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Characterization of a Freshwater Mussel (Unionidae) Community Immediately Downriver of Kentucky Lock and Dam in the Tennessee River

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ABSTRACT

Data on community characteristics, density, recruitment rates, presence of endangered species, and population demography of dominant species of freshwater mussels (Family Unionidae) were obtained at selected sites between RM 22.2 and 21.2 at a mussel bed immediately downriver of Kentucky Lock and Dam (RM 22.4) in the lower Tennessee River. The unionid fauna was dominated by 2 thick-shelled species, *Amblema plicata plicata* (Say, 1817) (39.43%) and *Fusconaia ebena* (I. Lea, 1831) (39.41%). Six species each comprised 1 to 5% of the collection and 15 species each made up less than 1% of the collection. No federally listed endangered species was found. The similarity of size structure of *A. p. plicata* and *F. ebena* suggested interspecific similarity in temporal variation in recruitment. Species diversity ($\log_{2.3026}$, 1.54–1.87) and evenness (0.629–0.811) were moderate at 6 sites where 10 quantitative 0.25-sq m samples were taken. Mean unionid density ranged from 9.2–128.0 individuals/sq m (overall average was 63.0/sq m). The minimum density required to sustain a reproductively viable population of an uncommon species is probably 2–3 individuals/100 sq m. Mean density of *Corbicula fluminea* (Muller, 1774) ranged from 6.0–26.4 individuals/sq m, which was considerably less than values reported by Williams (1), who collected at a series of sites between Kentucky Lock and Dam and the mouth of the Tennessee River in the mid 1960s.

INTRODUCTION

A rich, dense, and commercially harvestable assemblage of freshwater mussels (Family Unionidae) occurs downriver of Kentucky Lock and Dam in the lower Tennessee River (1, 2, 3). Commercial fishermen consider the bed to extend from the dam at RM 22.4 to RM 11.0, although mussel distribution in this reach is patchy (3). Thirty six species of unionids, including 2 federally listed endangered species, have been collected at this bed (3). This reach of the lower Tennessee River has stable sand and gravel substratum that is kept free of sediment by continuous flow from Kentucky Dam. Kentucky Lock and Dam is a multiple-purpose project that was completed in September 1944.

From August 31 to September 3, 1990, a survey was conducted to obtain data on community characteristics, density, recruitment rates, presence of endangered species, and population demography of dominant species of freshwater mussels between RM 22.2 and 21.2, a dense section of the bed located immediately downriver of the dam. The survey was conducted at the request of the U.S. Army Engineer District, Nashville as part of environmental studies necessary before completion of a second lock at Kentucky Lock and Dam. Construction of the lower approach for this new lock would require removal of about 59,000 cu yd (45,000 cu m) of sand and gravel, which would eliminate some live bivalves and their habitat. When commercial traffic enters and exists this new lock they will pass closer to valuable portions of the mussel bed than they have in the past.

STUDY AREA

The Tennessee River originates at the junction of French Broad and Holston Rivers near Knoxville, Tennessee and flows southwest into Alabama, then north through Tennessee and Kentucky to Paducah, Kentucky where it enters the Ohio River at RM 933. The river is

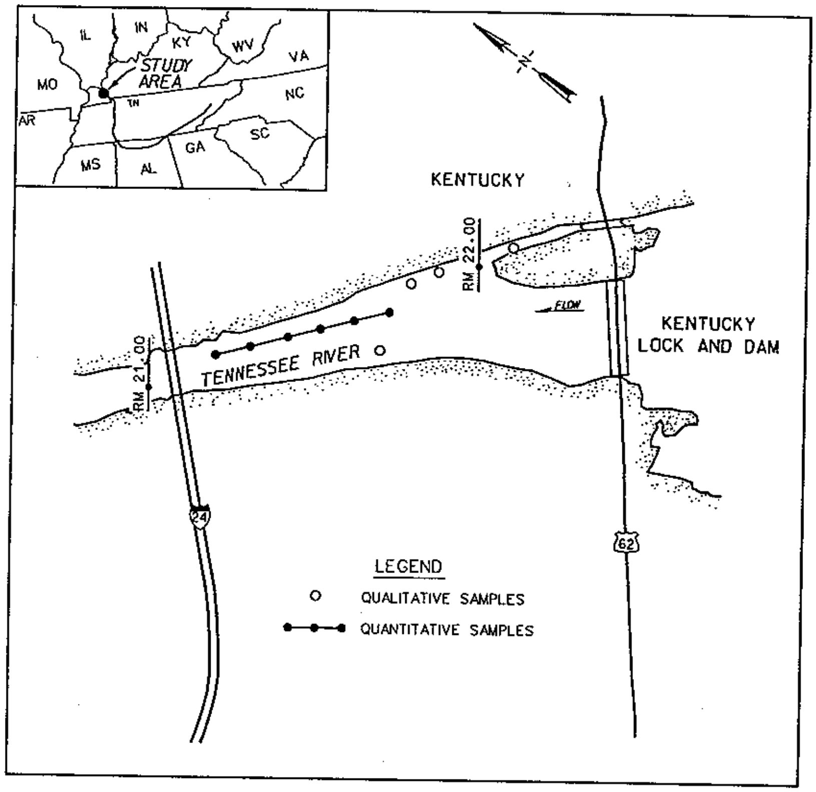

FIG. 1. Study areas on the lower Tennessee River.

1,050 km long with an average discharge of 1,834 cu m/s at Paducah (66 years of records (4)). Much of the river consists of a series of run-of-the-river reservoirs for navigation and hydroelectric power. Kentucky Lock and Dam is the last dam on the Tennessee River before its confluence with the Ohio River.

Quantitative and qualitative samples were obtained between RM 22.2 and RM 21.2, mainly along the right descending bank (Fig. 1). Sediment at sites where quantitative samples were collected consisted mainly of gravel (60.4–83.3%) with lesser amounts of sand (15.9–38.9%) and fines (0.2–1.1%). Percentage organic matter ranged from 0.62–4.90% by weight. Mussels were uncommon along the left descending bank in the study area, and virtually no mussels were found in the main channel. Sites were chosen to characterize areas that were likely to be affected by proposed construction of the second lock and movement of commercial vessels. Our study area contained one of the densest concentrations of mussels in this river reach (3). The study area is within a state mussel sanctuary located between RM 17.8 and 22.4 where commercial shell harvesting is prohibited.

METHODS

All sampling was accomplished by a dive crew equipped with surface air supply and communication equipment. Qualitative samples were obtained by three divers working simultaneously. 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 mussels were placed in each of three other bags. Each diver collected approximately 65 live mussels (some shells and rocks were inadvertently taken) for a total of about 185 mussels per site. Divers attempted to exclude the Asian clam, *Corbicula fluminea* (Muller, 1774), from qualitative samples. If *C. fluminea* was inadvertently collected, it was later eliminated from the sample. All mussels were brought to the surface, counted, and identified.

TABLE 1. Summary of relative species abundance and frequency of occurrence for freshwater mussels collected using qualitative techniques at five study areas upriver of the I-24 Bridge (see Fig. 1) in the lower Tennessee River, 1990.

Species	Total mussels	%	Total sites	%	Species rank
Amblema p. plicata (Say, 1817)	1,880	39.43	274	95.47	1
Fusconaia ebena (I. Lea, 1831)	1,879	39.41	259	90.24	2
Quadrula p. pustulosa (I. Lea, 1831)	241	5.05	141	49.13	3
Quadrula quadrula (Rafinesque, 1820)	175	3.67	113	39.37	4
Obliquaria reflexa Rafinesque, 1820	165	3.46	82	28.57	5
Megalonaias nervosa (Rafinesque, 1820)	73	1.53	58	20.21	6
Cyclonaias tuberculata (Rafinesque, 1820)	59	1.24	51	17.77	7
Elliptio crassidens (Lamarck, 1819)	57	1.20	47	16.38	8
Elliptio dilatata (Rafinesque, 1820)	35	0.73	31	10.80	9
Ellipsaria lineolata (Rafinesque, 1820)	30	0.63	27	9.41	10.5
Truncilla truncata Rafinesque, 1820	30	0.63	26	9.06	10.5
Potamilus alatus (Say, 1817)	27	0.57	23	8.01	12
Truncilla donaciformis (I. Lea, 1828)	26	0.55	22	7.67	13
Quadrula nodulata (Rafinesque, 1820)	18	0.38	18	6.27	14
Leptodea fragilis (Rafinesque, 1820)	17	0.36	17	5.92	15
Tritogonia verrucosa (Rafinesque, 1820)	16	0.34	15	5.23	16
Pleurobema cordatum (Rafinesque, 1820)	12	0.25	9	3.14	17
Ligumia recta (Lamarck, 1819)	9	0.19	9	3.14	18
Lampsilis teres (Rafinesque, 1820)	7	0.15	6	2.09	19
Anodonta imbecillis (Say, 1829)	4	0.08	4	1.39	20
Quadrula metanevra (Rafinesque, 1820)	3	0.06	3	1.05	21.5
Anodonta grandis Say, 1829	3	0.06	3	1.05	21.5
Lasmigona c. complanata (Barnes, 1823)	2	0.04	2	0.70	23
Total samples 287					
Total mussels 4,768					
Total species 23					

Ten quantitative samples (that included *C. fluminea*) were obtained at each of 6 sites 100 m apart (upriver to downriver in the center of the bed) in the area that would be dredged for lock construction. At each site ten 0.25-sq m quadrats were positioned approximately 1 m apart and arranged in a 2 by 5 matrix. A diver excavated all substratum to a depth of 10–15 cm. Material was sent to the surface in a 20 L bucket and transported to shore. Sediment was screened through a sieve series (finest screen with apertures of 6.4 mm). All live bivalves were picked from the sediment and placed in zipper-lock bags. Each bivalve was identified and total shell length (SL) was measured to the nearest 0.1 mm with a dial caliper.

RESULTS

Twenty three species and 4,768 freshwater mussels were obtained in 287 qualitative collections (Table 1). The fauna was dominated by 2 thick-shelled species, *Amblema plicata plicata* (Say, 1817) and *Fusconaia ebena* (I. Lea, 1831), which represented 39.43 and 39.41% of the fauna and were taken in 95.47 and 90.24% of the samples, respectively. Six species each comprised from 1 to 5% of the collection, and 15 species each comprised less than 1% of the collection. With the exception of *A. p. plicata* and *F. ebena*, all other unionids were taken in less than 50% of the samples; 14 species were found in less than 10% of the samples. Thin- and moderately thick-shelled species, *Anodonta grandis* Say, 1829, *Anodonta imbecillis* (Say, 1829), *Lampsilis teres* (Rafinesque, 1820) and *Leptodea fragilis* (Rafinesque 1820), usually associated with fine sand or silt, were uncommon and together comprised 0.65% of the assemblage. No live specimens of two endangered species, *Lampsilis abrupta* (Say, 1831) and *Plethobasus cooperianus* (I. Lea, 1834), previously collected in this river reach (3) were found.

A plot of cumulative species versus cumulative individuals illustrates the relationship between sampling effort and the ability to find uncommon species. Although a total of 4,768 individuals and 23 species were taken (Table 1), after 1,200 individuals had been found, all 23 species were identified (Fig. 2). This figure

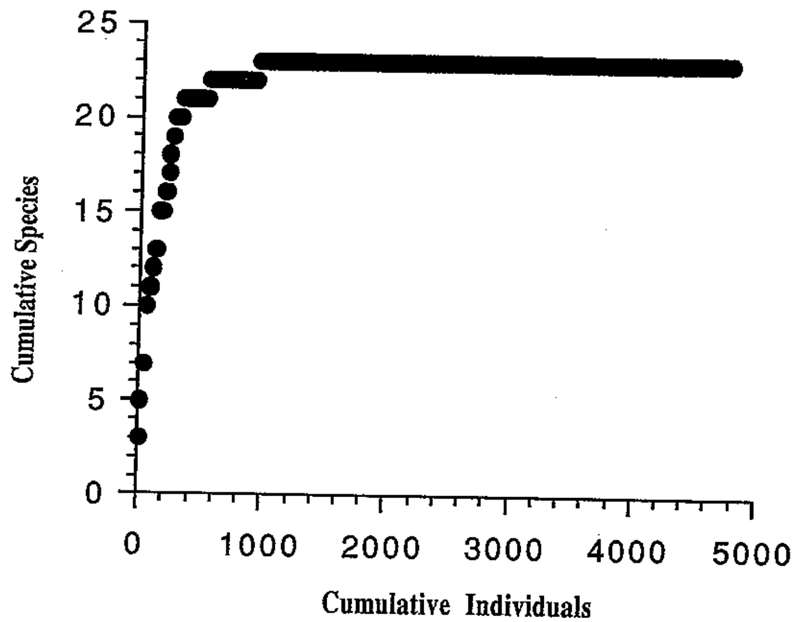

FIG. 2. The relationship between cumulative species and cumulative individuals for qualitative samples.

suggests that finding additional species with more sampling would be unlikely. If species were present and not collected, they would comprise less than 0.02% of the assemblage.

Mean unionid density at six sites ranged from 9.2 to 128.0 individuals/sq m (overall average was 63.0 individuals/sq m). Mean density of *C. fluminea* ranged from 6.0 to 26.4 individuals/sq m (Figure 3). Species diversity ($\log_{2.3026}$) ranged from 1.54 to 1.87, and evenness ranged from 0.629 to 0.811.

The *A. p. plicata* population ranged between 6 to 126 mm total SL (Fig. 4). The most abundant mussels occurred in 2 size classes: 10

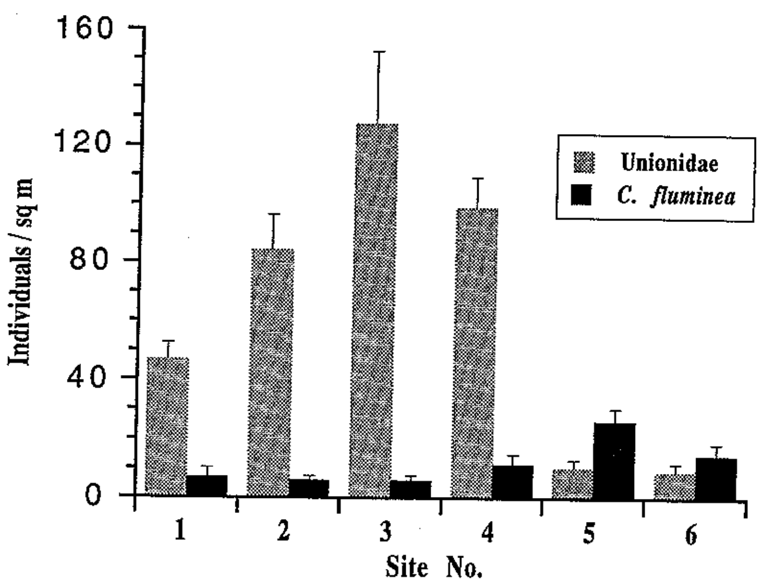

FIG. 3. Total density (individuals/sq m) of unionids and *Corbicula fluminea*.

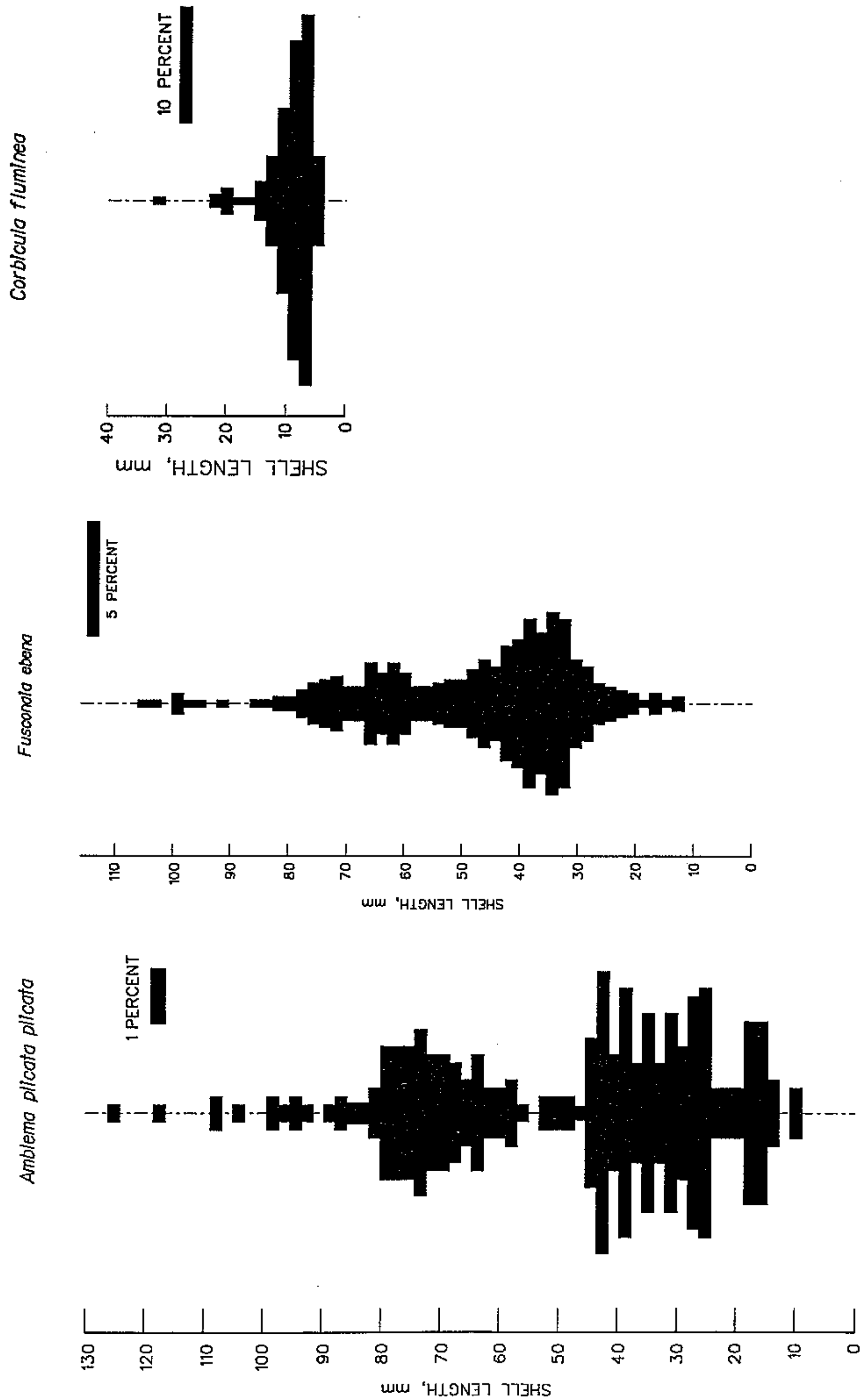

FIG. 4. Shell-length frequency histograms for *A. plicata*, *F. ebena*, and *C. fluminea*.

to 50 mm (62% of the population) and 54 to 88 mm (33% of the population). Several overlapping cohorts were included within each of these two SL ranges. A recently recruited cohort (probably the 1989 year class) had an average SL of 14–18 mm. Mussels ranging from 20 to 46 mm SL probably represented 3 largely overlapping cohorts. Two relatively abundant cohorts were centered at 22–26 mm and 36–44 mm SL, and an intermediate and less abundant cohort was between 28 and 34 mm. Individual cohorts could not be distinguished among the moderately large mussels ranging from 54 to 88 mm. The relative paucity of mussels between 46 and 56 mm is probably the consequence of 1 or 2 consecutive years of poor recruitment. Individuals greater than 100 mm comprised less than 2% of the total population. Although *A. p. plicata* can exceed 100 mm total SL, few individuals appeared to survive long enough to attain this size. Because the study area is within a mussel sanctuary, population structure should be unaffected by commercial harvest.

The size structure of *F. ebena* was similar to that of *A. p. plicata* (Fig. 4). *Fusconaia ebena* was characterized by two relatively abundant and broad size classes, and each consisted of multiple but indistinct cohorts. The smaller of these 2 groups included mussels ranging between 12 and 56 mm and comprised 72% of the population (compared to 62% in the 10- to 50-mm range of *A. p. plicata*). Mussels between 56 and 86 mm accounted for 28% of the total collection (compared to 31% in the 56 to 86 mm range of *A. p. plicata*). Individuals greater than 92 mm accounted for only 2% of the population.

The similarity of size structure among the 2 most abundant species populations may reflect interspecific similarity in temporal variation in recruitment. The paucity of mussels from 50 to 60 mm (relative to abundant size classes above and below this size range) for both populations could correspond to an interspecific simultaneity of one or more poor years of recruitment.

The low-density population of *C. fluminea* consisted almost entirely of small individuals between 4 to 13 mm, which probably represent spring recruits (Fig. 4). *Corbicula fluminea* usually exhibits spring and fall peaks of recruitment (5) unlike native unionids that have a single recruitment each year. Larger *C. fluminea* (18 to 24 mm) probably represent recruitment from the fall of 1989. Stable and thriving populations of *C. fluminea* sampled during the late summer usually show 3 to 5 cohorts, including many individuals from 20 to 35 mm (5, and references cited therein). The lack of complex size structure and large individuals plus low density indicates a population supported by low recruitment with subsequent poor survival.

DISCUSSION

The mussel assemblage in the reach of the Tennessee River immediately downriver of Kentucky Lock and Dam consisted almost entirely of thick-shelled species such as *A. p. plicata*, *F. ebena*, and *Quadrula* spp., and lesser numbers of *Elliptio* spp., *Megalonaias nervosa* (Rafinesque 1820), and *Pleurobema cordatum* (Rafinesque 1820). Thin- and moderately thick-shelled species (*L. fragilis*, *Potamilus alatus* (Say, 1817), and *Anodonta* spp.) together comprised only 0.65% of the qualitative collection. Within their range these thin-shelled species are found in appropriate substratum in large rivers (6, 7, 8). Each has multiple fish hosts (9) 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 probably be more thin-shelled species immediately downriver of the lock and dam if maximum water velocities were less.

Our sampling was concentrated only in the portion of the bed immediately downriver of the lock and dam. Results of previous studies (1, 2, 3, 10, 11) included samples taken downriver of our study area. In 1985, Sickle (3) reported collecting 36 species (34 living) at 51 sites between RM 22.4 and the mouth of the Tennessee River. Species absent from our study area that have been collected by ourselves and others farther downriver include fairly common species such as *Arcidens confragosus* (Say, 1829) and *Fusconaia flava* (Rafinesque, 1820). The slightly reduced richness immediately downriver of the lock and dam (23 species), compared with results of previously conducted studies that included sites located farther downriver, does not necessarily indicate a change in richness through time. The slightly more erosional characteristic of substratum closer to the dam has probably greatly reduced or eliminated some species. An examination of data collected by the earlier workers (summarized by Sickel, 3) indicates that community composition at the mussel bed (RM 22.4 to 11.0) has remained relatively stable through time regardless of completion of major hydropower dams in the watershed.

Total species richness in the study area is similar to that at other mussel beds in large rivers. At a mussel bed in the lower Ohio River near Olmsted, Illinois, 23 species of freshwater mussels were collected (12). In a survey of the upper Mississippi River, Miller et al. (13) 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 6 sites sampled (9.2–128.0 individuals/sq m with an overall average of 63.0 individuals/sq m) is within the range of density data from other large river mussel beds. In a survey of the upper Mississippi River, Miller et al. (13) reported that total mussel density ranged from 5.2 to 333.2 individuals/sq m at 16 sites (10 quantitative samples were taken at each). At half of those sites total density was greater than 50 individuals/sq m and at four sites it was greater than 100 individuals/sq m. 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/sq m, respectively (14).

This bed is within the reported range of the following federally listed endangered freshwater mussel species: *Pleurobema plenum* (I. Lea, 1840), *P. cooperianus*, *L. abrupta*, *Obovaria retusa* (Lamarck, 1819), *Potamilus capax* (Green, 1832), *Plethobasus cicatricosus* (Say, 1829), *Cyprogenia stegaria* (=*irrorata*) (Rafinesque, 1820), and *Epioblasma torulosa torulosa* (Rafinesque, 1820) (15). Two of these species, *P. cooperianus* and *L. abrupta*, have been collected in the lower Tennessee River. Sickel (3) collected a single *Plethobasus cooperianus* at RM 20.6 and two at RM 20.7 (just downriver of our study area) in 1985. This species was found near the mouth of the river at Paducah, Kentucky in 1931 by Ellis (as reported by van der Schalie, 11). Sickel (3) reported 2 specimens of *L. abrupta* at RM 14.75 and 1 at RM 21.36 (16) (just within our study area). In the latter survey a total of 9,367 mussels were collected between RM 21.1 and 21.5. This species was also collected by personnel of the Tennessee Valley Authority in 1978 at RM 22.0 (within our study area) as reported by Sickel (3).

Between RM 22.2 and 21.2 in the lower Tennessee River, *P. cooperianus* and *L. abrupta* are either absent or extremely uncommon (i.e., less than one individual per 5,000 unionids). The relationship between cumulative species and cumulative individuals (Fig. 2) illustrates that it would be unlikely (although probably not impossible) to find either of these species in the study area. If individuals of these species are present, they are probably not part of a viable population. Miller et al. (17) found what appears to be a viable population of *P. cooperianus* at a mussel bed in the lower Ohio River near Olmsted, Illinois. In the fall of 1990 they obtained 2 live specimens in 3 samples of 200 individuals each. *Plethobasus cooperianus* continues to exist in certain reaches of large rivers in densities high enough to be easily collected.

Based on our qualitative samples, the least common species, *Lasmigona complanata complanata* (Barnes, 1823), comprised 0.04 percent of the fauna. With an average of 63 mussles/sq m, the density of this uncommon species would be 0.0252 individuals/sq m. A density of 2–3 individuals per 100 sq meters could be considered the minimum necessary to sustain a reproductively viable population of an uncommon unionid. Two uncommon federally listed species, *P. cooperianus* and *L. abrupta*, were collected previously in our study area (3). However, these species are so uncommon in this river reach that they probably can not sustain themselves.

Williams (1) sampled the lower Tennessee River between Kentucky Lock and Dam and the Ohio River in the mid 1960s with an 8-ft brail and a Peterson dredge. He estimated that *C. fluminea* comprised 99.41% of the bivalve community; densities ranged from 17 to 1,147 individuals/sq yd (20.3 to 1,372 individuals/sq m). In the present survey, density of Asian Clams ranged from 6.0 to 26.4 individuals/sq m. Although quantitative data on *C. fluminea* were not collected throughout the lower Tennessee River, it appears that its densities in the study area have diminished considerably since the survey conducted by Williams (1). Physical conditions in this river reach have not changed since that survey (i.e., Kentucky Lock and Dam was operational in September 1944). It is likely that *C. fluminea* densities are now declining to equilibrium conditions as suggested earlier by Morton (18).

Turbulence, increased suspended sediments, and benthic scour caused by passage of commercial vessels entering and exiting the new lock could negatively affect freshwater mussels and their habitat (19). Results of additional study after the second lock has been completed will provide data on long-term trends in the bivalve fauna, as well as effects of construction and operation of the second lock.

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