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Fish Hosts for Four Species of Freshwater Mussels (Pelecypoda: Unionidae) in the Upper Tennessee River Drainage

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ABSTRACT.—Fish hosts were identified for glochidia of four freshwater unionid mussel species, *Epioblasma brevidens*, *E. capsaeformis*, *E. triquetra* and the endangered mussel, *Quadrula intermedia*, from the Powell River of the upper Tennessee River drainage. All four species exhibited high degrees of host specificity in laboratory tests. Host fish for *Epioblasma* spp. were restricted to a cottid, the banded sculpin (*Cottus carolinae*) and several percids: the greenside darter (*Etheostoma blennioides*), wounded darter (*E. vulneratum*), redline darter (*E. rufilineatum*), snubnose darter (*E. simoterum*), logperch (*Percina caprodes*) and dusky darter (*P. sciera*). Fish hosts identified for *Q. intermedia* were two cyprinids, the streamline chub (*Erimystax dissimilis*) and blotched chub (*E. insignis*). Host fishes for all four mussel species were fast-water species occupying the same riffle habitats as the mussels.

INTRODUCTION

The decline or recent extinction of several species of *Epioblasma* (=*Dysnomia* = *Plagiola*) and *Quadrula* spp. indicates a synecological problem between these taxa of freshwater mussels and changes in North American rivers and streams (Johnson, 1978). Most species of *Epioblasma* are either extinct (Stansbery, 1970, 1971, 1976) or candidates for federal listing as endangered (Clarke, 1981; Ahlstedt, 1983a, 1985; Neves, 1984). Although some species of the genus *Quadrula* are widespread, two rare and endangered members of the genus (*i.e.*, *Q. intermedia* and *Q. sparsa*) continue to survive as remnant populations in a few larger tributaries of the Tennessee River drainage (Ahlstedt, 1982, 1983b, 1984; Stansbery, 1973).

The purpose of this research was to identify fish hosts for glochidia of three species of *Epioblasma* and the endangered *Quadrula intermedia*. The reproductive biology of the sexually dimorphic *Epioblasma* species has not been previously reported, and most inferences on reproduction are based on the taxonomic position of the genus in the subfamily Lampsilinae (Heard and Guckert, 1970). Working with *Q. cylindrica strigillata*, Yeager and Neves (1986) reviewed the life history and reproductive biology of *Quadrula* species.

METHODS AND MATERIALS

Field methods.—In 1984 the three *Epioblasma* species were collected by snorkeling near the Virginia-Tennessee border between river miles 106.8 and 117.4 of the Powell River. Between 1981 and 1985, searches for *Quadrula intermedia* were conducted between Powell

River Miles (PRM) 99.2 and 117.4. Mussels were opened slightly by hand or with modified O-ring expanders to check for gravidity. Because of the propensity of *Quadrula* spp. to readily abort glochidia (Yeager and Neves, 1986), gravid mussels were placed in small-mesh cloth bags or plastic zip-lock bags and transported in insulated coolers of river water to a TVA laboratory in Norris, Tennessee. After aborting glochidia, all *Q. intermedia* were returned to their collection sites unharmed. Ages of mussels were estimated by the external growth ring method (Chamberlain, 1931; Crowley, 1957).

Experimental procedures for Epioblasma *spp.*—For the tests with *Epioblasma* spp., mature glochidia were obtained by excising the marsupial gills from gravid female mussels and rupturing the ovisacs with a probe. Glochidia of both genera were tested for maturity by exposing a small subsample to salt crystals, and were deemed suitable if they showed a strong, immediate closing response (Zale and Neves, 1982; Yeager and Neves, 1986).

To avoid prior exposure to infestations with glochidia, fish to be tested as hosts were collected from mussel-free sites or from sites known to have low mussel densities. Before infestation, experimental fish were anesthetized with tricaine methanesulfonate (MS-222), and the gills and fins were carefully inspected for any attached glochidia or parasite infestations. Infested fishes were excluded from experimental trials. Individual fish were infested by pipetting ca. 100–300 glochidia into the right branchial chamber. Each fish was exposed to glochidia only once. Fish were immediately checked for successful attachment of glochidia, held in a recovery chamber with fresh filtered spring water for a few minutes, and then returned to their holding chambers. Glochidia of *Epioblasma brevidens*, *E. capsaeformis* and *E. triquetra* were exposed to 26, 20 and 25 fish species, respectively (Table 1).

At 5 and 10 days postinfestation, all fish were anesthetized and inspected for retention of glochidia. Fish retaining glochidia after 10 days were isolated by species in aquaria containing filtered spring water. Beginning 11 days after infestation and every 2nd day thereafter, material from the bottoms of aquaria was siphoned through a 35-micron nylon-mesh sieve, and examined under a stereomicroscope.

Experimental procedures for Quadrula intermedia.—With the following exceptions, experimental procedures were conducted as for *Epioblasma* tests. No *Q. intermedia* were sacrificed to obtain glochidia. Mature glochidia were obtained from *Q. intermedia* by daily siphoning the bottom material of holding aquaria through a 100-micron mesh sieve and examining it through a binocular microscope.

In host experiments with *Quadrula intermedia*, all fish were sequestered by species immediately after infestation. Fish were anesthetized at 5-day intervals and inspected for retention of glochidia. If infestation was detected, that chamber was siphoned daily to check for sloughing of glochidia or juvenile mussels.

RESULTS AND DISCUSSION

Genus Epioblasma.—All three species of *Epioblasma* were gravid in the field with mature glochidia in May or June, and were spent by mid-July (Table 2). Only the outer demibranchs served as marsupia for these three species. Because gravid females were found on the first collection date in early May, the initial occurrence of gravidity was undoubtedly earlier. Gravid specimens of *E. brevidens* and *E. triquetra* were observed from 1 May to 5 June at water temperatures ranging from 15.0 to 17.8 C. Gravid *E. capsaeformis* were collected only until 18 May. During these periods 45% of *E. brevidens*, 58% of *E. capsaeformis* and 31% of *E. triquetra* females were gravid. Estimated ages of gravid females were: *E. brevidens*, 8–13 yr; *E. capsaeformis* 7–10 yr; and *E. triquetra*, 5–10 yr.

Fish hosts for *Epioblasma* spp. (Table 3) were restricted to six species of benthic, riffle-dwelling darters (family Percidae) and a sculpin (family Cottidae) also living in the same

TABLE 1.—Fish species and number tested as potential hosts for glochidia of the four mussel specie

Fish species	Mussel species			
	E. brevidens	*E. capsaeformis*	*E. triquetra*	*Q. intermedia*
	Number of fish infested			
Dorosoma cepedianum	—	—	—	1
Campostoma anomalum	1	2	4	1
Cyprinella galactura	2	3	1	8
C. spiloptera	2	1	2	22
Erimystax dissimilis	2	2	2	21
E. insignis	—	—	—	21
Lythrurus ardens	—	—	—	8
L. lirus	—	—	—	2
Luxilus chrysocephalus	1	—	1	6
L. coccogenis	3	1	2	1
Macrhybopsis aestivalis	—	—	—	2
Nocomis micropogon	1	—	1	3
Notropis amblops	1	4	1	3
N. ariommus	3	—	1	—
N. leuciodus	2	—	2	6
N. rubellus	2	1	2	2
N. spectrunculus	—	—	—	4
N. telescopus	1	—	1	—
Phenacobius uranops	1	—	—	—
Pimephales notatus	4	2	2	6
P. vigilax	—	—	—	1
Rhinichthys atratulus	—	—	—	3
Carpiodes sp. (juvenile)	—	—	—	1
Hypentelium nigricans	2	2	3	—
Moxostoma duquesnei	—	—	—	3
M. erythrurum	1	—	—	—
Ictalurus punctatus	—	—	—	3
Fundulus catenatus	—	2	—	4
Morone mississippiensis	—	—	—	1
Lepomis auritus	2	—	2	—
L. machrochirus	2	—	3	—
L. megalotis	—	2	—	—
Pomoxis annularis	—	—	—	1
Etheostoma blennioides	2	—	2	6
E. caeruleum	—	—	2	—
E. camurum	—	—	—	5
E. jessiae	3	3	1	—
E. rufilineatum	12	5	9	—
E. simotrerum	10	1	15	10
E. vulneratum	2	1	1	—
E. zonale	—	—	—	5
Percina caprodes	1	2	3	6
P. copelandi	—	1	3	—
P. evides	3	4	—	2
P. sciera	—	1	—	—
Cottus carolinae	13	1	4	5
Aplodinotus grunniens	—	—	—	1

TABLE 2.—Reproductive condition of females of *Epioblasma* spp. and *Quadrula intermedia* in the Powell River (*Epioblasma* collected 1984 only; *Quadrula* 1981–1985, all years combined)

Month	Number females collected (number gravid)			
	E. brevidens	*E. capsaeformis*	*E. triquetra*	*Q. intermedia*
April	—	—	—	15 (3)
May	8 (4)	12 (7)	14 (4)	49 (22)
June	3 (1)	0 (0)	2 (1)	81 (13)
July	4 (0)	1 (0)	4 (0)	2 (0)
October	—	—	—	0 (0)
Total collected (total gravid)	15 (5)	13 (7)	20 (5)	147 (38)

habitat as the mussels. Obligate fish hosts for endangered congeners of the *Epioblasma* species studied are also likely to be within these two groups of fishes. Periods of transformation were temperature-dependent and ranged between 16 and 45 days (Table 3).

Genus Quadrula.—The spawning period observed from 1981–1985 occurred each year between the last week of April and the 3rd wk of June (Table 2) at water temperatures between 16 and 24 C. The major period of gravidity occurred in May and early June at temperatures between 18 and 24 C. Unlike *Epioblasma* spp., gravid *Quadrula intermedia* used both the inner and outer (all 4) demibranchs as marsupia for developing glochidia. Ages of gravid females were estimated to be between 14 and 22 yr.

Glochidia of *Quadrula intermedia* exhibited a high degree of host specificity, successfully metamorphosing only on two closely related cyprinids (Table 3) among 34 species of fish in 10 families tested. The streamline chub *Erimystax dissimilis*, and blotched chub *Erimystax insignis* served as hosts for glochidia of *Q. intermedia*. Periods for complete transformation were temperature-dependent and varied between 24 and 47 days (Table 3). After 19–22 days, 101 partially transformed unviable glochidia were sloughed from 10 of the *E. dissimilis*. Five to 10 days after excystment, 39 of the fully transformed juveniles produced were subsequently released into adult mussel habitat at PRM 106.4 on the Powell River.

The two identified hosts of *Quadrula intermedia* are sympatric with the three extant populations of this mussel. Both hosts have greater geographical distributions than the mussel (Lee *et al.*, 1980), indicating that factors other than declining ranges for fish hosts have effected a range decline for this mussel. Both chubs co-occur with *Q. intermedia* in the moderate to swifter currents of large cobble and gravel shoals. Host specificity restricted to co-occurring cyprinid fish species has also been reported for the congeneric rabbit's foot mussel *Q. cylindrica* (Yeager and Neves, 1986). Other undetermined hybopsid species, *e.g.*, slender chub (*Erimystax cahn* which is sympatric in the Powell River, may also serve as hosts, but were not tested.

Implications for mussel conservation.—For effective conservation efforts of either declining mussel populations or attempts to establish transplanted populations, knowledge of mussel-fish host relationships is critical. Although undoubtedly incomplete, our findings provide criteria (known fish hosts) for selection of acceptable transplant sites, identify the stenotopic tendency of fish host relationships for the species, and establish a starting point for research directed towards recognition of other fish hosts within the currently identified fish families serving as hosts for the *Epioblasma* spp. studied or their endangered congeners.

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TABLE 3.—Fish species confirmed as hosts for the four mussel species

Host fish	Mussel species											
	E. brevidens			*E. capsaeformis*			*E. triquetra*			*Q. intermedia*		
	No. juveniles	Days to transform	Mean (C) temp.	No. juveniles	Days to transform	Mean (C) temp.	No. juveniles	Days to transform	Mean (C) temp.	No. juveniles	Days to transform	Mean (C) temp.
Etheostoma blennioides	9	34–37	17.0	—			—			—		
E. rufilineatum	28	16–33	16.3	1	25	15.8	—			—		
E. simoterum	3	25–34	16.9	—			—			—		
E. vulneratum	2	17	15.4	10	19–31	16.2	—			—		
Percina caprodes	104	28–45	16.7	—			—			—		
P. sciera	—			4	25	15.8	804	24–33	17.1	—		
Cottus carolinae	123	20–48	17.2	14	20–34	16.9	26	25–44	17.2	—		
Erimystax dissimilis	—			—			—					
Test 1	—			—			—			26[1]	24–29	19.2
Test 2	—			—			—			19	42–47	15
E. insignis	—			—			—			41	26–41	17.0

[1] An additional 101 juveniles excysted earlier on days 19–22, but died within 4 days

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Temporal Variation in Abundance of Peromyscus leucopus in Wooded Habitats of Eastern Kansas

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ABSTRACT.—White-footed mice (*Peromyscus leucopus*) were sampled during spring, summ and autumn on the Konza Prairie Research Natural Area, Kansas, from autumn 1981 spring 1988. Abundance was greater in gallery forest than in wooded outcrop habitat, though temporal patterns of abundance were similar with highs in 1981–1982 and 19 1986. Standard deviations (SD) of the common logarithm of abundance were ≤ 0.32 for e of four sites in spring, summer and autumn, except for one forest site in spring. Our values were similar to those reported for other populations of *P. leucopus*. Abundance o *leucopus* was related to its abundance in the previous season (spring abundance vs. that previous autumn, summer abundance vs. that in previous spring and autumn abundance that in previous summer), seed production by woody vegetation and precipitation, but factors that had a major influence on abundance of *P. leucopus* varied among spring, summ and autumn populations. Ambient temperature was unrelated to abundance of *P. leuco* during each of the 3 seasons studied.

INTRODUCTION

During the last 10–20 yr, ecologists have directed increasing efforts at establishin term studies of plant and animal populations in both natural and disturbed ecos (Franklin, 1989; Franklin *et al.*, 1990). Long-term studies provide insight into the te variation of abundance and other demographic characteristics and into populati sponses to disturbance (Magnuson, 1990). By temporal variation, we mean variation years of abundance measured at a specific time of year, but not pattern of variation the annual cycle of abundance. Two general aspects of the temporal variation of abun are of interest to ecologists. The first is the relative constancy of abundance ove (Connell and Sousa, 1983), or, in other words, some measure of variance about the population abundance over a multiyear period. A second aspect is the pattern of abun through time. In this case, it is the timing and magnitude of the highs and lows of lation abundance that are important and not a reduction of pattern to a statistical stat of mean and variance.

Multiyear studies of rodents generally have been directed at assessing patterns of dance, *i.e.*, the timing and magnitude of population highs and lows. However, true term studies (6 or more yr) devoted to analyses of population abundance of rodents r were centered on arvicolid rodents in an attempt to understand the causes of popu "cycling" in these small mammals (Tait and Krebs, 1985; Ostfeld, 1988). Less effo been directed towards long-term studies, *i.e.*, more than 5 yr of field data, of other ro although a number of studies of *Peromyscus* in North America and *Apodemus* in E have been conducted for 3–5 yr (Ostfeld, 1988). Recently, Ostfeld (1988) examine constancy of population abundance in rodents by estimating the standard deviation c common log (base 10) of population abundance (SD), using studies with 3 or more

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