Rafinesque,1820)	X	X
Truncilla truncata (Rafinesque,1820)	X	X
Truncilla donaciformis (I. Lea,1848)	X	
Total species	20	17
Total individuals	1,477	328

Table 3
Percent Species Abundance of Unionids Collected in the Upper Ohio River Using Qualitative Sampling Methods, October 1992

Species	RM 292.2	RM 289.8	RM 288.7	RM 287.0	RM 284.0	Total
E. crassidens	45.02	48.08	5.81	60.71	42.78	45.77
Q. p. pustulosa	25.62	19.03	41.86	8.67	20.10	20.92
Q. metanevra	3.98	7.68	24.42	4.59	13.40	7.99
P. cordatum	3.98	9.18	3.49	10.20	3.09	6.77
A. p. plicata	2.24	3.34	6.98	3.06	4.64	3.39
A. ligamentina	2.73	3.51	0.00	2.55	6.19	3.32
Q. quadrula	6.22	3.51	0.00	0.00	1.03	3.25
P. alatus	4.73	0.67	2.33	1.53	2.58	2.23
M. nervosa	1.00	0.50	0.00	4.08	2.06	1.29
F. subrotunda	0.00	1.00	0.00	2.55	0.00	0.74
L. recta	1.24	0.33	3.49	0.00	0.52	0.74
L. ovata	1.00	0.50	2.33	0.51	0.52	0.74
F. ebena	0.50	0.83	0.00	0.00	1.03	0.61
P. cyphyus	0.25	0.17	6.98	0.00	0.00	0.54
P. sintoxia	0.50	0.50	0.00	1.02	0.52	0.54
E. lineolata	0.50	0.50	0.00	0.00	0.52	0.41
O. reflexa	0.00	0.67	1.16	0.51	0.00	0.41
T. truncata	0.25	0.00	0.00	0.00	1.03	0.20
L. fragilis	0.25	0.00	0.00	0.00	0.00	0.07
T. donaciformis	0.00	0.00	1.16	0.00	0.00	0.07
Total species	18	17	11	12	15	21
Total individuals	402	599	86	196	194	1,477
Species diversity	1.74	1.72	1.76	1.48	1.80	1.82
Evenness	0.55	0.55	0.65	0.46	0.60	0.53
Dominance	0.28	0.28	0.24	0.39	0.25	0.27

Note: Evenness was calculated with the modified Hill's ratio (Ludwig and Reynolds 1988)

Table 4
Percent Occurrence of Unionids Collected in the Upper Ohio River Using Qualitative Sampling Methods, October 1992

Species	RM 292.2	RM 289.8	RM 288.7	RM 287.0	RM 284.0	Total
E. crassidens	100.00	100.00	66.67	100.00	100.00	97.78
Q. p. pustulosa	87.50	83.33	100.00	66.67	83.33	83.33
Q. metanevra	33.33	61.11	83.33	58.33	75.00	56.67
P. cordatum	37.50	66.67	16.67	75.00	41.67	53.33
A. ligamentina	37.50	44.44	0.00	33.33	66.67	41.11
A. p. plicata	25.00	38.89	50.00	25.00	58.33	36.67
Q. quadrula	58.33	41.67	0.00	0.00	16.67	34.44
P. alatus	29.17	8.33	33.33	25.00	33.33	21.11
M. nervosa	16.67	8.33	0.00	50.00	25.00	17.78
F. subrotunda	0.00	13.89	0.00	41.67	0.00	11.11
L. ovata	12.50	8.33	33.33	8.33	8.33	11.11
F. ebena	8.33	13.89	0.00	0.00	16.67	10.00
L. recta	12.50	5.56	50.00	0.00	8.33	10.00
P. sintoxia	4.17	8.33	0.00	16.67	8.33	7.78
E. lineolata	8.33	8.33	0.00	0.00	8.33	6.67
O. reflexa	0.00	11.11	16.67	8.33	0.00	6.67
P. cyphyus	4.17	2.78	50.00	0.00	0.00	5.56
T. truncata	4.17	0.00	0.00	0.00	16.67	3.33
L. fragilis	4.17	0.00	0.00	0.00	0.00	1.11
T. donaciformis	0.00	0.00	16.67	0.00	0.00	1.11
Total samples	24	36	6	12	12	90

Table 5
Percent Species Abundance of Unionids Collected in the Upper Ohio River Using Quantitative Sampling Methods, October 1992

Species	RM 292.0	RM 287.0	RM 283.9	Total
E. crassidens	40.88	37.97	22.32	33.84
Q. p. pustulosa	29.93	41.77	24.11	30.79
Q. metanevra	2.19	3.80	16.07	7.32
P. cordatum	12.41	3.80	0.00	6.10
A. ligamentina	5.11	0.00	5.36	3.96
O. reflexa	1.46	0.00	8.93	3.66
T. truncata	0.73	0.00	9.82	3.66
M. nervosa	0.00	3.80	3.57	2.13
E. lineolata	0.00	1.27	2.68	1.22
F. ebena	2.19	1.27	0.00	1.22
A. p. plicata	0.00	2.53	1.79	1.22
Q. quadrula	2.19	0.00	0.89	1.22
P. alatus	0.00	2.53	1.79	1.22
L. recta	1.46	0.00	1.79	1.22
P. sintoxia	1.46	0.00	0.00	0.61
P. cyphyus	0.00	0.00	0.89	0.30
L. ovata	0.00	1.27	0.00	0.30
Total individuals	137	79	112	328
Total species	11	10	13	17
Species diversity	1.61	1.46	2.09	1.93
Evenness	0.67	0.66	0.80	0.59
Dominance	0.27	0.32	0.15	0.22
% Individuals <30 mm	4.38	8.86	4.46	5.49
% Species <30 mm	9.09	10.10	15.38	11.76

Note: Evenness was calculated with the modified Hill's ratio (Ludwig and Reynolds 1988)

Table 6
Percent Occurrence of Unionids Collected in the Upper Ohio River Using Quantitative Sampling Methods, October 1992

Species	RM 292.0	RM 287.0	RM 283.9	Total
Q. p. pustulosa	65.00	62.50	45.00	57.50
E. crassidens	72.50	52.50	37.50	54.17
Q. metanevra	7.50	7.50	40.00	18.33
P. cordatum	32.50	7.50	0.00	13.33
A. ligamentina	17.50	0.00	15.00	10.83
T. truncata	2.50	0.00	27.50	10.00
O. reflexa	5.00	0.00	22.50	9.17
M. nervosa	0.00	5.00	10.00	5.00
A. p. plicata	0.00	5.00	5.00	3.33
E. lineolata	0.00	2.50	7.50	3.33
L. recta	5.00	0.00	5.00	3.33
F. ebena	7.50	2.50	0.00	3.33
P. alatus	0.00	5.00	5.00	3.33
Q. quadrula	5.00	0.00	2.50	2.50
O. retusa	5.00	0.00	0.00	1.67
L. ovata	0.00	2.50	0.00	0.83
P. cyphyus	0.00	0.00	2.50	0.83
Total samples	40	40	40	120

Table 7
Number of Individuals (N) and Mean, Minimum (Min), and Maximum (Max) Shell Length for Unionids Collected in the Upper Ohio River, October 1992

Species	N	Mean	Min	Max
	River Mile 292.0			
A. ligamentina	7	114.5	104.3	126.8
E. crassidens	56	104.4	89.2	116.9
F. ebena	3	101.5	96.2	104.6
L. recta	2	133.0	116.3	149.6
O. reflexa	2	56.8	55.7	57.8
P. cordatum	17	86.3	78.2	99.3
P. sintoxia	2	84.1	77.8	90.4
Q. metanevra	3	65.8	54.3	73.2
Q. p. pustulosa	41	48.5	20.8	61.5
Q. quadrula	3	63.5	61.3	67.6
T. truncata	1	33.6	33.6	33.6
Total individuals	137			
River Mile 287.0				
A. p. plicata	2	106.1	100.6	111.6
E. crassidens	30	101.5	90.4	114.1
E. lineolata	1	63.0	63.0	63.0
F. ebena	1	104.3	104.3	104.3
L. ovata	1	99.7	99.7	99.7
M. nervosa	3	181.2	176.0	190.5
P. alatus	2	54.5	52.9	56.0
P. cordatum	3	82.1	67.7	95.7
Q. metanevra	3	56.5	49.7	66.6
Q. p. pustulosa	33	44.8	20.8	59.4
Total individuals	79			
River Mile 283.9				
A. ligamentina	6	91.4	79.5	111.7
A. p. plicata	2	80.3	76.0	84.5
E. crassidens	25	98.7	90.6	111.4

(Continued)

Table 7 (Concluded)

River Mile 283.9				
E. lineolata	3	71.9	51.1	96.5
L. recta	2	116.6	107.1	126.0
M. nervosa	4	160.5	111.3	185.4
O. reflexa	10	46.1	32.1	60.4
P. alatus	2	38.3	36.2	40.5
P. cyphyus	1	81.5	81.5	81.5
Q. metanevra	18	64.8	42.2	82.8
Q. p. pustulosa	27	46.9	22.5	63.8
Q. quadrula	1	47.1	47.1	47.1
T. truncata	11	31.4	27.7	35.1
Total individuals	112			

Table 8
Density (individuals/sq m), Biomass (g/sq m), and Standard Error (SE) for Unionidae Collected at Each of Four Sites and Three Locations in the Upper Ohio River, October 1992

RM	Site	Density	SE	Biomass	SE
292.0	1	11.2[ab]	2.0	2,096.6[ab]	424.3
292.0	2	11.6[ab]	2.6	2,276.0[ab]	612.6
292.0	3	15.2[a]	2.1	2,485.9[ab]	524.1
292.0	4	16.8[a]	2.3	2,908.1[a]	399.7
287.8	1	10.4[ab]	2.1	1,713.1[abc]	393.7
287.8	2	7.6[b]	1.3	1,199.3[bc]	156.0
287.8	3	7.6[b]	1.1	694.8[c]	198.6
287.8	4	6.0[b]	0.9	696.4[c]	227.8
283.9	1	8.0[b]	2.2	1,444.3[bc]	608.1
283.9	2	14.8[a]	2.6	1,548.7[bc]	520.9
283.9	3	14.8[a]	2.0	1,608.5[abc]	347.3
283.9	4	7.2[b]	1.6	404.9[c]	102.5
Variation Among All Sites at All Locations					
F		3.49		3.47	
Pr > F		0.0003		0.0004	
Variation Among Sites at Each River Mile					
Density			**Biomass**		
	F	**Pr > F**	**F**	**Pr > F**	
RM 292.0	1.39	0.2622	0.49	0.6893	
RM 287.8	1.68	0.1876	3.50	0.2520	
RM 283.9	3.84	0.0175	1.67	0.1897	
Variation Among River Miles					
RM	**Site**	**Density**	**SE**	**Biomass**	**SE**
RM 292.0		13.7[a]	1.18	2,441.6[a]	243.8
RM 287.8		7.9[b]	.72	1,251.0[b]	142.0
RM 283.9		11.2[a]	1.17	1,075.9[b]	225.3
Variations Among All Sites at All Locations					
Density			**Biomass**		
F		7.71		12.7	
Pr > F		0.0007		0.0001	

Note: Means with the same superscript are not significantly different (P > 0.05).

Table 9
Density (individuals/sq m), Biomass (g/sq m), and Standard Error (SE) for *Corbicula fluminea* Collected at Each of Four Sites and Three Locations in the Upper Ohio River, October 1992

RM	Site	Density	SE	Biomass	SE
292.2	1	170.8^{f}	18.6	367.8^{e}	55.8
292.2	2	140.8^{f}	25.0	266.5^{e}	51.6
292.2	3	150.0^{f}	11.1	271.4^{e}	26.7
292.2	4	155.2^{f}	20.3	286.2^{e}	39.2
287.8	1	1,348.4^{e}	89.5	2,507.3^{d}	186.2
287.8	2	1,460.4^{e}	83.1	2,306.8^{d}	142.3
287.8	3	1,398.4^{e}	83.6	2,520.2^{d}	112.5
287.8	4	1,940.8^{d}	113.4	3,118.4^{c}	156.2
283.9	1	2,813.2^{c}	255.5	4,865.8^{b}	313.5
283.9	2	2,927.2b^{c}	86.9	5,286.5^{b}	118.6
283.9	3	3,192.4^{ab}	89.7	5,945.1^{a}	218.8
283.9	4	3,381.6^{a}	144.1	6,073.3^{a}	249.8
Variation Among All Sites at All Locations					
F		138.7		191.4	
Pr > F		0.0001		0.0001	
Variation Among Sites at Each River Mile					
Density			**Biomass**		
	F	**Pr > F**	**F**	**Pr > F**	
RM 292.2	0.42	0.7406	1.11	0.3562	
RM 287.8	8.58	0.0002	5.35	0.0038	
RM 283.9	2.60	0.0672	5.79	0.0024	
Variation Among River Mile					
RM	**Site**	**Density**	**SE**	**Biomass**	**SE**
292.2		154.2^{c}	9.5	298.0^{c}	22.5
287.8		1,537.0^{b}	58.6	2,613.2^{b}	87.5
283.9		3,078.6^{a}	84.5	5,542.7^{a}	138

(Continued)

Note: Means with the same superscript are not significantly different (P > 0.05).

Table 9 (Concluded)					
Variation Among All Sites at All Locations					
Density			Biomass		
F		602.03		3.47	
Pr > F		0.0001		0.0004	

Table 10
Correlation Coefficients and Probability Values Relating Grain Sizes of Sediments with Number and Biomass of Unionidae and *C. fluminea*, Upper Ohio River, October 1992

	>34.0 mm	12.7 to 34.0 mm	6.35 to 12.7 mm	<34.0 mm	*C. fluminea* Numbers	*C. fluminea* Biomass	Unionidae Numbers	Unionidae Biomass
>34.0 mm	1.0000	-0.8367	-0.8356	-0.9041	-0.7830	-0.7920	0.0528	0.2663
	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.5718	0.0037
12.7 to 34.0 mm		1.0000	0.7068	0.5376	0.7492	0.7303	-0.1594	-0.3398
		0.0000	0.0001	0.0001	0.0001	0.0001	0.0861	0.0002
6.35 to 12.7 mm			1.0000	0.6673	0.6191	0.6228	-0.0859	-0.2489
				0.0001	0.0001	0.0001	0.3573	0.0068
<34.0 mm				1.0000	0.6496	0.6778	0.0470	-0.1490
					0.0001	0.0001	0.6152	0.1088
C. fluminea Numbers					1.0000	0.9894	-0.1577	-0.3403
						0.0001	0.0854	0.0001
C. fluminea Biomass						1.0000	-0.1372	-0.3229
						0.0000	0.1351	0.0003
Unionidae Numbers							1.0000	0.8026
							0.0000	0.0001
Unionidae Biomass								1.0000
								0.0000

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13. ABSTRACT *(Maximum 200 words)*

A survey to assess community characteristics, density, population demography of dominant species, and the likelihood of finding endangered species of freshwater mussels (Unionidae) was conducted in the upper Ohio River (UOR) near Huntington, WV. Data will be used to analyze impacts of increased frequency of commercial navigation traffic resulting from the growth of barge traffic on the Ohio River because of increases in economic activities. A total of 1,477 individuals and 20 species of mussels were collected in the study area using qualitative methods. The fauna was dominated by two thick-shelled species (*Elliptio crassidens* and *Quadrula pustulosa*), which together comprised 66.7 percent of the fauna. Species diversity and evenness was moderate and ranged from 1.46 to 2.09 and 0.63 to 0.81, based on results of quantitative sampling. Evidence of recent recruitment for most species was low. The exception was the *Quadrula pustulosa pustulosa* population; approximately 12 percent of this population exhibited some evidence of recent recruitment. Total density of Unionidae ranged from 6.0 to 16.8 individuals/square meter. Total biomass of Unionidae ranged from 404.9 to 2,485.9 g/square meter. As with density, biomass values were not significantly different among sites at each RM ($P > 0.05$). *Corbicula flumninea* were more abundant in fine-grained sediments (moving upriver), although density of Unionidae appeared to be relatively unaffected by grain sizes.

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The results of future studies at these mussel beds will provide information necessary to evaluate the effects of commercial navigation vessels and other water resource development on freshwater molluscs at beds in this reach of the UOR.