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New or confirmed host identifications for ten freshwater mussels

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ABSTRACT: New or confirmed host identifications were performed for ten freshwater mussels. Fish species were infested with glochidia and monitored during laboratory experiments. Two methods were used: 1) feeding conglutinates to fish and 2) placing fish in aerated buckets of water containing glochidia in suspension. Aquaria contents were sampled every other day and examined for unmetamorphosed glochidia and metamorphosed juveniles under polarized light. Unmetamorphosed glochidia suggested unsuitable hosts, whereas metamorphosed juveniles indicated potentially suitable hosts. Johnny darter, largemouth bass, bluegill, and white shiner were hosts for *Elliptio fischeriana*. Bluegill and shield darter were hosts for *Fusconaia masoni*. Silver shiner and creek chub were hosts for *Fusconaia flava*. Striped shiner, streamline chub, smallmouth bass, largemouth bass, green sunfish, bluebreast darter, greenside darter, rainbow darter, and yellow perch were hosts for *Villosa iris iris*. Bluntnose minnow, sand shiner, striped shiner, smallmouth bass, largemouth bass, bluegill , and longear sunfish were hosts for *Lampsilis radiata luteola*. Green sunfish and banded killifish were hosts for *Lampsilis cardium*. Banded darter, bluebreast darter, and brown trout were hosts for the federally endangered *Epioblasma torulosa rangiana*. Longnose gar, largemouth bass, yellow perch, longear sunfish, bluegill, slenderhead darter, and logperch were hosts for *Megalonaias nervosa*. Largemouth bass and Tippecanoe darter were hosts for *Anodontoides ferussacianus*. Blackside darter, striped shiner, central stoneroller, and logperch were hosts for the federally endangered *Pleurobema clava*.

Keywords: Unionidae, reproduction, glochidia, hosts, parasitism.

Freshwater mussels (Bivalvia: Unionidae) are the most endangered group of animals in North America. No other group has as high a percentage of federally and state listed species as the unionids. In the United States, 69 taxa, including subspecies, are currently listed under the Endangered Species Act as endangered and threatened (USFW 1998). Yet, we know very little about the complex life history of these animals.

Identification of hosts for freshwater mussels is paramount in their conservation and management. Unionids are parasitic for a portion of their complex life history and require a vertebrate host; generally fish fulfill this role. Glochidia, the parasitic larval stage, attach to gills or fins during a transformation process to juveniles. Freshwater mussel species may have evolved to parasitize a specific fish species, a family of fish (Zale and Neves 1982a,b, Yeager and Saylor 1995), or taxonomically wide varieties of fish (Trdan and Hoeh 1982). At least one species of unionid completes it's glochidial metamorphosis to juveniles without a host (Barfield and Watters 1998, Lellis and King 1998), however most evidence suggests that freshwater mussels are obligate parasites.

Hosts for about one-third of the North American unionid species have been reported. Approximately 300 host-parasite relationships have been suggested, mostly based upon glochidial identification from naturally infected hosts. Of these, only one-third have been confirmed by laboratory transformation experiments (Watters 1994). Through identification of potential glochidia-host relationships, resource agency practices may be initiated to manage both the mussel and host species for continued preservation, conservation, and propagation of North American unionids.

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Methods

Gravid females of the northern lance, *Ellipto fischeriana* (Lea 1838), Atlantic pigtoe, *Fusconaia masoni* (Conrad 1834), Wabash pigtoe, *Fusconaia flava* (Rafinesque 1820), clubshell, *Pleurobema clava* (Lamarck 1819), rainbow, *Villosa iris iris* (Lea 1829), washboard, *Megalonaias nervosa* (Rafinesque 1820), fatmucket, *Lampsilis radiata luteola* (Lamarck 1819), northern riffleshell, *Epioblasma torulosa rangiana* (Lea 1839), plain pocketbook, *Lampsilis cardium* (Rafinesque 1820), and cylindrical papershell, *Anodontoides ferussacianus* (Lea 1834) were collected. *E. fischeriana* and *F. masoni* were collected from the Tar River, North Carolina in June 1997; *L. cardium*, *L. radiata luteola, P. clava* and *V. iris iris* were collected from Little Darby Creek, Ohio in July 1996; *M. nervosa* were collected from the Ohio River, West Virginia in September 1997; *A. ferussacianus* were collected from Spain Creek, Ohio in May 1996; *F. flava* were collected from the Scioto River, Ohio in September 1997; and *E. torulosa rangiana* was collected from French Creek, Pennsylvania in May 1997. Common and scientific names for fishes and mussels follow Robins *et al.* (1991) and Turgeon *et al.* (1988), respectively. Mussels were held in 38-liter flow-through aquaria at 20–21°C. Mussels were fed a suspended tri-algal mixture of *Chorella vulgaris*, *Ankistrodesmus falcatus* and *Chlamydomonas reinhardtii*.

Fish were collected from the same streams as the mussels by electrofishing and seining. Hatchery-raised largemouth bass and bluegill were obtained from the Ohio Division of Wildlife Hebron Fish Hatchery. Fishes were held in aquaria with no substrate and were fed every two days with either aquatic oligochaetes or goldfish.

Glochidia were removed from gravid females of all mussel species (except *F. masoni* and *E. fischeriana*) by inserting a water-filled insulin syringe into the ventral edge of the marsupium and flushing glochidia from the gills. A sub-sample of glochidia was tested for viability with salt; viable glochidia react by rapidly closing their valves. Glochidia were suspended in a container by agitation with an airstone. Potential hosts were then placed in the container and exposed for one hour. Infection with glochidia of *F. masoni* and *E. fischeriana* required hand-feeding of conglutinates to fish. Fish were starved for four days prior to increase the likelihood of consumption of conglutinates during the infection process. After exposure, the subjects were sorted by species into separate aquaria.

Aquaria were sampled every other day for up to 45 days. One liter of water was siphoned from each aquarium bottom, and passed through a 145 µm sieve. Debris was examined for glochidia with a stereomicroscope using the polarized light methods devised for detecting zebra mussel veligers (Johnson 1995). Metamorphosed juveniles were identified by the presence of two adductor mussels, a foot, and movement.

Results

Johnny darter, largemouth bass, bluegill, and white shiner were hosts for *Elliptio fischeriana*. Bluegill and shield darter were hosts for *Fusconaia masoni.* Silver shiner and creek chub were hosts for *Fusconaia flava.* Striped shiner, streamline chub, smallmouth bass, largemouth bass, green sunfish, bluebreast darter, greenside darter, rainbow darter, and yellow perch were hosts for *Villosa iris iris.* Rockbass, which was identified as a host by Neves (1983), Zale and Neves (1982a,b) was not identified as a host in this study of *V. iris iris*. Bluntnose minnow, sand shiner, smallmouth bass, largemouth bass, bluegill, and longear sunfish were hosts for *Lampsilis radiata luteola*. Largemouth bass (Weir 1977, Trdan 1981), bluegill (Weir 1977, Trdan 1981), and smallmouth bass (Coker *et al.* 1921) have previously been identified as potential hosts. Green sunfish and banded killifish were hosts for *Lampsilis cardium.* Banded darter, bluebreast darter, and brown trout were hosts for the federally endangered *Epioblasma torulosa rangiana*. Longnose gar, largemouth bass, yellow perch, longear sunfish, bluegill, slenderhead darter, and logperch were hosts for *Megalonaias nervosa*. Largemouth bass and Tippecanoe darter were hosts for *Anodontoides ferussacianus*. Blackside darter, striped shiner, central stoneroller, and logperch were hosts for the federally endangered *Pleurobema clava*.

Table 1 shows the fish species used in each experiment. Fish species on which glochidia metamorphosed to juveniles are depicted with a (X), species on which metamorphosis did not occur are represented with a (O). An asterisk (*) next to a potential host indicates a previously identified host.

Table 2 shows the results of host experiments, fish species and number for each unionid, days sampled (TDS), total number of excysted unmetamorphosed glochidia (TUG), total number of excysted metamorphosed juveniles (TMJ), date range of juvenile excystment (DJE), tranformation success as a percentage of total juveniles excysted divided by total glochidia excysted. Results for the *V. iris iris* and *L. cardium* are not available.

Discussion

Understanding the complex life history of unionids can provide information critical to the management and conservation of unionids in North America. Current knowledge of glochidial-host relationships leaves many gaps in our understanding of unionid reproductive biology. Occasionally the natural hosts may be as endangered as their mussel parasites, or they may be difficult to maintain in captivity (Watters and O'Dee 1998). We have identified suitable hosts for ten unionids under laboratory conditions. Combining laboratory identification and observation of naturally infested hosts may provide resource agencies with the ability to propagate unionids in captivity. The addition of known hosts to quarantined populations of unionids may provide resource managers the ability to allow natural reproduction and population propagation for eventual re-introduction of endangered, threatened, or species of "special concern" in the future. Host

Table 1. Results of host trial for *L. radiata luteola* (LR), *P. clava* (PC), *F. flava* (FF), *F. masoni* (FM), *E. fischeriana* (EF), *V. iris iris* (VII), *M. nervosa* (MN), *A. ferussacianus* (AF), *E. torulosa rangiana* (ET), and *L. cardium* (LC).
[X = Successful metamorphosis to juvenile, O = Unsuccessful metamorphosis to juvenile, * = Previously identified host].

	Mussels									
Fishes	**LR**	**PC**	**FF**	**FM**	**EF**	**VII**	**MN**	**AF**	**ET**	**LC**
Amiidae										
Bowfin									O	
Catostomidae										
Black redhorse						O				
Golden redhorse	O	O								
Jumprock				O						
Northern hogsucker									O	
Silver redhorse			O							
Quillback									O	
Centrarchidae										
Bluegill	X*[1]	O	O	X	X	O	X*[2]		O	
Green sunfish						X				X
Largemouth bass	X*[1]	O	O		X	X	X	X	O	
Longear sunfish	X	O	O			O	X			
Orangespot sunfish									O	
Redbreast sunfish					O					
Rock bass		O				O*[3]				
Smallmouth bass	X*[2]					X*[3]			O	
Cyprinidae										
Bigeye chub									O	
Bluehead chub				O	O					
Bluntnose minnow	X						O		O	
Central stoneroller	O	X				O	O		O	
Common carp									O	
Creek chub			X	O	O	O			O	
Goldfish		O	O		O				O	
Gravel chub	O					O				
Hornyhead chub						O				
Mimic shiner									O	
Redfin shiner	O					O				
River chub									O	
Rosyface shiner	O					O	O		O	
Sand shiner	X					O	O		O	
Satinfin shiner					O					
Silver shiner	O		X			O				
Silverjaw minnow									O	
Spotfin shiner	O					O	O		O	
Streamline chub						X				
Striped shiner		X				X	O			
Suckermouth minn.	O					O	O			
Swallowtail shiner				O						
White shiner					X				O	
Fundulidae										
Banded Killifish										X
Ictaluridae										
Channel Catfish									O	
Stonecat									O	

[1] Weir 1977 and Trdan 1981; [2] Coker *et al.* 1921; [3] Zale and Neves 1982a,b and Neves 1983

Table 1. Results of host trial for *L. radiata luteola* (LR), *P. clava* (PC), *F. flava* (FF), *F. masoni* (FM), *E. fischeriana* (EF), *V. iris iris* (VII), *M. nervosa* (MN), *A. ferussacianus* (AF), *E. torulosa rangiana* (ET), and *L. cardium* (LC), continued.
[X = Successful metamorphosis to juvenile, O = Unsuccessful metamorphosis to juvenile, * = Previously identified host].

	Mussels									
Fishes	**LR**	**PC**	**FF**	**FM**	**EF**	**VII**	**MN**	**AF**	**ET**	**LC**
Lepisosteidae										
Longnose gar							X			
Percidae										
Banded darter	O	O				O	O		X	
Blackside darter		X	O			O				
Bluebreast darter	O					X			X	
Glassy darter				O	O					
Greenside darter		O				X			O	
Johnny darter			O	O	X					
Logperch	O	X	O			O	X		O	
Rainbow darter	O	O	O			X			O	
Roanoke darter				O	O					
Saugeye									O	
Shield darter				X	O					
Slenderhead darter							X			
Tippecanoe darter	O	O				O		X	O	
Varigate darter		O				O	O			
Yellow perch						X	X			
Salmonidae										
Brown trout									X	

identification may provide information necessary to reverse or negate the decline of many unionid species.

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Table 2. Results of host experiments, fish species and number used for each unionid, total number of days sampled (TDS), total number of excysted unmetamorphosed glochidia (TUG), total number of excysted juveniles (TMJ), date range of juvenile excystment (DJE), tranformation success as the percentage of juveniles from total glochidia infestation (%).

Species (#)	TDS	TUG	TMJ	DJE	%
A. ferussacianus					
Tippecanoe darter (2)	32	8	3	32	27.3
Largemouth bass (1)	32	9	4	25-27	30.8
E. fischeriana					
Bluegill (2)	37	12	4	17-19	25.0
Largemouth bass (2)	37	4	1	21	20.0
White Shiner (4)	37	10	6	27-31	37.5
Johnny darter (3)	37	6	7	15	53.8
E. torulosa rangiana					
Brown Trout (1)	45	3	1	35	25.0
Bluebreasted darter (1)	45	10	1	33	9.1
Banded darter (3)	45	6	1	33	14.3
F. flava					
Creek chub (3)	32	1	1	20	50.0
Silver shiner (2)	32	1	8	20-24	88.9
F. masoni					
Bluegill (3)	37	3	7	19-31	70.0
Shield darter (5)	37	1	2	31	66.7
L. radiata luteola					
Bluegill (1)	46	810	116	12-34	12.5
Largemouth bass (2)	32	30	58	12-22	65.9
Smallmouth bass (2)	50	6	49	32-40	89.1
Longear sunfish (2)	44	29	4	28-30	12.1
Bluntnose minnow (2)	44	3	6	36-40	66.7
Sand shiner (2)	44	4	8	32-34	66.7
M. nervosa					
Bluegill (2)	34	119	21	8-24	15.0
Largemouth bass (2)	34	176	11	12-26	6.3
Longear sunfish (1)	34	422	109	8-24	20.5
Longnose gar (1)	44	76	155	17-41	67.1
Yellow perch (1)	34	498	138	8-22	25.7
Slenderhead darter (1)	34	12	14	12-15	53.8
Logperch (1)	34	6	2	19-22	25.0
P. clava					
Blackside darter (2)	32	26	45	20-25	63.4
Striped shiner (7)	32	12	69	20-25	85.2
Logperch (2)	32	0	5	20-23	100.0
Central stoneroller (3)	32	17	1	20	5.6

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