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FACTORS INFLUENCING THE DISTRIBUTION AND ABUNDANCE OF FRESHWATER MUSSELS IN THE BARREN RIVER, KENTUCKY, WITH EMPHASIS ON THE ROLE OF HOST FISHES

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AN ABSTRACT OF A THESIS

FACTORS INFLUENCING THE DISTRIBUTION AND ABUNDANCE OF FRESHWATER MUSSELS IN THE BARREN RIVER, KENTUCKY, WITH EMPHASIS ON THE ROLE OF HOST FISHES

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Master of Science in Biology

Five 150-m-long sampling sites were established within a 5 km reach of the Barren River. Twenty-seven species of mussels were collected including the federally endangered *Pleurobema plenum*. Mussel densities range from 1.0/m^2 to 6.3/m^2 and varied significantly. Species richness was similar among sites. *Amblema plicata* most frequently utilized sand and small gravel substrate in water 40 to 100 cm deep and velocities from 5 to 15 cm/s; the other 26 species, as a group, occurred over a somewhat broader range of habitats. Differences in mussel abundance among sites may be due to habitat requirements of juvenile mussels and host fishes. Mussels were most abundant on sites with high fish abundance.

Of 2,510 fish (43 species) examined, 4.1% were infected with glochidia. Infection rates were similar (4.0% to 5.5%) among four of the five sites. Only 1.5% of fish examined from the fifth site were infected. The number of fish infected on each site was significantly correlated ($P<0.05$) with fish species richness on each site. Amblemine glochidia were present on fish from December through July due to an extended period of infections by glochidia of *Megalonaias nervosa*. Seasonality of glochidial infections by anodontines and lampsilines generally agrees with reported periods.

Glochidial infections were observed on 25 fish species (11 families). Fourteen of these species have not been identified as a host for any of the mussel species collected. Amblemine glochidia infected the most species (19); anodontine and lampsiline glochidia infected eight and four fish species, respectively. Differences in host specificity occurred among species within subfamilies. Potential new hosts were identified for five mussel species and *Pleurobema* spp.

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FOREWORD

This thesis is presented in three sections: I. Distribution and abundance of freshwater mussels among various habitats in the Barren River, Kentucky; II. Seasonal and spatial variation in glochidial infections of fish in the Barren River, Kentucky; III. Host fish utilization by freshwater mussels in the Barren River, Kentucky.

Part II

Seasonal and Spatial Variation in Glochidial Infections of Fish in the Barren River, Kentucky

Abstract. Forty-six species of fish were collected from five 150-m-long sites. Of 2,510 fish examined, 4.1% were infected with glochidia. Infection rates ranged from 1.5% to 5.5% among sites. Seasonality of glochidial infections by anodontines and lampsilines generallly agrees with reported periods. Amblemine glochidia were present on fish from December through July because of an extended period of infection by glochidia of *Megalonaias nervosa*. The number of fish infected on each site was significantly correlated with fish species richness ($P<0.05$). Mussels were most abundant on sites with high fish abundance.

Introduction

The larval stage (glochidia) of most freshwater mussels are obligate parasites of fish. Some mussel species are host specific, utilizing a single fish species; others parasitize as many as 25 fish species (Gordon and Layzer 1989). Obviously, host fish play a vital role in the lifecycle of most mussel species. However, hosts of most mussel species are unknown (Fuller 1974).

Mussel subfamilies (Amblemidae, Anodontinae, and Lampsilinae) differ in length of brooding period and timing of glochidia release. Most amblemines are short-term brooders; they spawn in spring and release glochidia in

summer. Lampsilines and anodontines are long-term brooders which spawn in late summer and hold glochidia in their marsupia over winter for release in the spring and summer. However, there is variation in these reproductive periods within subfamilies. For instance, *Megalonaias nervosa* (an amblemine) reproduces and releases glochidia in the fall (Howard 1914). Lampsiline glochidia have been found in stream drift and on fishes throughout the year (Neves and Widlak 1988).

The timing of glochidial release may be synchronized with the seasonal movements of host fish. Glochidia of *Villosa vanuxemi* are released from October to May when the species' host, the banded sculpin (*Cottus carolinae*), is most available (Zale and Neves 1982). *Villosa nebulosa* and *Lampsilis fasciola* released glochidia when their centrarchid hosts were present in the riffle habitat occupied by the mussels.

This study examines seasonal and spatial variation in glochidial infections of fish by mussel subfamilies and *M. nervosa*. The role of fish species richness in determining spatial differences in infection frequencies is examined. The ecological relationship between the mussel and fish faunas of the Barren River is also discussed.

Materials and Methods

The study area was a 5-km reach of the Barren River described in Part I. Five 150-m-long sites were established in riffle, run, and pool habitats.

Fish were collected on each site from October 1990 to September 1991 in all months except November. A variety of gear was used depending upon water levels. Experimental gill nets were 45.7 m long with six equal size panels of mesh from 1.9 to 6.4-cm bar measure. Two sizes of hoop nets were used: large nets had 91-cm-diameter hoops, a front mesh of 5.1-cm and back mesh of 3.8-cm; small nets had 51-cm-diameter hoops and 3.8-cm mesh throughout. Large nets were used in areas of sufficient depth to completely submerge the hoops. In shallower sites, the small nets were used. Both baited and unbaited sets were made and the time of each recorded. A 30.5-m-long seine with 6.4-mm mesh was used on the four shallowest sites when water levels allowed. The number of seining stations established within a study site was determined by the habitat present. A 6.1-m-long seine with 6.4-mm mesh was used on several dates when water levels prevented use of the large seine. Electrofishing was conducted with a boat-mounted DC unit. Each site was sampled by making three passes upstream. One pass was made along each bank and one in the center of each site.

Analysis of variance was used to test the hypothesis that mean catch/h electrofishing and mean catch/haul of the 30-m seine did not differ significantly among sites.

All fish collected were retained. Small individuals were fixed in 10% buffered formalin in the field and transferred to 70% ethanol (ETOH) in the laboratory. Large individuals were placed on ice and then frozen within 48 h.

Fish were examined for glochidial infections using a dissecting microscope with 10-70X magnification. Glochidia were removed with a probe and preserved in 70% ETOH. Length, height, and hinge length of each glochidium was measured to the nearest 5 μm with a compound microscope (100 X) fitted with an ocular micrometer. Valve length was the maximum anterior-posterior distance across the shell. Height was measured from the hinge to the ventral margin. Hinge length was the distance between the intersections of the hinge and the anterior and posterior shell margins. Dimensions of glochidia removed from fish were compared with those of glochidia obtained from gravid mussels and to measurements reported in the literature (Lefevre and Curtis 1912; Ortmann 1912; Surber 1912,1915; Matteson 1948; Yokley 1972; Hoggarth 1988; Waller et al. 1988; Jirka and Neves 1991; Weaver et al. 1991). Glochidia of *M. nervosa* were identified to species while others were identified to subfamily.

The relationship between fish species richness and infection frequencies was tested using Pearson's correlation coefficient.

Results

Twenty-seven species of mussels were collected from the five sites including the federally endangered *Pleurobema plenum* (see Part I). Mussel density ranged from 1.0/m^2 on sites 4 and 5 to 6.3/m^2 on site 1. Species richness was similar among sites ranging from 16 to 20 species.

A total of 6,736 fish representing 46 species, 16 families, and 11 orders was collected (Table 1). The fish fauna was dominated by catostomids (12 species), centrarchids (9 species), and cyprinids (7 species). The number of fish collected was highly variable among months due to fluctuating water levels. The steelcolor shiner (*Cyprinella whipplei*) was the most abundant fish species followed by emerald shiners (*Notropis atherinoides*), spotfin shiners (*Cyprinella spilopterus*), gizzard shad (*Dorosoma cepedianum*), brook silversides (*Labidesthes sicculus*), and bluegills (*Lepomis macrochirus*). The greatest number of fish (2,106) was collected on site 1 with the most species (33) occurring on site 3 (Table 2). Both the fewest fish collected (163) and lowest species richness (19) occurred on site 4.

Catch-per-unit-effort (CPUE) for each gear differed among sites (Table 3). Comparisons of catch among sites

were limited to fish collected by electrofishing and the 30-m seine because of low catches in other gears. No fish were collected in small hoop nets. Mean CPUE electrofishing varied significantly among sites (ANOVA; $F_{(4,69)} = 3.30$; $P=0.0157$). Mean CPUE electrofishing on site 5 was significantly lower than on other sites (Duncan's Multiple Range Test, $P<0.05$) possibly due to riffle habitat. Mean catch per haul of the 30-m seine was not significantly different among sites (ANOVA; $F_{(3,21)} = 0.21$; $P>0.80$).

Glochidial infection rates varied among months; highest incidence of glochidia infections of fish (41%) occurred in March (Figure 1). No glochidia were found on 729 fish examined in September nor on 176 fish in October. Because only five fish were collected in February, the absence of attached glochidia may not be representative.

Seasonality of glochidial infections was evident for each mussel subfamily and for *M. nervosa*. Glochidia of *M. nervosa* occurred on fish from December through May, whereas those of other amblemines were present from May through July (Figure 2). Fish infected with anodontine glochidia were collected from March through May with lampsiline infections occurring from March through August.

Overall infection rates were similar among four of the five sites and ranged from 4.0% to 5.5% (Table 2). Just 1.5% of fish examined from site five, a riffle habitat, were infected. The number of infected fish collected on each

site was significantly correlated with the number of fish species collected on each site ($r=0.90$; $P<0.04$). A positive, though not statistically significant relationship occurred between the percentage of fish infected on each site and the number of fish species collected on each site ($r=0.61$; $P>0.20$).

Discussion

Seasonality of glochidial infections by anodontines and amblemines (other than *M. nervosa*) in the Barren River was similar to other streams (Coker et al. 1921; Yokley 1972; Wiles 1975; Neves and Widlak 1988; Weaver et al. 1991). Period of infection by lampsiline glochidia agrees with other studies with the exception of Neves and Widlak (1988) who reported infections by lampsiline glochidia throughout the year. The timing and extended period of infections of fish by glochidia of *M. nervosa* is atypical of amblemines which are considered to be short-term summer brooders. In the upper Mississippi River, most female *M. nervosa* were gravid in October and no gravid specimens were collected in November (Howard 1914). Glochidia were released immediately upon maturation. In artificial propagation trials, longevity of infections by *M. nervosa* glochidia ranged from 2 to 6 months (Howard 1914). *Megalonaias nervosa* in the Barren River are following this pattern. Glochidia are likely being released in November and December based on the time when *M. nervosa* glochidia were first observed on fish.

The six month period over which infections by glochidia of *M. nervosa* occurred may be due to an extended period of attachment to the host, rather than an extended period of glochidia release.

Although spatial variation in overall infection rates was low, a significant relationship occurred between the number of fish infected and fish species richness on each site. The positive correlation between the percentage of fish infected on each site and number of fish species collected on each site suggests that fish species richness may be an important factor in determining infection frequencies. If so, maintenance of fish diversity should be a priority in the conservation and management of freshwater mussels.

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Table 1. Fish species and number collected on five sites on the Barren River from October 1990 to September 1991

Family Species		Number
Lepisosteidae		
Longnose gar	*Lepisosteus osseus*	27
Spotted gar	*L. oculatus*	2
Clupeidae		
Gizzard shad	*Dorosoma cepedianum*	803
Hiodontidae		
Mooneye	*Hiodon tergisus*	13
Esocidae		
Muskellunge	*Esox masquinongy*	2
Cyprinidae		
Common carp	*Cyprinus carpio*	3
Streamline chub	*Erimystax dissimilis*	49
Bluntnose minnow	*Pimephales notatus*	307
Spotfin shiner	*Cyprinella spilopterus*	899
Steelcolor shiner	*C. whipplei*	2,059
Emerald shiner	*Notropis atherinoides*	1,202
Rosyface shiner	*N. rubellus*	4
Catostomidae		
River carpsucker	*Carpiodes carpio*	4
Highfin carpsucker	*C. velifer*	3
Quillback	*C. cyprinus*	2
Blue sucker	*Cycleptus elongatus*	1
Spotted sucker	*Minytrema melanops*	13
Northern hog sucker	*Hypentelium nigricans*	18
Smallmouth buffalo	*Ictiobus bubalus*	3
Silver redhorse	*Moxostoma anisurum*	21
River redhorse	*M. carinatum*	19
Black redhorse	*M. duquesnei*	23
Golden redhorse	*M. erythrurum*	62
Shorthead redhorse	*M. macrolepidotum*	54
Ictaluridae		
Channel catfish	*Ictalurus punctatus*	29
Flathead catfish	*Pylodictis olivaris*	4
Brindled madtom	*Noturus miurus*	1
Cyprinodontidae		
Blackstripe topminnow	*Fundulus notatus*	1

Table 1 (continued)

Family Species		Number
Poeciliidae		
Eastern mosquitofish	*Gambusia holbrooki*	26
Atherinidae		
Brook silverside	*Labidesthes sicculus*	434
Cottidae		
Banded sculpin	*Cottus carolinae*	4
Percichthyidae		
White bass	*Morone chrysops*	1
Centrarchidae		
Rockbass	*Amblolites rupestris*	2
Warmouth	*Lepomis gulosus*	3
Bluegill	*L. macrochirus*	322
Longear sunfish	*L. megalotis*	89
Smallmouth bass	*Micropterus dolomieu*	1
Largemouth bass	*M. salmoides*	1
Spotted bass	*M. punctatus*	89
White crappie	*Pomoxis annularis*	4
Black crappie	*P. nigromaculatus*	2
Percidae		
Greenside darter	*Etheostoma blennioides*	2
Slenderhead darter	*E. phoxocephala*	1
Logperch darter	*Percina caprodes*	28
Sauger	*Stizostedion canadense*	7
Sciaenidae		
Freshwater drum	*Aplodinotus grunniens*	92

Table 2. Species richness and incidence of glochidial infections of fish collected from five sites on the Barren River from October 1990 to September 1991

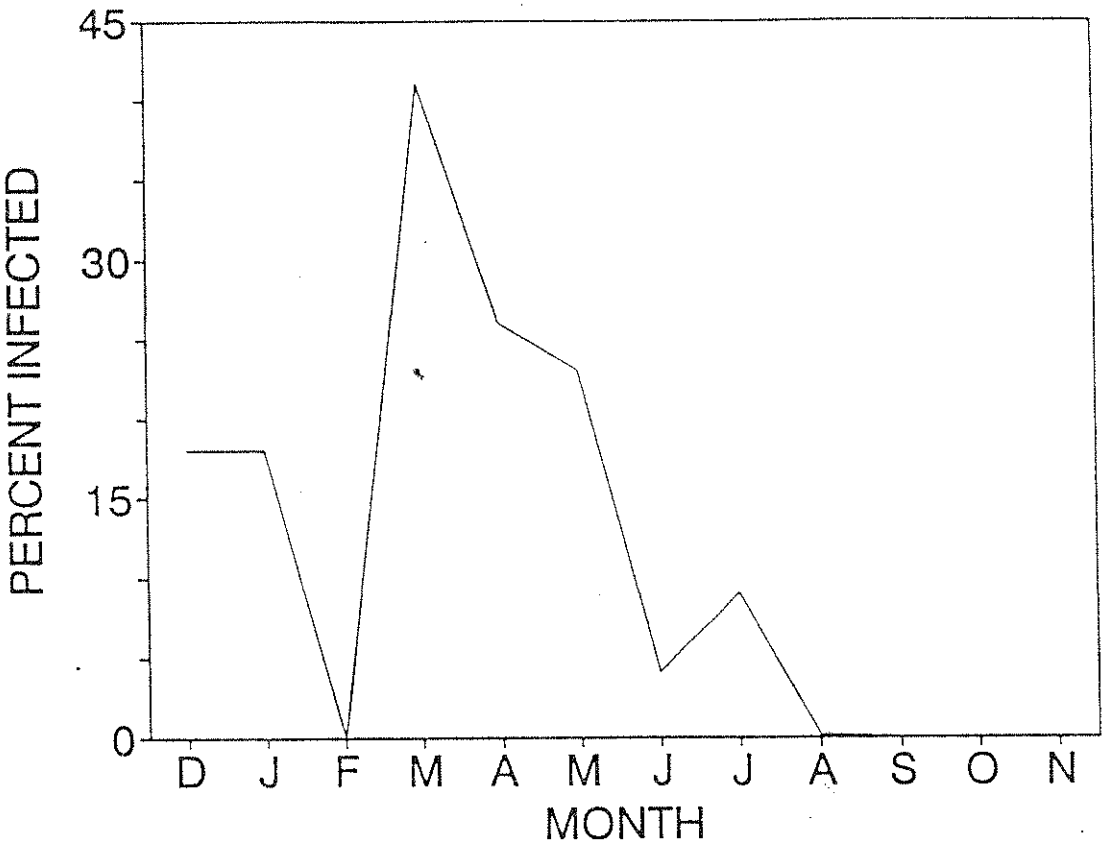
	Site				
	1	2	3	4	5
Number of Fish Collected	2,106	1,447	1,490	163	1,530
Number of Fish Species	28	32	33	19	20
Number of Fish Examined	580	570	684	111	547
Number of Fish Infected	32	23	35	4	8
Percent Infected	5.5	4.0	5.1	4.1	1.5

Table 3. Mean catch-per-unit-effort (number/seine haul or number/hour for other gears) on five sites on the Barren River from October 1990 to September 1991. Standard errors were not calculated for catch of the 6-m seine due to combined samples

	Site									
	1		2		3		4		5	
Gear	Mean Catch	SE	Mean Catch	SE	Mean Catch	SE	Mean Catch	SE	Mean Catch	SE
Electrofishing	119.1	22.3	93.0	22.5	103.3	28.0	70.3	25.9	16.3	11.4
30-m seine	230.6	139.5	156.4	56.3	198.5	85.2	-	-	308.8	240.1
6-m seine	15.3	-	105.0	-	15.4	-	-	-	23.6	-
Gill net	<1	-	<1	-	<1	-	<1	-	<1	-
Large hoop net	<1	-	<1	-	<1	-	<1	-	<1	-

FIGURE 1. Overall monthly incidence of glochidial infections of fish collected from the Barren River (October 1990 to September 1991).

FIGURE 2. Monthly incidence of infections of fish in the Barren River by glochidia of *Megalonaias nervosa*, other amblemines, anodontines, and lampsilines (October 1990 to September 1991).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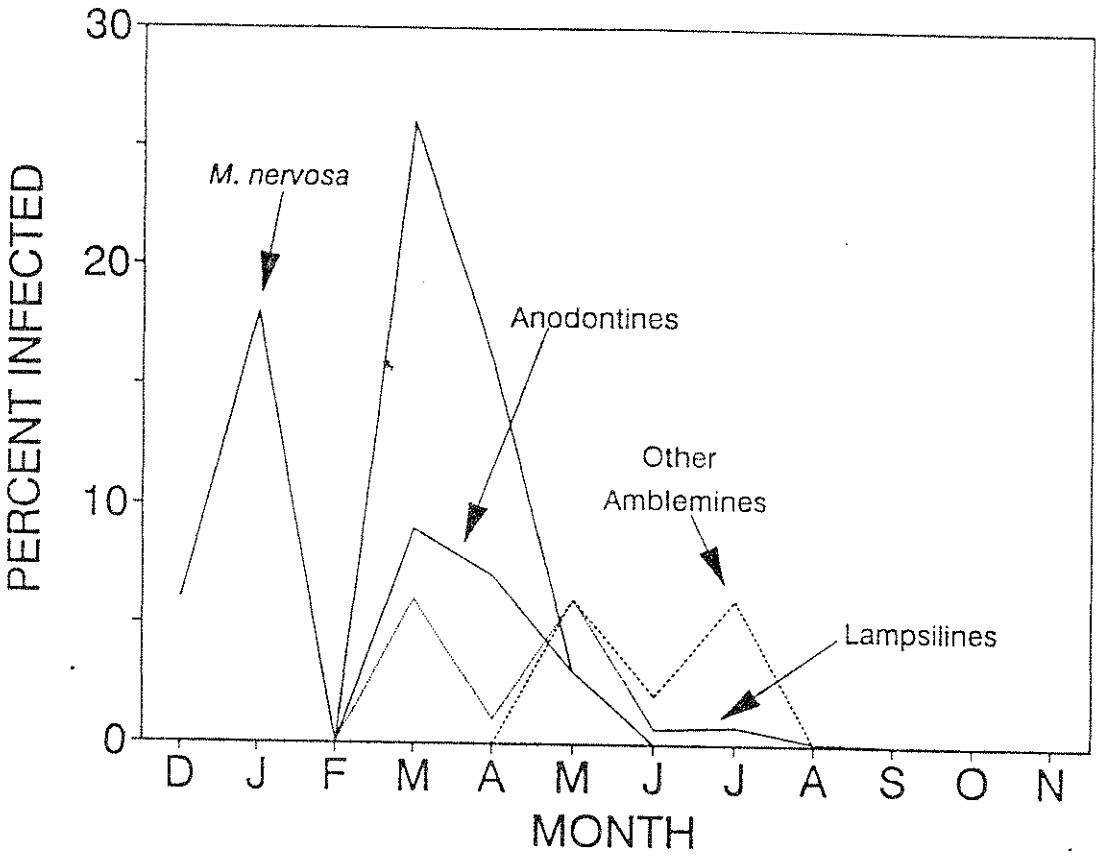
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Part III

Host Fish Utilization by Freshwater Mussels in the Barren River, Kentucky

Abstract. Of 2,510 fish examined (43 species), 4.1% were infected with glochidia. Overall, 25 fish species (11 families) were infected; 14 of these species are not known hosts of any mussel species occurring in the Barren River. Amblemine glochidia occurred on a diversity of fishes (19 species). Eight fish species were infected with anodontine glochidia while those of lampsilines utilized only five species. Differences in the degree of host specificity was evident within the amblemines. Glochidia of *Amblema plicata* occurred on 12 species of fish while those of *Quadrula pustulosa* were found only on channel catfish. Overlap in host utilization occurred between amblemines and the other subfamilies but not among anodontines and lampsilines. Potential new hosts are identified for five mussel species and *Pleurobema* spp.

Introduction

The lifecycle of most freshwater mussel species includes a parasitic larval stage (glochidia). Glochidia develop in the marsupia of female mussels after fertilization of eggs and are discharged into the water. Once free, they must attach to a suitable host or die. Glochidia of most mussel species parasitize fish. Some species are host specific, utilizing a single host; others

parasitize as many as 25 fish species (Gordon and Layzer 1989). Glochidia that contact a fish usually attach to gills or fins and become encysted in fish tissue. During encystment, glochidia digest host tissues and possibly tissue fluids until they develop into juveniles and excyst (Stein 1971). Obviously, host fish play a vital role in the lifecycle of most mussel species. However, hosts of many mussel species are unknown (Fuller 1974).

Some mussel species maximize the likelihood of glochidial attachment by attracting fish. A portion of the mantle of *Lampsilis cardium* is brightly colored and is extended and waved with the current (Coker et al. 1921). *Epioblasma capsaeformis* attracts potential hosts with a bright blue mantle flap (Hill 1986). Fish approach the mussel and attempt to feed on the waving tissue. When the fish contacts the mussel, glochidia are discharged. Glochidia of some mussel species are released in groups (conglutinates) which may resemble aquatic insects or small fish often preyed upon by larger fishes (Stein 1971; Gordon and Layzer 1989). Conglutinates may result in higher intensities of glochidial infections (Neves and Widlak 1988). Anodontine glochidia are normally released singly, and are suspended in the water column by mucous strands and left to drift into contact with a host (Stein 1971). This means of dispersal is augmented by the tremendous number of glochidia (up to 3.5 million) which can be released by a

single female (Surber 1912; Coker et al. 1921; Neves and Widlak 1988). However, the proportion of released glochidia which successfully attach to a host is very low. Of 4,800 fish examined by Neves and Widlak (1988) over a one year period, only 14% had encysted glochidia. Holland-Bartels and Kammer (1989) found glochidial infections on just 4% of 2,000 fish examined from June through August. Although not all species examined may have been hosts, these low rates of infection suggest that host abundance may play an important role in determining reproductive success.

This study examines host utilization by a diverse assemblage of freshwater mussels in the presence of a diverse fish fauna. Differences in host specificity within and among mussel subfamilies are examined. Potential new hosts are identified which require confirmation by induced infections.

Materials and Methods

Five 150-m-long sites were established in riffle, run, and pool habitats of the Barren River, Kentucky (see Part I for site descriptions). Mussel species composition was evaluated on each site in 1991 by timed diving. Two divers, either snorkeling or using SCUBA equipment, collected mussels on each site for 30 minutes. Mussels collected were identified to species and returned to the site.

Fish were collected on each site from October 1990 to September 1991 in all months except November 1990. A

variety of gear, including seines and electrofishing, was used depending upon water levels (see Part II). All fish collected were retained. Small individuals were fixed in 10% buffered formalin in the field and transferred to 70% ethanol (ETOH) in the laboratory. Large individuals were placed on ice and then frozen within 48 h.

Fish were examined for glochidial infections with a dissecting microscope at 10-70X magnification. All gill arches and fins were removed from fish greater than approximately 100 mm in length and examined individually. Smaller fish were examined whole. Glochidia were removed with a probe and preserved in 70% ETOH. The location of glochidia on each infected fish was recorded. Length, height, and hinge length of each glochidium was measured to the nearest 5 μm with a compound microscope (100 X) fitted with an ocular micrometer. Length was the maximum distance between the anterior and posterior shell margins. Height was measured from the hinge to the ventral margin. Hinge length was defined as the distance between the points where the hinge intersected with the anterior and posterior shell margins. Dimensions of glochidia removed from fish were compared with those of glochidia obtained from gravid mussels and to measurements reported in the literature (Lefevre and Curtis 1912; Ortmann 1912; Surber 1912, 1915; Matteson 1948: Yokley 1972; Hoggarth 1988; Waller et al. 1988; Jirka and Neves 1991; Weaver et al. 1991). When

possible, glochidia were identified to species or to a group of several species with similar dimensions and shapes; others were identified to subfamily.

Results

Twenty-seven species of mussels including the federally endangered *Pleurobema plenum* were collected from the study area (see Part I).

Of 2,510 fish examined (43 species), 4.1% were infected with glochidia. Overall, 25 species of fish (11 families) were infected (Table 1). Fourteen of these species have not been identified as a host for any mussel species occurring in the Barren River. Glochidia were never found on seven species which are known hosts for one or more mussel species present; however, six of these fish species were rarely collected. Highest rates of infection occurred in Percichthyidae (100%), Hiodontidae (45%), Ictaluridae (32%), Lepisosteidae (27%), and Sciaenidae (12%).

Anodontine glochidia were identified by their distinctive triangular shape. With few exceptions, anodontine glochidia were larger in all dimensions than amblemine and lampsiline glochidia (Table 2; Figures 1 through 3). Lampsiline and amblemine glochidia overlapped considerably in size of each dimension measured. Amblemine glochidia are generally more rounded than those of lampsilines with the exception of *Quadrula pustulosa*. Glochidia of *Q. pustulosa* (an amblemine) are similarly

shaped to those of *Ellipsaria lineolata* (a lampsiline). However, glochidia of *E. lineolata* are higher than those of *Q. pustulosa* allowing separation of the species.

Amblemine glochidia occurred on 19 species of fish from 10 families (Table 3). Anodontine glochidia were found on eight species of fish with lampsilines infecting just five species. Four fish species, longnose gar (*Lepisosteus osseus*), gizzard shad (*Dorosoma cepedianum*), golden redhorse (*Moxostoma erythrurum*), and flathead catfish (*Pylodictis olivaris*) were utilized by both anodontines and amblemines. Lampsilines and amblemines each infected channel catfish (*Ictalurus punctatus*) and spotted bass (*Micropterus punctatus*); however, no host fish were common to both anodontines and lampsilines. In three instances, anodontine glochidia occurred on the same individual fish (longnose gar, gizzard shad, and flathead catfish) with glochidia of *Megalonaias nervosa*. An individual golden redhorse and a sauger (*Stizostedion canadense*) were infected with anodontine glochidia and those of *Amblema plicata*. Glochidia of *A. plicata*, along with those of another amblemine, also occurred on one mooneye (*Hiodon tergisus*).

Amblemines displayed varying levels of host specificity (Table 3). Glochidia of *A. plicata* were found on 12 species and *M. nervosa* on eight fish species. In contrast, glochidia of *Q.pustulosa* occurred only on channel catfish and glochidia of *Pleurobema* spp. only on mooneye and

steelcolor shiner (*Cyprinella whipplei*). Eight known amblemine hosts were infected while 13 fish species previously not identified as hosts of amblemines occurring in the Barren River, were also infected.

Within the anodontines, glochidia of *Lasmigona complanata* and *L. costata* were separated from *Anodonta grandis* and *Arcidens confragosus* and from each other based upon dimensions. Glochidia of *L. complanata* are smaller in each dimension than those of other anodontines present. Glochidia of *L. costata* are shorter in length and taller in height than glochidia of *A. grandis* and *A. confragosus*. Glochidia of both *L. complanata* and *L. costata* occurred on gizzard shad and river redhorse (*Moxostoma carinatum*) while glochidia of *A. grandis* or *A. confragosus*, occurred on four fish species. None of the fishes infected with anodontine glochidia were known hosts of an anodontine species occurring in the Barren River.

Lampsiline glochidia were rarely found on fish. Glochidia of *Potamilus alatus* infected freshwater drum (*Aplodinotus grunniens*), a known host. Glochidia of other lampsilines occurred on just four fish species, none of which are known hosts of lampsiline species collected.

Most infected fish carried few encysted glochidia, (generally one to five); however, one freshwater drum, captured in April 1991, was infected with 232 *P. alatus*

glochidia. This was the only instance of such a high intensity of infection.

Glochidia of *M. nervosa* occurred as frequently on fins as on gills of fish, particularly in the case of longnose gar and gizzard shad. Anodontine glochidia occurred more frequently on gills (92%) than on fins while lampsiline infections were restricted to gills.

Discussion

The low prevalence of glochidial infections on centrarchids, cyprinids, and percids was unexpected. Members of these families are frequently utilized as hosts (Gordon and Layzer 1989). Host utilization by mussel subfamilies in this study differs from results of other studies. Amblemine glochidia infected a diversity of fishes. Other studies have found amblemines infecting only cyprinids (Zale and Neves 1982; Neves and Widlak 1988). However, these studies were done on smaller systems with very different mussel faunas. In this study, amblemines infected four cyprinids, but at rates of just 1% to 6%.

Fishes utilized by lampsilines also differed from other studies. Highest prevalence of infections by lampsiline glochdia (16%) occurred on channel catfish. Lampsiline glochidia did not occur on three ictalurid species examined by Neves and Widlak (1988); however, centrarchids were utilized as in this study. Differences in host utilization among systems varying in diversity and size are poorly

understood. Until more hosts are identified and mechanisms influencing host utilization are identified, no definite conclusions can be drawn.

Lack of identified hosts also hinders discussion of hypotheses concerning the role of host specificity in determining mussel distribution and abundance. The ability to survive in a wide range of habitats and utilization of many fishes as hosts, may allow a mussel species to become widely distributed and abundant. *Amblema plicata* exhibits these traits and dominates the mussel fauna of the Barren River. However, the lack of information concerning habitat requirements and host utilization for most mussel species limits conclusions concerning the role of host specificity in determining mussel distribution and abundance.

Infections of fins of gizzard shad and longnose gar by *M. nervosa* glochidia are possibly due to the feeding habits of gizzard shad (detritivore) and morphology of longnose gar (high fin surface area, small buccal cavity). The low prevalence of infections on fins by anodontine glochidia was unexpected. The hooks of anodontine glochidia are thought to be an adaptation for attachment to fins (Lefevre and Curtis 1912). However, the higher prevalence of infections on gills observed in this study and by Wiles (1975) suggests that the hooks are simply an adaptation for attachment, regardless of the location on the fish.

Catostomids, though common members of river fish

assemblages, have been relatively ignored in host studies. In this study, catostomids have been identified as potential hosts of *A. plicata, L. complanata,* and *L. costata*. Also relatively common in rivers of the southeastern United States, spotted bass (*Micropterus punctatus*) have been infrequently tested even though congeners have been identified as hosts of many mussel species. Steelcolor shiners (*Cyprinella whipplei*) and mooneyes (*Hiodon tergisus*) were identified as potential hosts of *Pleurobema* spp. Host(s) of federally endangered *P. plenum* are unknown; steelcolor shiners and mooneyes are candidates worthy of examination. For successful implementation of recovery plans, hosts of *P. plenum* and other endangered mussels must be identified.

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Table 1. Prevalence of glochidial infections of fishes collected from the Barren River from October 1990 to September 1991. Asterisks indicate fish species which are known hosts of one or more mussel species in the Barren River

Family	Species	Number Examined	Percent Infected by Subfamily		
			Amblemine	Anodontine	Lampsiline
Lepisosteidae	*Lepisosteus osseus**	29	24	3	-
	L. oculatus	2	-	-	-
Clupeidae	*Dorosoma cepedianum**	234	9	2	-
Hiodontidae	*Hiodon tergisus*	11	45	-	-
Esocidae	*Esox masquinongy*	1	-	-	-
Cyprinidae	*Pimephales notatus**	133	-	-	-
	*Cyprinus carpio**	3	-	-	-
	Notropis atherinoides	307	<1	-	-
	N. rubellus	3	-	-	-
	Cyprinella spilopterus	357	<1	-	-
	C. whipplei	453	1	-	-
	Erimystax dissimilis	46	2	-	-
Catostomidae	*Moxostoma duquesnei*	22	5	-	-
	M. erythrurum	55	5	2	-
	M. carinatum	17	-	24	-
	M. macrolepidotum	46	-	2	-
	M. anisurum	17	-	-	-
	Hypentelium nigricans	16	6	-	-
	Minytrema melanops	12	-	-	-
	Ictiobus bubalus	4	-	-	-
	Carpiodes carpio	4	-	25	-

Table 1. (continued)

Family	Species	Number Examined	Percent Infected by Subfamily		
			Amblemine	Anodontine	Lampsiline
Catostomidae (continued)	*C. cyprinus*	3	-	-	-
	*C. velifer**	2	-	-	-
Ictaluridae	*Ictalurus punctatus**	25	12	-	16
	*Pylodictis olivaris**	3	67	33	-
Cyprinodontidae	*Fundulus notatus*	1	-	-	-
Poeciliidae	*Gambusia holbrooki*	19	-	-	-
Atherinidae	*Labidesthes sicculus**	181	-	-	<1
Cottidae	*Cottus carolinae**	4	-	-	-
Percichthyidae	*Morone chrysops**	1	100	-	-
Centrarchidae	*Lepomis gulosus**	3	67	-	-
	*L. macrochirus**	148	<1	-	-
	L. megalotis	67	-	-	2
	*Ambloplites rupestris**	1	-	-	-
	*Pomoxis annularis**	4	75	-	-
	*P. nigromaculatus**	2	-	-	-
	Micropterus punctatus	66	2	-	5
	*M. salmoides**	1	-	-	-

Table 1. (continued)

Family	Species	Number Examined	Percent Infected by Subfamily		
			Amblemine	Anodontine	Lampsiline
Percidae	*Etheostoma blennioides*	1	-	-	-
	Percina caprodes	24	4	-	-
	P. phoxocephala	1	-	-	-
	*Stizostedion canadense**	5	-	20	-
Sciaenidae	*Aplodinotus grunniens**	73	12	-	-

Table 2. Dimensions of glochidia measured in this and other studies as cited (ranges are mean ± 1 SD)

Species (code)	Dimensions (μm) Length	Height	Hinge Length	Citation
Anodonta grandis (A)	350-362	352-358	250-258	(Hoggarth 1988)
	366-380	371-396	272-281	(Current Study)
Arcidens confragosus (B)	354-364	353-355	239-253	(Hoggarth 1988)
Lasmigona complanata (C)	290-296	295-309	195-208	(Hoggarth 1988)
L. costata (D)	341-347	363-375	239-243	(Hoggarth 1988)
	353-377	380-414	249-271	(Current Study)
Amblema plicata (E)	200	200	-	(Surber 1912)
	185-200	195-215	-	(Howard 1914)
Cyclonaias tuberculata (F)	348-362	288-300	127-139	(Jirka and Neves 1991)
Elliptio crassidens (G)	130	150	-	(Ortmann 1912)
	150	160	-	(Surber 1915)
Fusconaia flava (H)	150	150	-	(Ortmann 1912)
F. subrotunda (I)	130	150	-	(Ortmann 1912)

Table 2 (continued)

Species (code)	Dimensions (μm) Length	Height	Hinge Length	Citation
Megalonaias nervosa (J)	254-268	341-351	147-153	(Hoggarth 1988)
Pleurobema cordatum (K)	140	150	-	(Yokley 1972)
	160	175	-	(Surber 1915)
P. oviforme (L)	164-174	158-166	118-128	(Weaver et al. 1988)
P. sintoxia (M)	160	160	-	(Surber 1915)
Quadrula pustulosa (N)	233-245	292-303	98-106	(Current Study)
	230	300	-	(Lefevre and Curtis 1912)
Q. quadrula (O)	85	90	-	(Surber 1915)
Tritogonia verrucosa (P)	87-93	98-102	43-45	(Hoggarth 1988)
	119-125	106-112	46-52	(Jirka and Neves 1991)
Actinonaias ligamentina (Q)	245-263	221-235	123-135	(Jirka and Neves 1991)
	220	243	125	(Hoggarth 1988)
Ellipsaria lineolata (R)	232-242	316-326	87-94	(Hoggarth 1988)
	248-258	316-354	87-109	(Current study)

Table 2 (continued)

Species (code)	Dimensions (μm) Length	Height	Hinge Length	Citation
Lampsilis cardium (S)	244-254	277-289	107-115	(Hoggarth 1988)
L. ovata (T)	232	270-278	113-119	(Hoggarth 1988)
	303-315	257-271	117-125	(Jirka and Neves 1991)
Leptodea fragilis (U)	71-73	80-82	30-36	(Hoggarth 1988)
Ligumia recta (V)	205-217	257-263	106-112	(Hoggarth 1988)
Obliquaria reflexa (W)	214-220	213-223	118-126	(Hoggarth 1988)
Potamilus alatus (X)	213-225	370-386	96-108	(Hoggarth 1988)
Ptychobranchus fasciolaris (Y)	170-176	180-194	78-88	(Hoggarth 1988)
Truncilla truncata (Z)	60	70	-	(Surber 1912)

Table 3. Fish species utilization and rates of infection by mussel species and subfamilies in the Barren River from October 1990 to September 1991. Asterisks indicate known hosts

Mussel species or subfamily	Fish Species	Number Examined	Percent Infected
Anodontines			
Lasmigona complanata	Longnose gar	29	3
	Gizzard shad	234	<1
	River redhorse	17	18
	Sauger	5	20
L. costata	Gizzard shad	234	<1
	River redhorse	17	6
Other	Golden redhorse	55	2
	Shorthead redhorse	46	2
	River carpsucker	4	25
	Flathead catfish	3	33
Amblemines			
Megalonaias nervosa	Longnose gar	29	24
	Gizzard shad*	234	6
	Flathead catfish*	3	67
	White bass*	1	100
	Warmouth	3	67
	White crappie*	4	75
	Spotted bass	66	2
	Freshwater drum*	73	1
Amblema plicata	Mooneye	11	36
	Emerald shiner	307	<1
	Spotfin shiner	357	<1
	Steelcolor shiner	453	<1
	Streamline chub	46	2
	Black redhorse	22	5
	Golden redhorse	55	5
	Northern hog sucker	16	6
	Channel catfish*	25	4
	Bluegill*	148	<1
	Logperch	24	4
	Freshwater drum	73	10
Quadrula pustulosa	Channel catfish*	25	8

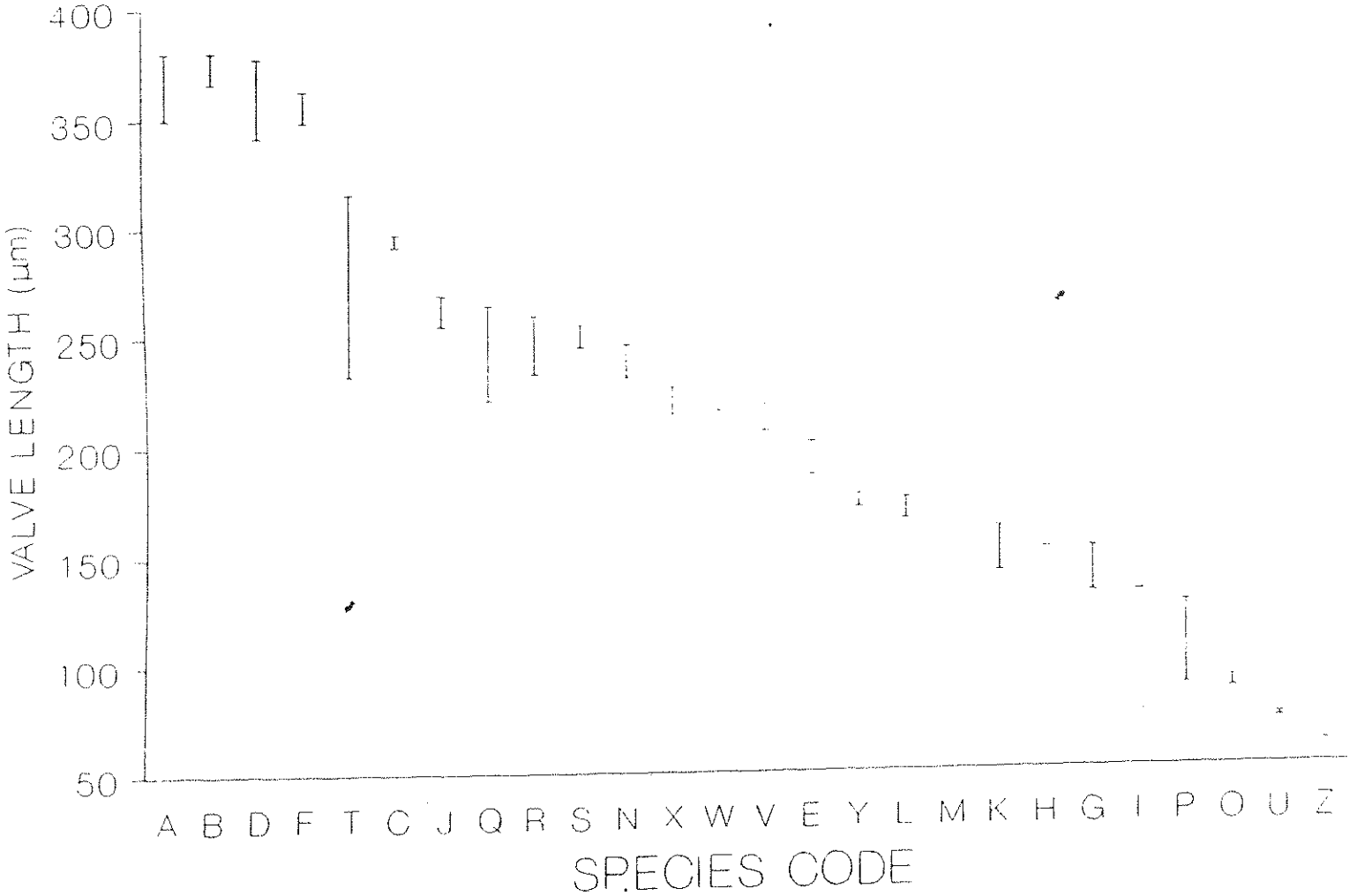
Table 3 (continued)

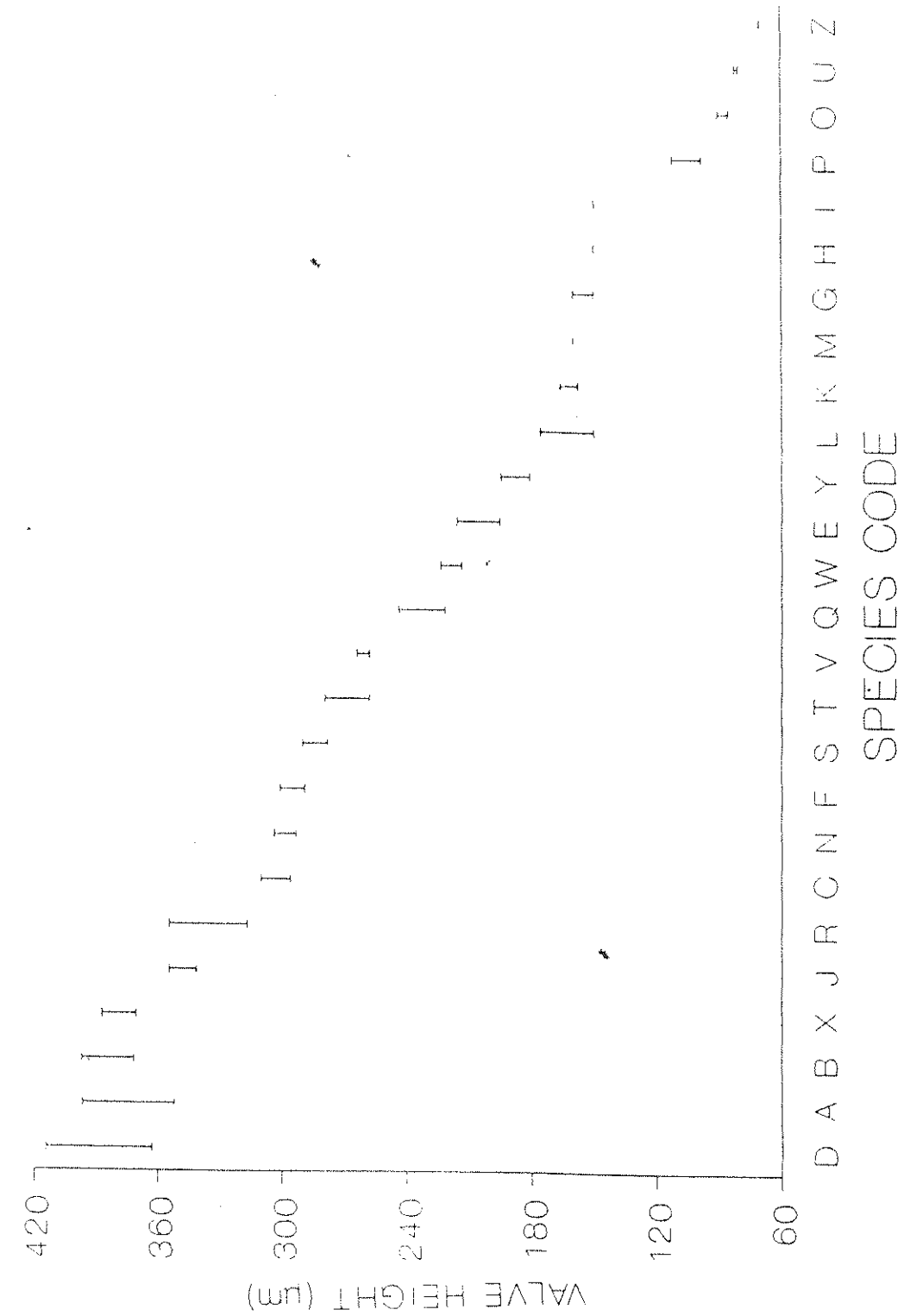
Mussel species or subfamily	Fish Species	Number Examined	Percent Infected
Amblemines (continued)			
Pleurobema spp.	Mooneye	11	9
	Steelcolor shiner	453	<1
Other	Freshwater drum	73	1
Lampsilines			
Potamilus alatus	Freshwater drum	73	3
Other	Channel catfish	25	16
	Brook silverside	181	<1
	Longear sunfish	67	2
	Spotted bass	66	5

FIGURE 1. Glochidial valve lengths of 26 species of freshwater mussels measured in this and other studies as cited (ranges are mean ± 1 SD). Species codes and citations are presented in Table 2.

FIGURE 2. Glochidial valve heights of 26 species of freshwater mussels measured in this and other studies as cited (ranges are mean ± 1 SD). Species codes and citations are presented in Table 2.

FIGURE 3. Glochidial hinge lengths of 18 species of freshwater mussels measured in this and other studies as cited (ranges are mean ± 1 SD). Species codes and citations are presented in Table 2.


400
350
300
250
200
150
100
50
VALVE LENGTH (µm)
A B D F T C J Q R S N X W V E Y L M K H G I P O U Z
SPECIES CODE


VALVE HEIGHT (µm)
420
360
300
240
180
120
60
D A B X J R C N F S T V Q W E Y L K M G H I P O U Z
SPECIES CODE

Distribution and Abundance of Freshwater Mussels Among Various Habitats in the Barren River, Kentucky

Abstract. Five 150-m-long sites were established in riffle, run, and pool habitats within a 5 km reach of the Barren River. Overall, 27 species of mussels were collected including the federally endangered *Pleurobema plenum*. Mean number of mussels differed significantly among sites ($P<0.05$). Mussel density ranged from 1.0/m^2 to 6.3/m^2 among sites. Species richness was similar among sites. *Amblema plicata* most frequently utilized sand and small gravel substrates in water 40 to 100 cm deep and velocities $\leq$ 15 cm/s; the other 26 species, as a group, utilized a slightly wider range of habitats. Differences in mussel abundance among sites may be due to habitat requirements of juvenile mussels and host fishes.

Introduction

Many studies have examined factors affecting the distribution and abundance of freshwater mussels, but in many cases these studies have not been definitive. Strayer (1981) was unable to determine any consistent differences in microhabitats of 21 species in Michigan. Holland-Bartels (1990) found few interspecific differences in habitat use among 30 species in the upper Mississippi River. Habitat parameters most frequently examined are substrate, depth, and water velocity. Most mussel species have broad

tolerances for substrate composition (Horne and McIntosh 1979). Distributions of *Anodonta grandis* and *Elliptio complanata* in Lake Bernard, Ontario, varied with substrate composition (Ghent et al. 1978). The thin shell and wide ventral angle of *A. grandis* restricted its distribution to fine substrates in deeper water. *Elliptio complanata* was confined to shallow shoreline areas with coarse sand and gravel. With its heavier shell, *E. complanata* is apparently better adapted to this habitat.

The thin, inflated shell of *A. grandis* appears to be an adaptation to fine substrates; however, *Leptodea fragilis* and *Proptera ohiensis* also have thin shells but occupy coarse substrates in areas with relatively high water velocity (Gordon and Layzer 1989). Their narrow ventral angles may be an adaptation for burrowing in coarse substrates. *Leptodea fragilis* tend to burrow deeply into the substrate and greatly extend the foot enabling the mussel to maintain position.

There is a lack of information concerning the influence of water velocity in determining mussel distributions. Apparently, adults of many species are able to survive over a wide range of velocities (Holland-Bartels 1990). In the Middle Thames River, Ontario, mussels most frequently utilized shallow, low velocity areas with coarse substrate (Salmon and Green 1983). Water velocity likely plays a major role in determining distributions of juvenile mussels

when they excyst from their fish host (Holland-Bartels 1990). An area of otherwise suitable habitat may be unavailable if high water column velocities prevent juveniles from settling.

Habitat requirements of juvenile mussels are largely unknown. Neves and Widlak (1987) found no consistent trends between substrate composition and density of juveniles; however they believed density was correlated with water velocity. Juveniles occur most frequently in areas of moderate velocity and coarse substrates (Coker et al. 1921; Neves and Widlak 1987).

This study examines abundance and species richness of freshwater mussels among various habitats. Habitat utilization is described for *Amblema plicata*. Other species were grouped for analyis of habitat utilization.

Study Area

The study was conducted on a 5 km reach of the Barren River downstream of Lock and Dam One, Warren County, Kentucky. The river originates at Fountain Run in southern Kentucky, flows northwest for 209 km, and enters the Green River near Morgantown. The Barren River has a drainage area of 4,925 km^2.

The two rivers have historically been used for transportation of coal. A series of locks and dams were constructed on the Green River and one lock and dam on the Barren River by the Commonwealth of Kentucky in 1886. Dam

Number Four on the Green River failed in 1965, ending navigation on both rivers (U.S. Army Corps of Engineers 1977). During the course of this study, water levels fluctuated over a range of 5 m due to operation of the dam at Barren River Lake, 40 km upstream.

The mussel fauna of the Green River drainage is among the most diverse in the United States. Isom (1974) reported 77 species from the drainage; 35 of these species have been collected from the Barren River (Clench and van der Schalie 1944). In the most recent survey of the mussel fauna of the Green River drainage, 46 species were recorded from the Green River within the Mammoth Cave National Park Boundary (Cicerello and Hannan 1990). Seven of these species (*Cumberlandia monodonta, Cyprogenia stegaria, Epioblasma rangiana, Obovaria retusa, Pleurobema clava, P. plenum*, and *Villosa ortmanni*) are federally endangered or candidates for listing (U.S. Fish and Wildlife Service 1990).

The ichthyofauna of the Barren River drainage is diverse. A total of 122 fish species are known from the drainage including five endemics (Burr and Warren 1986). The fish species assemblage includes 31 cyprinids, 25 percids, 14 catostomids, and nine ictalurids.

Materials and Methods

Five 150-m-long sampling sites were established in riffle, run, and pool habitats. Two transects perpendicular to the flow were established on each site for mussel

collection and habitat measurements. A 1.6 mm diameter cable (tagline) marked in 3-m increments was used to mark transects. Endpoints of each transect were permanently established by painting markers on large trees. One end of the cable was anchored to a tree with a chain while the remaining cable was taken across the river, attached to a tree, and drawn taught with a wire grip and come-a-long.

Habitat Measurements

Depth and velocity measurements were taken at 3-m intervals along each transect. A digital velocity meter and top-setting wading rod were used for depths $\leq$ 1.2 m. When depth exceeded 1.2 m, a cable suspension system was used. The boat was attached to the tagline such that the bow was positioned directly below the cable. A sounding reel mounted on the boat was used to lower a Price AA current meter for velocity measurements. Depth was measured with a gauge mounted on the sounding reel. Discharge ranged between 3.0 and 3.3 m^3/s among transects when depths and velocities were measured. The IFG4 program of the Physical Habitat Simulation System (PHABSIM) (Bovee 1982) was used to model depths and velocities for a discharge of 3.0 m^3/s.

The dominant substrate occurring at each 3-m interval along a transect was visually determined using the following particle size categories: fines (<0.625 mm), sand (0.625 to 2.0 mm), small gravel (>2.0 to 33.0 mm), large gravel

(34.0 to 63.0 mm), and boulder (>256 mm). Cobble substrate and bedrock did not occur in the study area.

Mussel Sampling

Mussels were sampled with two methods. Quantitative sampling involved placing two 0.25-m^2 quadrats side-by-side at each 3-m interval along a transect. Quadrats were constructed from 9.5 mm diameter steel bar. Mussels were collected by digging within each quadrat either by hand or with a hand rake. Mussels were identified to species and returned to the quadrat. Analysis of variance was used to test the hypothesis that the mean number of mussels collected differed significantly among sites. The hypothesis that mussels were uniformly distributed among substrate types, depths, and water velocities was tested with a Chi-Square Goodness-of-Fit-Test.

Because too few mussels were collected in the quadrat samples to accurately depict species composition, a timed dive was also used. Two divers, either snorkeling or using SCUBA equipment collected mussels for 30 minutes on each site. All mussels collected were identified as above and returned to the substrate.

The Shannon-Weiner Index (Shannon 1948) was used to evaluate species diversity for the timed-dive samples. This index takes into account both the number of species

(richness) which occur in a sample and the number of individuals of each species (evenness).

$$H' = -\Sigma\ p_i \ln p_i$$

where p_i is the proportional abundance of the i^{th} species.

Results

Overall, 27 species of mussels were collected including the federally endangered *Pleurobema plenum* (Table 1). A total of 241 mussels of 22 species was collected from 273 quadrats. The mean number of mussels collected differed significantly among sites (ANOVA; $F_{(4,268)} = 18.77$; $P < 0.0001$). Highest density ($6.3/m^2$) occurred on site 1 (Table 2). Density declined on downstream sites to $1.0/m^2$ on sites 4 and 5. Qualitatively, 505 mussels of 27 species were collected. The number collected on a site ranged from 26 on site 4 to 134 on site 5 and the number of species from 13 (site 4) to 18 (site 3). Species richness was less variable among sites than the total number of individuals collected. Shannon-Weiner diversity values ranged from 1.85 on site 1 to 2.19 on site 2. *Amblema plicata* was the most abundant species on all sites comprising 40% of the total number collected.

The high number of mussels collected by timed-diving on site 5 may be an overestimate of abundance. Mussels were more vulnerable to this method of collection on site 5 due to shallow, riffle habitat. When results of quantitative and qualitative sampling are combined, species richness was

similar among sites ranging from 16 (site 4) to 20 (sites 1 and 2). Individuals of six species were collected on all sites and 10 species on four of five sites.

Physical Habitat

Sites 1 through 3 were dominated by sand and small gravel substrate (Figure 1). Site 4 had a high proportion of fines (33%) and boulders (22%). Substrate on site 5 consisted of small and large gravel with fines and sand collectively comprising 27%.

Sites 1 and 2 were similar in depth as were sites 3 and 5 (Figure 2). Depth at the 50th percentile on sites 1 and 2 was 60 cm, with maximum depths of 90 and 118 cm, respectively. Sites 3 and 5 were shallower (50 and 70 cm maximum depths, respectively). The 50th percentile depth on site 4 was 210 cm (360 cm maximum). Velocities at the 50th percentile were 8 cm/s on site 1 and 10 cm/s on site 2 with maximum velocities $\leq$20 cm/s (Figure 3). The 50th percentile velocity on site 3 was higher (25 cm/s) with a maximum of 35 cm/s. All velocities measured on site 4 were less than 5 cm/s. The 50th percentile velocity on site 5 (12 cm/s) was similar to site 1 and 2; however, the maximum velocity was 55 cm/s.

Habitat Use

With the exception of *A. plicata*, too few observations were available to determine habitat use on a species basis. The remaining 26 species were grouped for analysis of habitat use.

Amblema plicata were not uniformly distributed among substrate types (χ^2 = 14.24; df = 4; P<0.01), depths (χ^2 = 17.55; df = 6; P<0.01), or water velocities (χ^2 = 27.30; df = 7; P<0.005). The other species group was also not uniformly distributed among substrate types (χ^2 = 17.36; df = 4; P<0.005), depths (χ^2 = 20.04; df = 6; P<0.005), or water velocities (χ^2 = 28.00; df = 7; P<0.005). Sand and small gravel substrates were used in higher proportion than their availability by both *A. plicata* and the other species (Figures 4 and 5). Use of depths from 40 to 100 cm by *A. plicata* was proportionally higher than availability while other species utilized depths from 20 to 120 cm in higher proportion than availability (Figures 6 and 7). Velocities of 5 to 15 cm/s were used by *A. plicata* in higher proportion than availability (Figure 8). Other species used a broader range of velocities proportionally higher than their availability (Figure 9). Both groups exhibited low use of fines and boulder substrates, depths >120 cm, and velocities <5 cm/s and >35 cm/s.

Discussion

Lowest density and species richness occurred on the pool site which was characterized by fines and boulders and low water velocities. The low use of fine substrates may be due to the fact that most species in the Barren River have heavy shells and are better adapted to coarse substrates. Boulders are an unsuitable substrate because there are few crevices in which mussels can maintain position.

A velocity of 35 cm/s appears to be a threshold level at a base discharge of 3 m^3/s for the Barren River. At greater discharges, higher velocities may scour substrate and mussels. This velocity threshold undoubtedly varies within and among river systems due to local geology and channel morphology.

Overall, the mussels of the Barren River used a wide range of the habitat parameters examined. The variety of habitats utilized by *A. plicata* was not surprising as the species is a known habitat generalist (Holland-Bartels 1990). The remaining 26 species also appear to be habitat generalists; 15 of these species occurred on at least four sites. Differences in habitat preference among species may occur; however, too few observations of habitat use were available to determine any preferences on a species basis. The mussel assemblage of the Barren River has 17 species in common with the upper Mississippi River. Slight differences in habitat use among these species occurred in the upper

Mississippi River; however, distributions of many species overlapped. In small streams of Michigan, Strayer (1981) detected no obvious differences in habitat use of 21 species and concluded that mussel distributions may be due to dispersal of mussels over a heterogeneous environment where competition is low. The ability to survive in a wide range of habitats is likely advantageous to a mussel species due to early life history characteristics. The habitat into which a juvenile is deposited is determined by movements and habitat requirements of host fish as well as water column and bottom velocities (Holland-Bartels 1990).

Differences in mussel abundance among sites could not be attributed to a single factor. Distribution and abundance patterns may be determined by habitat requirements of both juvenile mussels and their fish hosts. Low abundance and species richness on the pool site (site 4) may be due to poor survival of juvenile mussels or an avoidance of the site by host fishes. Adults but no juveniles of 16 species were collected on the pool site. Neves and Widlak (1987) found lowest juvenile densities in pool habitats. The pool habitat of site 4 may be limiting to many lotic fishes (Catostomidae, Cottidae, Percidae). An avoidance of the site by infected fish could result in lower recruitment of juveniles. Unfortunately, habitat requirements of juvenile mussels are largely unknown. Neves and Widlak (1987) found highest densities behind boulders in riffles

and runs. Juveniles have been shown to utilize areas of swift water with coarse substrate (Coker et al. 1921); similar habitat did not occur on the pool site but did occur in a large portion of sites where mussels were more abundant. Differences in mussel abundance among sites suggest that habitat requirements of juvenile mussels and their respective fish hosts may play an important role in determining mussel distribution and abundance.

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Table 1. Number of each mussel species collected by timed diving (T) and quadrat samples (Q) on five sites on the Barren River during 1991

Subfamily / Species	Site and Method									
	1		2		3		4		5	
	T	Q	T	Q	T	Q	T	Q	T	Q
Anodontinae										
Anodonta grandis	-	-	-	-	-	-	1	-	-	-
Arcidens confragosus	-	-	-	-	-	-	-	-	3	1
Lasmigona complanata	1	-	-	-	-	-	2	1	8	-
L. costata	4	1	2	1	1	-	-	-	6	-
Ambleminae										
Amblema plicata	58	38	27	31	42	10	13	5	61	3
Cyclonaias tuberculata	1	-	-	-	-	-	-	-	-	-
Elliptio crassidens	-	1	2	-	3	1	1	-	6	-
Fusconaia flava	-	1	2	-	-	-	-	-	-	-
F. subrotunda	-	1	-	-	3	-	1	-	-	1
Megalonaias nervosa	16	4	24	6	13	10	1	1	2	-

Table 1 (continued)

Subfamily / Species	Site and Method									
	1		2		3		4		5	
	T	Q	T	Q	T	Q	T	Q	T	Q
Lampsilinae (continued)										
Leptodea fragilis	–	2	–	–	1	–	1	–	1	–
Ligumia recta	–	–	–	–	1	–	–	–	–	–
Obliquaria reflexa	–	–	1	2	–	2	1	2	–	–
Potmilus alatus	1	–	–	–	–	–	1	–	22	2
Ptychobranchus fasciolaris	17	14	7	3	12	3	–	–	1	–
Truncilla truncata	–	4	1	5	–	2	1	–	–	3

Table 2. Mussel species richness, density, and diversity on five sites on the Barren River during 1991

Total Number of Species Collected by Both Sampling Methods	20	20	19	16	18
Density (number/m^2) From Quantitative Sampling	6.3	5.2	3.5	1.0	1.0
Shannon-Weiner Diversity (H)	1.84	2.19	2.12	1.93	1.84

FIGURE 1. Substrate composition on five sites on the Barren River.

FIGURE 2. Cumulative distribution of depths occurring on five sites on the Barren River at a river discharge of 3 m^3/s. Numbers correspond to site numbers.

FIGURE 3. Cumulative distribution of mean water column velocities occurring on five sites on the Barren River at a river discharge of 3 m^3/s. Numbers correspond to site numbers.

FIGURE 4. Proportional use by *Amblema plicata* and availability of each substrate in the Barren River at a river discharge of 3 m^3/s. Solid bars represent availability.

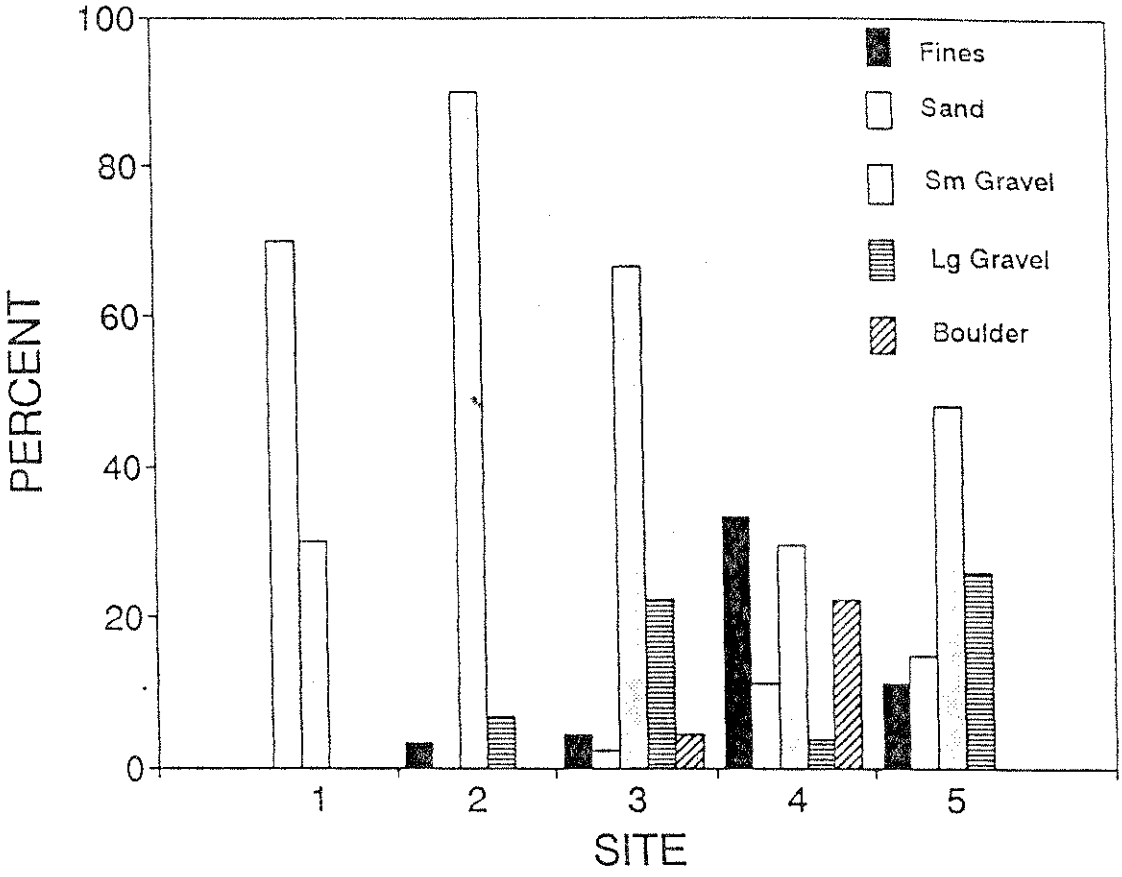
FIGURE 5. Proportional use by the mussel species assemblage of the Barren River (excluding *Amblema plicata*) and availability of each substrate at a river discharge of 3 m^3/s. Solid bars represent availability.

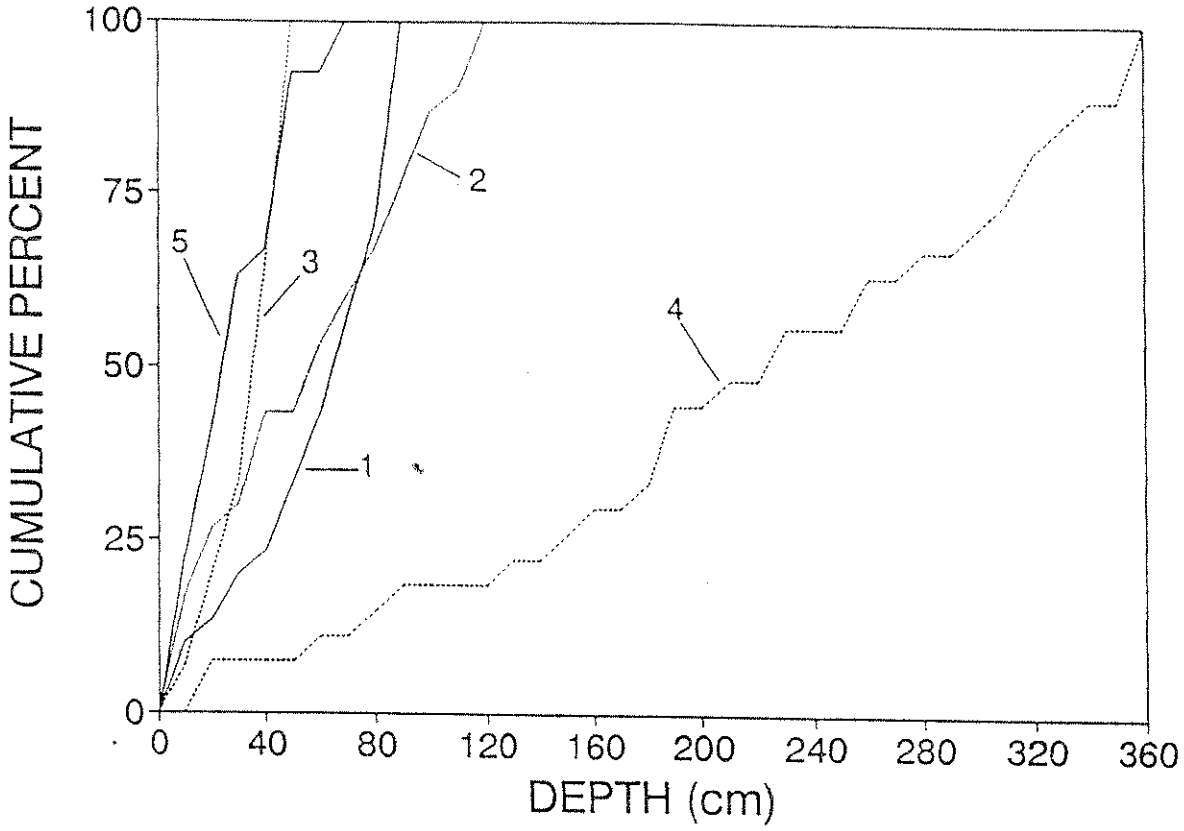
FIGURE 6. Proportional use by *Amblema plicata* and availability in each 20 cm depth category (upper range of depth category indicated) in the Barren River at a river discharge of 3 m^3/s. Solid bars represent availability.

FIGURE 7. Proportional use by the mussel species assemblage of the Barren River (excluding *Amblema plicata*) and availability in each 20 cm depth category (upper range of depth category indicated) at a river dishcharge of 3 m^3/s. Solid bars represent availability.

FIGURE 8. Proportional use by *Amblema plicata* and availability in each 5 cm/s velocity category (upper range of velocity category indicated) in the Barren River at a river discharge of 3 m^3/s. Solid bars represent availability.

FIGURE 9. Proportional use by the mussel species assemblage of the Barren River (excluding *Amblema plicata*) and availability in each 5 cm/s velocity category (upper range of velocity category indicated) at a river discharge of 3 m^3/s. Solid bars represent availability.


100
80
60
40
20
0
PERCENT
1
2
3
4
5
SITE
Fines
Sand
Sm Gravel
Lg Gravel
Boulder


CUMULATIVE PERCENT
100
75
50
25
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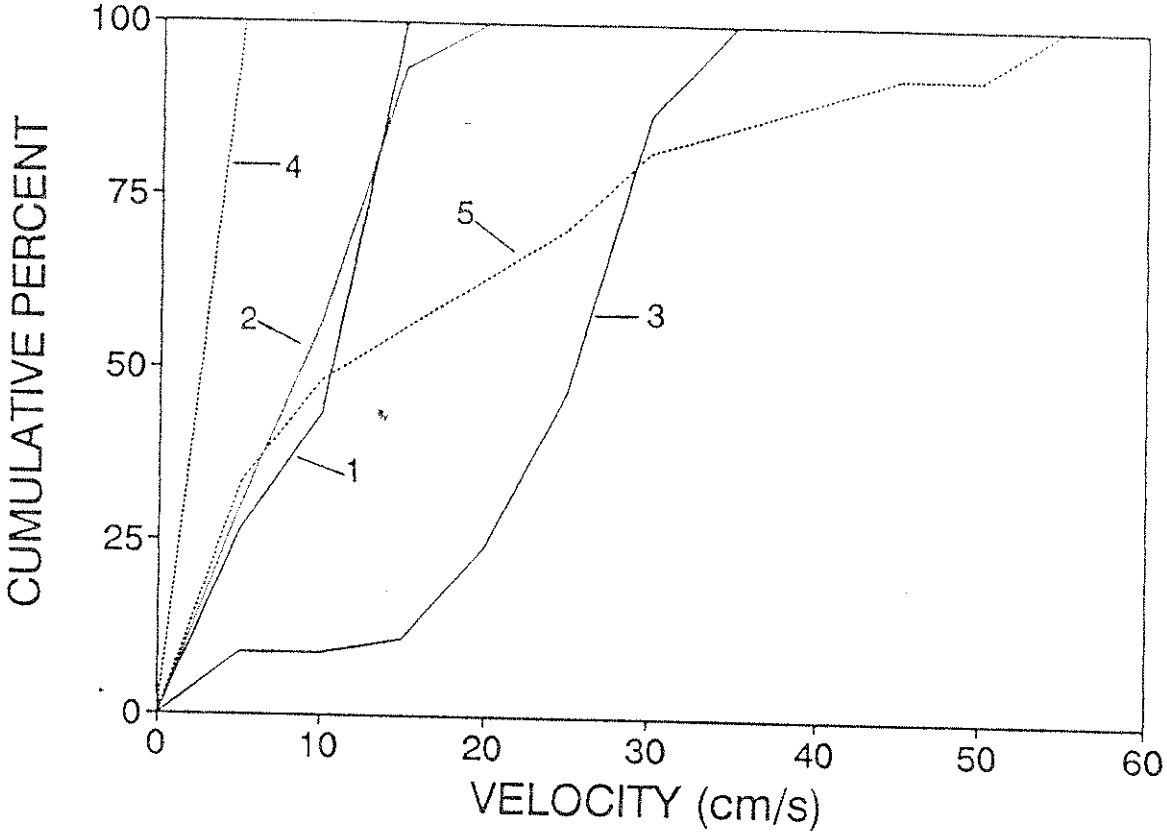
0
40
80
120
160
200
240
280
320
360
DEPTH (cm)
1
2
3
4
5


100
75
50
25
0
CUMULATIVE PERCENT
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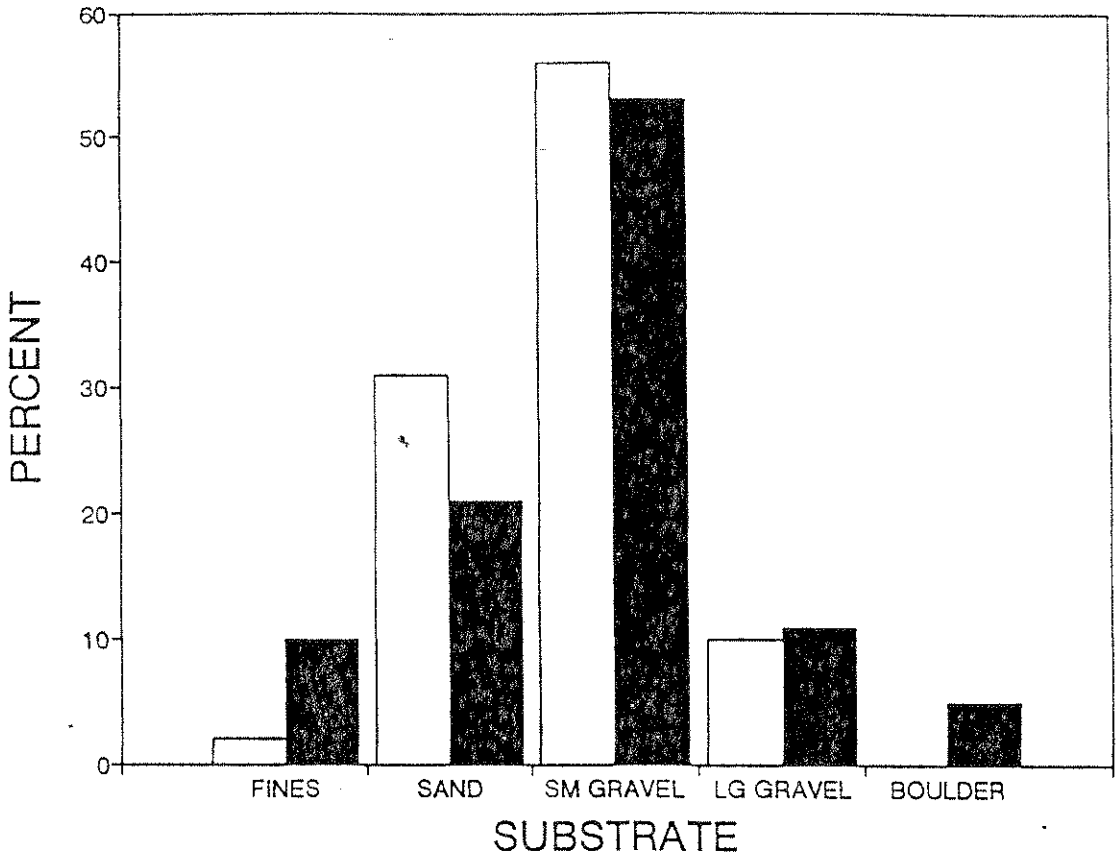
5
2
3
1
0
10
20
30
40
50
60
VELOCITY (cm/s)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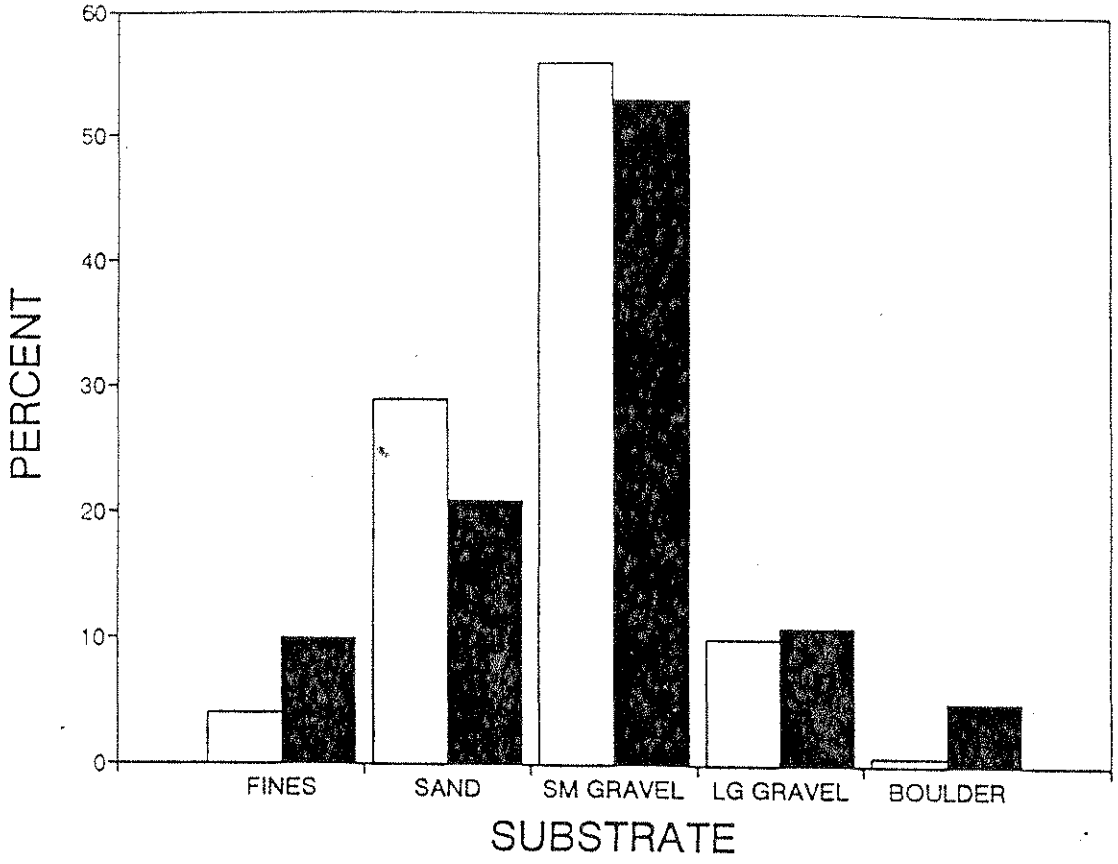
40
30
20
10
0
PERCENT
FINES
SAND
SM GRAVEL
LG GRAVEL
BOULDER
SUBSTRATE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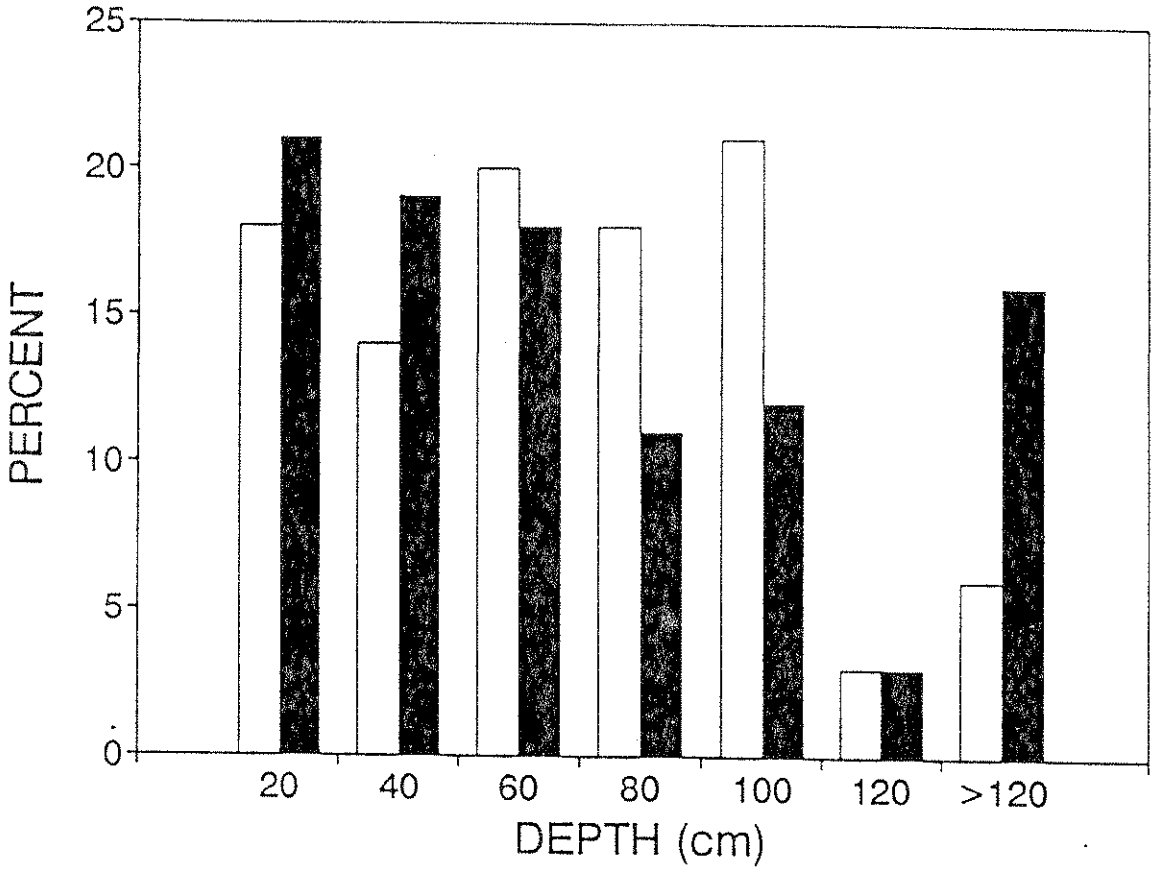
BOULDER
SUBSTRATE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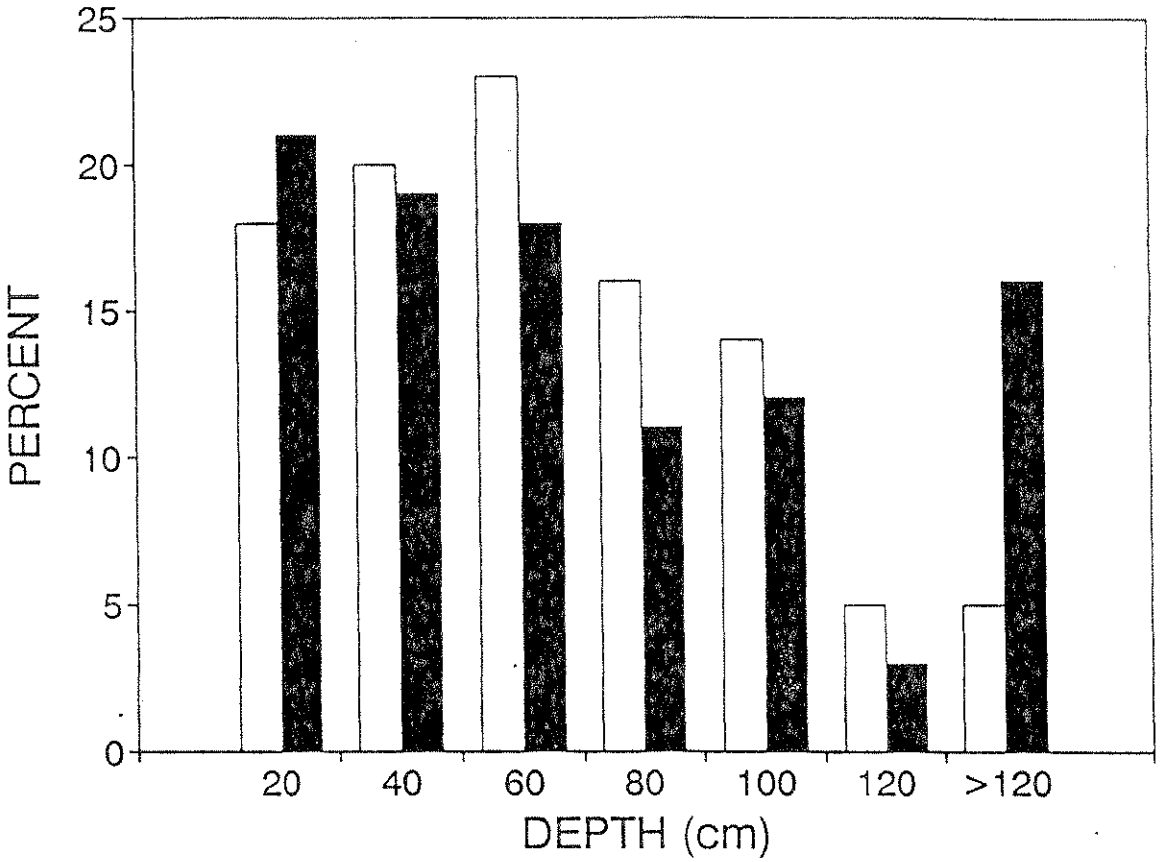
20
15
10
5
0
PERCENT
20
40
60
80
100
120
>120
DEPTH (cm)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20
15
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PERCENT
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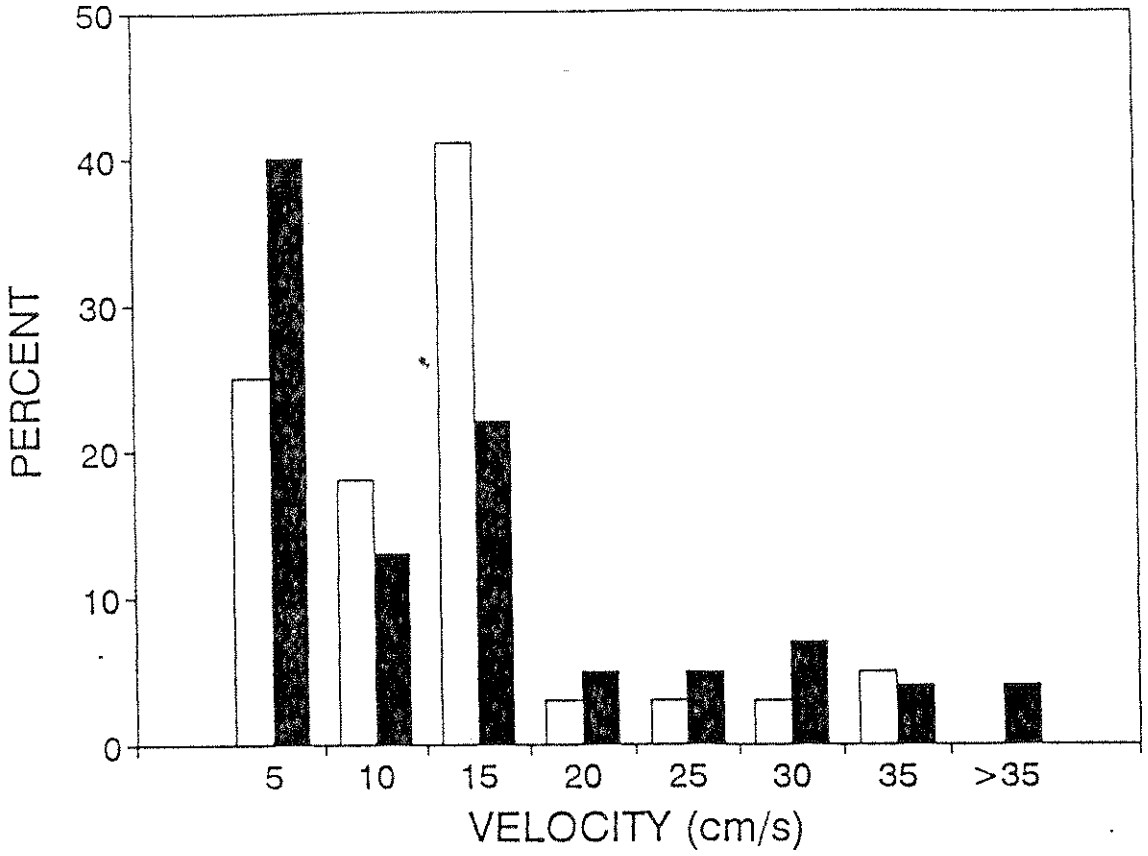
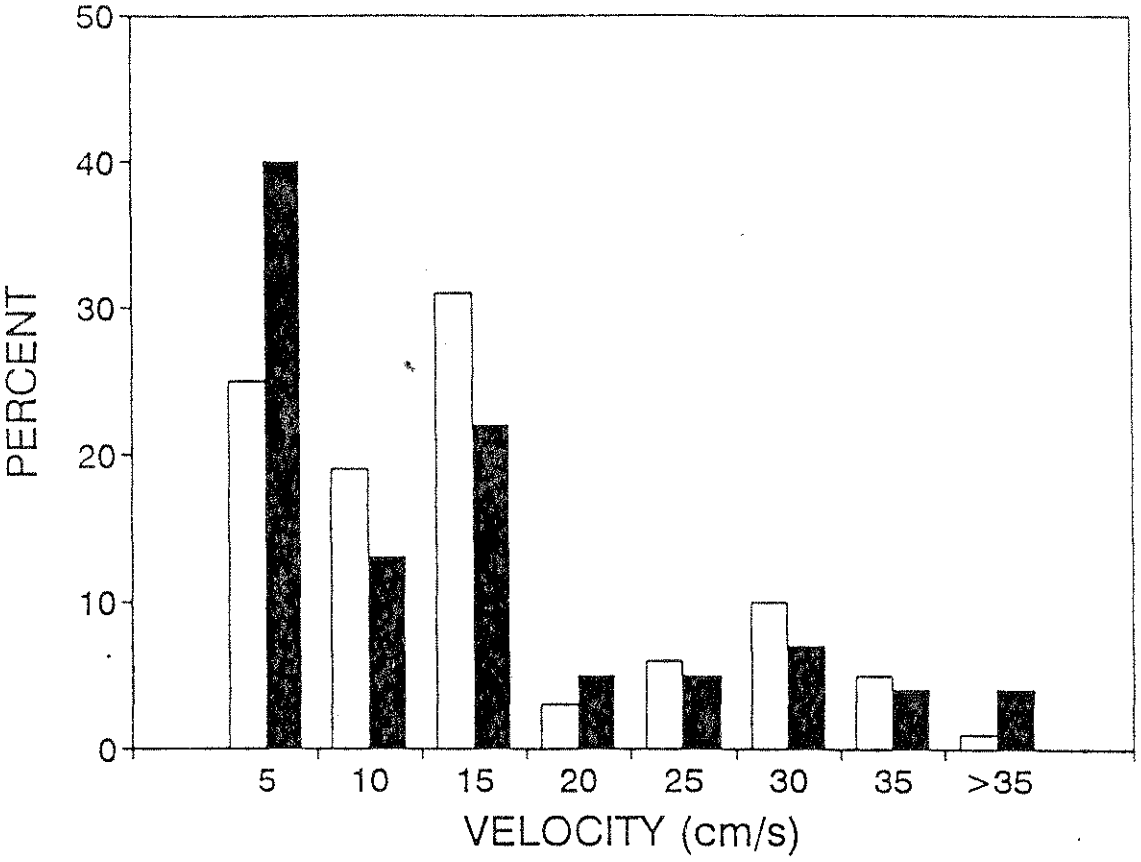
100
120
>120
DEPTH (cm)


50
40
30
20
10
0
PERCENT
5
10
15
20
25
30
35
>35
VELOCITY (cm/s)


50
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PERCENT
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35
>35
VELOCITY (cm/s)