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Qualitative versus Quantitative Sampling to Evaluate Population and Community Characteristics at a Large-river Mussel Bed

ANDREW C. MILLER AND BARRY S. PAYNE
Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi 39180-6199

ABSTRACT.—Quantitative and qualitative sampling methods were used to study community characteristics, density, recruitment rates and population demography of abundant species of freshwater mussels (Family: Unionidae), at Ohio River Miles 444.2–445.6 in July 1989 and September 1990. Mean unionid densities (±SD) based on 100, 0.25-sq m total substratum samples at four sites ranged from 4.4 ± 6.8 to 52.4 ± 13.9 individuals/sq m. Mean densities of *Corbicula fluminea* ranged from 66.8 ± 67.7 to 1352.8 ± 96.1 individuals/sq m. Shannon-Weaver species diversity $\log_{2.3026}$ (2.32 to 2.50) and evenness (0.76 to 0.90) at these sites indicated an equitable distribution of species within the community. Individuals of two abundant species, *Quadrula pustulosa pustulosa* and *Pleurobema cordatum,* were represented by most size classes, indicating generally sustained recruitment with some annual variation. Both sampling methods provided similar estimates of community composition, species richness, diversity and evenness. A comparison of these results with those from a previous survey at this bed indicates no major changes in biotic conditions between 1984 and 1989–1990.

INTRODUCTION

The William H. Zimmer Power Station, located on the Ohio River near Cincinnati, Ohio, was recently converted from nuclear to coal power. This required construction of a harbor and a loading facility for coal, lime and fuel oil. The station began limited operation in 1990, and coal deliveries by barge started early that year. When operating at full capacity, the station requires a minimum of one barge load of coal per day. Personnel from resource agencies have expressed concern that coal deliveries by barge could damage a rich and diverse mussel (Family: Unionidae) assemblage located immediately downriver of the power station. This mussel bed was studied by Williams (1969), Dames and Moore (1980), Stansbery and Cooney (1985), Environmental Science and Engineering (1988), and Williams and Schuster (1989). Historical information on bivalves of the Ohio River can be found in Rhoads (1899), Keup *et al.* (1963), Bickel (1966), Taylor (1980, 1989), Neff *et al.* (1981) and Tolin *et al.* (1987).

In July 1989 and September 1990 we used a four-person dive crew to collect molluscs using quantitative (0.25 sq m total substratum) and qualitative methods (retrieving specific numbers of live mussels encountered by touch). The objective was to obtain baseline information on community characteristics, density (individuals/sq m), recruitment rates and population demography of abundant species of Unionidae. Our data can be used to evaluate future effects of coal deliveries by barge. The purpose of this paper is to present results of the study, to contrast results obtained using quantitative and qualitative methods, and to compare our findings with those from a previous survey (Stansbery and Cooney, 1985).

STUDY AREA

The study area is located between River Miles (RM) 444.2 and 445.6, which is about 0.8 km N of Moscow, Clermont County, Ohio (Fig. 1). The area is upriver of Markland

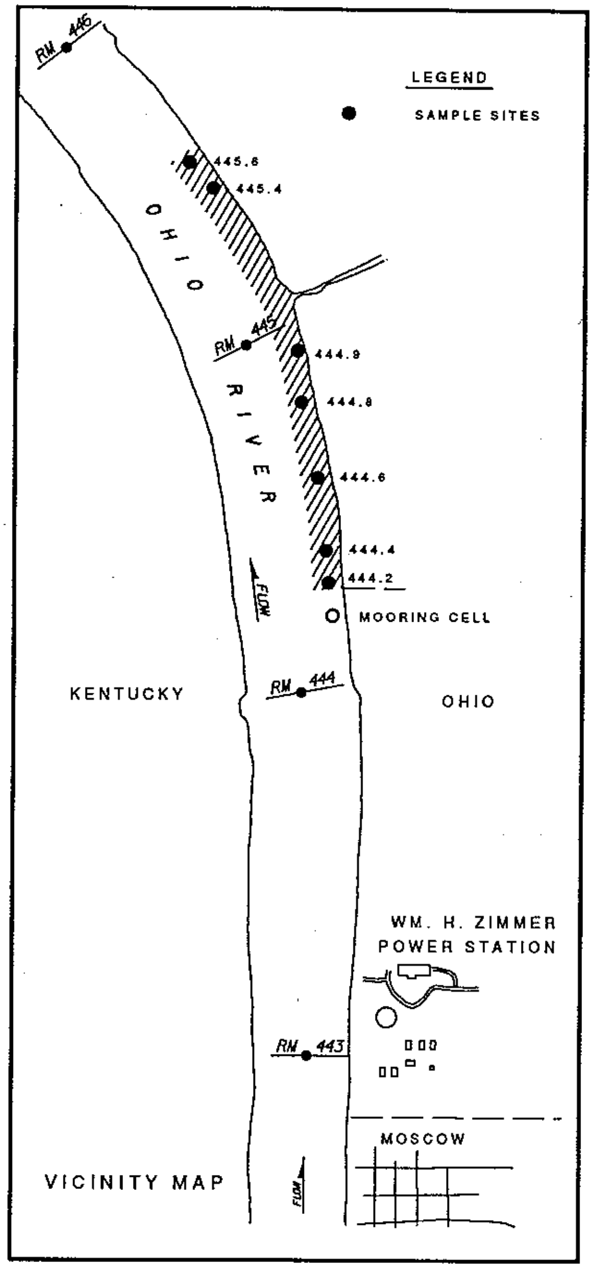

FIG. 1.—Map of the study area and sampling sites in the Ohio River, 1989–1990. *See* text for further description

Lock and Dam (RM 531.5) and downriver of Meldahl Lock and Dam (RM 436.0). The mussel bed is approximately 714 km downriver of industrial effluents from Pittsburgh and 44 km upriver of those from Cincinnati.

For the period of record (1970–1990), minimum and maximum discharge of the Ohio River at Markland Lock and Dam was 289 and 12,367 cu m/sec, respectively. During the two study periods, 21–24 July 1989 and 17–20 September 1990, mean discharges were 2057 and 2065 cu m/sec, respectively. Percentages of gravel, sand and silt at the three sites where quantitative samples were collected were 70%, 25% and 5% (RM 444.2); 73%, 22% and 5% (RM 444.4); and 77%, 21% and 2% (RM 444.6). Along the lower one-third of the bed, divers reported areas of exposed bedrock interspersed with gravel and sand.

Harbor construction for the power station affected only the upper portion of the mussel bed. At RM 444.2, downriver of the last barge mooring cell in the harbor, divers reported piles of sediment and evidence of physical disturbance. This was caused by movement of the dredge and workboats, since no dredging took place downriver of the last mooring cell.

METHODS

Molluscs were collected by a dive crew equipped with surface air supply and communication equipment. Qualitative collections were obtained by three divers working simultaneously at each site. Each diver placed a specific number of live mussels in each of four nylon bags; five mussels were placed in the first bag, and 20 were placed in each of the other three bags. Thus, each diver collected approximately 65 live mussels for a total of approximately 195 mussels. Actual numbers varied because divers occasionally miscounted or collected dead mussels.

Divers were instructed to retain all live mussels encountered by touch since visibility was less than 15 cm near the substratum-water interface. There was no intentional selection based on size or shape. Divers were instructed to exclude the Asian clam, *Corbicula fluminea,* from qualitative samples; if this species was inadvertently collected, it was later excluded. All mussels were brought to the surface, identified and counted.

Total substratum (quantitative) samples were obtained by having a diver excavate all sand, gravel, shells and live molluscs to a depth of 10–15 cm within a 0.25-sq m aluminum quadrat. Material was sent to the surface in a 20-liter bucket and transported to shore. Sediment was screened through a sieve series (finest screen with apertures of 6.4 mm). All live bivalves were placed in 4-liter zipper-lock bags and preserved in 10% buffered formalin.

In the laboratory, each mussel was identified and total shell length (SL) measured to the nearest 0.1 mm using a dial caliper. Nomenclature for unionidae is consistent with Turgeon *et al.* (1988). All *Corbicula fluminea* in each sample were counted. Percent species abundance, percent occurrence, species diversity (H′) (Shannon and Weaver, 1949) and evenness (J = H′/Hmax′) (Pielou, 1969) were calculated separately for data collected using qualitative and quantitative methods.

Both types of sampling methods were used to collect mussels in 1989 and 1990 (Table 1). In 1989, mussels were collected using qualitative methods at six of seven sites that spanned the mussel bed (Table 1, Fig. 1). In addition, 10 quantitative (total substratum) samples were taken at each of three subsites at RM 444.4 and 444.6. Subsites were 5–10 m apart. At each subsite, quadrats were placed approximately 1 m apart in a 2 × 5 matrix.

In 1990, qualitative methods were used to collect samples at three sites approximately 100 m apart (upriver to downriver and parallel to shore) at RM 444.2. In addition, 20 total substratum samples (10 at each of two closely spaced subsites) were obtained at each of the two upriver sites at RM 444.2 (*see* Table 1). No major changes in habitat conditions, percent community composition, total density or recruitment were noted between study

TABLE 1.—Location and year that sites were sampled using qualitative and quantitative methods in the Ohio River Mile 444.2–445.6. *See* text for further description

Qualitative methods		Quantitative methods		
Site	Year	Site	Total quadrats	Year
444.4	1989	444.4	30	1989
444.6	1989	444.6	30	1989
444.8	1989			
444.9	1989			
445.4	1989			
445.6	1989			
444.2-a	1990	444.2-a	20	1990
444.2-b	1990	444.2-b	20	1990
444.2-c	1990			

Note. Sites a, b, and c at 444.2 were located 100 m apart (from upriver to downriver) and parallel to shore

years. Therefore, data from 1989 and 1990 were combined for these analyses. However, only data from samples collected in 1989 using quantitative methods were used to analyze demography of two abundant species of Unionidae.

RESULTS

Twenty-five species of freshwater mussels (Family: Unionidae) were collected using qualitative techniques (Table 2). The fauna consisted almost entirely of thick-shelled species, and was dominated by *Pleurobema cordatum* (20.3%), *Quadrula pustulosa* (18.7%) and *Q. metanevra* (15.6%). Ten species were common, and each comprised 10.0–1.5% of the unionid fauna. The remaining 12 species were uncommon and each comprised less than 1% of the Unionidae. Each of the three most abundant species was found in more than 74% of the 108 samples (Table 2). Fourteen species were found in 73.2–10.2%, and eight species were taken in less than 10% of the samples collected using qualitative methods.

A total of 24 species were identified in all samples collected with quantitative methods. The most abundant species was *Quadrula pustulosa pustulosa,* which comprised 26.3% of the fauna. The next most abundant species, *Pleurobema cordatum* and *Q. metanevra,* comprised 13.6 and 7.7% of the fauna, respectively (Table 2). Percent species abundance estimated using quantitative and qualitative methods spanned three orders of magnitude (Fig. 2). Both sampling techniques depicted an even distribution of species within the community and yielded similar estimates of diversity (all samples combined, Table 2).

Comparison of the relative abundance of mussels collected by qualitative vs. quantitative methods (Table 2) indicates some minor biases associated with qualitative sampling. Obviously, the rarest species are likely to be missed by either technique. Therefore, comparisons made to evaluate sampling bias should be restricted to species comprising a substantial fraction (0.5% abundance) of mussels obtained by one method. Species whose relative abundance was most overestimated by qualitative vs. quantitative sampling were (in order to degree of overestimation): *Lampsilis ovata, Megalonaias nervosa, Plethobasus cyphyus, Quadrula metanevra,* and *Pleurobema cordatum.* These species share the characteristics of being quite large as adults, having highly sculptured shells, or not burying deeply in the substratum. Species whose relative abundance was most underestimated by qualitative vs. quantitative

TABLE 2.—Percentage abundance and frequency of occurrence of freshwater mussels collected using qualitative and quantitative methods, Ohio River Miles 444.2–445.6, 1989–1990. Data also from Stansbery and Cooney (1985) who collected at the same mussel bed in 1984 by hand, with a brail and with a diver

	This survey (1989–1990)				Stansbery and Cooney (1985)
	Qual methods		Quant methods		
Species	Abund	Occur	Abund	Occur	
Pleurobema cordatum (Rafinesque, 1820)	20.3	82.4	13.6	60.0	11.3
Quadrula p. pustulosa (Lea, 1831)	18.7	89.8	26.3	85.0	12.3
Q. metanevra (Rafinesque, 1820)	15.6	74.1	7.7	43.0	15.4
Amblema p. plicata (Say, 1817)	10.0	73.2	8.2	46.0	8.8
Obliquaria reflexa Rafinesque, 1820	7.4	63.9	9.1	54.0	14.0
Ellipsaria lineolata (Rafinesque, 1820)	4.6	44.4	5.9	39.0	1.9
Megalonaias nervosa (Rafinesque, 1820)	4.3	41.7	1.5	12.0	3.3
Elliptio crassidens (Lamarck, 1819)	4.0	38.0	3.1	22.0	6.2
Q. quadrula (Rafinesque, 1820)	2.8	30.6	2.3	18.0	10.6
Fusconaia ebena (I. Lea, 1831)	2.3	37.0	2.2	14.0	0.9
Q. nodulata (Rafinesque, 1820)	2.2	24.1	2.3	20.0	2.8
Plethobasus cyphyus (Rafinesque, 1820)	1.5	18.5	0.7	6.0	0.4
F. flava (Rafinesque, 1820)	1.5	21.3	3.8	25.0	5.1
Cyclonaias tuberculata (Rafinesque, 1820)	0.9	13.0	1.1	9.0	1.0
Potamilus alatus (Say, 1817)	0.8	12.0	0.6	5.0	1.0
Truncilla truncata Rafinesque, 1820	0.7	12.2	7.3	57.0	1.1
Tritogonia verrucosa (Rafinesque, 1820)	0.6	10.2	0.3	3.0	0.8
Lampsilis ovata (Say, 1817)	0.6	9.3	0.1	1.0	0.2
Actinonaias ligamentina (Lamarck, 1819)	0.3	4.6	1.1	8.0	0.4
Leptodea fragilis (Rafinesque, 1820)	0.2	3.7	1.0	9.0	1.4
Ligumia recta (Lamarck, 1819)	0.2	2.8	0.5	4.0	0.1
Lasmigona costata (Rafinesque, 1820)	0.1	1.8	0.1	1.0	0.1
Elliptio dilatata (Rafinesque, 1820)	0.1	1.8	—	—	0.4
Lampsilis abrupta (Say, 1831)	0.1	0.9	—	—	—
Anodonta grandis Say, 1829	0.1	0.9	—	—	0.1
Truncilla donaciformis (I. Lea, 1828)	—	—	1.0	8.0	0.1
Pleurobema coccineum (Conrad, 1834)[a]	—	—	0.1	1.0	0.3
Potamilus ohiensis (Rafinesque, 1820)	—	—	—	—	0.1
Toxolasma parvus (Barnes, 1823)	—	—	—	—	0.1
Anodonta suborbiculata Say, 1831	—	—	—	—	0.1
Total mussels	1798		875		2432
Total samples	108		100		—
Total sites	9		4		—
Total species	25		24		29
Species diversity ($\log_{2.3026}$)	2.40		2.48		2.54
Maximum diversity ($\log_{2.3026}$ richness)	3.22		3.18		3.37
Evenness (J)	0.74		0.78		0.75

[a] *Pleurobema coccineum* (Conrad, 1834) was referred to as *P. sintoxia* by Stansbery and Cooney (1985)

sampling were (in order of degree of underestimation): *Truncilla truncata, Leptodea fragilis, Actinonaias ligamentina, Ligumia recta* and *Fusconaia flava*. *Truncilla truncata* is both small and smooth, and the other four species are smooth and have been found burrowed deeply in the substratum.

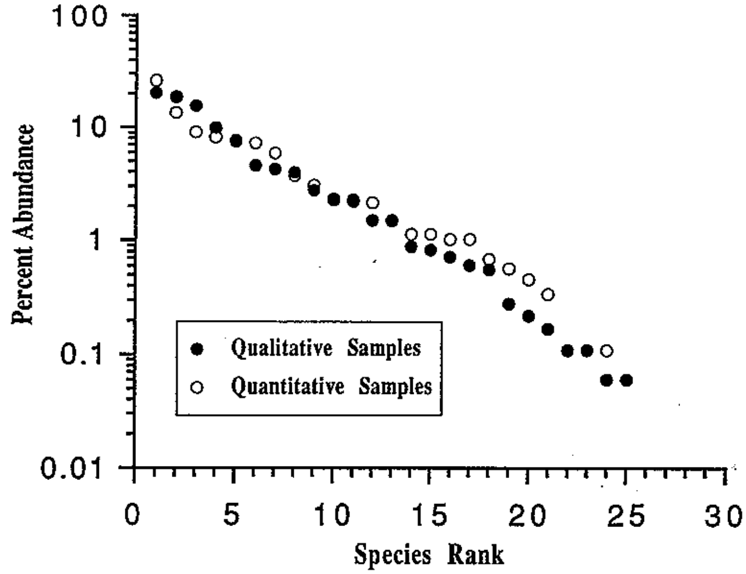

FIG. 2.—Percent abundance vs. species rank for unionids collected using qualitative and quantitative methods, Ohio RM 444.2–445.6, 1989–1990

Three uncommon species, *Elliptio dilatata, Lampsilis abrupta* and *Anodonta grandis,* were obtained in qualitative but not quantitative samples. Two species, *Truncilla donaciformis* and *Pleurobema coccineum,* were obtained in quantitative but not qualitative samples. *Truncilla donaciformis* is small as an adult (<50 mm) and is unlikely to be taken using qualitative methods. However, differences involving presence or absence of the rarest species result more from chance than from choice of method.

Richness, species diversity and evenness did not vary among sites regardless of whether qualitative or quantitative techniques were used. At the nine sites sampled using qualitative methods, species richness ranged from 16 to 18, diversity ranged only from 2.14 to 2.32, and evenness ranged from 0.76 to 0.82 (Table 3). At the four sites sampled using quantitative methods, species richness ranged from 18 to 21, diversity ranged from 2.32 to 2.50, and evenness ranged from 0.76 to 0.90. Mean values for diversity obtained using quantitative (2.43, variance = 0.0072) and qualitative methods (2.22, variance = 0.0043) were not significantly different at the 0.05 level (diversity indices compared based on methods in Poole, 1974). Like richness, diversity and evenness, percentage of individuals less than 30 mm long, an indication of recent recruitment that can be reliably estimated only using quantitative collecting methods, was similar among sites.

In contrast to the intersite similarity in species diversity, percent abundance of two species, *Pleurobema cordatum* and *Quadrula pustulosa pustulosa* was variable among sites regardless of technique. Among the nine sites sampled qualitatively, abundance of *P. cordatum* ranged from 7.8 to 32.1%, and *Q. p. pustulosa* ranged from 11.3 to 26.5%. In the quantitative collection, abundance of *Q. p. pustulosa* ranged from 23.2 to 28.8%, and *P. cordatum* ranged from 2.0 to 17.4%.

The relationship between cumulative number of species and cumulative number of individuals collected illustrates the difficulty of obtaining uncommon species (Fig. 3). Collecting mussels using quantitative methods obtained species at a slightly more rapid rate than using

TABLE 3.—Intersite similarity of mussel community characteristics based on qualitative and quantitative methods, Ohio River Mile 444.2–445.6, 1989–1990

	Qualitative methods				
Site	Total mussels	Total species	Species diversity	Evenness	
444.4	168	16	2.16	0.78	
444.6	206	16	2.17	0.78	
444.8	215	18	2.18	0.76	
444.9	204	17	2.14	0.76	
445.4	205	17	2.32	0.82	
445.6	187	17	2.24	0.79	
444.2-a	196	17	2.20	0.78	
444.2-b	211	16	2.22	0.80	
444.2-c	206	17	2.32	0.82	
	Quantitative methods				
Location	Total mussels	Total species	Species diversity	Evenness	% Individuals <30 mm SL
444.4	344	21	2.32	0.76	10.8
444.6	275	20	2.40	0.90	12.0
444.2-a	99	18	2.50	0.86	9.1
444.2-b	157	20	2.49	0.83	10.8

qualitative techniques. However, after 700 individuals had been collected, both techniques characterized the assemblage in a similar manner.

At 10 subsites, mean unionid densities (±SD) ranged from 4.4 ± 6.8 to 52.4 ± 13.9 individuals/sq m (Table 4). Mean densities of *Corbicula fluminea* at these sites ranged from 66.8 ± 67.7 to 1352.8 ± 96.1 individuals/sq m (Table 4). *Corbicula fluminea* outnumbered Unionidae by 33 and 20 times at RM 444.4 and RM 444.6, respectively. At closely spaced sites at RM 444.2, *C. fluminea* outnumbered native Unionidae by 5.7 and 27.6 times, respectively.

An inverted teardrop shape generally characterized the shell length histogram of the *Quadrula pustulosa pustulosa* population (Fig. 4). This shape is an expected result of relatively consistent annual recruitment to a population of moderately long-lived individuals whose growth slows with increasing age and size. Ten percent of the *Q. p. pustulosa* population consisted of recent recruits less than 30 mm long, including mussels as small as 14–16 mm long. An additional 15% consisted of mussels 30–40 mm long, including a relatively strong cohort centered at 34–6 mm. At least 3 year-classes are probably included among the mussels less than 40 mm long. The remaining 75% of the population was greater than 40 mm long, with most mussels measuring 48–62 mm. Mussels greater than 40 mm long probably include 6 or more year-classes.

The size demography of the next most abundant species in quantitative samples, *Pleurobema cordatum*, had a generally bimodal appearance (Fig. 4). Moderately large mussels ranging from 62–100 mm and including multiple cohorts comprised approximately 50% of the population. Likewise, moderately small mussels ranging from 24–58 mm and including multiple cohorts comprised the other 50% of the population. Intermediate-sized mussels (58–62 mm long) were lacking. Only 2% of the *P. cordatum* population consisted of recent recruits less than 30 mm long, and no mussels less than 24 mm long were obtained. The

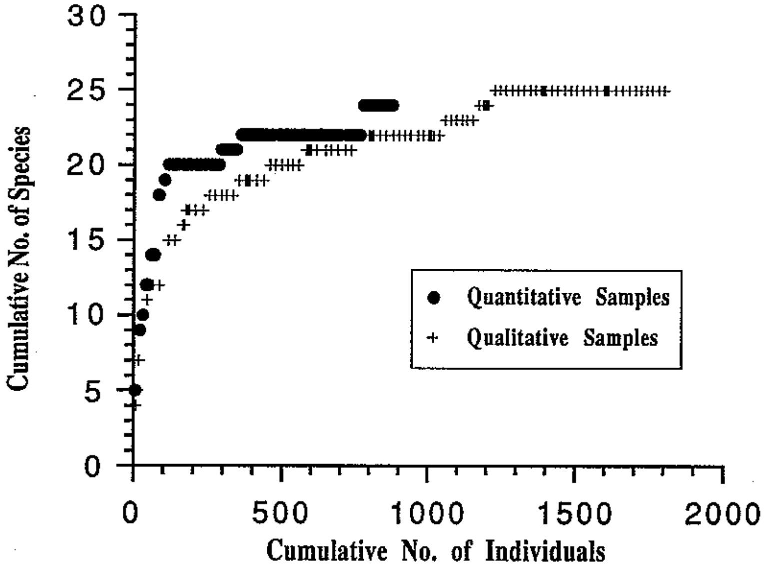

FIG. 3.—Cumulative number of species vs. cumulative number of individuals for unionids collected using qualitative and quantitative methods, Ohio RM 444.2–445.6, 1989–1990

lack of intermediate-sized and very small mussels and the equal abundance of moderately small and moderately large mussels indicate less consistent strength in annual recruitment of *P. cordatum* relative to *Quadrula pustulosa pustulosa*.

DISCUSSION

In 1984 Stansbery and Cooney (1985) collected mussels at this bed with a brail, by hand along the shore and with a diver. Collections by their diver were semiquantitative; although premeasured areas of river bottom were searched, total substratum samples were not

TABLE 4.—Summary of density estimates (individuals/sq m) for freshwater mussels and *Corbicula fluminea*, Ohio River Mile 444.2–445.6, 1989–1990. Subsites were 5–10 m apart

		Unionidae		*C. fluminea*	
Location	Subsite	Mean	SD	Mean	SD
	1	30.0	15.2	1092.4	358.4
444.4	2	39.6	28.1	1238.0	258.3
	3	40.4	15.8	1352.8	96.1
444.6	1	46.4	17.1	1009.2	110.3
	2	52.4	13.9	939.6	141.1
	3	38.8	10.7	796.8	140.6
444.2-a	1	4.4	6.8	66.8	67.7
	2	35.2	25.8	161.6	81.5
444.2-b	1	31.2	9.8	613.2	92.4
	2	22.0	4.3	857.6	88.7

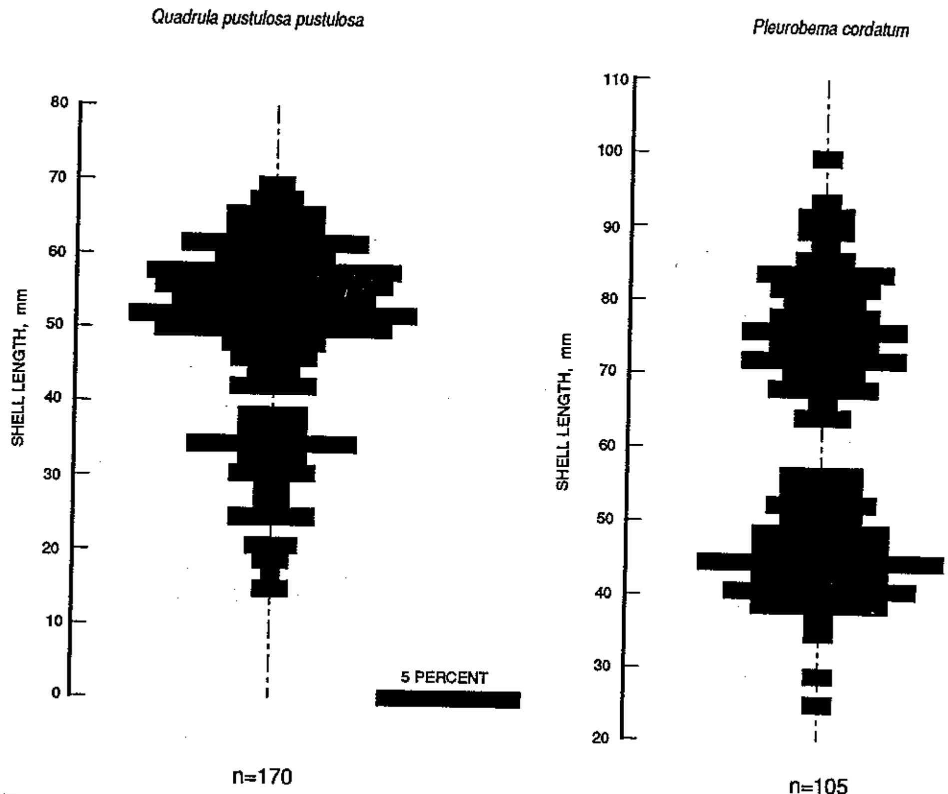

FIG. 4.—Length-frequency histograms for *Quadrula pustulosa pustulosa* and *Pleurobema cordatum* obtained from quantitative sampling methods at Ohio River Mile 444.2–445.6, July 1989

obtained. They obtained a grand total of 2432 individuals and 29 species (Table 2). When results from our qualitative and quantitative collections in 1989 and 1990 are combined, we took 2673 individuals and identified 27 species. We found *Lampsilis abrupta* which was not collected by Stansbery and Cooney (1985). However, they took three species nearshore that we did not collect (*Potamilus ohiensis, Toxolasma parvus* and *Anodonta suborbiculata*). Twenty-six species were common to both surveys. Although sampling techniques differed, estimates of species richness, species diversity, evenness and community composition were similar (Table 2).

Regardless of sampling method and when data from Stansbery and Cooney (1985) are considered, the species can be considered evenly distributed within the community (Table 2). By comparison, at two inshore sites in the lower Tennessee River, a mollusc assemblage was strongly dominated by *Fusconaia ebena,* which comprised 71 and 74% of the Unionidae (Way *et al.,* 1990). At those sites on the lower Tennessee River, evenness was approximately one-half (0.39 and 0.38) the values for all sites combined from the present study (0.74 and 0.78, using qualitative and quantitative methods, respectively) (Table 2).

Lampsilis abrupta, listed as endangered by the U.S. Fish and Wildlife Service (1991) and the Commonwealth of Kentucky (Branson *et al.,* 1981), had not been reported at this site by previous workers. Although uncommon, this species has not been extirpated from the

Ohio River. Tolin *et al.* (1987) found *L. abrupta* farther upriver along the West Virginia border. *Plethobasus cyphyus,* listed as endangered by the Commonwealth of Kentucky (Branson *et al.,* 1981), was collected at this location using qualitative and quantitative techniques in 1989. This species has been found by us in a dense and diverse bed in the lower Ohio River near Olmsted, Illinois, and comprised 0.19% of the fauna at a site stabilized by wing dams in Pool 10 of the upper Mississippi River (Miller, 1988). Two *Lasmigona costata* (one in 1989 and one in 1990) were collected using qualitative methods. Stansbery and Cooney (1985) reported a single specimen, although this species was not found at this bed by other workers. This uncommon mussel inhabits sand and gravel substratum in rivers in the Mississippi drainage (Murray and Leonard, 1962; Parmalee, 1967).

Each sample obtained with qualitative methods contained 187–215 individuals and 16–18 species, a number slightly more than half the total species at this bed (Table 3). In a sample of this size only one individual would be taken, on average, of a species that comprised 0.5% of the assemblage. A sample of approximately 200 individuals obtained using qualitative methods would be sufficient to find common and fairly common but not uncommon species. By increasing the sample size to 1798 (by grouping all nine samples taken with qualitative methods) eight more species were found (Fig. 3). A ninefold increase in sample size resulted in a 32% increase in species richness.

When results from quantitative and qualitative sampling methods are compared, similar values for important community descriptors (percent species abundance, species richness, evenness and diversity) are obtained. If appropriate numbers of individuals can be collected, qualitative methods should be considered if the objective is to census the majority of mussel species present. Potential sources of collector bias in the use of qualitative methods include small physical size, the extent to which mussels are burrowed and thus cryptic, and shell sculpture which enables a diver working under conditions of limited visibility to distinguish smooth mussels from gravel and cobble. Comparison of the relative abundance of different species of mussels with respect to sampling method indicated that these biases result in small differences in community structure.

In comparison with other large-river mussel beds, mussel density (4.4 to 52.4) can be considered low to moderate. Densities at RM 444.2 were ca. 50% less than those farther downriver, presumably because of disturbance when the harbor was constructed. At two inshore sites in the lower Tennessee River (32 quantitative samples were collected at each), mean mussel densities were 187.7 and 151.0 individuals/sq m (Way *et al.,* 1990). At a bed in the lower Ohio River near Olmsted, Illinois, mean densities of Unionidae ranged from 9–47 individuals/sq m (Miller and Payne, 1988).

Stansbery and Cooney (1985) reported that *Corbicula fluminea* was "the most common shell seen along the shore" in 1984, although they provided no estimates of density. Cincinnati is close to the northernmost extension of the range for this species (McMahon, 1983). Density of *C. fluminea,* approximately 1000 individuals/sq m (Table 3), should be considered moderate. Values as high as 2286 to 11,522 individuals/sq m (Graney *et al.,* 1980), 3397 to 23,689 individuals/sq m (Cherry *et al.,* 1986) and 10,000 to 20,000 individuals/sq m (Eng, 1979) have been reported. A dense and diverse assemblage of mussels exists at this shoal although *C. fluminea* outnumbered native bivalves by 5.7 to 33 times.

Although not all age and size classes were equally abundant, *Quadrula pustulosa pustulosa* and *Pleurobema cordatum* populations exhibited evidence of reasonably consistent recruitment. These results can be contrasted with a bed on the lower Ohio River where Payne and Miller (1989) reported that 71% of the most abundant species, *Fusconaia ebena,* belonged to a single cohort with an average SL of 15.8 mm. In the present study, *F. ebena* in this size category comprised approximately 20% of the population.

Stansbery and Cooney (1985) and Taylor (1989) expressed concern that mussel stocks in large rivers were declining. Data collected by Stansbery and Cooney (1985) can be compared with results of this survey to determine if biotic conditions at this bed have changed through time. Although the previous workers did not provide information on density and demography, there appears to have been little or no change in species diversity or richness at this bed between 1984 and 1989–1990 (Table 2).

Estimates of density, recruitment and detailed analyses of population demography require quantitative total substratum samples (Miller and Payne, 1988). However, sampling with quantitative methods in large rivers is difficult and expensive. Resource agency personnel interested mainly in searching for rare or endangered species or calculating community parameters, such as diversity and evenness, should consider qualitative methods.

Continued use of inland waterways to transport bulk commodities (Dietz *et al.*, 1983) has caused planners and biologists in government agencies to express concern regarding the possible negative effects of the 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, percent species abundance, community composition and population demography. The results of future studies at this mussel bed, to be conducted after the power station has operated for several years, will provide information necessary to evaluate the effects of coal deliveries by barge on freshwater molluscs.

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