Field and Laboratory Determination of Substrate Preferences of Unionid Mussels[1]

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ABSTRACT. Substrate preferences were investigated in the field and in the laboratory for *Anodonta grandis* spp., *Lampsilis radiata radiata, L. radiata luteola,* and *Elliptio dilatata*. Habitat substrate type, water depth, and current velocity were measured either for individual mussels or for 1-m^2 plots by SCUBA or snorkeling. In the laboratory, individual mussels were presented with a choice of sand or gravel substrates in a 0.6×1.8 m tank with overhead lighting. *Elliptio dilatata,* which was found only in the Indian River, Michigan occurred in greatest density in 2.5-cm gravel bottoms with current velocities of 0.40 to 0.54 mps. This species displayed no substrate preference in laboratory tests. *Lampsilis radiata radiata* from Fish Lake, Michigan, showed a preference for sand bottom in shallow water in the field and sand in the laboratory; Indian River specimens were most abundant in sand and fine gravel in the field and showed no substrate preference in the laboratory. *Lampsilis radiata luteola* showed no substrate preference in the Cuyahoga River, Ohio, but chose sand more frequently in laboratory tests. *Anodonta grandis* spp. was most abundant in deep water (5.3 m), mud bottoms in Fish Lake and in fine sediments (mud or sand) in the Cuyahoga River. Bottoms of thick (>1 m) mud in shallow water were occupied only by *A. grandis* spp. in Fish Lake; lake and river *A. grandis* spp. preferred sand in laboratory tests. Results indicate that water velocity was a more important habitat requirement than substrate for *E. dilatata,* whereas *A. grandis* spp. had a clear preference for finer substrates, even in quiet water. *Lampsilis radiata radiata* and *L. radiata luteola* were broad in habitat tolerances but avoided deep, soft mud.

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INTRODUCTION

The literature concerning unionid mussels abounds with references to habitat preferences of individual species (Baker 1928). Much of this information was collected by fisheries surveys in the late 1800s and early 1900s. Recent habitat information has been derived by increasingly modern sampling and analysis techniques (Negus 1966, Fuller 1974, Burky 1983, Strayer 1981, Tevesz et al. 1985), but methodology and conclusions vary. Little, if any, experimental determination of habitat requirements has been performed. As a result, our understanding of niche overlap among different unionid species for simple tolerances such as water velocity, substrate composition, and water depth is poor (Strayer 1981). Determination of the habitat preferences of fluvial unionids poses particular problems because the habitat of a given individual at any time may result from a combination of factors, including current velocity and its resultant sorting activity, water depth, available substrate types, and recent changes in fluvial dynamics.

Many hours of collecting unionids by snorkeling and observing them *in situ* indicated that methods were needed to separate the factors of current speed and bottom type and to determine whether an individual unionid is able to actively choose one substrate over another. The present study was designed to provide such information from experimental and field investigations of habitat preferences for *Anodonta grandis* spp., *Lampsilis radiata luteola, L. radiata radiata,* and *Elliptio dilatata.*

METHODS AND MATERIALS

STUDY AREAS. The Cuyahoga River was sampled from the State Rt. 82 bridge (Portage County, Ohio) to the Camp Hi Canoe Livery, 3 km upstream. The Indian River in the Michigan Upper Peninsula was examined 50 m upstream and downstream from the U.S. Forest Service Highway 13 bridge (Alger County); Fish Lake was accessed from a public boat ramp on the north shore. All sampling was conducted either by snorkeling or SCUBA.

FLUVIAL SAMPLING. A portable equipment carrier was constructed from an automobile inner tube secured to an aluminum snow

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disk fitted with mounting brackets for a pygmy current meter (Teledyne-Gurley) and other equipment. Headphones of the current meter were replaced with a waterproof signal device which could be heard underwater. An anchor kept the work platform from drifting while samples were taken.

Two approaches were used for fluvial sampling. In the Indian River, where mussel density was moderate, a metal, 1-m^2 frame was used for quadrat sampling. After placing and securing the frame, the enclosed bottom area was worked by hand to a depth of about 8 cm to expose mussels present. Visibility was maintained by working upstream from the downstream side of the sampling frame. Numbers, species, and shell lengths of all unionids, as well as water depth, current velocity, and bottom composition were recorded for each 1-m^2 quadrat examined. Because mussels in the Cuyahoga River were widely dispersed, data were collected only for individual mussels which were located by slowly snorkeling upstream through all possible habitats. Species identification, shell length, associated bottom type, current velocity, and water depth were recorded for each mussel seen. Equal time (200 min) was spent examining areas of low($<$0.01 mps), moderate ($>$0.01-0.2 mps), and fast ($>$0.2 mps) current velocities.

FISH LAKE SAMPLING. Three areas with different habitat characteristics were sampled: sandy bottom at depth of 0.8 m; mud bottom ($\geq$1 m in thickness) at depth of 0.8 m; and mud (3.8 cm in thickness) over muddy sand bottom at depth of 5.3 m. Belt transects were established in each of these areas by securing a 30-m guide rope on the bottom; sampling was accomplished by moving a 1-m^2 metal frame along this guide rope. The deep transect was examined by SCUBA.

Representative mussel specimens were identified by Dr. David Stansbery of The Ohio State University Museum of Zoology, where voucher specimens were deposited. Living mussels were returned to their habitats by implanting them into the bottom.

EXPERIMENTAL SUBSTRATE PREFERENCE DETERMINATION. A procedure used by Meier-Brook (1969) to evaluate substrate preferences of *Pisidium* was modified for use with unionids. The bottom of a tank (1.0 m long × 0.53 m wide × 0.30 m high) was covered with 8 to 10 cm of sand or gravel substrates (Fig. 1). Gravel was obtained from a nearby creek and sorted with screens to sizes ranging from 1.5 to 2.5 cm in diameter. Fine sand was washed with tap water several times and sifted through a 1.5-mm mesh before use. Spring water was added to a depth of 15 cm over the substrates and heavily aerated except during experimental runs, when water currents were not desired. The interface of sand and gravel was prepared by carefully separating the two substrates with glass plates which were removed before each experiment on substrate choice. Diffused lighting was situated directly over the experimental tank. Mussels were used within 24 h of field collection.

Substrate preferences were determined by placing mussels about 15 cm apart in the substrate interface (Fig. 1) and by recording the substrate that each mussel moved to. After 3 h, mussels were removed, the water was heavily aerated, the substrate interface was renewed, and the mussels were replaced. Mussels used in repetitive trials were reoriented in the substrate interface in the opposite direction as the previous run to avoid left or right-turning preferences being interpreted as substrate choices. Chi-square (X^2) analysis using two-tailed test P-values was used to analyze the data on substrate preferences.

RESULTS

Anodonta grandis grandis Say 1829, *Lampsilis radiata luteola* Lamarck 1819, *Ligumia masuta* Say 1817, *Lasmigona complanata* Barnes 1823, *Lasmigona costata* Rafinesque 1820, *Lasmigona compressa* Lea 1829, and *Strophitus undulatus undulatus* Say 1817 were collected in the Cuyahoga River. Only the first two species were common enough to provide meaningful data. *Lampsilis radiata luteola* was found in all substrates examined and showed no preference (fine vs. coarse: $X^2 = 1.80$, 1 df, $P < 0.20$; Table 1) for any one, although more individuals were found in sandy gravel and clean gravel than in finer sediments of mud, muddy sand, or clean sand. *Anodonta grandis grandis* was most abundant in finer substrates (fine vs. coarse: $X^2 = 42.37$, 1 df, $P < 0.001$; Table 1) and was significantly different in bottom-type preference from *L. radiata luteola* ($X^2 = 24.5$, 1 df, $P < 0.001$; Table 1).

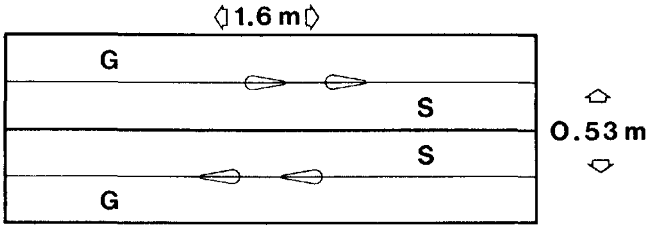

FIGURE 1. Substrate choice tank as viewed from above. Mussels were placed on the sand (S) and gravel (G) interface as shown.

Of the five mussel species (*Elliptio dilatata* Rafinesque 1820, *Lampsilis radiata radiata* Gmelin 1791, *Anodonta cataracta marginata* Say 1817, *Anodontoides ferrusacianus* Lea 1834, and *Strophitus undulatus undulatus*) found in the Indian River, only *L. radiata radiata* and *E. dilatata* were sufficiently common for use in the present study. Data for these species are given in Table 2. *Elliptio dilatata* was not found in sand, but increased in frequency with greater substrate coarseness and current velocity. *Lampsilis radiata radiata* was observed in all substrates sampled, but was absent from areas of fast ($>$0.48 mps) current.

Lampsilis radiata radiata and *A. grandis* spp. were the only common mussels in Fish Lake, with *L. costata* and *Villosa iris iris* Lea 1829 being rare (Table 3). *Lampsilis radiata radiata* was most common in shallow water with sand bottom and was absent from shallow water with

TABLE 1

Numbers of Anodonta grandis grandis and Lampsilis radiata luteola collected from various substrates in the Cuyahoga River, Ohio.

Substrate types	Mean current (mps)	*Anodonta grandis grandis*	*Lampsilis radiata luteola*
Fine			
Mud	0.01	37	3
Sandy mud	0.08	17	3
Sand	0.09	11	1
Coarse			
Sandy gravel	0.16	8	4
Gravel	0.27	1	9

TABLE 2

Numbers and densities of Lampsilis radiata radiata and Elliptio dilatata collected from various substrates in the Indian River, Michigan.

Substrate type	Area sampled, (m^2)	Mean current velocity (mps)	*Lampsilis radiata radiata*			*Elliptio dilatata*		
			N	No./m^2	X^2	*N*	No./m^2	X^2
Sand	14	0.13	3	0.2	3.5	0	0	31.8
Sandy gravel	25	0.22	20	0.5	1.6	50	2.0	0.8
Gravel	9	0.47	6	0.7	0.06	59	6.6	72.8
					5.16*			104.6*

*Critical value of X^2 for 3 df at $P = 0.001$ is 16.27.

TABLE 3

Anodonta grandis spp. and Lampsilis radiata radiata collected from various substrates in Fish Lake, Michigan.

Substrate type	Water depth (m)	*Anodonta grandis* spp. N	No./m^2	*Lampsilis radiata radiata* N	No./m^2
Sand**	0.8	4	0.13	317	10.6
Deep mud*	0.8	4	0.04	0	0
Mud on sand**	5.3	10	0.33	6	0.2

*90 m^2 of this substrate were sampled because of mussel sparsity; 30 m^2 of other substrates listed were sampled.

**X^2 = 143.6 (1 df, $P < 0.001$) for difference in distribution of *A. grandis* spp. and *L. radiata radiata* between shallow water sand and mud on sand bottoms in deep water.

deep mud substrate. In contrast, *A. grandis* spp. occurred at low frequency in all areas sampled. They were more common in mud substrates, and were the only mussels present in shallow water with a bottom of deep mud.

In the laboratory, *Anodonta grandis* from the Cuyahoga River and Fish Lake showed a significant ($P < 0.001$) preference for sand (Table 4). *Lampsilis radiata luteola* from the Cuyahoga River showed a significant preference for sand ($P < 0.01$), whereas Indian River *L. radiata radiata* showed no substrate preference. *Lampsilis radiata radiata* from Fish Lake preferred sand ($P < 0.001$); *Elliptio dilatata* showed no preference.

DISCUSSION

Mussels in the three ecosystems examined showed varying microhabitat specificity. Although *L. radiata luteola* and *A. grandis grandis* were often found in the same microhabitats in the Cuyahoga River, *A. grandis grandis* preferred finer substrates and was more commonly associated with such substrates.

Although *L. radiata luteola* displayed a slight preference for sand in the laboratory, its distribution in the field indicates that this species has broad habitat tolerances. Substrate preferences also influence distribution of *L. radiata luteola* and *A. grandis grandis* populations along the length of the Cuyahoga River. During a recent study of unionid distribution in the Upper Cuyahoga River (M. K. Huehner, unpublished data), *L. radiata luteola* was absent from the slow water and mud bottom of the northern portion of the river, but was common downstream, where current speed and substrate coarseness increased. *Anodonta grandis grandis* was, however, the dominant species in the northern, slow water areas of the river. Similar findings were reported by Tevesz et al. (1985) for *A. grandis grandis* and *L. radiata luteola* in the Vermillion River, Ohio.

TABLE 4

Unionid substrate preferences in the laboratory.

Species and Source	N	Substrate* Sand	Gravel	X^2	P
Anodonta grandis ssp.					
Cuyahoga River, Ohio	21	72	20	29.4	<0.001
Fish Lake, Michigan	31	85	11	57.0	<0.001
Lampsilis radiata luteola					
Cuyahoga River, Ohio	15	37	17	7.4	<0.01
Lampsilis radiata radiata					
Indian River, Michigan	10	24	14	2.6	<0.20
Fish Lake, Michigan	26	43	13	34.8	<0.001
Elliptio dilatata					
Indian River, Michigan	26	32	42	1.5	<0.20

*Numbers indicate the number of times each substrate was chosen during trials. N = the number of mussels that produced substrate choices during all the trials. Not every mussel moved during each trial.

Elliptio dilatata and *L. radiata radiata* showed major microhabitat differences in the Indian River. Although *E. dilatata* was more common in gravel, it did not show this preference in laboratory tests, suggesting that high water velocity was the environmental factor that this species favored.

Laboratory tests showed no difference in substrate choice between *Anodonta grandis* spp. and *L. radiata radiata* from Fish Lake. However, their natural distributions differ and indicate that the latter species was limited by excessively deep mud in shallow water and probably also by deeper water. *Anodonta grandis* has previously been noted for its ability to survive in deep water (Reigle 1967).

In the present study, *Anodonta grandis* spp. was consistent in its affinity for fine substrates in the laboratory and field for both subspecies tested, all habitats, and in widely-spaced populations. The strong association of species of *Anodonta* with mud or sand bottoms in quiet water has been documented widely (Baker 1928, Tevesz and McCall 1979).

Consistency in substrate preference did not occur for *ampsilis radiata radiata* or *L. radiata luteola*. Tevesz and McCall (1979) found *L. radiata siliquoidea* (=*luteola*) in deep mud substrates in Lake Erie. They concluded that inflated shell structure probably prevented these mussels from sinking deeply into the mud. The shells of *L. radiata luteola* from the Cuyahoga River (which flows into Lake Erie) were very thick (≤1 cm on large specimens), and were probably not as buoyant in soft mud as their Lake Erie counterparts. *Lampsilis radiata radiata* from Fish Lake showed a strong affinity for sand in both the field and laboratory, whereas individuals from the Indian River 3.4 km away showed no such specificity, further suggesting that fluvial and lacustrine ecotypes of this species occur in nature. *Lampsilis radiata radiata* and *L. radiata luteola* are apparently very broad in their habitat tolerances (Clarke 1981, Tevesz et al. 1985) and demonstrate marked behavioral and morphological plasticity from one habitat to another. The well-documented plasticity of a particular unionid species for variability of shell configuration (Baker 1928) in different habitats is probably instrumental in permitting survival in a wide range of potential environments. *Lampsilis radiata* spp. apparently possess broad fundamental niche tolerances of which only a limited understanding can be obtained by studying the realized niche characteristics of a single isolated population.

The results of the substrate choice experiments indicated that an individual mussel can change its microhabitat by moving from less to more suitable substrate conditions. Active habitat selection is most likely in systems with high substrate heterogeneity, such as small to medium-sized streams, and could be particularly important to mussels displaced downstream by temporary current surges. Roscoe and Reddings (1964) and Valentine and Stansbery (1971) indicated that mass displacement of mussel populations can occur in a matter of hours during floods in streams of moderate size. Furthermore, Matteson (1955) proposed that mussels are carried downstream during their lifetimes, with upstream recruitment occurring from infected fish. Pryor (1967) reported that larger mussel species, as well as larger individuals of a given species, were situated in coarser substrates on the upstream portions of river point bars, whereas smaller individuals occupied finer sediments in slower water downstream. Although the above reports indicate that transport and deposition by current (especially during floods) are important in distributing unionids in streams, results of the present study demonstrate that microhabitat selection by unionids may not be a passive result of sorting by current. Furthermore, substrate selection may play an important role in the movement of juvenile unionids to adult habitat.

The sometimes wide variations between intra- and inter-site substrate specificity reported for many unionids (Strayer 1981, Tevesz and McCall 1979) makes determination of a clearly preferred habitat difficult. Use of experimental substrate choice trials such as those described in this study provides an additional approach for assessing the fundamental and realized niche for these species.

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