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CO-OCCURRENCE OF NATIVE FRESHWATER MUSSELS (UNIONIDAE) AND THE NON-INDIGENOUS *CORBICULA FLUMINEA* AT TWO STABLE SHOALS IN THE OHIO RIVER, U.S.A.

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ABSTRACT

Patterns of co-occurrence between native freshwater mussels (Family: Unionidae) and the non-indigenous Asian Clam (*Corbicula fluminea*) were analyzed using 403 diver-collected total substratum samples from spatially heterogeneous, stable, gravely shoals at two locations in the Ohio River. Total mean density (individuals/0.25 sq m) of *C. fluminea* in 1989, 1990 and 1991 in the Middle Ohio River (MOR, near Cincinnati, Ohio) and for seven non-consecutive years, 1983-92, in the Lower Ohio River (LOR, near Olmsted, Illinois) was 194.2 (± 98.8 (SD)) and 156.3 (± 121.9), respectively. Total mean density of unionids was 8.7 (± 5.6) and 13.7 (± 11.5) in the MOR and LOR, respectively. In the MOR, mean biomass (g/0.25 sq m) of *C. fluminea* was about double that of the Unionidae (1460.8 *vs.* 761.2); whereas in the LOR biomass values were similar (440.9 and 439.0 for *C. fluminea* and Unionidae, respectively). For 1989-91 in the MOR, correlation coefficients relating native and non-indigenous bivalve density (0.14, 0.27 and 0.21) and biomass (– 0.11, 0.16 and 0.26) were low and not significant ($p > 0.05$). Correlation coefficients in the LOR were non-significant ($p > 0.05$) for five of seven years for density and were nonsignificant for biomass for six of seven years. For both locations, the majority of correlation coefficients for density and biomass (15 of 20) were weakly positive between native and non-indigenous bivalves. Unionids and *C. fluminea* co-occur without apparent competition at these stable shoals.

KEY WORDS: *Corbicula*, Unionidae, competition, co-occurrence.

INTRODUCTION

In a paper published seven years after *Corbicula fluminea* (Müller 1774) was first reported in the United States, Parmalee (1945) discussed nuisance aspects of this species and stated that impact of the Asian Clam on the biology of the Illinois River and related fauna "remains to be seen." Nearly 20 years later, Keup *et al.* (1963) reported that because of its rapid growth and development, *C. fluminea* could out-compete "other invertebrates for space and food." Williams (1969) suggested that *C. fluminea* could "crowd out domestic species when they become established in beds in large enough numbers." Van der Schalie (1973) described the freshwater mussels (Unionidae) of the Duck River drainage in central Tennessee and suggested that *C. fluminea* "may crowd out the native mussels where they still remain."

Concern in the United States over competition between native and non-indigenous species has increased since publication of those papers, mainly due to passage of legislation designed to ensure adequate supplies of clean water, protect endangered species, and preserve valuable wildlife habitats. A literature search on competition between native and non-indigenous mollusks yielded more than 25 papers that dealt directly or indirectly with this topic. However, careful examination of each paper, and those cited therein, revealed that most were speculative and lacked quantitative data.

Since the early 1980s, we have used divers to collect quantitative total substratum samples for mollusks at stable shoals in large rivers in the eastern United States. The purpose of this paper is to examine patterns of co-occurrence of *Corbicula fluminea* and native bivalves at two locations in the Ohio River. A rigorous examination of competition between native and non-indigenous bivalves using quantitative data is required, especially since another non-indigenous mollusk, the Zebra Mussel (*Dreissena polymorpha*), has recently been introduced into North America (Roberts, 1990). Zebra Mussels are epifaunal and not infaunal as are *C. fluminea* and native bivalves. They will attach to native unionids, thereby physically interfering with feeding and shell closure (Masteller & Schloesser, 1991). Their rapid growth rates, early maturity, and ability to attach to firm substrata and to tolerate extreme crowding indicate that *D. polymorpha* is very likely to have a profound effect on native freshwater mussels.

STUDY AREA

Data were obtained at two mussel beds in the Ohio River first reported by Williams (1969). The first bed is located along the right descending bank of the middle Ohio River (MOR) between river miles (RM) 444.2 and 445.6 immediately upriver of Cincinnati, Ohio. The second bed is along the right descending bank of the lower Ohio River (LOR) between RM 966.0 and 969.2 and upriver of Cairo, Illinois. Both shoals are spatially heterogeneous and stable, and the substratum consists of firmly packed gravelly sands with little or no evidence of recent sedimentation. Where mussels were collected, velocity at the substratum-water interface ranged between 15 and 40 cm/sec, and depths ranged from 2 to 6 m. Sites were separated by 0.5 km or more but were similar with respect to depth and water velocity. When surveys were conducted, *Dreissena polymorpha* had not been collected in the MOR. During the 1992 survey in the LOR, only two *D. polymorpha* were collected. Therefore, this non-indigenous species had no effect on either Unionidae or *Corbicula fluminea* at either location during the study period.

During most years, sites were divided into two or three subsites separated by 10 to 30 m (Table 1). For more information on mussels in the Ohio River, see Williams (1969), Williams & Schuster (1982) and Taylor (1989). For literature specific to the bed in the MOR, see Stansbery & Cooney (1985) and Miller & Payne (1993). For information specific to the mussel bed in the LOR, see Miller *et al.* (1986b), Miller & Payne (1988) and Payne & Miller (1989).

METHODS

Molluscs were collected by a dive crew equipped with surface-supplied air and communication equipment. At each site or subsite, four to ten 0.25-sq m quadrat samples, separated by 1 m, were collected (Table 1). All sand, gravel, shells and live mollusks within the quadrat were excavated by a diver to a depth of 10-15 cm. 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). Live bivalves were placed in 4-liter zipper lock bags and preserved in 10% buffered formalin. In the laboratory, each bivalve was identified and total shell length was measured to the nearest 0.1 mm using a dial caliper. In addition, total

TABLE 1. Summary information on the number of sites, subsites and quadrats collected at two gravelly shoals in the middle and lower Ohio River.

Location	No. of Sites	No. of Subsites/ Site	Total Sites or Subsites	No. of Quadrats/ Subsite or Site	Total Quadrats
Middle Ohio River					
1989	2	3	6	10	60
1990	4	0	4	10	40
1991	4	0	4	10	40
Total					140
Lower Ohio River					
1983	4	0	4	6	24
1985	1	0	1	15	15
1986	4	2	8	8	64
1986	1	0	1	4	4
1987	1	2	2	10	20
1990	1	2	2	5	10
1990	2	0	2	10	20
1991	2	1	2	10	20
1992	2	3	6	10	60
1992	1	2	2	10	20
1992	1	0	1	6	6
Total					263

blotted wet weight (total weight of the shell plus viscera) was determined with a top loading balance. If time permitted, the Unionidae were processed in the field and returned to the river unharmed. Nomenclature for the Unionidae is consistent with Williams *et al.* (1993). Voucher specimans are being held at the laboratory in Vicksburg, Mississippi, U.S.A. A second series has been deposited in the collections of the Museum of Zoology, University of Michigan.

Samples were collected in the MOR in the summer or fall of 1989, 1990 and 1991. Samples were collected in the LOR in the fall of 1983, 1985, 1986, 1987, 1990, 1991 and 1992. A total of 140 and 263 quantitative samples were taken in the MOR and LOR, respectively (Table 1).

RESULTS

Characterization of the Mollusk Community at Both Locations

In 1983 in the LOR, the Unionidae consisted mainly of *Fusconaia ebena* (I. Lea 1831) and *Truncilla donaciformis* (I. Lea 1828); each comprised 65% and 17% of the community, respectively. Six species each comprised from 1% to 3%, and the remaining species each comprised less than 1% of the community (Miller *et al.*, 1986b). In the MOR in 1989 and 1990, the Unionidae was dominated by *Pleurobema cordatum* (Rafinesque 1820) and *Quadrula pustulosa pustulosa* (I. Lea 1831); each comprised 13.6% and 26.3% of the community, respectively. Five species (*Quadrula metanevra* (Rafinesque 1820), *Amblema plicata plicata* (Say 1817), *Obliquaria reflexa* Rafinesque 1820), *Ellipsaria lineolata* (Rafinesque 1820), and *Truncilla truncata* (Rafinesque 1820)) each comprised 5.9% to 9.1% of the community. Sixteen species each made up less than 4% of the community (Miller & Payne, 1993). More than 20 species have been collected at both beds.

In 1983, the maximum shell length of *Fusconaia ebena* in the LOR was approximately 100 mm; however, 71% of the population belonged to a single cohort with a mean shell length of 15.8 mm (Payne & Miller, 1988). In the MOR, the shell length of *Quadrula pustulosa pustulosa* and *Pleurobema cordatum* ranged from approximately 10-70 mm and 25-100 mm, respectively. *Corbicula fluminea* at both locations usually consisted of two cohorts with a maximum shell length of about 35 mm.

Patterns of Co-Occurrence

Based on data collected during all study years, mean density (individuals/0.25 sq m) of *Corbicula fluminea* in the MOR and LOR was 194.2 (± 98.8 (SD) and 156.3 (± 121.9)) (Table 2). Maximum density in the LOR (657.0) was 1.6 times greater than that at the MOR (398.0). Mean density of unionids was slightly greater in the LOR (13. 7 ± 11.5) than in the MOR (8.7 ± 5.6).

TABLE 2. Summary statistics for bivalves collected at two gravelly shoals in the middle and lower Ohio River (SD = standard deviation).

	No./0.25 sq m		g/0.25 sq m	
	C. fluminea	Unionids	*C. fluminea*	Unionids
Middle Ohio River				
Min	0.0	0.0	0.0	0.0
Max	398.0	30.0	7008.4	3509.8
Mean	194.2	8.7	1460.8	761.2
SD	98.8	5.6	1321.3	597.0
n	140	140	140	140
Lower Ohio River				
Min	0.0	0.0	0.0	0.0
Max	657.0	57.0	1576.7	2837.0
Mean	156.3	13.7	440.9	439.0
SD	121.9	11.5	403.4	431.5
n	263	263	263	263

TABLE 3. Regression equations relating density or biomass of Unionidae (y) with density or biomass of *C. fluminea* (x) at two gravelly shoals in the middle and lower Ohio River.

Parameter/year	y	r	n	p
	Middle Ohio River			
Density				
1989	0.0095x + 7.75	0.14	60	> 0.05
1990	0.014x + 4.27	0.27	40	> 0.05
1991	0.045x + 3.60	0.21	40	> 0.05
Biomass				
1989	-0.215x + 1091.4	-0.11	60	> 0.05
1990	0.156x + 543.3	0.16	40	> 0.05
1991	0.082x + 502.1	0.26	40	> 0.05
	Lower Ohio River			
	y	r	n	p
Density				
1983	0.036x + 2.95	0.57	24	< 0.01
1985	0.152x + 3.15	0.45	15	> 0.05
1986	0.007x + 3.33	0.23	68	> 0.05
1987	0.014x + 15.92	0.06	20	> 0.05
1990	1.163x + 10.29	0.59	30	< 0.01
1991	-0.108x + 14.20	-0.08	20	> 0.05
1992	0.010x + 14.26	0.07	86	> 0.05
Biomass				
1983	0.074x + 67.93	0.11	24	> 0.05
1985	0.225x + 524.63	0.20	15	> 0.05
1986	-0.158x + 334.30	-0.22	68	> 0.05
1987	0.733x + 233.36	0.29	20	> 0.05
1990	-12.849x + 1131.55	-0.23	30	> 0.05
1991	-103.404x + 844.45	-0.46	20	< 0.05
1992	0.343x + 220.21	0.16	86	> 0.05

Mean density of *Corbicula fluminea* was 22.3 and 11.4 times greater than total density of the Unionidae in the MOR and LOR (Table 2).

Mean total biomass (g/0.25 sq m) of *Corbicula fluminea* was 1460.8 (± 1321.3) and 440.9 (± 403.4) in the MOR and LOR, respectively. In the MOR, the mean biomass of *C. fluminea* was about double that of the Unionidae (761.2 ± 597.0). In the LOR, the total mean biomass of *C. fluminea* was similar to that of the Unionidae (439.0 ± 431.5).

The total number and biomass of native *versus* non-indigenous bivalves were compared in each of 140 quadrats collected in the MOR in 1989, 1990 and 1991 (Table 3). For each year, correlation coefficients relating native and non-indigenous bivalve density (0.14, 0.27 and 0.21) and biomass (– 0.11, 0.16 and 0.26) were non-significant ($p > 0.05$). Although relationships were weak, five of six were positive.

The total number and biomass of native and non-indigenous bivalves were compared in each of 263 quadrats collected in seven non-consecutive years from 1983-92 at multiple sites in the LOR (Table 3). In the LOR, correlation coefficients for density ranged from –0.08 to 0.57; five of seven were not significant ($p > 0.05$). Correlation coefficients for total biomass ranged from –0.46 to 0.29; six of seven were not significant. Ten of 14 correlation coefficients were positive.

These data illustrate that notable negative relationships do not exist between *Corbicula fluminea* and Unionidae at these two locations in the Ohio River (Fig. 1). The majority of relationships were positive (although not necessarily significant), which suggests that conditions suitable for *C. fluminea* may have favored native mussels. There is no evidence that the Unionidae are

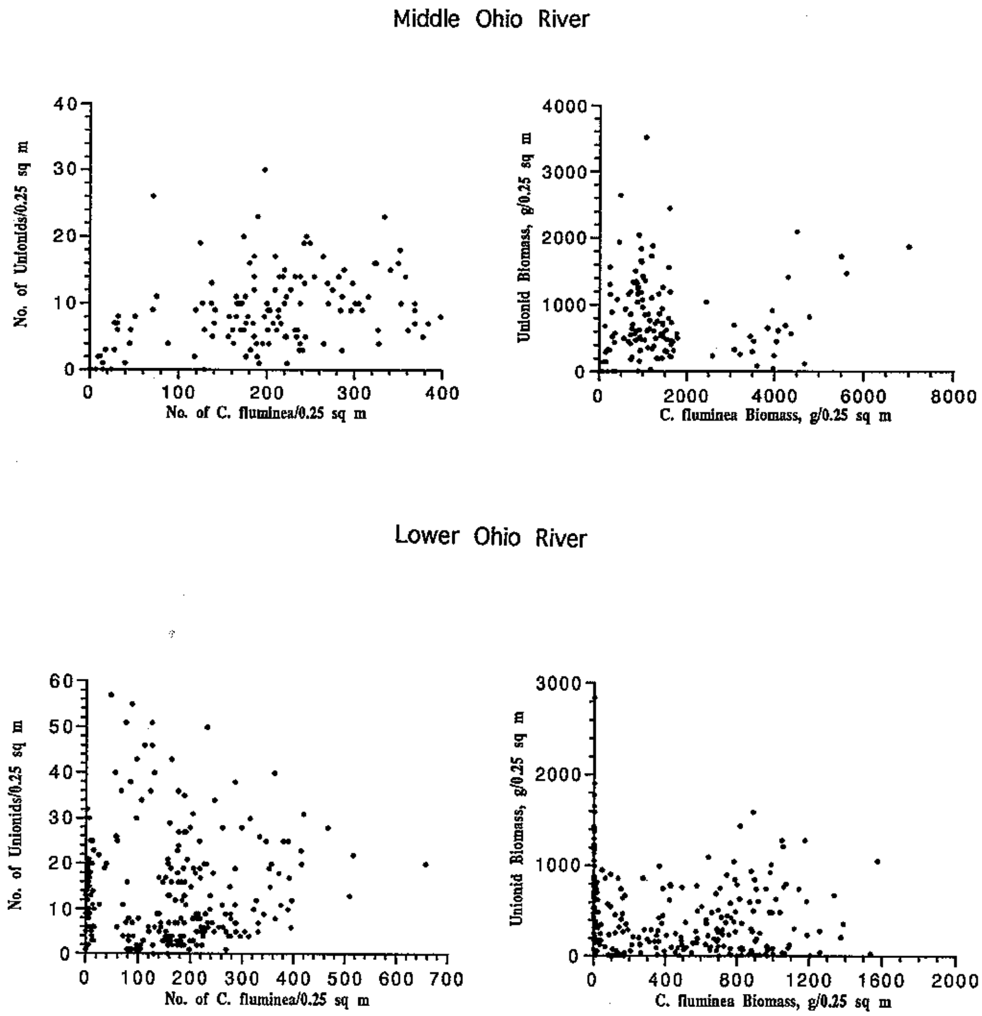

FIG. 1. Mean density and biomass for three consecutive years (1989-1991) in the middle Ohio River, and for seven non-consecutive years (1983-1992) in the lower Ohio River.

being excluded from these shoals where dense populations of *C. fluminea* occur. It is especially notable that negative effects of *C. fluminea* were not found, although Asian Clams dominated native species in numbers at both locations and in biomass in the MOR.

DISCUSSION

Clarke (1988) reviewed papers on sympatry of unionids and *Corbicula fluminea* in the Ohio-Mississippi and Coastal Atlantic drainages. In the former area, species-rich unionid assemblages were found at sites that also supported at least moderate densities of *C. fluminea*; *i.e.*, there appeared to be no evidence of competition. Most papers (Taylor, 1980; Taylor & Hughart, 1981; Cooper, 1984; Hartfield & Rummel, 1985; Miller & Harris, 1987) did not contain quantitative data. However, papers cited by Clarke that included quantitative data (specifically Starnes & Bogan, 1982; Miller *et al.*, 1986a, 1986b) were not taken from studies specifically designed to analyze relationships between Unionidae and *C. fluminea*. Clarke (1988) concluded that field data from the Ohio-Mississippi drainage did not provide evidence of a positive or negative relationship between native and non-indigenous bivalves.

Clarke (1988) contrasted results from the Ohio-Mississippi drainage with similar studies conducted in the Atlantic Coastal drainage. Clarke & Neves (1984) reported that the disappearance of *Canthyria collina* in the James River coincided with the invasion and spread of *Corbicula fluminea*. However, the authors acknowledged that dam construction and pollution from a sewage treatment, wood treatment, and a chemical plant were other possible explanations.

A study conducted by Gardner *et al.* (1976) in the Altamaha River, Georgia suggested that there was evidence of competition between native and non-indigenous bivalves. Gardner *et al.* (1976) described density and distribution of *Corbicula fluminea* and "bivalves other than *Corbicula*" that were "mainly Sphaeriidae, but included some Unionidae: *Lampsilis dolabraeformis* Lea, *Canthyria spinosa* Lea and *Elliptio hopetonensis* Lea." They collected five to 10 samples four or five times a year at four stations between October 1971 and October 1975. Sediments were collected with a Petersen dredge (0.025 sq m) and were washed through a screen series with the smallest aperture of 2.00 mm. Density of *C. fluminea* increased from 0/sq m in 1971 to a maximum of 10,000/sq m in 1974. This was accompanied by a decrease in other bivalves (Sphaeriidae and some Unionidae) from 200/sq m to 0/sq m by mid 1974. Gardner *et al.* (1976) suggested that *C. fluminea*, with densities as high as 710/sq m, had replaced Unionidae in sloughs and sandbars. Earlier, Sickel (1969) had reported Unionid densities of 16 individuals/sq m on these sand bars.

As a possible explanation for the inverse relationship between native and non-indigenous bivalves, Gardner *et al.* (1976) listed morphological characteristics that provided Asian Clams with a competitive advantage over the Unionidae. These workers could not quantitatively explain cause and effect except to state that inverse relationships could be due to "some form of competition." They admitted that internal variability at study locations during the fall of 1972 and winter and spring of 1973 could have been caused by "sampling bias as a result of clumped distribution." Sickel (1986) reviewed the paper by Gardner *et al.* (1976) and suggested that deteriorating water quality and over-harvesting could have contributed to decline of unionids in the Altamaha River.

Gardner *et al.* (1976) can be commended for providing quantitative data on the introduction and spread of *Corbicula fluminea* in the Altamaha River. However, their paper would be more useful if the Sphaeriidae and the Unionidae had been analyzed separately. An unknown percentage of the density decline by native bivalves was attributable to Sphaeriidae. Rapid fluctuations in density of short-lived Sphaeriidae are much more likely than for the longer lived Unionidae; these two dissimilar faunal elements should not have been lumped for analysis.

Gardner *et al.* (1976) suggested that *Corbicula fluminea* is more tolerant of adverse conditions of habitat than the Unionidae and cited several papers in support of this hypothesis. Actually, *C. fluminea* is less tolerant of reduced water temperatures than unionids. Horning & Keup (1964) describe extensive mortality of Asian Clams (but presumably not unionids) in the Ohio River near Cincinnati due to an extremely cold winter (also see McMahon, 1983). We have found that under laboratory conditions, *C. fluminea* is much more susceptible to suspended sediments than unionids. With respect to reduced temperatures and elevated suspended sediments, the Unionidae have an advantage over *C. fluminea*.

Sickel (1973) described results of a survey for bivalves in the Flint River in Georgia. He reported that "where the *Corbicula* were most dense there were no unionids, even though the habitat appeared suitable. This indicates some form of competition ... ," Sickel (1973) did not quantitatively examine patterns of co-occurrence of unionids and *C. fluminea*, but rather described qualitative observations made while collecting. Regardless, the statement by Sickel (1973) was later quoted and discussed by Gardner *et al.* (1976) as one of several possible explanations for the decline of unionids in the Altamaha River.

The objective of studies described in the earlier cited papers (Parmalee, 1945; Keup *et al.*; 1963; van der Schalie, 1973) as well as Sickel (1973, 1986) was to report on local bivalve distribution. The discussion of interaction between *Corbicula fluminea* and native bivalves was brief and not the major intent of the studies. One should not be overly critical of papers in which possible effects of *C. fluminea* on native fauna are discussed. However, citing these papers as evidence of anything but a possible relationship is not warranted.

Results of previously conducted surveys have not always indicated competition between *Corbicula fluminea* and native bivalves. In a study of the Chesapeake Bay drainage of the Delmarva Peninsula, Handwerker *et al.* (1990) concluded that "it does not seem likely that the demise of native species will be directly attributable to the Asian Clam." In a survey of the main channel of the Black Warrior and Tombigbee rivers in western Alabama, Williams *et al.* (1992) reported that densities of Asian Clams were low and did not appear to be negatively affecting native bivalves.

Fuller & Imlay (1976) discussed competition between *Corbicula fluminea* and unionids in a disturbed and an adjacent undisturbed river reach. They reported "dead mussel shells and abundant living *Corbicula* below the confluence of the Waccamaw River with the Intracoastal Waterway (Horry County, northeastern South Carolina) where the river is profoundly altered by human activities." Above the confluence, where the river was little disturbed, unionids dominated *C. fluminea*. The authors concluded that *C. fluminea* did not dominate indigenous bivalves in natural habitats, at least in the type of situation they described. Fuller & Imlay (1976) suggested that leaving habitats undisturbed "may be man's best defense against domination of the benthos by *Corbicula*."

Fuller & Imlay (1976) did not present enough information to allow for a detailed analysis of their findings. Densities and size demography of Unionidae and *Corbicula fluminea* would be needed, preferably for more than a single year. Their conclusions certainly do not apply to the shoals in the Ohio River we studied that are little affected by pollution, sedimentation, or dredging, yet are still dominated by *C. fluminea*.

Fuller & Richardson (1977) reported that *Corbicula fluminea* had physically displaced or uprooted native mussels in the undisturbed South Savannah River, Georgia. The authors contrasted this observation with an earlier observation (Fuller & Imlay 1976) that *C. fluminea* competed with unionids successfully in disturbed habitats. In the South Savannah River, Fuller & Richardson (1977) observed "unusually large numbers of uprooted mussels and often found a unionid, about to be dislodged, surrounded by these clams." Fuller & Richardson (1977) cited Gardner *et al.* (1976) and suggested that physical displacement of unionids by *C. fluminea* could be an explanation. Fuller & Richardson (1977) did not provide quantitative information indicating that a significant number of native mussels had been dislodged by *C. fluminea* in the undisturbed habitat.

Kraemer (1979) reported that *Corbicula fluminea* was "prominent" on the bottom of the highly managed (dredged) Arkansas River Navigation System. In the comparatively un-managed Buffalo River, *C. fluminea* was "not nearly as conspicuous a part of the benthos." She suggested that this species has certain morphological, reproductive and trophic advantages over the Unionidae. Some of the advantages that she cited (two spawning periods per year, ability to reach sexual maturity within a year, no requirement for host fishes, and high growth rates) enable *C. fluminea* to rapidly and successfully colonize previously disturbed habitats. Asian Clams are adapted to opportunistic colonization of regularly disturbed habitats; however, these attributes are not inappropriate in undisturbed habitats. These characteristics are responsible for *C. fluminea* rapidly achieving high densities in new habitats (Ingram *et al.*, 1964; Bickel, 1966; Morton, 1979). The slower growing Unionidae, which require host fishes for recruitment and dispersal, cannot rapidly colonize new habitats.

Habitats that are disturbed every one to two years by dredging, nutrients and other chemicals, or erosive action of high discharge, could support moderate to high densities of *Corbicula fluminea* (especially small, young individuals) during certain periods. Permanent populations of unionids, most of which are much longer-lived than *C. fluminea*, cannot develop in areas that are regularly disturbed. It is unreasonable to assume that *C. fluminea* preferentially seeks out disturbed habitats. Our data indicate that in large rivers, unionids and *C. fluminea* inhabit similar areas. Frequent disturbance would eliminate unionids but not necessarily Asian Clams.

An appropriate example of competition between native and non-indigenous mollusks was presented by Harman (1968a, 1968b). Abundances of the European prosobranch *Bithynia* *tentaculata* and native pleurocerid snails were approximately equal when adequate periphyton was available for grazing. However, *B. tentaculata* also filters suspended material from the water column (Tashiro & Colman 1982). Therefore, in eutrophic conditions the ability to filter-feed provided a competitive advantage for non-indigenous species. Although this is compelling evidence in favor of habitat conditions differentially affecting the ability of two groups to coexist, it has little relevance to competition between unionids and *Corbicula fluminea* in large rivers.

Boozer & Mirkes (1979) reported that the ability of the fingernail clam (*Musculium partumeium*) to bysally attach to the wall of a sedimentation basin provided it with a competitive advantage over *Corbicula fluminea*. The presence of a byssus and the larger size of *M. partumeium* at settlement (1.3 mm as compared with 0.22 mm for *C. fluminea* when released) enabled fingernail clams to use the vertical surface of the wall that was largely unavailable to Asian Clams. The situation discussed by Boozer & Mirkes (1979) has little relevance to native clams and *C. fluminea* that are both infaunal. Stone *et al.* (1982) reported that thick- and thin-shelled sympatric unionid species successfully colonized sites with slightly different substrata.

Neves (1987) suggested that competition with Asian Clams could be one of several factors causing unexplained recent mortalities of unionids. He cited Gardner *et al.* (1976), Fuller & Richardson (1977) and Sickel (1986) in support of this hypothesis, although close inspection of those papers has revealed little quantitative information. Neves (1987) also cited Cohen *et al.* (1984), who reported that resident Asiatic Clams could filter a volume of water equivalent to that in a 6-km reach of the Potomac River in 3 to 4 days. It has been suggested that competition between these two groups is not exclusively spatial (Sickel, 1973); presumably large numbers of *C. fluminea* could stress unionid populations by reducing particulate food (Clarke, 1988; Neves, 1987) or sperm (Clarke, 1988).

Leff *et al.* (1990) studied *Elliptio complanata* and *Corbicula fluminea* in a backwater tributary of the Savannah River, South Carolina, U.S.A. They estimated that *C. fluminea* caused only localized reduction in seston. Low levels of seston could exclude bivalves and are certainly responsible for their decreased numbers in lower order streams. However, most large rivers where unionids are common, such as the Ohio River, have such a large volume of well-mixed water that it is very unlikely seston concentrations could be locally affected by filter-feeders. Leff *et al.* (1990) reported that the correlation between *C. fluminea* and *E. complanata* in two transects where quantitative samples were collected was 0.091 and 0.223 ($p > 0.05$).

Bivalve populations at these two shoals in the Ohio River were unaffected by dredging, cold temperatures or aerial exposure. Our data, which include 403 0.25-sq m samples collected for multiple years, show no evidence of competition between native and non-indigenous bivalves. Under most conditions, there was a slight positive relationship; conditions suitable for Unionidae also favored *Corbicula fluminea*. We have found no evidence of competition between the Unionidae and *C. fluminea* at two stable gravelly shoals in the Ohio River. The majority of papers that discussed competition between native and non-indigenous bivalves lack quantitative data on density or size demography and are speculative. The only authors who collected quantitative data that allowed for hypothesis testing (Leff *et al.*, 1990) concluded that there were no relationships between native mussels and *C. fluminea*. None of the previously cited papers described results of a long-term ecological study, considered necessary for identifying and resolving environmental issues (Franklin, 1987).

In 1988, an exotic bivalve from Europe, *Dreissena polymorpha*, was first collected in Lake St. Clair, Michigan (Hebert *et al.*, 1989). Because this species is epifaunal, it can attach to unionids and thereby physically interfere with feeding and shell closure (Masteller & Schloesser, 1991), as well as limiting colonizable substrata (Lewandowski, 1976; Yount, 1990). *Corbicula fluminea* and unionids are infaunal and can co-exist in the substratum. Because of its epifaunal mode of existence, the negative effects of *D. polymorpha* on infaunal bivalves (*C. fluminea* and Unionidae) will be clearly evident.

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