ISSN NO. 0892-6506

MALACOLOGY DATA NET

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VOLUME 3, NUMBERS 1-4, APRIL 4, 1992

Malacology Data Net is published by ECOSEARCH, Inc., 325 East Bayview Boulevard, Portland, Texas 78374.

An Examination of the Glochidia - Host Relationships Reported in the Literature for North American Species of Unionacea (Mollusca: Bivalvia)

MICHAEL A. HOGGARTH
The Ohio Department of Transportation
Bureau of Environmental Services
25 South Front Street, Room 608
Columbus, Ohio 43215

ABSTRACT

Hosts for about one quarter of the North American species of unionid glochidia have been reported. An examination of this body of literature shows that a total of 279 glochidia - host relationships have been suggested. One hundred and sixty one of these relationships are based on the identification of glochidia from naturally infected hosts. Only 59 of this number have been confirmed by laboratory transformation experiments. An additional 97 relationships are based on laboratory transformation experiments alone with no evidence given to suggest that the parasites and their hosts actually encounter each other in their natural environment. The remaining 21 relationships are based on laboratory infections alone, on inference, or on unspecified evidence. It is suggested that some of this information may be incorrect while a majority still requires testing in the field or laboratory.

INTRODUCTION

Seventeen years ago Fuller (1974) published a list of fish hosts for the parasitic larval stage of the Unionacea known as a glochidium. His list resulted from a compilation of published and unpublished reports on glochidia - host relationships. This table has been widely used as a source of information regarding the life histories of these mollusks (Clarke, 1981, 1985; Oesch, 1984; and others). It should be noted, however, that Fuller stated that some of the relationships were merely implied and had not been tested.

The present paper is an update of Fuller's table (his Table 1) with two additions: a complete citation to the study and an indication as to the type of evidence given. Fuller (1974) demonstrated that a list of this type can highlight what is known and what is still to be discovered about these relationships.

Acknowledgments:- I wish to thank Dr. D.H. Stansbery, The Ohio State University Museum of Zoology, for access to many of the references used in this study. The Ohio State University, Department of Zoology, The Ohio Department of Transportation and The National Science Foundation (BSR-8401209) supported this effort, or supported me while I was working on this project. I thank Drs. J.D. Williams, U.S. Fish and Wildlife Service and A.H. Clarke, ECOSEARCH, Inc., for reviewing the manuscript.

MATERIALS AND METHODS

This study was confined to the literature. No new glochidia - host relationships are proposed herein. An attempt was made to locate each article in which a host for a glochidium of North American freshwater mussel was reported. References cited by Fuller (1974) were examined with the exception of Mermilliod (1973). However, that study was summarized by Fuller and the title of the paper identified the evidence used to determine the proposed relationships. The malacological literature and the Zoological Record were also searched for additional sources. Eighteen articles published since 1974, containing glochidial host information, were found. Two additional articles, published prior to 1974, were also located (Connor 1905, Tedla and Fernando 1969). The proposed hosts of <u>Margaritifera hembeli</u> (Conrad 1838) resulted from an unpublished masters thesis (Hill 1987).

RESULTS

Table 1 lists the hosts that have been reported for the glochidia of North American species of Margaritiferidae and Unionidae. Ninety two species of fish and one salamander (<u>Necturus maculosus</u>) have been implicated as hosts for a total of 63 species of freshwater mussels. Because most glochidia have more than one reported host, a total of 279 glochidia - host relationships are identified. This number does not include studies in which the glochidia were not identified to species.

One hundred and sixty one of these relationships are based on the identification of glochidia taken from naturally infected hosts. These glochidia were identified by shape, size and by structures visible with light microscopy. Only 59 of these relationships have been confirmed by laboratory infection and transformation experiments. During this type of experiment a glochidium of known identity, taken from the marsupial gill of a female of known identity, is allowed to come in contact with a potential host. If the glochidium attaches to the host, becomes encapsulated by tissues of the host, and transforms into a juvenile, then there is evidence of a parasitic relationship.

Another group of proposed relationships (97) are based on laboratory transformation experiments

Table 1. Proposed glochidia-host relationships for North American Unionacea.

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
Margaritiferidae								
Margaritifera margaritifera eastern pearlshell	*Salmo trutta* brown trout	Clarke & Berg 1959:18			X			
	Salmo solar Atlantic salmon	Cunjak & McGladdery 1991:355		X				
	Salvelinus fontinalis brook trout	Clarke & Berg 1959:18			X			
falcata western pearlshell	*Oncorhynchus tshawytscha* chinook salmon	Davis 1946:35		X		X		
		Fustish *et al*. 1978:155	X					
		Karna & Millemann 1978:531		X				
	Oncorhynchus kisutch coho salmon	Karna & Millemann 1978:531		X				
	Oncorhynchus mykiss rainbow trout	Davis 1937:35		X		X		
		Murphy 1942:94		X		X		
		Karna & Millemann 1978:531		X				
	S. trutta	Murphy 1942:94		X			X	
	Oncorhynchus clarki cutthroat trout	Karna & Millemann 1978:531		X				
	S. fontinalis	Murphy 1942:94		X				
	Rhinichthys osculus speckled dace	Murphy 1942:94		X				
	Richardsoninus egregius Lahontan redside dace	Murphy 1942:94		X				
	Catostomus tahoensis Tahoe sucker	Murphy 1942:94				X		
hembeli Louisiana pearlshell	*Luxilus chrysocephalus* striped shinen	Hill 1987:10		X				
	Lythrurus umbratilis redfin shiner	Hill 1987:10		X				
	Notemigonus crysoleucas golden shiner	Hill 1987:10		X				

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	NT	LI	LT	BI	NS
Unionidae								
Anodonta								
beringiana	Oncorhynchus nerka	Cope 1959:159	X					
Yukon floater	sockeye salmon							
	O. tshawytscha	Cope 1959:159	X					
	Gasterosteus aculeatus	Cope 1959:159	X					
	threespine stickleback							
grandis	Lepisosteus osseus	Trdan & Hoeh 1982:383				X		
giant floater	longnose gar							
	Alosa chrysochloris	Surber 1913:106	X					
	skipjack herring	Wilson 1916:340	X					
	Dorosoma cepedianum	Wilson 1916:339	X					
	gizzard shad							
	Cyprinus carpio	Lefevre & Curtis 1910:103	X					
	common carp	Morrison In Clarke & Berg 1959:39						X
	L. chryso~~leucas~~	Lefevre & Curtis 1910:103	X					
	cephalus	Read & Oliver 1953:76	X					
		Trdan & Hoeh 1982:383				X		
	Rhinichthys atratulus	Trdan & Hoeh 1982:383				X		
	blacknose dace							
	Semotilus atromaculatus	Trdan & Hoeh 1982:383				X		
	creek chub							
	Margariscus margarita	Trdan & Hoeh 1982:383	X					
	pearl dace							
	L. umbratilis	Trdan & Hoeh 1982:383				X		
	Luxilus cornutus	Trdan & Hoeh 1982:383	X			X		
	common shiner							
	Notropis heterodon	Trdan & Hoeh 1982:383	X			X		
	blackchin shiner							
	Notropis heterolepis	Trdan & Hoeh 1982:383	X			X		
	blacknose shiner							
	Campostoma anomalum	Trdan & Hoeh 1982:383	X			X		
	central stoneroller							
	Ameiurus natalis	Wilson 1916:338	X					
	yellow bullhead							

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	<u>Fundulus diaphanus</u>	Trdan & Hoeh 1982:383				X		
	banded killifish							
	<u>Labidesthes sicculus</u>	Trdan & Hoeh 1982:383	X			X		
	brook silverside							
	<u>Pimephales notatus</u>	Trdan & Hoeh 1982:383	X			X		
	bluntnose minnow							
	<u>Culaea inconstans</u>	Morrison <u>In</u> Clarke & Berg 1959:38						X
	brook stickleback	Trdan & Hoeh 1982:383				X		
	<u>Morone chrysops</u>	Wilson 1916:340	X					
	white bass							
	<u>Pomoxis annularis</u>	Lefevre & Curtis 1910:103	X					
	white crappie	Wilson 1916:340	X					
		Morrison <u>In</u> Clarke & Berg 1959:38						X
	<u>Pomoxis nigromaculatus</u>	Wilson 1916:340	X					
	black crappie	Trdan & Hoeh 1982:383	X			X		
	<u>Ambloplites rupestris</u>	Lefevre & Curtis 1910:103	X					
	rock bass	Tucker 1928:126				X		
		Trdan & Hoeh 1982:383	X			X		
	<u>Micropterus salmoides</u>	Wilson 1916:339	X					
	largemouth bass	Penn 1939:101				X		
		Morrison <u>In</u> Clarke & Berg 1959:39						X
		Trdan & Hoeh 1982:383	X					
	<u>Lepomis cyanellus</u>	Wilson 1916:338	X					
	green sunfish	Tucker 1928:126				X		
		Trdan & Hoeh 1982:383	X					
	<u>Lepomis macrochirus</u>	Lefevre & Curtis 1910:103	X					
	bluegill	Wilson 1916:339	X					
		Penn 1939:101				X		
		Morrison <u>In</u> Clarke & Berg 1959:38						X
		Trdan & Hoeh 1982:383	X			X		
	<u>Lepomis megalotis</u>	Penn 1939:101				X		
	longear sunfish							
	<u>Lepomis gibbosus</u>	Trdan & Hoeh 1982:383				X		
	pumpkinseed sunfish							
	<u>Perca flavescens</u>	Lefevre & Curtis 1910:103	X					
	yellow perch	Trdan & Hoeh 1982:383	X			X		

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	NT	LI	LT	BI	NS
	Etheostoma nigrum	Hankinson 1908:235	X					
	johnny darter	Morrison *In* Clarke & Berg 1959:39						X
		Trdan & Hoeh 1982:383	X			X		
	Etheostoma exile	Morrison *In* Clarke & Berg 1959:39						X
	Iowa darter	Trdan & Hoeh 1982:383	X			X		
	Etheostoma caeruleum	Trdan & Hoeh 1982:383	X			X		
	rainbow darter							
	Aplodinotus grunniens	Wilson 1916:338	X					
	freshwater drum							
cataracta	*C. carpio*	Lefevre & Curtis 1910:104			X			
eastern floater	*Catostomus commersoni*	Wiles 1975:36, 39	X					
	white sucker							
	L. gibbosus	Conner 1905:142	X					
implicata	*Alosa pseudoharengus*	Johnson 1946:112	X					
alewife floater	alewife	Davenport & Warmuth 1965:R76				X		
	C. commersoni	Davenport & Warmuth 1965:R76				X		
	Morone americana	Davenport & Warmuth 1965:R76				X		
	white perch							
	L. gibbosus	Davenport & Warmuth 1965:R76				X		
imbecillis	*S. atromaculatus*	Clarke & Berg 1959:42					X	
paper pondshell	*F. diaphanus*	Trdan & Hoeh 1982:383				X		
	Gambusia affinis	Stern & Felder 1978:233	X					
	mosquitofish							
	A. rupestris	Trdan & Hoeh 1982:383				X		
	M. salmoides	Trdan & Hoeh 1982:383				X		
	Lepomis gulosus	Stern & Felder 1978:233	X					
	warmouth sunfish							
	L. cyanellus	Tucker 1927:288				X		
		Trdan & Hoeh 1982:383				X		
	L. macrochirus	Stern & Felder 1978:233	X					
		Trdan & Hoeh 1982:383				X		
	L. gibbosus	Trdan & Hoeh 1982:383				X		

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	Lepomis marginatus dollar sunfish	Stern & Felder 1978:233	X					
	P. flavescens	Trdan & Hoeh 1982:383				X		
californiensis California floater	G. affinis	D'Eliscu 1972:57				X		
Anodontoides ferussacianus cylindrical papershell	Petromyzon marinus sea lamprey	Wilson & Ronald 1967:1085	X					
	Cottus bairdi mottled sculpin	Morrison In Clarke & Berg 1959:36						X
Simpsonaias ambigua salamander mussel	Necturus maculosus mudpuppy	Howard 1915:7	X			X		
		Howard 1951:2	X			X		
Strophitus undulatus squafoot	S. atromaculatus	Howard In Baker 1928:201				X		
	Fundulus zebrinus plains killifish	Ellis & Keim 1918:18			X			
	M. salmoides	Howard In Baker 1928:201				X		
	L. cyanellus	Ellis & Keim 1918:18			X			
Alasmidonta viridis slippershell mussel	E. nigrum	Morrison In Clarke & Berg 1959:30						X
	C. bairdi	Morrison In Clarke & Berg 1959:30						X
	Cottus carolinae banded sculpin	Zale & Neves 1982b:386		X				
marginata elktoe	Moxostoma macrolepidotum shorthead redhorse	Howard & Anson 1922:80	X					
	Hypentelium nigricans northern hog sucker	Howard & Anson 1922:80	X					
	C. commersoni	Howard & Anson 1922:80	X					
	A. rupestris	Howard & Anson 1922:80	X					
	L. gulosus	Howard & Anson 1922:80	X					

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	NT	LI	LT	DI	NS
Arcidens confragosus rock-pocketbook	*Anguilla rostrata* American eel	Wilson 1916:338	X					
	D. cepedianum	Surber 1913:105	X					
		Wilson 1916:339	X					
	P. annularis	Surber 1913:105	X					
		Wilson 1916:340	X					
	A. rupestris	Surber 1913:105		X				
		Wilson 1916:338	X					
	A. grunniens	Wilson 1916:338	X					
Lasmigona compressa creek heelsplitter	*Lebistes reticulatus* guppy	Tompa 1979:189				X		
costata fluted-shell	*C. carpio*	Lefevre & Curtis 1910:111			X			
complanata white heelsplitter	*C. carpio*	Lefevre & Curtis 1910:111				X		
	P. annularis	Lefevre & Curtis 1912:168				X		
	M. salmoides	Lefevre & Curtis 1910:110				X		
	L. cyanellus	Lefevre & Curtis 1912:168				X		
Megalonaias nervosa washboard	*Amia calva* bowfin	Howard 1914c:31	X					
	A. rostrata	Surber 1915:8	X					
		Wilson 1916:338	X					
		Coker *et al*. 1921:52	X					
	A. chrysochloris	Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	D. cepedianum	Howard 1914c:31	X					
		Coker *et al*. 1921:152	X					
	Carpiodes velifer highfin carpsucker	Howard 1914c:32			X			
	Ictalurus punctatus channel catfish	Howard 1914c:32			X			
		Coker *et al*. 1921:152				X		
	Ameiurus nebulosus brown bullhead	Coker *et al*. 1921:152				X		

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	Ameiurus melas	Howard 1914c:32			X			
	black bullhead	Coker *et al*. 1921:152				X		
	Noturus gyrinus	Coker *et al*. 1921:153	X					
	tadpole madtom							
	Pylodictis olivaris	Howard 1914c:31	X					
	flathead catfish	Coker *et al*. 1921:153	X			X		
	M. chrysops	Howard 1914c:31 32	X			X		
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	P. annularis	Coker *et al*. 1921:153	X			X		
	P. nigromaculatus	Howard 1914c:32			X			
		Coker *et al*. 1921:153				X		
	M. salmoides	Howard 1914c:32			X			
	L. macrochirus	Howard 1914c:32			X			
		Coker *et al*. 1921:153	X			X		
	L. cyanellus	Coker *et al*. 1921:152				X		
	Stizostedion canadense	Howard 1914c:32			X			
	sauger							
	A. grunniens	Surber 1913:105		X				
		Howard 1914c:32			X			
		Surber 1915:8	X					
		Wilson 1916:338	X					
		Coker *et al*. 1921:152	X			X		
Quadrula								
quadrula	*P. olivaris*	Howard & Anson 1922:74	X					
mapleleaf								
cylindrica	*Cyprinella galactura*	Yeager & Neves 1986:335				X		
rabbitsfoot	whitetail shiner							
	Cyprinella spiloptera	Yeager & Neves 1986:335				X		
	spotfin shiner							
	Notropis amblops	Yeager & Neves 1986:335				X		
	bigeye chub							
metanevra	*L. cyanellus*	Surber 1913:115	X					
monkeyface		Wilson 1916:338	X					

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	L. macrochirus	Surber 1913:115	X					
		Howard 1914c:17	X					
		Wilson 1916:339	X					
		Coker et al. 1921:152	X					
	S. canadense	Howard 1914c:17	X					
		Coker et al. 1921:153	X					
		Pearse 1924:181	X					
intermdeia Cumberland monkeyface	Erimystax dissimilis streamline chub	Saylor In Hill 1986:36				X		
	Erimystax insignis blotched chub	Saylor In Hill 1986:36				X		
nodulata wartyback	I. punctatus	Wilson 1916:339	X					
		Coker et al. 1921:152	X					
	P. olivaris	Coker et al. 1921:153	X					
	P. annularis	Surber 1913:115	X					
		Wilson 1916:340	X					
		Coker et al. 1921:153	X					
	P. nigromaculatus	Howard 1914c:15			X			
	M. salmoides	Howard 1914c:15			X			
	L. macrochirus	Howard 1914c:15			X			
pustulosa pimpleback	Scaphirhynchus platorynchus shovelnose sturgeon	Coker et al. 1921:153	X					
	I. punctatus	Howard 1912:68	X					
		Howard 1914c:11				X		
		Coker et al. 1921:152	X			X		
	A. nebulosa us	Howard 1914c:11				X		
		Coker et al. 1921:152				X		
	A. melas	Howard 1912:68	X					
		Howard 1914c:11				X		
		Coker et al. 1921:152	X			X		
	P. olivaris	Howard 1912:68	X					
		Howard 1914c:11				X		

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
		Wilson 1916:339	X					
		Coker *et al*. 1921:153	X					
	P. *annularis*	Wilson 1916:340	X					
Amblema								
plicata	*Lepisosteus platostomus*	Coker *et al*. 1921:152				X		
threeridge	shortnose gar	Howard & Anson 1922:77			X			
	Esox lucius	Wilson 1916:339	X					
	northern pike	Coker *et al*. 1921:152	X					
	M. *chrysops*	Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	P. *annularis*	Surber 1913:115	X					
		Howard 1914c:26 27	X			X		
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	P. *nigromaculatus*	Howard 1914c:26 27	X			X		
		Coker *et al*. 1921:153				X		
	A. *rupestris*	Stein 1968:46				X		
	M. *salmoides*	Lefevre & Curtis 1912:168				X		
		Howard 1914c:27				X		
		Coker *et al*. 1921:153	X			X		
	L. *gulosus*	Coker *et al*. 1921:152	X					
		Pearse 1924:181	X					
	L. *macrochrius*	Howard 1914c:27				X		
		Stein 1968:46				X		
	L. *cyanellus*	Stein 1968:46				X		
	L. *gibbosus*	Wilson 1916:339	X					
		Coker *et al*. 1921:152	X					
		Stein 1968:46				X		
	S. *canadense*	Surber 1913:115	X					
		Howard 1914c:34	X					
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	P. *flavescens*	Howard 1914c:27				X		
		Coker *et al*. 1921:153				X		
		Stein 1968:46				X		

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	NT	LI	LT	BI	NS
Fusconaia								
ebena	*A. chrysochloris*	Surber 1913:115	X					
ebonyshell		Howard 1914c:18	X					
		Wilson 1916:340	X					
		Howard 1917:96				X		
		Coker 1919:22				X		
		Coker *et al*. 1921:153	X			X		
	P. annularis	Howard 1914c:18	X					
	P. nigromaculatus	Howard 1914c:18	X					
	M. salmoides	Howard 1914c:18	X					
flava	*P. annularis*	Wilson 1916:340	X					
Wabash pigtoe		Coker *et al*. 1921:153	X					
	P. nigromaculatus	Surber 1913:115	X					
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	L. macrochirus	Howard 1914c:25			X			
Plethobasus								
cyphyus	*S. canadense*	Surber 1913:115	X					
sheepnose		Wilson 1916:340	X					
Pleurobema								
oviforme	*C. galactura*	Neves 1983:158				X		
Tennessee clubshell	*L. cornutus*	Neves 1983:158						X
	Nocomis micropogon river chub	Neves 1983:158						X
	C. anomalum	Neves 1983:158						X
cordatum	*Lythrurus ardens* rosefin shiner	Yokley 1972:361				X		
Ohio pigtoe	*L. macrochirus*	Surber 1913:115	X					
		Coker *et al*. 1921:153	X					
Elliptio								
crassidens	*A. chrysochloris*	Howard 1914c:40	X					
elephant-ear								
dilatata	*D. cepedianum*	Wilson 1916:339	X					
spike								

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	P. olivaris	Howard 1914c:27	X					
	P. annularis	Howard 1914c:27	X					
		Wilson 1916:340	X					
	P. nigromaculatus	Howard 1914c:27	X					
	S. canadense	Howard 1914c:27	X					
complanata eastern elliptio	*F. diaphanus*	Wiles 1975:36 39	X					
	P. flavescens	Lefevre & Curtis 1912:168				X		
		Matteson 1948:708				X		
Uniomerus tetralasmus pondhorn	*N. crysoleucas*	Stern & Felder 1978:233	X					
Cyprogenia ~~*stegaria*~~ aberti fanshell	*Carassius auratus* goldfish	Chamberlain 1934:60			X			
Glebula rotundata round pearlshell	*L. cyanellus*	Parker *et al*. 1984:56				X		
	L. macrochirus	Parker *et al*. 1984:56				X		
Actinonaias ligamentina mucket	*A. rostrata*	Coker *et al*. 1921:152	X					
	N. gyrinus	Coker *et al*. 1921:152	X					
	M. chrysops	Surber 1913:115	X					
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X			X		
	P. annularis	Lefevre & Curtis 1912:168				X		
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X			X		
	P. nigromaculatus	Howard 1914c:36			X			
		Coker *et al*. 1921:153				X		
	A. rupestris	Lefevre & Curtis 1910:108				X		
	Micropterus dolomieui smallmouth bass	Coker *et al*. 1921:153		X				
		Howard & Anson 1922:69						X
	M. salmoides	Lefevre & Curtis 1910:109				X		
		Lefevre & Curtis 1912:168				X		
		Wilson 1916:339	X					
		Reuling 1919:340				X		

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	NT	LI	LT	BI	NS
		Coker *et al.* 1921:153	X			X		
		Howard & Anson 1922:76				X		
	L. cyanellus	Lefevre & Curtis 1912:168				X		
		Wilson 1916:338	X					
		Coker *et al.* 1921:152	X					
	L. macrochirus	Wilson 1916:339	X					
		Coker *et al.* 1921:153	X					
	S. canadense	Coker *et al.* 1921:153				X		
		Pearse 1924:181	X					
	P. flavescens	Lefevre & Curtis 1910:108				X		
		Coker *et al.* 1921:153	X			X		
Obovaria olivaria hickorynut	*S. platorhynchus*	Howard 1914a:43				X		
		Coker *et al.* 1921:153	X			X		
Ellipsaria lineolata butterfly	*L. cyanellus*	Surber 1913:115	X					
		Wilson 1916:338	X					
	S. canadense	Surber 1913:115	X					
	A. grunniens	Howard 1914a:43 44	X			X		
		Wilson 1916:338	X					
		Coker 1919:30						X
		Coker *et al.* 1921:152		X				
		Howard & Anson 1922:78						X
Leptodea fragilis fragile papershell	*A. grunniens*	Howard 1912:67						X
		Wilson 1916:338	X					
Potamilus ohiensis pink papershell	*P. annularis*	Surber 1913:115	X					
		Wilson 1916:340	X					
	A. grunniens	Coker & Surber 1911:181		X				
		Surber 1912:8						X
		Surber 1913:115	X					
		Wilson 1916:338	X					
		Howard & Anson 1922:73						X

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
alatus	A. grunniens	Howard 1912:67						X
pink heelsplitter		Wilson 1916:338	X					
purpuratus	A. grunniens	Surber 1913:105		X				
bleufer		Surber 1915:6	X					
		Wilson 1916:338	X					
Truncilla								
truncata	S. canadense	Wilson 1916:340	X					
deertoe	A. grunniens	Wilson 1916:338	X					
donaciformis	S. canadense	Surber 1913:115	X					
fawnfoot		Wilson 1916:340	X					
	A. grunniens	Surber 1912:8		X				
		Howard 1912:67						X
		Surber 1913:115	X					
		Howard 1914a:44	X					
		Wilson 1916:338	X					
		Howard & Anson 1922:73						X
Toxolasma								
parvus	P. annularis	Mermilliod 1973:235	X					
lilliput	L. gulosus	Wilson 1916:338	X					
	L. cyanellus	Mermilliod 1973:235	X					
	L. macrochirus	Mermilliod 1973:235	X					
	Lepomis humilis orangespotted sunfish	Mermilliod 1973:235	X					
lividus	L. cyanellus	Gooch In Hill 1986:17				X		
purple lilliput	L. megalotis	Gooch In Hill 1986:17				X		
texasensis	L. gulosus	Stern & Felder 1978:233	X					
Texas lilliput	L. macrochirus	Stern & Felder 1978:233	X					
Medionidus								
conradicus	Etheostoma flabellare fantail darter	Zale & Neves 1982a:2538	X			X		
Cumberland moccasinshell	Etheostoma rufilineatum redline darter	Zale & Neves 1982a:2538	X			X		

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	NT	LI	LT	DI	NS
Ligumia								
recta	*A. rostrata*	Coker *et al*. 1921:152	X					
black sandshell	*P. annularis*	Lefevre & Curtis 1912:168				X		
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
		Clarke & Berg 1959:52						X
	M. salmoides	Lefevre & Curtis 1912:168				X		
	L. macrochirus	Lefevre & Curtis 1912:164			X			
		Wilson 1916:339	X					
		Coker *et al*. 1921:193	X					
		Clarke & Berg 1959:52						X
	S. canadense	Pearse 1924:181	X					
subrostrata	*M. salmoides*	Lefevre & Curtis 1912:168				X		
pondmussel	*L. gulosus*	Stern & Felder 1978:233	X					
	L. cyanellus	Lefevre & Curtis 1912:168				X		
		Stern & Felder 1978:233	X					
	L. macrochirus	Lefevre & Curtis 1912:184					X	
		Stern & Felder 1978:233	X					
Villosa								
nebulosa	*G. affinis*	Neves *et al*. 1985:15				X		
Alabama rainbow	*A. rupestris*	Zale & Neves 1982a:2538	X			X		
	M. dolomieui	Zale & Neves 1982a:2538	X			X		
	Micropterus punctulatus spotted bass	Neves *et al*. 1985:15				X		
	M. salmoides	Neves *et al*. 1985:15				X		
	Micropterus notius Sawannee bass	Neves *et al*. 1985:15				X		
vanuxemi	*C. bairdi*	Neves *et al*. 1985:15				X		
mountian creekshell	*Cottus baileyi* black sculpin	Neves *et al*. 1985:15				X		
	Cottus cognatus slimy sculpin	Neves *et al*. 1985:15				X		
	C. carolinae	Zale & Neves 1982a:2538	X			X		

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
Lampsilis								
teres	*S. platorhynchus*	Surber 1913:115	X					
yellow sandshell		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	Lepisosteus spatula	Wilson 1916:339	X					
	alligator gar	Coker *et al*. 1921:152				X		
	L. platostomus	Howard 1914a:43				X		
		Wilson 1916:339	X					
		Reuling 1919:337				X		
		Coker *et al*. 1921:152	X			X		
		Howard & Anson 1922:74				X		
		Jones 1950:22						X
	L. osseus	Wilson 1916:339	X					
		Reuling 1919:337				X		
		Coker *et al*. 1921:152	X			X		
		Jones 1950:20						X
	P. annularis	Surber 1913:115	X					
		Wilson 1916:340	X					
		Coker *et al*. 1921:153	X					
	P. nigromaculatus	Surber 1913:115	X					
	M. salmoides	Wilson 1916:339	X					
		Coker 1919:32						X
	L. gulosus	Wilson 1916:338	X					
	L. cyanellus	Surber 1913:115	X					
		Coker *et al*. 1921:152	X					
	L. humilis	Surber 1913:115	X					
		Coker *et al*. 1921:153	X					
L. radiata	*P. flavescens*	Tedla & Fernando 1969:710				X		
eastern lampmussel								
L. luteola	*N. gyrinus*	Coker *et al*. 1921:153	X					
fatmucket	*M. chrysops*	Corwin 1920:81					X	
		Coker *et al*. 1921:153				X		
	P. annularis	Coker *et al*. 1921:153				X		
		Howard 1922:77	X					

Unionids	Vertebrate host	Reference Author date:page	Type of evidence NI	 NT	 LI	 LT	 BI	 NS
		Trdan 1981:246	X					
	P. nigromaculatus	Coker *et al*. 1921:153				X		
		Howard 1922:77				X		
		Trdan 1981:246	X					
	A. rupestris	Evermann & Clark 1918:260			X			
		Evermann & Clark 1920:49			X			
	M. dolomieui	Corwin 1920:81					X	
		Coker *et al*. 1921:153				X		
	M. salmoides	Howard 1914b:45				X		
		Reuling 1919:338				X		
		Coker *et al*. 1921:153				X		
		Howard 1922:66 67				X		
		Arey 1923:378				X		
		Trdan 1981:246	X					
	L. gulosus	Trdan 1981:246	X					
	L. macrochirus	Evermann & Clark 1918:260			X			
		Evermann & Clark 1920:49			X			
		Coker *et al*. 1921:153	X			X		
		Howard 1922:77				X		
		Trdan 1981:246	X					
	S. canadense	Corwin 1920:81					X	
		Coker *et al*. 1921:153				X		
	Stizostedion vitreum	Corwin 1920:81					X	
	walleye	Corwin 1921:307				X		
		Coker *et al*. 1921:153	X			X		
		Trdan 1981:246	X					
		Waller & Mitchell 1989:84				X		
	P. flavescens	Corwin 1920:81					X	
		Coker *et al*. 1921:153	X			X		
		Pearse 1924:165	X					
		Trdan 1981:246	X					
higginsi	*E. lucius*	Waller & Hollard-Bartels 1988:120				X		
Higgins eye	*M. salmoides*	Sylvester *et al*. 1984:556			X			
		Waller & Hollard-Bartels 1988:120				X		

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	M. dolomieui	Waller & Hollard-Bartels 1988:120				X		
	L. cyanellus	Waller & Hollard-Bartels 1988:120				X		
	L. macrochirus	Waller & Hollard-Bartels 1988:120				X		
	S. canadense	Surber 1913:115	X					
		Wilson 1916:340	X					
		Coker et al. 1921:153	X					
	S. vitreum	Sylvester et al. 1984:556			X			
		Waller & Hollard-Bartels 1988:120				X		
	P. flavescens	Waller & Hollard-Bartels 1988:120				X		
	A. grunniens	Wilson 1916:338	X					
		Coker et al. 1921:152	X					
ventricosa	P. annularis	Wilson 1916:340	X					
plain pocketbook		Coker et al. 1921:153	X			X		
	M. dolomieui	Coker et al. 1921:153				X		
	M. salmoides	Lefevre & Curtis 1912:182				X		
		Reuling 1919:339				X		
		Coker et al. 1921:153				X		
	L. macrochirus	Coker et al. 1921:153				X		
	S. canadense	Wilson 1916:340	X					
		Coker et al. 1921:153	X					
	P. flavescens	Coker et al. 1921:153				X		
fasciola wavy-rayed lampmussel	M. dolomieui	Zale & Neves 1982a:2538	X			X		
Epioblasma brevidens cumberlandian combshell	Etheostoma blennioides greenside darter	Yeager In Hill 1986:44				X		
	Etheostoma maculatum spotted darter	Yeager In Hill 1986:44				X		
	E. rufilineatum	Yeager In Hill 1986:44				X		
	Etheostoma simoterum Tennessee snubnose darter	Yeager In Hill 1986:44				X		

Unionids	Vertebrate host	Reference Author date:page	NI	NT	LI	LT	BI	NS
	Percina caprodes logperch	Yeager *In* Hill 1986:44				X		
	C. carolinae	Yeager *In* Hill 1986:44				X		
capsaeformis oyster mussel	*E. maculatum*	Yeager *In* Hill 1986:46				X		
	E. rufilineatum	Yeager *In* Hill 1986:46				X		
	Percina sciera dusky darter	Yeager *In* Hill 1986:46				X		
	C. carolinae	Yeager *In* Hill 1986:46				X		
triquetra snuffbox	*P. caprodes*	Yeager *In* Hill 1986:47				X		
	C. carolinae	Yeager *In* Hill 1986:47				X		

Type of evidence: NI NT LI LT BI NS

NI-Natural Infection without transformation; NT-Natural Transformation; LI-Laboratory Infection without transformation; LT-Laboratory Transformation; BI-By Infrence; A relationship was not observed however there was evidence of a relatioship (e.g. a population of *A. imbecillis* occuring in a new pond that was stocked with *M. salmoides*.) NS-Not specified; no evidence was given. Scientific names for the Unionidae follow Stansbery and Borror (1983). Unionid common names follow Turgeon *et al*. (1990) while fish scientific and common names follow Robins *et al*. (1991).

alone. For these relationships, no evidence was found that would indicate the glochidium and potential host actually encounter each other in their natural environment. Finally, 10 relationships are based on laboratory infection alone (transformation was not observed), one is the result of both natural and laboratory infection (transformation was not observed), six are based on populations of mussels found in ponds stocked with a single species of fish, and four are not substantiated by any evidence given by the authors or found in the literature.

DISCUSSION

Since Leydig (1866) first discovered glochidia embedded in the fins of a fish, investigators have attempted to understand the nature of this particular host - parasite relationship. The primary objective of early studies was to uncover the events that occur during transformation from glochidium to juvenile (Braun, 1878; Schmidt, 1885; and others). These studies also demonstrated that artificial infection techniques could be employed to determine the identity of hosts. In North America, the staff of the U.S. Bureau of Fisheries became particularly interested. They were responsible for a large mussel fishery, for use in the pearl button industry, and the resource appeared to be diminishing due to over harvesting and habitat deterioration. They used artificial infection experiment to determine hosts for many of the commercially important species (Lefevre and Curtis, 1910, 1912; Surber, 1912, 1913, 1915; and others). Even so, hosts for only about one quarter of the North American species have been proposed.

Is the information provided by these, and subsequent studies, sufficient to accept the proposed host - parasite relationship? It is clear from the evidence summarized in Table 1 that many of the included studies would fail the currently accepted test of transformation from glochidium to juvenile. Of the 279 proposed relationships only about half (156) have resulted from transformation experiments. Furthermore, 97 of these have been demonstrated in the laboratory but have not been substantiated by field observations.

It is suggested that many of the proposed relationships are untested and potentially false. A single example, selected because the author provided photographs of the glochidia examined, demonstrates this point exactly. Wiles (1975) reported glochidia of _Anodonta cataracta_ Say, 1817 on the fins of _Catostomus commersoni_ (Lacepede, 1803) and suggested a host - parasite relationship between the two. However, his photograph (his Figure 6) is of the glochidium of _Alasmidonta undulata_ (Say, 1817) not _A. cataracta_. See Rand and Wiles (1982) for electron micrographs of the glochidium of _A. cataracta_ and Clarke (1981) for _A. undulata_ or Hoggarth (1988) for both species.

How many more relationships, based on natural infections, are incorrect can not be determined, but the previous example is probably not an isolated case. Waller et al. (1988) have shown that the shape and size of lampsiline glochidia can vary so much as to make these characters very unreliable for use in determining species. They found that scanning electron microscopy (SEM) revealed useful characters for glochidial identification, however. Likewise, Rand and Wiles (1982) distinguished two species of _Anodonta_ on the basis of glochidial characters and Clarke (1981, 1985) and Hoggarth (1988) demonstrated many characters of use for species identification.

Glochidia located on fish currently deposited in museum collections might be used to identify potential hosts although fixation of vertebrates in acidic formalin, rather than buffered formalin, may produce unsatisfactory material for SEM examination and might eliminate or reduce the potential value of this resource. Still, much could be gained by examining natural glochidial infections with SEM rather than relying on glochidial size and shape for species identification.

LITERATURE CITED

Arey, L.B., 1923. Observations on an acquired immunity to a metazoan parasite. Journal of Experimental Zoology, 38:377-381.

Baker, F.C., 1928. The Fresh Water Mollusca of Wisconsin. Part II. Pelecypoda. Bulletin of the Wisconsin Geologic and Natural History Survey, 70:1-495.

Braun, M., 1878. Ueber die postembryonale Entwicklung unserer Susswassermuscheln (Anodonta). Zoologischer Anzeiger, 1:7-10.

Chamberlain, T.K., 1934. The glochidial conglutinates of the Arkansas Fanshell, Cyprogenia aberti (Conrad). Biological Bulletin, 66:55-61.

Clarke, A.H., 1981. The tribe Alasmidontini (Unionidae: Anodontinae), Part I: Pegias, Alasmidonta, and Arcidens. Smithsonian Contributions to Zoology, 326:1-101.

Clarke, A.H., 1985. The tribe Alasmidontini (Unionidae: Anodontinae), Part II: Lasmigona and Simpsonaias. Smithsonian Contributions to Zoology, 399:1-75.

Clarke, A.H. and C.O. Berg, 1959. The freshwater mussels of central New York with an illustrated key to the species of northeastern North America. Cornell University Agricultural Experimental Statation Memoirs, 367:1-79.

Coker, R.E., 1919. Fresh-water mussels and mussel industries of the United States. Bulletin of the U.S. Bureau of Fisheries, 36:13-89. Separately issued as Bureau of Fisheries Document Number 865.

Cunjak, R.A. and S.E. McGladdery, 1991. The parasite-host relationship of glochidia (Mollusca: Margaritiferidae on the gills of young-of-year Atlantic salmon (*Salmo salar*). Canadian Journal of Zoology, 69:353-358.

Ellis, M.M. and M. Keim, 1918. Notes on the glochidia of *Strophitus edentulus pavonius* (Lea) from Colorado. The Nautilus, 32:17-18.

Evermann, B.W. and H.W. Clark, 1918. The Unionidae of Lake Maxinkuckee. Proceedings of the Indiana Academy of Science, 1917:251-285.

Evermann, B.W. and H.W. Clark, 1920. Lake Maxinkuckee. A physical and biological survey, Volume II. Biology. Indiana Department of Conservation, Indianapolis. pp. 512.

Fuller, S.L.H., 1974. Clams and mussels (Mollusca:Bivalvia). In C.W. Hart, Jr. and S.L.H. Fuller (eds.): Pollution Ecology of Freshwater Invertebrates. New York: Academic Press, pp. 215-273.

Fustish, C.A. and R.E. Millemann, 1978. Glochidiosis of salmonid fishes. II. Comparison of tissue response of Coho and Chinook salmon to experimental infection with *Margaritifera margaritifera* (L.)(Pelecypoda: Margaritiferidae). Journal of Parasitology, 64:155-157.

Hankinson, T.L., 1908. A Biological Survey of Walnut Lake, Michigan. Wynkoop Hullenbeck Crawford Co. State Printers, Lansing, Michigan. pp.155-288.

Hill, A.M., 1987. The glochidia (larvae) of the freshwater mussel Margaritifera hembeli (Unionacea: Margaritiferidae) fish host species, morphology and period of fish host infection. M.S. thesis, Northwestern State University, Louisiana. 32 pp.

Hill, D.M., 1986. Activity 3: Identification of fish hosts. Tennessee Valley Authority Office of Natural Resources and Economic Development Cumberlandian Mollusk Conservation Program. Edited and compiled from Gooch, C.H. 1984. Cumberlandian mollusk conservation program, activity 3, a. identification of fish hosts for Conradilla caelata. Unpublished annual report. Saylor, C.F. 1984. Cumberlandian mollusk conservation plan (CMCP) activity 3, Quadrula intermedia fish host determination. unpublished annual report. Yeager, B.L. 1983. Methods and results of CMCP activity 3 investigations in 1983. unpublished annual report. Tennessee Valley Authority, Office ofNatural Resources and Economic Development,Norris, Tennessee. pp.57

Hoggarth, M.A., 1988. The use of glochidia in the systematics of the Unionidae (Mollusca: Bivalvia). Ph.D. Dissertation, The Ohio State University, Columbus, 340 pp.

Howard, A.D., 1912. The catfish as a host for fresh-water mussels. Transactions of the American Fisheries Society, 42:65-70.

Howard, A.D., 1914a. Some cases of narrowly restricted parasitism among commercial species of fresh water mussels. Transactions of the American Fisheries Society, 44:41-44.

Howard, A.D., 1914b. A new record in rearing fresh-water pearl mussels. Transactions of the American Fisheries Society, 44:45-47.

Lefevre, G. and W.C. Curtis, 1910. Experiments in the artificial propagation of fresh-water mussels. Bulletin of the U.S. Bureau of Fisheries, 28:615-626. Separately issued as Bureau of Fisheries Document Number 671.

Lefevre, G. and W.C. Curtis, 1912. Studies on the reproduction and artificial propagation of freshwater mussels. Bulletin of the U.S. Bureau of Fisheries, 30:105-201. Separately issued as Bureau of Fisheries Document Number 756.

Leydig, F., 1866. Mittheilung uber den parasitismus junger Unioniden an Fischen in Noll. Tubingen, Inaugural- Dissertation. Frankfort.

Matteson, M.R., 1948. Life history of Elliptio complanatus (Dillwyn, 1817). American Midland Naturalist, 40:690-723.

Mermilliod, W., 1973. "An investigation for the natural host of the glochidia of Toxolasma parva" Undergraduate research paper, Lousiana State University at Bataon Rouge. In: S.L.H. Fuller. 1974. Clams and mussels (Mollusca:Bivalvia). In: C.W. Hart, Jr. and S.L.H. Fuller (eds.): Pollution Ecology of Freshwater Invertebrates. New York: Academic Press, pp. 215-273.

Murphy, G., 1942. Relationship of the fresh-water mussel to trout in the Truckee River. California Fish and Game, 28:89-102.

Neves, R.J., 1983. The status of freshwater mussel research in Virginia. Report of Freshwater Mussels Workshop, 26-27 October 1982, A.C. Miller (compiler). U.S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi. pp.155-168.

Neves, R.J., L.R. Weaver and A.V. Zale, 1985. An evaluation of host fish suitability for glochidia of Villosa vanuxemi and V. nebulosa (Pelecypoda:Unionidae). American Midland Nauralist, 113:13-19.
Oesch, R.D., 1984. Missouri Naiades A guide to the mussels of Missouri. Missouri Department of Conservation, Jefferson City, 270 pp.
Parker, R.S., C.T. Hackney and M.F. Vidrine, 1984. Ecology and reproductive strategy of a south Louisiana freshwater mussel, Glebula rotundata (Lamarck) (Unionidae: Lampsilini). Freshwater Invertebrate Biology, 3:-53-5-8.
Pearse, A.S., 1924. The parasites of lake fishes. Transactions of the Wisconsin Academy of Science and Arts Letters, 21:161-194.
Penn, G.H., 1939. A study of the life cycle of the freshwater mussel, Anodonta grandis, in New Orleans. The Nautilus, 52: 99-101.
Rand, T.G. and M. Wiles, 1982. Species differences of the glochidia of Anodonta cataracta Say, 1817 and Anodonta implicata Say, 1829 (Mollusca: Unionidae) by scanning electron microscopy. Canadian Journal of Zoology, 60:1722-1727.
Read, L.B. and K.H. Oliver, 1953. Notes of the ecology of the fresh-water mussels of Dallas County. Field and Labratory, 21:75-80.
Reuling, F.H., 1919. Acquired immunity to an animal parasite. Journal of Infectious Dissease, 24:337-346.
Robins, C.R.,R.M. Bailey, C.E. Bond, J.R. Brroker, E.A. Lachner, R.N. Lea, and W.B. Scott, 1991. Common and Scientific Names of Fishes from the United States and Canada. American Fisheries Society Special Publicaiton , Bethesda, Maryland.

Schmidt, F., 1885. Beitrag zur kenntniss der postembryonalen Entwicklung der Najaden. Archiv fur Naturgeschichte,51:201-234.

Stansbery, D.H. and K.G. Borror, 1983. A list of the recent freshwater bivalve mollusks of the Holartic Region catalogued into The Ohio State University Museum of Zoology collections. The Ohio State University Museum Reports for 1983 Number 2, 3pp.

Stein, C.B., 1968. Studies in the life history of naiad, Amblema plicata (Say, 1817). American Malacological Union Annual Reptort, 968:46-47.

Stern, E.M. and D.L. Felder, 1978. Identification of host fish for four species of freshwater mussels (Bivalvia: Unionidae). American Midland Naturalist, 100:233-236.

Surber, T., 1912. Identification of the glochidia of freshwater mussels. Report of the U.S. Commission of Fisheries for 1912 and Speceial Papers, pp.1-10. Separately issued as Bureau of Fisheries Document Number 771.

Surber, T., 1913. Notes on the natural hosts of fresh-water mussels. Bulletin of the U.S. Bureau of Fisheries, 32:110-116. Separately issued as Bureau of Fisheries Document Number 778.

Surber, T., 1915. Identification of the glochidia of fresh- water mussels. Report of the U.S. Commission of Fisheries for 1914, Appendix V, pp. 1-9. Separately issued as Bureau of Fisheries Document Number 813.

Sylvester, J.R., L.E. Holland and T.K. Kummer, 1984. Observations on burrowing rates and comments on host specificity in the endangered mussel Lampsilis higginsi. Journal of Freshwater Ecology, 2:555-559.

Waller, D.L. and L.E. Holland-Bartels, 1988. Fish hosts for glochidia of the endangered freshwater mussel Lampsilis higginsi Lea (Bivalvia: Unionidae). Malacological Review, 21:119-122.

Waller, D.L. and L.G. Mitchell, 1989. Gill tissue reactions in walleye Stizostedion vitreum vitreum and common carp Cyprinus carpio to golchidia of the freshwater mussel Lampsilis radiata siliquoidea. Disease of Aquatic Organisms, 6:81-87.

Wilson, C.B., 1916. Copepod parasites of fresh-water fishes and their economic relations to mussel glochidia. Bulletin of the U.S. Bureau of Fisheries, 34:331-374. Separately issued as Bureau of Fisheries Document Number 824.

Wilson, K.A. and K. Ronald, 1967. Parasite fauna of the sea lamprey (Petromyzon marinus von Linne) in the Great Lakes region. Canadian Journal of Zoology, 45:1083-1092.

Yeager. B.L. and R.J. Neves, 1986. Reproductive cycle and fish hosts of the rabbit's foot mussel, Quadrula cylindrica strigillata (Mollusca:Unionidae) in the upper Tennessee River drainage. The Nautilus, 116:329-340.

Yokley, P., Jr., 1972. Life history of Pleurobema cordatum (Rafinesque, 1820) (Bivalvia:Unionacea). Malacologia, 11:351-364.

Zale, A.V. and R.J. Neves, 1982a. Fish hosts of four species of lampsiline mussels (Mollusca:Unionidae) In Big Moccasin Creek, Virigina. Canadian Journal of Zoology, 60:2535-2542.

Zale, A.V. and R.J. Neves, 1982b. Identification of a fish host for Alasmidonta minor (Mollusca:Unionidae). American Midland Naturalist, 107:386-388.

Naiades (Bivalvia: Unionidae) of Sugar Creek, East Fork White River Drainage, in Central Indiana

Jeff L. Harmon
538 Noack Road
Greenwood, IN 46143

ABSTRACT

The freshwater mussel population of Sugar Creek, East Fork White River drainage, was surveyed during 1990. Thirty-five species, plus the Asiatic Clam, *Corbicula fluminea* (Müller, 1774), were collected from twenty-seven Sugar Creek stations and sixteen sites from five of Sugar Creek's major tributaries, Little Sugar Creek (North), Buck Creek, Snail Creek, Little Sugar Creek (South), and Youngs Creek. Twenty-three species were collected alive, including State endangered *Epioblasma triquetra* (Rafinesque, 1820), and State species of special concern *Lampsilis fasciola* Rafinesque, 1820, and *Villosa lienosa* (Conrad, 1834). Also collected were fresh dead specimens of State species of special concern *Villosa fabalis* (I. Lea, 1831) as well as weathered or subfossil specimens of State endangered *Epioblasma torulosa rangiana* (I. Lea, 1839), *Pleurobema clava* (Lamarck, 1819) and *Quadrula cylindrica cylindrica* (Say, 1817) and State species of special concern *Simpsonaias ambigua* (Say, 1825). 599 live mussels were collected from Sugar Creek and its tributaries. Overall the three most abundant species were *Amblema plicata plicata* (Say, 1817) (28.7%), *Lampsilis siliquoidea* (Barnes, 1823) (23.2%) and *Actinonaias ligamentina* (Lamarck, 1819) (14.0%).

INTRODUCTION

From the decline in the commercial value of mussel shells as a raw material for pearl buttons in the 1940s, until the 1960s when mussels again became a valuable natural resource for the cultured pearl industry, little attention was given to the mussels of Indiana. Krumholz, Bingham and Meyer's (1970) survey of the commercially valuable mussels of the Wabash and White Rivers in 1966 and 1967 marked a renewed interest in the conservation of this resource. However, a comprehensive effort to determine the diversity, distribution and status of the freshwater mussels of many of Indiana's smaller streams is needed. This survey was intended to provide information on the status of the freshwater mussel population of Sugar Creek.

Sugar Creek, part of the East Fork White River drainage in central Indiana, originates in the western edge of Henry County approximately seven miles west of New Castle. It flows southwesterly through Hancock, Shelby and Johnson Counties before joining the Big Blue River within the boundaries of Camp Atterbury in southern Johnson County to form the Driftwood River. Sugar Creek is free flowing with the exception of an old mill dam within Camp Atterbury that has been breached and presently has little affect on stream flow.

Sugar Creek's watershed drains approximately 474 square miles in Hancock, Henry, Johnson, Madison, Marion and Shelby Counties. Major tributaries include Little Sugar Creek (North), Buck Creek, Snail Creek, Little Sugar Creek (South) and Youngs Creek. The "North" and "South" designations used for the two Little Sugar Creeks are for clarity and are not part of the streams' official names.

METHODS

Twenty-seven collection stations on Sugar Creek proper and sixteen stations on five of Sugar Creek's major tributaries were surveyed for freshwater mussels from February 8, 1990 to October 8, 1990 (Table 1 and Fig. 1). Living and dead shells were collected by hand. Collection times for live material ranged from one-quarter hour to two hours and averaged approximately one hour per site. All live mussels collected were identified and returned to the stream.

Specimens were placed in four categories according to condition as follows: live, fresh dead, weathered and subfossil. Fresh dead specimens were those with periostracum intact and little or no staining or discoloring of the nacre. Weathered specimens were generally differentiated from the subfossil shells by the presence of all or most of the periostracum.

A voucher set comprised of one specimen of each species collected from the watershed was deposited in the Indiana State Museum. Additionally, a collection of specimens of each species from each site, when available, were deposited in the Mollusc Collection of the Illinois Natural History Survey, Champaign, Illinois (INHS 10714 - INHS 11281). All scientific names used follow nomenclature accepted by the American Fisheries Society.

Table 1. Collection stations on Sugar Creek and its tributaries surveyed in 1990.

SITE #	LOCATION
Sugar Creek	
1.	Henry County; Co Rd 100N bridge 0.25 m E of Co Rd 900W; Sections 6 & 7, T17N, R9E
2.	Henry County; Co Rd 900W bridge; Section 7, T17N, R9E and Section 12, T17N, R8E
3.	Henry County; Co Rd 100N bridge between Co Rds 900W and 975W; Sections 1 & 12, T17N, R8E
4.	Hancock County; Co Rd 1000N bridge E of Co Rd 1100E; Section 14, T17N, R8E
5.	Hancock County; Co Rd 900N 0.1 m E of Co Rd 1000E; Section 22, T17N, R8E
6.	Hancock County; Nashville Rd bridge; Section 18, T17N, R8E
7.	Hancock County; Co Rd 1000N bridge, 0.1 m E of Co Rd 500E; Section 11, T17N, R7E
8.	Hancock County; Troy Rd approx. 0.1 m N of bridge, 0.5 m W of Eden; Section 21, T17N, R7E
9.	Hancock County; Co Rd 700N bridge; Section 36, T17N, R6E
10.	Hancock County; Co Rd 300N bridge; Sections 14 & 23 T16N, R6E
11.	Hancock County; Co Rd 100S bridge; Section 4, T15N, R6E
12.	Hancock County; Co Rd 200S bridge; Section 9, T15N, R6E
13.	Hancock-Shelby County Line; Hancock Co Rd 600S bridge, Section 32, T15N, R6E
14.	Shelby County; Co Rd 1100N bridge; Section 6, T14N, R6E
15.	Shelby County; Co Rd 700N bridge upstream to Railroad bridge; Section 25, T14N, R5E
16.	Shelby County; London Rd at upstream end of Broad Ripple Camp; Section 1, T13N, R5E

Table 1 (cont'd). Collection stations on Sugar Creek and its tributaries surveyed in 1990.

SITE # LOCATION

Sugar Creek

17. Shelby County; London Rd downstream of Broad Ripple Camp; Section 12, T13N, R5E
18. Shelby County; Co Rd 400N bridge; Section 12, T13N, R5E
19. Shelby County; Co Rd 275N bridge; Section 23, T13N, R5E
20. Johnson County; Co Rd 350N bridge, 0.75 m E of Needham; Section 34, T13N, R5E
21. Shelby County; State Road 44 bridge; 6 m E of Franklin; Section 14, T12N, R5E
22. Johnson County; End of lane East off Shelby County Co Rd 875W; Section 27, T12N, R5E
23. Johnson County; Greensburg Rd bridge; Section 34, T12N, R5E.
24. Johnson County; Co Rd 400S bridge 1.5 m ESE of Amity; Section 9, T11N, R5E
25. Johnson County; U.S. 31 bridge; Section 17, T11N, R5E
26. Johnson County; Camp Atterbury, old dam site; Section 20, T11N, R5E
27. Johnson County; Large sand bar in Camp Atterbury; Section 29, T11N, R5E

Little Sugar Creek (North)

28. Hancock County; Co Rd 300W bridge; Sections 33 & 34, T15N, R6E
29. Shelby County; Co Rd 600W bridge to mouth, Section 7, T14N, R6E

Buck Creek

30. Marion County; Prospect Street bridge; Sections 10 & 15, T15N, R5E

Table 1 (cont'd). Collection stations on Sugar Creek and its tributaries surveyed in 1990.

SITE # LOCATION

Buck Creek

31. Marion County; East McGregor Rd bridge; Section 15, T14N, R5E
32. Marion County; East Maze Rd bridge; Section 22, T14N, R5E
33. Shelby County; Co Rd 875W bridge; Section 35, T14N, R5E

Snail Creek

34. Shelby County; Co Rd 400N bridge; Sections 8 & 17, T13N, R6E
35. Shelby County; London Rd bridge; Section 13, T13N, R5E

Little Sugar Creek (South)

36. Johnson County; Co Rd 500N bridge; Sections 20 & 21, T13N, R5E
37. Johnson County; Co Rd 350N bridge; Section 33, T13N, R5E
38. Johnson County; Co Rd 700E bridge; Section 4, T12N, R5E

Youngs Creek

39. Johnson County; South Street bridge, Franklin; Section 23, T12N, R4E
40. Johnson County; U.S. 31 bridge; Section 25, T12N, R4E
41. Johnson County; Co Rd 400S bridge; Sections 5 & 8, T11N, R5E
42. Johnson County; State Highway 252 bridge; Section 8, T11N, R5E
43. Johnson County; Co Rd 500S bridge; Section 17, T11N, R5E

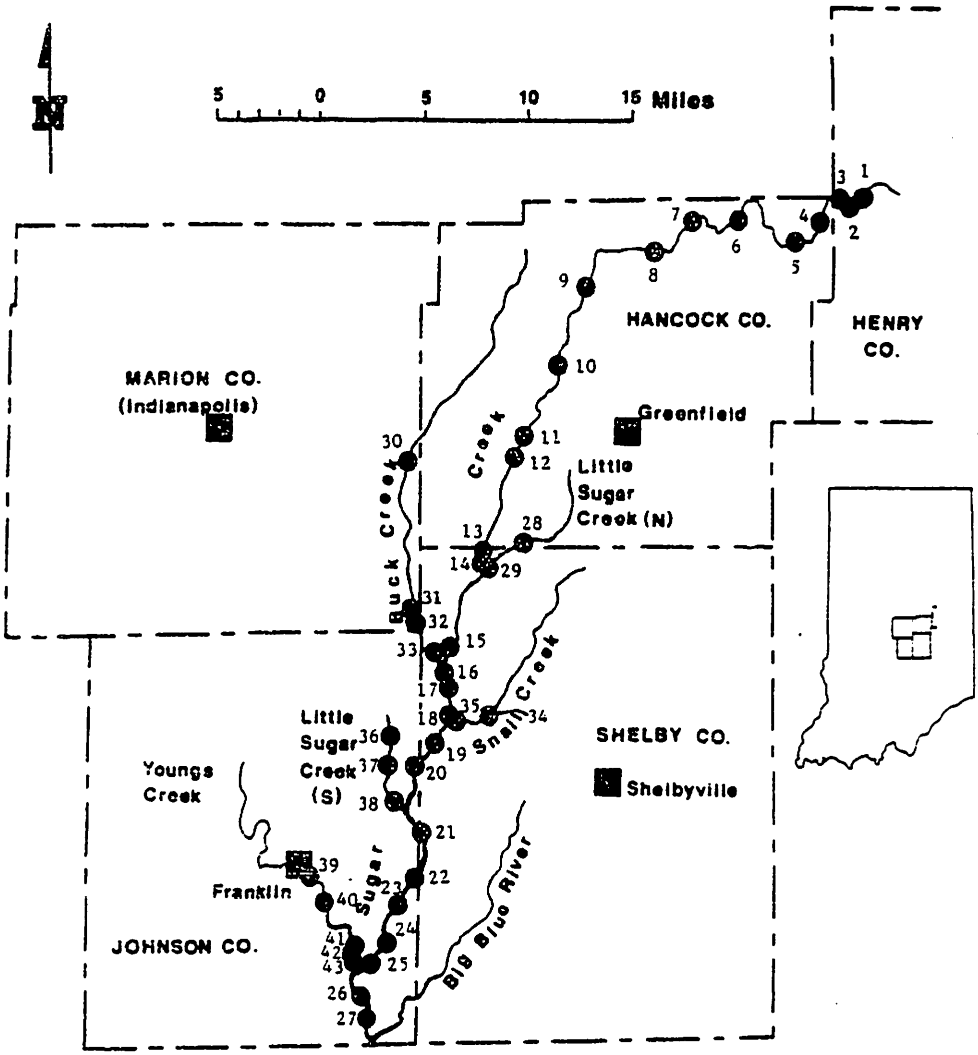

Figure 1. Collection sites on Sugar Creek and its tributaries surveyed in 1990.

RESULTS

Thirty-five species of mussels, plus the Asian clam *Corbicula fluminea*, were represented in the Sugar Creek watershed in this survey (Table 2). Of the 35 species found, 23 species were collected alive. Five additional species were found as fresh dead specimens. The remaining seven species were collected as weathered or subfossil specimens only. A total of 492 live specimens were observed in Sugar Creek proper with an additional 107 individuals found in the five major tributaries for a watershed total of 599 living specimens observed during this survey. Three species, *Amblema plicata plicata* (28.7%), *Lampsilis siliquoidea* (23.2%) and *Actinonaias ligamentina* (14.0%), comprised approximately 66% of the live mussels noted. Single live specimens were observed of three species, *Epioblasma triquetra*, *Lampsilis fasciola* and *Pleurobema coccineum*, making these the rarest of the living species encountered in Sugar Creek. Thirteen species were represented by fewer than 10 live individuals.

The number of live species per station ranged from 0 to 15, while the number of live specimens observed per site ranged from 0 to 140. Sites 8 and 12 provided the most abundant and diverse populations of living mussels with 140 (15 species) and 123 (12 species) live individuals, respectively, for a total of 263 live individuals, or 44% of the total observed. No live mussels were observed at 19 of the 43 collection stations and no shells were found at three sites.

A total of 13 species were collected live from Sugar Creek's five main tributaries. Sixty-two live specimens, or 58.0% of the living mussels collected from these tributaries were *Lampsilis siliquoidea*. Ten or fewer living individuals of the remaining 12 species were collected from these tributaries. Six additional species were collected fresh dead while three more were collected as weathered or subfossil.

DISCUSSION

Seven species, *Simpsonaias ambigua*, *Cyclonaias tuberculata*, *Elliptio crassidens*, *Pleurobema clava*, *Quadrula cylindrica cylindrica*, *Epioblasma torulosa rangiana* and *Leptodea fragilis*, were collected only as weathered or subfossil shells. Condition of the shells collected indicate that three of these, *Cyclonaias tuberculata*, *Quadrula cylindrica cylindrica* and *Epioblasma torulosa rangiana*, are likely extirpated from the Sugar Creek watershed. *Cyclonaias tuberculata* was apparently never a common species as only a single subfossil specimen was collected. The remaining four species may still inhabit the stream but were represented by weathered specimens only. Based on this survey, *Pleurobema clava* was historically the most widespread of these species and may still survive in upper portions of Sugar Creek within Hancock County.

In addition to the living and fresh dead specimens of *Epioblasma triquetra* noted during this survey, recent fresh dead collections of this species from Graham Creek (Harmon, 1989) indicate that the East Fork White River drainage may harbor the last populations of the snuffbox in Indiana. Cummings and Berlocher (1990) found only shells of this species in their survey of the Tippecanoe River.

Assuming the extirpation of the seven species represented only by weathered of subfossil

Table 2. Species distribution by site for Sugar Creek mussels collected in 1990.
= live specimens, x = fresh dead specimens, o = weathered or subfossil specimens

		SUGAR CREEK												
		1	2	3	4	5	6	7	8	9	10	11	12	13
SUBFAMILY ANODONTINAE														
Alasmidonta marginata	Say, 1818	-	-	-	-	-	-	x	2	x	x	x	x	o
Alasmidonta viridis	(Raf., 1820)	-	o	-	-	2	-	x	x	o	-	o	o	o
Anodonta grandis	Say, 1829	-	o	-	-	2	o	-	7	x	x	o	x	o
Anodonta imbecillis	Say, 1829	-	-	-	-	-	-	-	-	-	-	-	x	-
Anodonta suborbiculata	Say, 1831	-	-	-	-	-	-	-	-	-	-	-	-	-
Anodontoides ferussacianus	(I. Lea, 1834)	x	x	-	-	1	-	-	x	o	-	-	1	-
Lasmigona complanata complanata	(Barnes, 1823)	-	-	-	-	-	x	-	-	-	x	x	1	-
Lasmigona compressa	(I. Lea, 1829)	-	-	-	-	2	-	-	1	x	-	x	x	-
Lasmigona costata	(Raf., 1820)	-	-	-	-	-	-	-	10	o	-	x	x	o
Simpsonaias ambigua	(Say, 1825)	-	-	-	-	-	-	-	-	-	-	-	-	-
Strophitus undulatus	(Say, 1817)	-	-	-	-	-	-	-	4	-	x	x	1	-
SUBFAMILY AMBLEMINAE														
Amblema plicata plicata	(Say, 1817)	-	-	-	-	-	-	-	30	3	x	15	102	9
Cyclonaias tuberculata	(Raf., 1820)	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio crassidens	(Lam., 1819)	-	-	-	-	-	-	-	-	-	-	-	-	-
Elliptio dilatata	(Raf., 1820)	-	-	-	-	-	-	-	13	14	-	x	6	10
Fusconaia flava	(Raf., 1820)	-	-	-	-	-	-	-	2	x	-	x	x	x
Pleurobema clava	(Lam., 1819)	-	-	-	-	-	-	-	o	o	-	o	o	o
Pleurobema coccineum	(Conrad, 1834)	-	-	-	-	-	-	-	-	-	-	-	1	x
Quadrula cylindrica cylindrica	(Say, 1817)	-	-	-	-	-	-	-	-	-	-	-	-	-
Quadrula pustulosa pustulosa	(I. Lea, 1831)	-	-	-	-	-	-	-	-	-	-	-	2	-
Tritogonia verrucosa	(Raf., 1820)	-	-	-	-	-	-	-	-	-	-	-	3	-
SUBFAMILY LAMPSILINAE														
Actinonaias ligamentina	(Lam., 1819)	-	-	-	-	-	-	-	-	-	x	x	3	5
Epioblasma torulosa rangiana	(I. Lea, 1839)	-	-	-	-	-	-	-	-	-	-	-	-	-
Epioblasma triquetra	(Raf., 1820)	-	-	-	-	-	-	-	x	-	-	x	x	o
Lampsilis cardium	(Raf., 1820)	-	-	-	-	-	o	-	6	1	x	x	1	o
Lampsilis fasciola	Raf., 1820	-	-	-	-	-	-	-	1	x	-	x	x	-
Lampsilis siliquoidea	(Barnes, 1823)	-	-	-	-	4	o	1	48	9	x	x	1	1
Leptodea fragilis	(Raf., 1820)	-	-	-	-	-	-	-	-	-	-	-	-	-
Obovaria subrotunda	(Raf., 1820)	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptychobranchus fasciolaris	(Raf., 1820)	-	-	-	-	-	-	-	6	1	-	x	1	5
Toxolasma lividus	(Raf., 1831)	-	-	-	-	-	-	x	2	o	o	x	x	-
Toxolasma parvus	(Barnes, 1823)	-	-	-	-	o	-	-	-	-	-	-	-	-
Villosa fabalis	(I. Lea, 1831)	-	-	-	-	-	-	-	-	-	-	-	-	-
Villosa iris	(I. Lea, 1829)	-	-	-	-	-	-	x	6	x	-	x	x	1
Villosa lienosa	(Conrad, 1834)	-	-	-	-	-	-	x	2	2	-	x	x	o
Corbicula fluminea	(Müller, 1774)	-	-	-	-	-	-	-	x	x	x	x	x	x

SITES														TRIBUTARY SITES															
14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
-	o	o	x	x	o	x	o	o	x	o	o	o	x	-	o	-	-	x	x	-	-	-	o	-	-	-	-	x	-
-	o	-	o	o	-	-	-	-	-	-	-	-	-	o	-	-	o	o	x	-	o	1	x	o	-	-	o	-	-
o	-	-	-	o	-	-	-	-	x	-	o	o	x	1	1	-	-	-	-	-	x	-	o	o	-	o	-	-	-
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o	-	o	x	o	o	-	-	o	x	-	-	x	x	5	x	-	o	o	x	-	x	1	1	x	x	x	x	x	x
-	4	o	1	2	2	-	x	x	o	-	-	x	x	-	1	-	-	2	6	-	o	-	-	-	x	-	1	x	-
-	-	-	x	o	-	-	-	-	-	o	-	x	-	2	1	-	-	-	x	-	x	-	o	o	-	-	x	x	o
o	1	o	1	x	o	x	o	o	x	x	o	x	1	-	2	-	-	o	1	-	o	-	-	o	-	o	x	x	-
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x	1	1	o	o	o	o	o	1	x	o	o	1	o	-	8	-	o	o	1	o	o	-	-	-	-	o	o	x	-
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x	2	11	2	o	14	x	x	35	x	x	x	9	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-
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x	o	2	x	x	-	-	x	x	x	x	o	x	o	-	o	-	o	o	1	-	x	-	-	-	-	-	-	-	-
o	-	o	o	x	o	o	-	o	o	x	o	o	o	-	o	-	o	o	x	o	x	-	-	-	-	o	-	-	-
x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	x	x	x	x	x	x	x	-	x	x	x	-	x	x	x

specimens, and the continued presence of all fresh dead species, the Sugar Creek watershed continues to support 80% of its original freshwater mussel diversity.

ACKNOWLEDGEMENTS

I would like to express my appreciation to Greg McKay, Indiana Department of Environmental Management (IDEM), for assistance with collections at sites 15, 29 and 33 and to Max Henschen, IDEM, Kevin Cummings, Illinois Natural History Survey, and Dr. David Stansbery, Ohio State University, for assistance with identification of difficult specimens and for providing museum specimen information. This survey was funded by a grant from the Indiana Department of Natural Resources' Nongame and Endangered Wildlife Program.

Literature Cited

Cummings, K.S. and J.M.K. Berlocher. 1990. The naiades or freshwater mussels (Bivalvia: Unionidae) of the Tippecanoe River, Indiana. Malacological Review. 23(1):83-98.

Harmon, J.L. 1989. Freshwater bivalve mollusks (Bivalvia: Unionidae) of Graham Creek, a southeastern Indiana stream. Malacology Data Net. 2(5/6):113-121.

Krumholz, L.A., R.L. Bingham and E.R. Meyer. 1970. A survey of the commercially valuable mussels of the Wabash and White Rivers of Indiana. Proc. Indiana Acad. Sci. 79:205-226.

ONTARIO'S SYDENHAM RIVER, AN IMPORTANT REFUGIUM FOR NATIVE FRESWATER MUSSELS AGAINST COMPETITION FROM THE ZEBRA MUSSEL DREISSENA POLYMORPHA.

Arthur H. Clarke

SUMMARY

A unionid survey of the Sydenham River, Ontario, was carried out by the writer and associates in August, 1991, precisely 20 years after a similar survey. 26 mussel species had been found in 1971 and 25 species in 1991. In 1991 two species occurred which had not been found previously, one species was rediscovered which had not been seen since 1963, and eight species, collected in 1971 or previously by others, were not found. Three of the missing species are characteristic of headwaters and those habitats were not well searched in 1991, so it is believed that they probably still exist there. Five of the missing species occur chiefly in riffles and those habitats in the Sydenham are now covered by silt, so those species may now be gone from that System.

It is also significant that the introduced zebra mussel, *Dreissena polymorpha*, has not penetrated the Sydenham System from Lake St. Clair, even though it has had 4 years to do so. It is postulated that this failure is probably attributable to the lack of boat traffic in the Sydenham River.

Despite some apparent loss of species the Sydenham River System is still the richest system for Unionidae in Canada and one of the richest small river systems in North America. It is therefor an important

refugium for native pearly mussels against possible extinction from competition with the recently introduced zebra mussel. We urge that the Sydenham River System be made an ecological preserve and that its fauna be protected through legislation.

1. INTRODUCTION

The Sydenham River System, located just north of the more extensive Thames River System, drains an area about 60 miles long and more than 20 miles wide in southwestern Ontario. Both rivers flow into the smallest of the six Great Lakes, Lake St. Clair. The country roundabout the Sydenham River System is mainly farmland and, unlike the Thames River System, no major cities exist within its watershed. In addition the water is hard, containing from 170 to 270 ppm $CaCO_2$, and ecological conditions for Unionidae are excellent.

Between August 21 to 25, 1971, the author and the late Louise R. Clarke conducted a mussel survey of the Sydenham River (see Clarke, 1972). Searches were carried out at eleven stations ranging from far upstream (near Ilderton, Middlesex County) to far downstream (near Tupperville, Kent County). 26 living species of unionids were found. When other records based of collections by H. D. Athearn in 1963, Carol B. Stein in 1965 and 1967, and the writer in 1974 were added, the total number of unionid species known from the Sydenham System increased to 33. That total represented, by far, the largest number of unionid species known from any river system in Canada.

In 1977 I pointed out that four Sydenham River species, *Simpsonaias ambigua* (Say), *Anodonta imbecillus* Say, *Villosa fabalis* (Lea), and *Dysnomia* (now *Epioblasma*) *torulosa rangiana* (Lea), apparently lived nowhere else in Canada and recommended that the Sydenham should be protected from harmful pertubations. Although no official action was taken, Canadian conservationists became increasingly aware that the Sydenham River System was unique and worthy of protection.

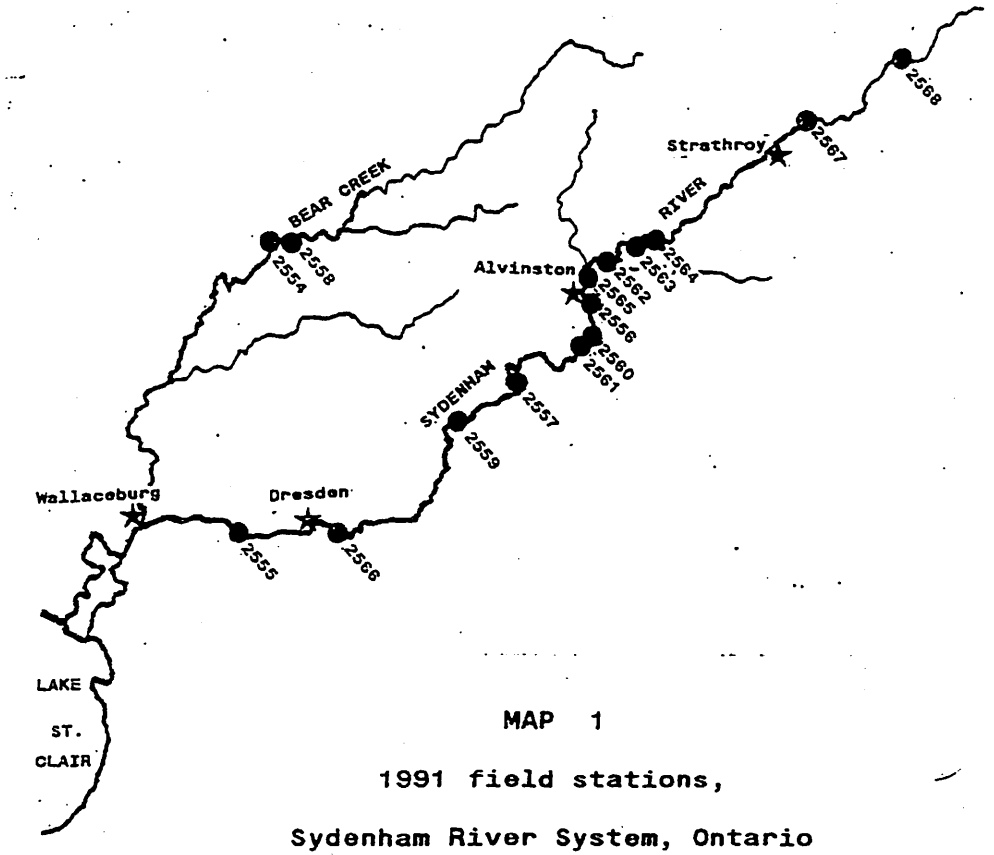
Recently, Mackie & Topping (1988) reported the results of a mussel survey carried out in 1985. They recorded the presence of only 13 unionid species sti living in the Sydenham System. Among the apparently missing species were the four unique species cited which appeared to be endangered in Canada. Soon thereafter, alarmed by the apparent disappearance of those species, the Nature Conservancy of Canada expressed interest in having another survey carried out, and early in 1991 an agreement was signed betwe ECOSEARCH, Inc. and Lambton Wildlife Inc. to conduct such a survey.

Acknowledgments.- I wish to thank my wife, Judith J. Clarke, for assistance during the entire program; Ji Duckworth of Lebanon, Tennessee, for excellent field assistance during the second half of the field program; Mike Oldham of the Ontario Ministry of Natural Resources and his assistant, Mary Blewitt, f field assistance; Dr. Joe Loter of Corpus Christi State University for statistical analyses of the dat the Ontario Nature Conservancy for encouragement; Peter and Joan Banks for their kind hospitality; and Lambton Wildlife Inc. and Imperial Oil Ltd. (Volunte Involvement Program) for generous financial support.

2. MATERIALS AND METHODS

The mussel survey work was carried out from Augu 13 and 18 and from August 24 to August 27, 1991. See Map 1. An effort was made to revisit all of the productive sites searched previously by the Clarkes (which, coincidentally, had been studied between August 21 and 25, 1971, precisely 20 years earlier) and to examine additional sites around Alvinston, Lambton County. Earlier studies had shown that the greatest mussel diversity occurred in the Alvinston area. A list of the sites investigated is given in Table 1. For comparative purposes a similar format t that used in the 1972 paper is used in the table her

In 1971 a representative collection was made of live-collected specimens for the National Museum of



MAP 1

1991 field stations,

Sydenham River System, Ontario

(Scale : 1 inch = 11.1 miles).

Natural Sciences, National Museums of Canada but in 1991, except for a few specimens needed for other research, after examination and tabulation all live specimens were returned unharmed, in natural orientation, close to their original locations in the river.

TABLE 1
Survey Stations and Ecological Data. (Except for Stations 2554 and 2558 (Bear Creek) All Stations are in the Sydenham River and are in Headwater to Mouth Sequence).

Sta. No.	Location	Width (est. ft.)	Bottom	Person Hours Spent
2568	2.5 mi NE of Coldstream	10-20	m,gr	0.4
2567	2.2 mi NE of Strathroy	40	m	0.8
2564	6.2 mi NE of Alvinston	50	m,gr,r	2.5
2563	4.6 mi NE of Alvinston	60	m,gr,r	8.0
2562	2.8 mi NE of Alvinston	75	m,gr,r	5.0
2565	1.8 mi NE of Alvinston	100	m,gr,r	1.5
2556	0.2 mi E of Alvinston	100	m,r,gr	1.5
2560	3.0 mi SSE of Alvinston	75	r,gr	5.0
2561	3.2 mi SSE of Alvinston	100	m	0.7
2557	3.5 mi NE of Shetland	150	m	1.5
2559	0.7 mi NNE of Shetland	100	m,r	1.6
2469	0.4 mi S of Croton	200	m	0.8
2566	0.5 mi N of Dawn Mills	200	m.r,gr	3.5
2555	0.7 mi N of Tupperville	125	m	0.7
2558	3.6 mi NE of Brigden	50	m,wf	1.0
2554	3.4 mi NE of Brigden	50	m,gr	4.5

Abbreviations: gr, gravel; m, mud; r, rocks; s, sand; wf, wood fragments.

3. RESULTS

A tabulation of the Unionidae found is presented in Table 2. All specimens recorded were found alive or freshly dead unless designated by an asterisk (which signifies empty shells other than those freshly dead). Anononta imbecillus and Villosa fabalis are therefor counted as being alive since, although they occurred only as empty shells, their nacre was shiny. All other species recorded as living were actually observed alive.

During all of our work a close watch was maintained for Dreissena polymorpha but no specimens were seen. D. polymorpha is thought to be a serious threat to the very survival of many of our native freshwater mussel species, and its presence or absence in the Sydenham was believed to be significant.

4. DISCUSSION

In 1991 we found 25 unionid species (23 living and two as empty shells) in the Sydenham River System. 24 species occurred in the main Sydenham River and 4 were found in Bear Creek. One of the Bear Creek species, Anodonta imbecillus, was not found in the main Sydenham River but the other 3 species were found there. Two species, Carunculina parva (one live specimen) and Truncilla donaciformis (one moderately recent shell with dull nacre), which were found in 1991 in the main river, had not previously been recorded from the Sydenham River System. Since both are known to occur in the nearby Lake Erie Drainage, however, their presence is not surprising.

In an effort to discern possible faunal changes it is useful to compare the 1991 results with those of previous surveys, i.e. with those described by Mackie & Topping (1988) (survey done in 1985), Clarke (1972) (survey done in 1971), LaRocque & Oughton (1937) (based on miscellaneous specified sources), and on records from the work of H. D. Athearn and Carol B. Stein (in Clarke, 1972 and 1983, and in Mackie & Topping, 1988).

The Mackie & Topping study reported the results of a series of 60-minute surveys carried out at 22 stations in the Sydenham River System, with additional visits to 10 stations, all by Mr. Robert Turland and Mr. Bruce Kilgour. Most of their identifications were verified by Dr. Mackie or by Ms. Topping. The collectors reported 13 species living in the main Sydenham River, all of the same species (except Cyclonaias tuberculata) living in the North Branch of the Sydenham and its major tributaries (Bear Creek and Black Creek), and 14 additional species as empty shells only.

All of the living species reported by Mackie & Topping were found by us in 1971, and all reported by them except one (the headwater species Anodontoides ferussacianus) was also found by us in 1991. Empty shells of 5 species, which we did not find in 1991, were also reported by them as having been found in 1985. Those included two other headwater species, Alasmidonta viridis and Lasmigona compressa, and three species commonly found in or near downstream riffle habitats, Lampsilis fasciola, Epioblasma torulosa rangiana, and E. triquetra.

Unfortunately it must be stated that the reduced number of living species found by the collectors, whose data were used by Mackie and Topping, may well have been due primarily to the fact that insufficient time was spent at each locality. Further, it appears likely that the some of the records for species which are sometimes difficult for non-specialists to identify may have been based on misidentifications. Since specific information is unavailable about the authenticity of all of the identifications in that paper, in cases where species reports appear to be incongruous we have decided not to consider them further.

Our 1971 survey had yielded 26 species from the main river. Three of those species, Alasmidonta viridis (Raf.) (recorded in my 1972 paper as A. calceola (Lea)), Lasmigona compressa (Lea), and Anodontoides ferussacianus, are ordinarily found mainly in headwater streams and that habitat was not sufficiently studied in 1991 to rule out their presence in the Sydenham System. One species, the rare Villosa fabalis (Lea), found in 1991 but not in 1971, had been found previously (in 1963) by Athearn. It had apparently been present in 1971 but simply not found by us. Therefore only two species which had been

TABLE 2

Unionidae Observed

Species or Subspecies	Station Number (first 2 digits (25) omitted) 68	67	64	63	62	65	56	60	61	57	59	69	66	55	58	54
SUBFAMILY AMBLEMINAE																
Amblema plicata	.	.	25	99	99	25	*	12	50	30	*	1	10	.	.	*
Fusconaia flava	.	.	.	2	3	.	*	.	.	*	.	.	.	.	.	.
Quadrula quadrula	.	.	1	.	.	.	.	.	.	.	.	3	1	.	.	*
Quadrula pustulosa	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Elliptio dilatata	.	.	2	1	4	.	.	.	.	.	.	.	.	.	.	.
Pleurobema coccineum	.	.	.	4	1	.	.	.	.	.	.	.	.	.	.	.
Cyclonaias tubercul.	.	.	3	5	7	1	1	2	.	.	.	.	2	.	.	.
SUBFAMILY ANODONTINAE																
Alasmidonta marginata	.	.	1	21	1	.	*	5	.	.	.	5	.	.	.	*
Lasmigona complanata	.	2	.	2	2	1	.	.	25	.	.	12	2	.	3	25
Lasmigona costata	.	.	12	40	50	.	2	23	.	.	.	.	6	.	.	.
Anodonta grandis	.	.	5	.	.	4	*	.	5	.	.	1	.	.	1	2
Anodonta imbecillus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	6
Strophitus undulatus	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
SUBFAMILY LAMPSILINAE																
Ptycho. fasciolaris	.	.	2	5	4	.	.	3	.	.	.	.	.	.	.	.
Truncilla donaciform.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.
Truncilla truncata	.	.	.	1	.	1	1	.	.	.	.	.	2	.	.	.
Proptera alata	.	.	.	.	.	.	.	.	.	.	.	8	20	.	.	*
Carunculina parva	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Obovaria subrotunda	.	.	1	1	.	.	.	.	.	.	.	1	2	.	.	.
Leptodea fragilis	.	.	.	2	.	.	1	3	.	1	.	1	10	.	3	1
Actinonaias carinata	.	.	9	4	10	8	.	3	.	.	.	1	18	.	.	.
Ligumia recta	.	.	25	16	22	12	.	1	.	.	.	.	.	.	.	.
Lampsilis ventricosa	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.
L. radiata siliquoidea	.	.	1	4	.	.	1	.	.	*	.	.	.	.	.	.
Villosa fabalis	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Total specimens	.	2	87	211	203	52	7	52	80	31	.	33	74	1	7	34
Total sp. + ssp.	.	1	12	17	11	7	6	8	3	2	.	9	11	1	3	4
Max Diversity = Ln(above)	NA	.	2.40	2.83	2.39	1.94	1.79	2.07	1.09	0.69	NA	2.19	2.39	.	1.09	1.38
Shannon-Weaver Div Index	NA	.	1.88	1.79	1.51	1.40	1.74	1.61	0.83	0.14	NA	1.74	1.94	.	1.00	0.80
Evenness (DivIndx/MaxDiv)	NA	NA	0.75	0.63	0.63	0.72	0.97	0.77	0.75	0.20	NA	0.79	0.81	NA	0.91	0.57

* = Only Shells of Dead Mussels Found NA = Not Available or Not Defined)

Natural Logarithms (Ln) Used for Shannon-Weaver Diversity Index Calculations found in the main river in 1971 appear to be absent in 1991, viz. Lampsilis fasciola (Raf.), and Villosa iris (Lea).

Collections by H.D. Athearn in 1963 and 1967 yielded most of the same species found by us in 1971 and three other species in addition, viz. Simpsonaias ambigua (Say) Villosa fabalis (Lea), and Epioblasma triquetra (Raf.). V. fabalis was found "living" in 1991. Carol Stein (1965 and 1967) found two additional species, Anodonta imbecillus (Say) and Epioblasma torulosa rangiana(Lea). The former was found "alive" in 1991 but the latter has not been found by anyone since 1967.

LaRocque & Oughton (1937) listed 22 valid species from the Lake St. Clair Drainage. That drainage, of course, includes the Thames River System as well as the Sydenham River System and several small creeks. Although most of the species listed are now known to be members of the Sydenham River System fauna, two species, Obliquaria reflexa (Raf.) and Obovaria olivaria (Raf.) are not. It is uncertain, however, whether those two species occurred in the Sydenham or the Thames River System.

The Sydenham River System mussel fauna represents an important Canadian national resource. It is therefore desirable to analyze the available data in such a manner that, in addition to total number of species, other parameters will also be available for use in assessing future faunal changes. Since diversity is widely recognized as one of the most sensitive criteria for assessing community health, we have calculated the Shannon-Weaver Diversity Coefficient (H'), Maximum Diversity (H'max), and the Evenness Coefficient (J') for each of the research stations.

The formulae used are as follows:

$$H' = \frac{(n \times \log_n n) - (f_1 \times \log_n f_1)}{n}$$

$$H'_{max} = \log_n n_{sp}$$

$$J' = \frac{H'}{H'max}$$

In the formulae n = total number of specimens, f_1 = number of specimens of species A, B, etc., and n_{sp} = number of species.

The results of the diversity calculations are given in Table 2. Conclusions about the results of these calculations are given below.

5. CONCLUSIONS

A. CHANGES IN MUSSEL COMMUNITY COMPOSITION

The Sydenham River still supports the most diverse freshwater mussel fauna in Canada. Comparisons between the results of collections made in 1963, 1965, 1967, 1971, 1985, and 1991 indicate that although the mussel fauna has remained much the same over that period, a few species previously recorded from the Sydenham River System appear to be missing. These are Simpsonaias ambigua, Lampsilis fasciola, Villosa iris, Epioblasma torulosa rangiana, and E. triquetra. Three additional species (Anodontoides ferussacianus, Alasmidonta viridis, and Lasmigona compressa, found in 1971 but not found in 1991, are believed to be still present in the Sydenham System. They are mainly headwater species and that habitat was not well searched in 1991. Many small tributaries, in fact, of both the North Sydenham River and the Sydenham River have never been surveyed for mussels.

Two species, Carunculina parva (alive) and Truncilla donaciformis (one empty shell), not previously recorded from the Sydenham, have now been found there. Nevertheless there is an apparent loss of five other species over the past two decades and that is, of course, most unfortunate.

All of the missing species, (S. ambigua, V. iris, L. fasciola, E. t. rangiana, and E. triquetra) are partly or wholly riffle species. During our recent survey we noted that most of the riffles are now covered with silt. This may indicate that excessive silt is now entering the river, or that obstructions to flow have accumulated to the point were average discharge rates have been reduced, or both. At any rate, a correlation between loss of those species, and apparent loss of clean riffle habitat, appears to exist.

It should also be mentioned that <u>Alasmidonta marginata</u>, which is also a riffle species, <u>was</u> present in 1991, however, so the correlation just described may involve loss of habitat for the glochidial hosts rather than, or in addition to, habitat for the juvenile or adult mussels themselves. Five fish species (white sucker, northern hog sucker, shorthead redhorse, rock bass and warmouth) are known to function as hosts for <u>A. marginata</u>, and multiple fish hosts, of course, provide a unionid species with wide tolerances for ecological pertubations. The host for the ecologically aberrant <u>S. ambigua</u> is the mudpuppy (an amphibian), and the hosts for the other, apparently now missing, mussels are still unknown.

B. REGIONAL DIVERSITY AND DENSITY.

Examination of the results of diversity calculations given in Table 2 shows wide variation in the values obtained. This has been brought about by the fact that the principle objective of the program was to determine how many mussel species still live in the Sydenham System, so those sites which appeared to be the most ecologically diverse and productive were searched for longer periods of time than presumably less-productive sites. This procedure did meet the objective of revealing a fairly large number of species, but it was not the best method of acquiring data for diversity comparisons. This is because even in areas of equal richness and diversity, as more and more specimens are found, more uncommon and rare species begin to appear. Shannon-Weaver diversity values increase as the numbers of species increase, however. Further, the significance of statistical measures increase with increasing numbers of specimens and some of the samples are very small. Therefore, results of diversity calculations can only be rigorously compared if the numbers of specimens in each sample are approximately the same.

Even with these limitations, however, it appears probable that the diversity measures may provide useful comparative information if collections of equivalent numbers of specimens are made in later years.

We have also attempted to produce an approximate measure of relative species richness by dividing the number of specimens found at each site by the man hours spent there. The results of such calculations, expressed as specimens per hour for Sydenham River stations (in order of decreasing values), are: Station 2561, 42.9; 2569, 41.2; 2562, 40.6; 2564, 34.8; 2565, 34.7; 2563, 26.4; 2566, 21.1; 2557, 20.71 2560, 10.4; 2556, 4.7; 2567, 2.5; 2555, 1.4; 2568, 0; 2559, 0. The values for the Bear Creek stations are: 2558, 7.0; 2554, 7.6.

Comparison of those values with the upstream-downstream sequence used in Tables 1 and 2 shows very little correlation. The most productive site, Station 2561, was a mud flat completely exposed by low water in which the mussels were particularly obvious. (They were all later transferred to deeper water). Surprisingly, the site with the second highest value for specimens per hour (Station 2569) is also a muddy area at a far downstream site. Most of the other high or moderate specimens/hour values are from riffle areas (one would expect riffles to be the most productive areas) and the least productive sites are at the extreme downstream or upstream ends of the reach sampled (Stations 2555 and 2568) and at a site apparently severely altered by man (Station 2559).

C. THE ZEBRA MUSSEL

Finally, it is important to note that the zebra mussel Dreissena polymorpha is still absent from the Sydenham River. That species has had at least four years to invade the Sydenham from Lake St. Clair and it has not done so. More evidence from studies elsewhere is of course desirable, but I believe that absence of the zebra mussel provides important support for the theory that D. polymorpha is dramatically impeded from invading free-flowing rivers in an upstream direction unless transported upstream attached to the hull of a ship or by other artificial means.

That is good news indeed. If the theory is correct it may mean that the Sydenham River System is a natural refugium for our native unionids, a refugium which will protect many of them from the devastating threat now posed by the zebra mussel. Other non-navigable streams will also probably provide refugia but few in North America still harbor as rich a unionid fauna as the Sydenham River System. Further, this phenomenon may also provide the rationale under which refugia may be created elsewhere for protection of some of our most vulnerable species of North American Unionidae.

LITERATURE CITED

Clarke, Arthur H., 1972 : On the Distribution of Unionidae in the Sydenham River, southern Ontario. Malacological Review, 6; 63-64.

_______________, 1977 : The Endangered Molluscs of Canada. Pp.148-150 *in* Canada's Threatened Species and Habitats. Edited by T. Mosquin & L. Suchal. Canadian Nature Federation. Special Publication No. 6 , 185 pages.

_______________, 1981 : The Freshwater Molluscs of Canada. Ottawa: National Museum of Natural Sciences / National Museums of Canada. 446 pages.

LaRocque, Aurele & John Oughton, 1937 : Preliminary Account of the Unionidae of Ontario. Canadian Journal of Research (D) 15:147-155.

Mackie, G. L. & Jane M. Topping, 1989 : Historical Changes in the Unionid Fauna of the Sydenham River Watershed and Downstream Changes in Shell Morphometrics of Three Common Species. The Canadian Field-Naturalist 102:617-626.

Distribution of the Unionidae in South Central Ohio

G. Thomas Watters
171 Wells Street, Marietta, OH 45750-3461

ABSTRACT

The river systems of unglaciated south central Ohio, while not containing the diversity of unionids of glaciated regions to the north, are important to a general understanding of naiad diversity, past and present. Evidence of present species distribution mediated by flooding of intervening lowlands and paleodistributions (Teays River) is found in this region, as is data demonstrating that some species occur only in glaciated land in Ohio. The study area contains river systems ranging from pristine streams of antiquity to severely impacted systems that have become uninhabitable to unionids in modern times. Evidence is given to suggest that, in some cases, modified streams may recover at least part of their unionid fauna.

INTRODUCTION

The river systems in south central Ohio are the oldest in the state, particularly those in the unglaciated Hocking Hills region (the foothills of the Appalachian Mountains). While northern rivers and their faunas were repeatedly covered by ice during periods of glaciation, southern rivers remained flowing, though in highly modified courses. Ohio is one of the few states with a diverse naiad fauna that has sizable areas of both glaciated and unglaciated terrain. This south central region remains one of Ohio's "wildest" large tracts of contiguous land, and thus is of particular interest to biologists. However, large sections have been lost to farming, clear-cutting, strip-mining, inadequate sewage treatment, and unrestrained sand and gravel operations. Entire river systems have been altered beyond recognition. Several of the largest streams and rivers in this area have been investigated: Muskingum River [Bates, 1970; Stansbery & King, 1983; Stansbery & Cooney, 1985; Stansbery *et al.*, 1985]; Scioto River [Stansbery, 1961]. However, most of the smaller streams had never been investigated in a comprehensive manner. This study reports the status and composition of the naiad fauna of these smaller systems at the edge of the glaciated/unglaciated demarcation in Ohio.

MATERIALS AND METHODS

The State of Ohio issued a collecting permit in 1987 to the author for both nonendangered and state endangered species of unionids for collection by hand, rake, and glass-bottomed viewing box. Collections were thus limited to areas where these methods were possible. Deeper regions were rare in the streams studied, and these areas (*i.e.*, the Hocking River from Federal Creek to the Ohio River) were not sampled. However, the study was fortuitously conducted during an extremely dry year and sites normally beyond hand-collecting were easily accessible. In general, approximately 1 1/2 man-hours were spent at each site, depending upon the number of naiads encountered. Numbers of each species and their condition (live, dead, weathered, or subfossil) were noted in a field notebook. Voucher specimens were usually taken for deposition at the Museum of Zoology, Ohio State University (OSUM), in compliance with the collection permit. Historical records for the study area were obtained from the Museum of Zoology, OSU. The study area is illustrated in Fig. 1. Collection sites are shown in Fig. 2; specific locality information may be found in Watters (1988a). A list of the drainages is given in Table 1, and the distributions of species for the study area are given in Table 2.

SPECIES ACCOUNTS

Evidence of 37 species was found in this study, and 33 (89%) were still living in the study area. These species and their distributions are briefly commented upon, and unless otherwise noted, the comments refer only to the range of the species within the study area. Species accounts are in alphabetical order and follow the systematics of Stansbery & Borror (1983). "Common" names are adopted from Turgeon (1988). While I do not support the use of these common names for unionids, they are included here for completeness, although they lack any heuristic value. Descriptions of recorded habitats are compiled from Parmalee (1967), Starrett (1971), Buchanan (1980), Taylor (1983), Oesch (1984), Stansbery, Newman, Borror & Stein (1985), and personal field observations.

Actinonaias ligamentina carinata (Barnes, 1823)
(Mucket)

This species was very rare in the study area and its distribution there is difficult to explain. A single living individual was found in the middle reach of Symmes Creek. No other specimens in any condition were found in the study. There are OSUM records for single locations in Salt and Ohio Brush Creeks. This suggests a human-mediated fortuitous introduction of the species into less than optimum habitats with little survival. This wide-

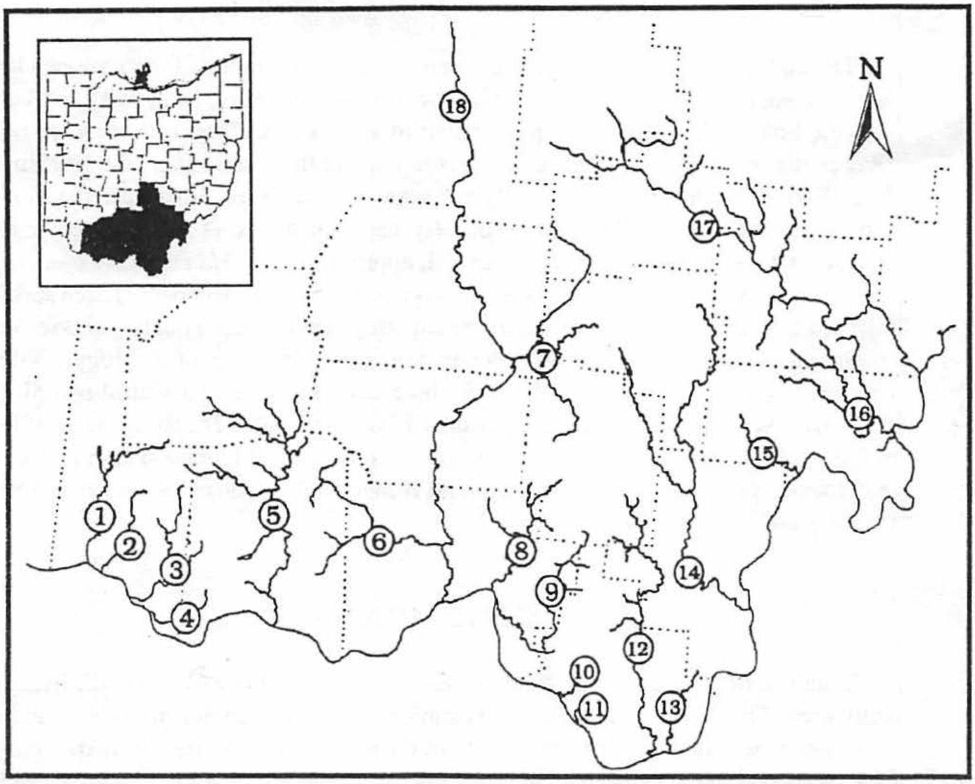


Figure 1. The study area. 1. White Oak Creek; 2. Straight Creek; 3. Eagle Creek; 4. Big Threemile Creek; 5. Ohio Brush Creek; 6. Scioto Brush Creek; 7. Salt Creek; 8. Little Scioto River; 9. Pine Creek; 10. Storms Creek; 11. Ice Creek; 12. Symmes Creek; 13. Indian Guyan Creek; 14. Raccoon Creek; 15. Leading Creek; 16. Shade River; 17. Hocking River; 18. Scioto River.

ranging species may be locally abundant in many areas of Ohio, and occurs in a broad range of river sizes. Stansbery & Cooney (1985) pointed out that it has largely replaced the subspecies *A. l. ligamentina* (Lamarck, 1819) in the past 100-150 years, perhaps due to man-made modifications of the habitat. It was rare in the adjacent Ohio River near Moscow, Ohio (Stansbery & Cooney, 1985) and uncommon in the Ohio portion of the Ohio River in general (Williams & Schuster, 1989), although common within the Belleville Pool (pers. obs., 1990).

Table 1. River systems included in study.

River systems	Drainage area (sq. km)	Length mainstem (km)	Mean gradient (m/km)
Big Threemile Creek	62	22	5.0
Eagle Creek	400	50	3.2
Hocking River	3,110	152	0.9
Ice Creek	101	24	5.0
Indian Guyan Creek	200	51	2.0
Leading Creek	393	48	1.4
Little Scioto River	606	66	2.0
Long Run	8	5	5.0
Ohio Brush Creek	1,131	91	1.6
Pine Creek	481	77	1.6
Raccoon Creek	1,778	174	0.7
Salt Creek	1,438	74	1.8
Scioto Brush Creek	1,752	58	1.4
Shade River	575	61	1.4
Storms Creek	101	26	4.9
Straight Creek	174	35	4.5
Symmes Creek	926	112	0.5
White Oak Creek	608	78	2.2

Table 2. Species recorded from this study. E - Ohio endangered; EGC - Eagle Creek; HKR - Hocking River; IGC - Indian Guyan Creek; LEC - Leading Creek; LSR - Little Scioto River; OBC - Ohio Brush Creek; PNC - Pine Creek; RAC - Raccoon Creek; SYC - Symmes Creek; SBC - Scioto Brush Creek; SHR - Shade River; SAC - Salt Creek; WOC - White Oak Creek; 1 - species associated with Scioto River; 2 - species generally absent from unglaciated Ohio.

E	Taxa	EGC	HKR	IGC	LEC	LSR	OBC	PNC	RAC	SYC	SBC	SHR	SAC	WOC		1	2
	Actinonaias l. carinata						X			X			X				
	Actinonaias l. ligamentina		X														
	Alasmidonta viridis						X			X							
	Amblema plicata plicata		X				X		X	X	X		X	X			
	Anodontoides ferussacianus	X	X	X	X	X	X	X	X	X		X	X	X			
	Anodonta grandis	X	X		X	X	X	X	X	X	X	X	X	X			
	Anodonta imbecillis		X			X		X	X	X	X		X				
	Cyclonaias tuberculata						X			X							
	Elliptio dilatata		X			X			X	X	X						
	Epioblasma triquetra		X							X	X					X	X
	Fusconaia flava		X		X	X	X	X	X	X	X	X	X				
*	Lampsilis ovata						X										
	Lampsilis radiata luteola	X	X		X	X	X	X	X	X	X	X	X	X			
*	Lampsilis teres						X			X							
	Lampsilis ventricosa	X	X		X	X	X	X		X	X	X	X	X			
	Lasmigona complanata	X	X		X	X	X	X		X		X	X				
	Lasmigona compressa		X							X			X				
	Lasmigona costata		X				X		X	X	X		X	X			X
	Leptodea fragilis	X	X		X	X	X	X		X	X	X	X	X			
*	Megalonaias nervosa						X										
	Obliquaria reflexa						X										
	Obovaria subrotunda		X			X	X	X		X		X	X				
*	Pleurobema clava		X				X										X
	Pleurobema sintoxia		X			X				X							
	Potamilus alatus	X	X		X	X	X	X		X	X		X				
	Potamilus ohiensis		X				X	X		X							
	Ptychobranchus fasciolaris		X				X			X	X						X
*	Quadrula c. cylindrica						X										
*	Quadrula fragosa								X								
	Quadrula p. pustulosa		X						X		X						
	Quadrula quadrula	X	X		X	X	X		X	X	X	X	X				
	Simpsonaias ambigua					X				X							
	Strophitus u. undulatus	X	X		X	X	X	X		X	X	X	X	X			
	Toxolasma parvus	X	X						X	X			X	X			
	Truncilla donaciformis		X				X			X							X
	Truncilla truncata		X			X	X										
	Tritogonia verrucosa		X			X	X			X	X		X				
	Uniomerus tetralasmus									X							
*	Villosa fabalis										X					X	
	Villosa i. iris										X		X			X	
*	Villosa lienosa							X		X	X		X	X			

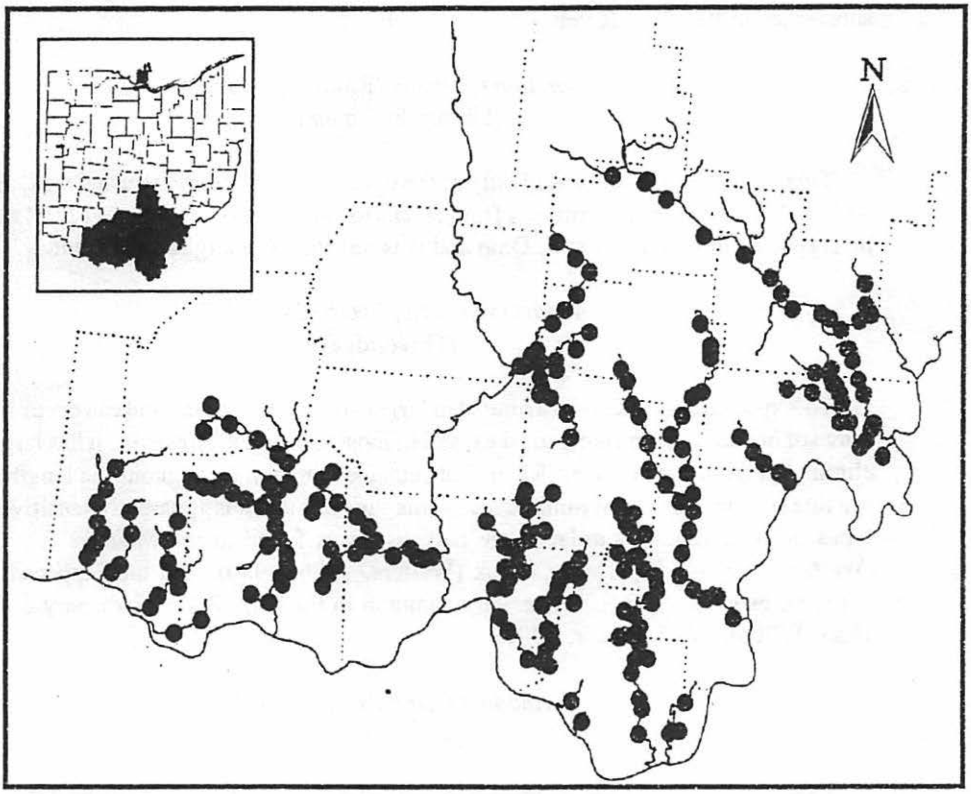


Figure 2. Locations of collecting sites.

Actinonaias ligamentina ligamentina (Lamarck, 1819)
(Mucket)

Subfossil fragments apparently referable to this subspecies were found in the Hocking River at three sites above the White's Mill Dam in Athens, Hocking County. This subspecies is apparently extirpated from the state and replaced to some extent by *A. l. carinata*. However, no records of *A. l. carinata* are known from the Hocking River. The nominate subspecies (or ecophenotype) was more adapted to the run sections of rivers, while

A. l. carinata may live in slower water. Stansbery & Cooney (1985) did not find this subspecies in the Ohio River.

Alasmidonta viridis (Rafinesque, 1820)
(Slippershell mussel)

This small species was found only in the upper reaches of Ohio Brush Creek. Although widely distributed in the Midwest from creeks to small rivers (Clarke, 1981), it appears to be absent from larger rivers in Ohio and was not found in unglaciated country.

Amblema plicata plicata (Say, 1817)
(Threeridge)

This species was widely distributed in larger streams and rivers and can occur in a broad range of habitats, from rivers to lakes, and in most substrates. However, it has largely been eliminated from the Hocking River, but remains common throughout the length of more pristine systems such as Symmes Creek. This suggests that it is apparently sensitive to some types of pollution. A similar range reduction was found in the Maumee River system (Watters, 1988b), Big Darby Creek (Watters, 1986, 1990), and the Tippecanoe River (Cummings *et al.*, 1987). It was very common in the Ohio River (Stansbery & Cooney, 1985; Williams & Schuster, 1989).

Anodonta grandis Say, 1829
(Giant floater)

This was a very common and widespread species, typically occurring in slow water, in pooled regions anywhere along the length of streams and rivers. It frequently is able to invade and colonize impounded areas, often being one of only a few species present in silted or muddy reaches. The taxon *A. g. corpulenta* Cooper, 1834, is of uncertain status. It may represent an ecophenotype or a distinct subspecies now being assimilated by subspecies *A. g. grandis* (Stansbery, pers. comm.). It may be impossible to place some specimens in one group or the other. For this reason, both taxa have been referred to as *A. grandis* in this report.

Anodonta imbecillis Say, 1829
(Paper pondshell)

A widespread but very sporadic species, seldom common in Ohio (Watters, 1988c). Like other *Anodonta* species, it seems to prefer slow water in ponds, impoundments, and back-water areas. It was most common in the Lake Rupert impoundment of Little Raccoon Creek. It may be a facultative parasite.

Anodontoides ferussacianus (Lea, 1834)
(Cylindrical papershell)

Another widespread species, generally limited to the extreme headwaters, often in intermittent pools where it may be the only naiad present. This taxon is extremely variable and may represent more than one species, or isolated, distinct subpopulations of one species.

Cyclonaias tuberculata (Rafinesque, 1820)
(Purple wartyback)

This species was not found in the 1987 survey, but was known from single specimens from Salt and Ohio Brush Creeks (OSUM). It is apparently susceptible to pollution, occurring only in the more pristine systems in the state.

Elliptio dilatata (Rafinesque, 1820)
(Spike)

In glaciated parts of Ohio, this species may be ubiquitous, occurring in a wide range of habitats and substrates. It is sensitive to modifications and is experiencing a range reduction in some areas (Watters, 1988b). In unglaciated areas it is limited to the Scioto River tributaries and the Hocking River, although it may be extirpated from the latter. Both systems originate in glaciated land. It has not been distributed through lowland flooding from Scioto Brush Creek to Ohio Brush Creek, as other "Scioto" species may have been.

Epioblasma triquetra (Rafinesque, 1820)
(Snuffbox)

This uncommon, Federal Category 2 species is largely associated with Scioto River tributaries in unglaciated Ohio. It is a riffle/run species limited to the middle to lower reaches of good quality streams, such as Scioto Brush Creek.

Fusconaia flava (Rafinesque, 1820)
(Wabash pigtoe)

Another wide-ranging but sensitive species, found in a number of habitats. In this study it generally occurred in the middle river reaches, with the exception of Symmes Creek, where it was found from the mouth upstream into very small tributaries. It was not found living above the White's Mill Dam on the Hocking River in this study. It was rare in the Ohio River (Stansbery & Cooney, 1985; Williams & Schuster, 1989 [as *F. undata*]; pers. obs., 1990).

Lampsilis ovata (Say, 1817)
(Ridged pocketbook)

This Ohio endangered species is known from the study area by a single specimen from Ohio Brush Creek (OSUM records). The specimen was collected in the lower portion of that creek, which has historically harbored several rare species not known from the remaining systems in this study.

Lampsilis radiata luteola (Lamarck, 1819)
(Fatmucket)

This is the most ubiquitous species in the state, avoiding only the largest rivers. It is apparently tolerant of some pollution and impoundment, and in some cases was the only naiad encountered. In several areas it was abundant. In the Little Scioto River over 300 living specimens were found in less than 20 m of narrow stream. This species was not found in Raccoon Creek and Indian Guyan Creek, two heavily impacted systems. Studies have shown that this species is able to tolerate overlain silt up to 18 cm deep, while sensitive species such as *Fusconaia flava* experience 50% mortality at 10 cm coverage (Marking & Bills, 1980). The absence of living or fresh-dead specimens in the middle of its range in a stream may be a good environmental indicator of pollution or other modification.

Lampsilis teres (Rafinesque, 1820)
(Yellow sandshell)

A single female of this Ohio endangered species, among the rarest in the state, was found in Ohio Brush Creek below an area being used for sand and gravel removal from the streambed. The specimen was not gravid. Apparently the last living individual collected within the state was found in 1959 on the Ohio shore of the Ohio River. It was not found by Stansbery & Cooney (1985) in the Ohio River, and was very rare in the Ohio River study of Williams & Schuster (1989). This species occurs to the south and west of Ohio to the Gulf of Mexico and Rio Grande and north-west to South Dakota. Ohio is at the northeast limit of its range. It has a wide range of habitats, from slow to swift rivers, from silt to cobble substrates.

Lampsilis ventricosa (Barnes, 1823)
(Plain pocketbook)

A common species found in nearly all reaches of the streams studied, occasionally in large numbers (*i.e.*, Leading Creek). In Symmes Creek it occurs from the mouth to the smallest continuously flowing creeks. It is intolerant of modification and was not found below urban areas. In the Hocking River, it was not found above the White's Mill Dam. It is not typically a species of big rivers and was rare in the Ohio River (Stansbery & Cooney, 1985; pers. obs., 1990).

Lasmigona complanata (Barnes, 1823)
(White heelsplitter)

This species was found sporadically in the study area and locally was common. It generally occupies the lower stretches of streams but may range into the headwaters. In Symmes Creek a peculiar, stunted form is common in the smallest headwater creeks. With the exception of Symmes Creek, this species prefers quiet backwater with sand/mud substrates (Clarke, 1985). It appears to be tolerant of some types of pollution and was abundant below a waste water treatment plant outfall on the Hocking River.

Lasmigona compressa (Lea, 1829)
(Creek heelsplitter)

Although Clarke (1985) stated that this species may be found in rivers, in the study area it was limited to small streams, often being found in sand and mud in relatively quiet water adjacent to a run or riffle. It is uncommon in Ohio. Its distribution in unglaciated Ohio suggests inter-river capture across lowlands from Salt Creek into Symmes Creek and the upper Hocking River.

Lasmigona costata (Rafinesque, 1820)
(Fluted-shell)

Although sporadic, it may be very common when present. Large populations were found in Ohio Brush Creek, where it may have been transferred from Scioto Brush Creek. In this study it was found to occupy the middle and lower reaches of streams in sand and mud. It was conspicuously absent from Symmes and Pine Creeks and the Little Scioto River, suggesting an intolerance of unglaciated habitats by its host or itself. A single specimen each was found in the Ohio River by Stansbery & Cooney, 1985, at Moscow, and at the Belleville

Pool (pers. obs., 1990).

Leptodea fragilis (Rafinesque, 1820)
(Fragile papershell)

A common species in the lower and middle reaches of most streams, where it firmly imbeds itself in sand and mud. When not buried, it is among the most active of naiads encountered, commonly seen moving for relatively long distances over the substrate. It was not found above the White's Mill Dam on the Hocking River.

Megalonaias nervosa (Rafinesque, 1820)
(Washboard)

This riverine species is rare within the state outside of the Ohio River proper, where it may be common (Stansbery & Cooney, 1985). A single record exists for Ohio Brush Creek (OSUM records).

Obliquaria reflexa Rafinesque, 1820
(Threehorn wartyback)

This is strictly a large river and lake species that occasionally is found in the larger tributaries. It may be abundant under the proper conditions (*i.e.*, the lower Muskingum River [Stansbery & King, 1983; Stansbery & Cooney, 1985; pers. obs., 1990]) and occurs in a wide variety of large stream regimens. In this study a single fresh-dead specimen was found in the species-rich area of lower Ohio Brush Creek. This undoubtedly represents a stray occurrence.

Obovaria subrotunda (Rafinesque, 1820)
(Round hickorynut)

This species occurs in Salt Creek and may have spread to neighboring Pine and Symmes Creeks and Little Scioto River through flooding of the intervening lowland. It is apparently sensitive to pollution and modification. In the essentially pristine Middle Fork Salt Creek, over 170 specimens of this typically uncommon species were found in middens at a single site, along with the superficially similar *Corbicula*, a preferred prey of muskrats. It was once distributed throughout the Hocking River but was found living only in Federal Creek in this study.

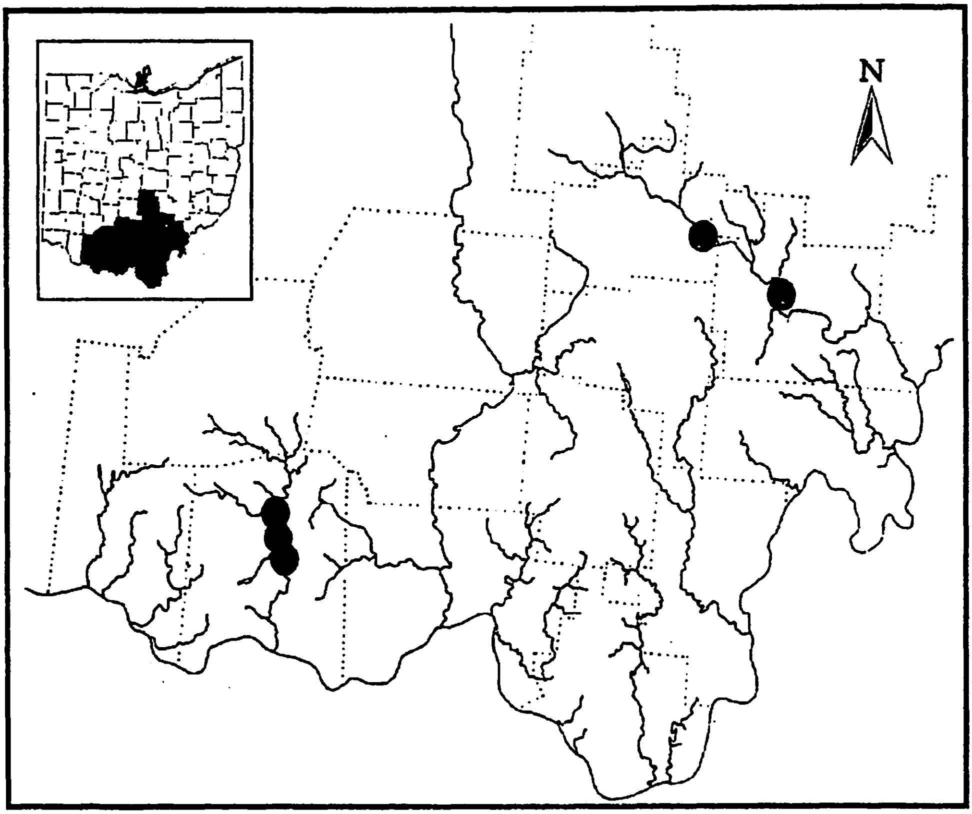


Figure 3. Range of Pleurobema clava *in the study area.*

Pleurobema clava (Lamarck, 1819)
(Clubshell)

This Ohio endangered and Federal Category 2 species has been extirpated from most of its original range, as evidenced from weathered and subfossil specimens found in other surveys (Watters, 1986, 1988b, 1990). This study presents new evidence that it was even more widespread than previously believed, and therefore has been eliminated from an even greater part of that range. First records of this species are recorded for Ohio Brush Creek and the Hocking River (Fig. 3). These data show that this species was once not uncommon in the middle reaches of these systems, but is undoubtedly absent from them now. No living or fresh-dead specimens were seen. This species is particularly sensitive to siltation and/ or pollutants.

Pleurobema sintoxia (Rafinesque, 1820)
(Round pigtoe)

No evidence was found that this widespread species is now living in the study area, although it has historically been found in the Little Scioto River, Salt Creek, and the Hocking River (above White's Mill Dam). These may be stray occurrences. It occurs in many river reaches elsewhere and may have distinct ecomorphs depending on its position in the river, where it may be known by *coccineum, catillus, solida,* and other names. It is generally uncommon in Ohio, and was very rare in the Ohio River (Stansbery & Cooney, 1985) at Moscow, although more common in the Belleville Pool (pers. obs., 1990).

Potamilus alatus (Say, 1817)
(Pink heelsplitter)

This species was found in most of the Ohio tributaries but was uncommon to rare in the Ohio River itself (Stansbery & Cooney, 1985; Williams & Schuster, 1989; pers. obs., 1990). In the Hocking River it did not occur above the White's Mill Dam. It lives in a wide variety of habitats from deep, still pools to shallow, flowing streams, and may be locally abundant. In this study it was found to prefer sand/mud substrates in back-water areas.

Potamilus ohiensis (Rafinesque, 1820)
(Pink papershell)

This previously Ohio endangered species was found in Ohio Brush Creek, Pine Creek, Salt Creek, and the Hocking River. It was delisted in Ohio in 1990 as the result, in part, of these records. It was rare except for the Hocking River where it was locally common in the channelized portion adjacent to Ohio University, but did not occur above the White's Mill Dam. This is generally thought of as a large stream/river species, but in this study it was found in Pine Creek in 15 cm of water in a stream 2 m wide. Like *Leptodea fragilis*, it is a deeply buried species.

Ptychobranchus fasciolaris (Rafinesque, 1820)
(Kidneyshell)

This species, so common in other areas of Ohio (Watters, 1986, 1988b, 1990), was found living only in Scioto Brush Creek, and as dead specimens in the Hocking River and

Ohio Brush Creek. It (and/or the host) is apparently sensitive to pollution and modifications and may be intolerant of unglaciated regions in Ohio.

Quadrula cylindrica cylindrica (Say, 1817)
(Rabbitsfoot)

This striking, Ohio endangered species is known from the study area only by a single dead specimen taken from Ohio Brush Creek (OSUM records). It has been eliminated from most of its range in Ohio.

Quadrula fragosa (Conrad, 1835)
(Winged mapleleaf)

The type locality of this species is the Scioto River, but specimens from other rivers labeled as such may represent a different taxon. A species from the upper Mississippi River system (St. Croix River, in particular) has recently become Federally Endangered under the name *fragosa*. It is unlikely that it is that species, and probably represents an undescribed taxon. A probable specimen of *fragosa* recently was found in the Ohio River (Cicerello *et al.*, 1991). Two specimens referable to *fragosa* were collected in 1930 in the middle reach of Raccoon Creek (OSUM records) (Fig. 4). That creek supports no naiads beyond its headwaters, and no shell material has survived its highly acidic water. This species has undoubtedly been extirpated from Ohio and most of range.

Quadrula pustulosa pustulosa (Lea, 1831)
(Pimpleback)

This species was found only in Scioto Brush Creek, and the Hocking River below White's Mill Dam. There are historic records for above this dam. It is typical of larger streams and rivers (it was abundant to common in the Ohio River [Stansbery & Cooney, 1985; Williams & Schuster, 1989; pers. obs., 1990], and the Maumee River system [Watters, 1988b]), rarely venturing into headwater areas.

Quadrula quadrula (Rafinesque, 1820)
(Mapleleaf)

This species was found in the lower reaches of most systems studied, although it was seldom common. It was not found above White's Mill Dam on the Hocking River. It occurs in large streams and lakes, in gravel and sand/mud.

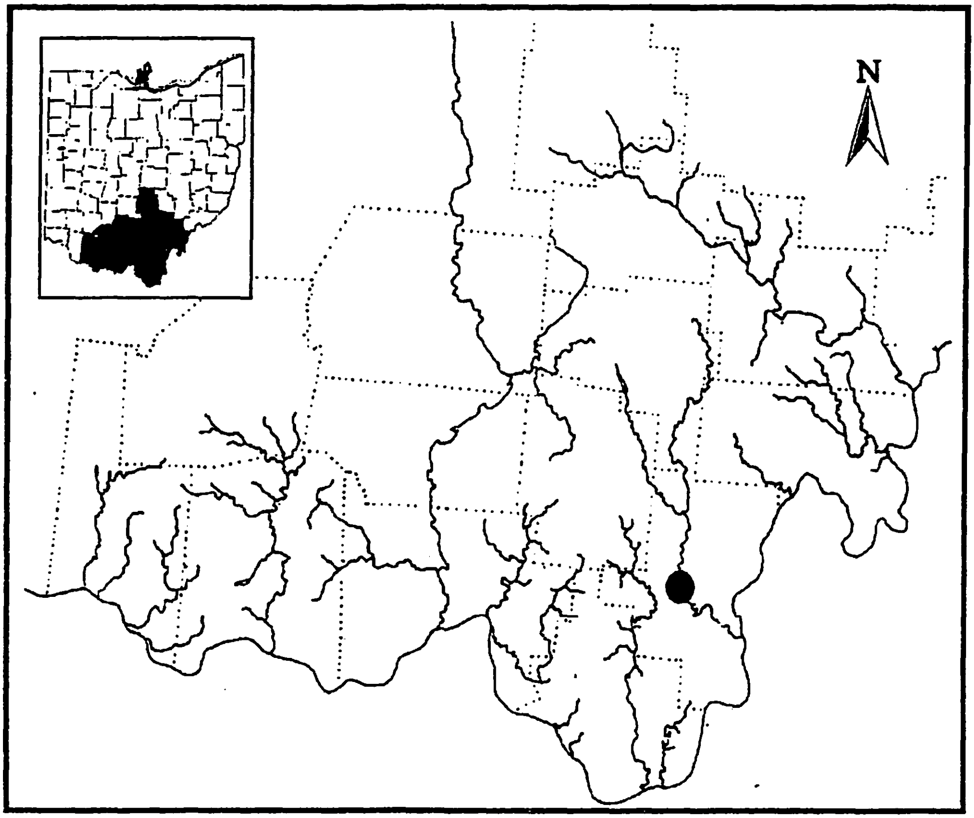


Figure 4. Range of Quadrula fragosa *in the study area.*

Simpsonaias ambigua (Say, 1825)
(Salamander mussel)

This small, previously Ohio endangered species is the only naiad in North America known to utilize a non-fish host, the mudpuppy *Necturus*. Other unionacean-amphibian relationships are known for non-North American species (Seshaiya, 1941). Perhaps because of its uniqueness, its habitat is better known than that of most species. It occurs under large, flat rocks, fallen trees, and similar submerged places along with its host (Clarke, 1985). Historically, it has been locally abundant, but now appears to be rare (Clarke, 1985). In the

1987 survey a dead specimen was found in the lower Little Scioto River. OSUM has a record from Salt Creek. The Little Scioto River locale is exposed bedrock, swept clean of all but the largest rocks, offering little habitat for any naiads other than the salamander mussel. No mudpuppies were seen but most rocks were too large to lift by one individual. (The introduced Asiatic clam *Corbicula* was present in enormous numbers in every niche and pothole in the substrate.)

Strophitus undulatus undulatus (Say, 1817)
(Squawfoot)

This common species was found in all streams of any appreciable size with the exception of Raccoon Creek. It is most typical of headwater reaches, where it may occur along with the similar *Anodontoides ferussacianus* in intermittent pools, but it may be found in all but the largest streams. It is quite variable and may represent more than one taxon.

Toxolasma parvus (Barnes, 1823)
(Lilliput)

This is a very small species which may be overlooked in the best of surveys, which may account, in part, for its sporadic distribution. It prefers sand/mud or mud in still water. Individuals were most common in the Lake Rupert impoundment of Little Raccoon Creek, where they were found exposed, lying on their sides on the submerged blacktop of Twp. Rt. 25.

Tritogonia verrucosa (Rafinesque, 1820)
(Pistolgrip)

This species was found in the lower and middle reaches of the larger streams in this study, where it was occasionally quite common. It preferred sand/mud in the slower water adjacent to runs and riffles.

Truncilla donaciformis (Lea, 1828)
(Fawnsfoot)

Although reported from most sizes of rivers, it was found in this study only in the lower reaches of the larger streams and was nowhere common. It was rare in the Ohio River (Stansbery & Cooney, 1985; pers. obs., 1990). This species or its host may be intolerant of unglaciated regions.

Truncilla truncata Rafinesque, 1820
(Deertoe)

Like *T. donaciformis*, this species has been reported from a wide range of habitats but was found in this study only in the lower reaches of Ohio Brush Creek, Little Scioto River, and the middle reach of Hocking River (weathered dead). It was also rare in the Ohio River (Stansbery & Cooney, 1985; pers. obs., 1990).

Uniomerus tetralasmus (Say, 1825)
(Pondhorn)

A very sporadic species in Ohio, which is on the eastern limit of its range. OSUM has a single record of a specimen from the swamp region of Jackson County. This area is the common origin of the Little Scioto River, and Little Salt, Pine, Symmes, and Raccoon Creeks. However, this species is not known from any of those systems.

Villosa fabalis (Lea, 1831)
(Rayed bean)

This is a small, newly Ohio endangered and Federal Category 2 species of sporadic occurrence in the state. It was found "living" (dead individuals with adductor muscle in middens) in Scioto Brush Creek (Fig. 5). It has been recorded from water willow stands in riffles, an observation supported by this study. This rare species has generally been overlooked by collectors and state agencies alike.

Villosa iris iris (Lea, 1830)
(Rainbow)

With the exception of a single living individual in the headwaters of Symmes Creek, this species was found only in Scioto Brush Creek, where it was not uncommon. This is a fairly common naiad in other Scioto tributaries such as Little Darby Creek (Watters, 1986, 1990), but apparently is intolerant of unglaciated areas. The taxa is one of a complicated series of ecomorphs, sibling species, or subspecies that require much further study.

Villosa lienosa (Conrad, 1834)
(Little spectacle case)

This species is very rare in the state and was previously known from only a handful of localities (Jenkinson & Kokai, 1977). It was listed as Ohio endangered in 1990. In the course

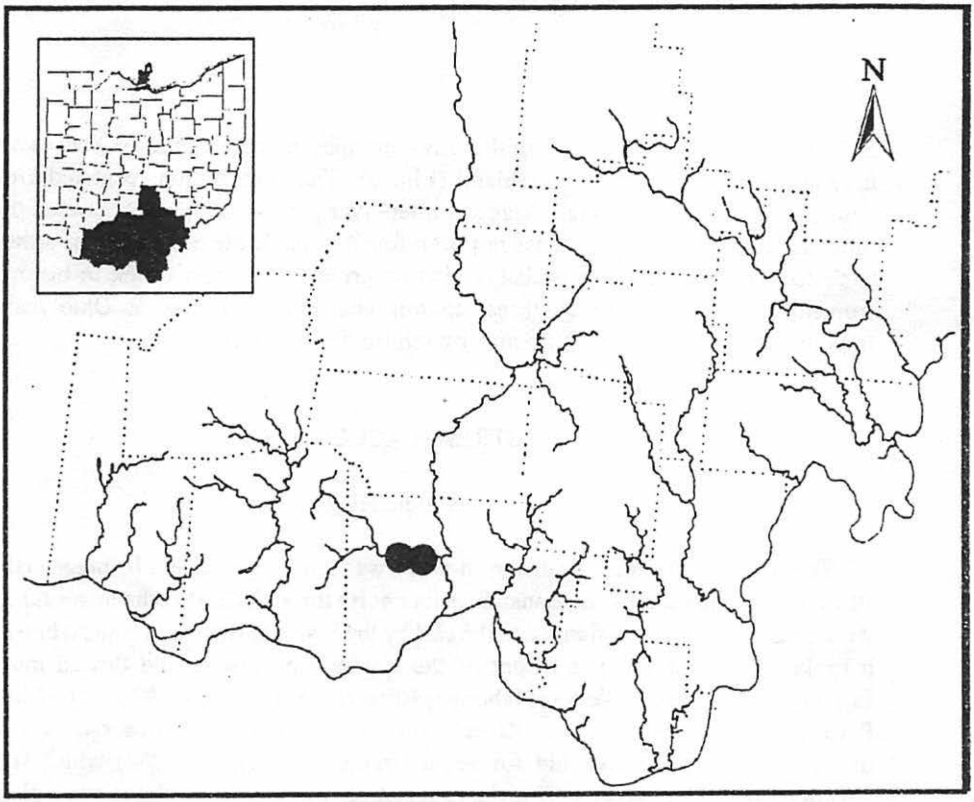


Figure 5. Range of Villosa fabalis *in the study area.*

of this survey, several new populations were discovered in Symmes Creek, Middle Fork Salt Creek, and Pine Creek. The populations appeared to be healthy, and gravid females were present. All individuals were found in a similar habitat: small, clear, cool, canopied headwater streams with a sand bottom and clay banks. Most specimens occurred in the clay banks.

The distribution of this species in Ohio suggests both dispersal through lowland flooding and the remnant of a Teays River influence. The largest concentration of individuals occurs in the headwaters of Little Salt Creek, Pine Creek, and Symmes Creek. These systems, as well as the Little Scioto River and Raccoon Creek, have their origins in the swamp region of Jackson County. Tributaries of these systems may approach within 300 m of each other here and are connected by marshland (Fig. 6). This distribution, centered around this common swampland, strongly suggests inter-river passage of species between the uppermost tributaries. This species has not been found in the Little Scioto River, although it is expected to occur there. It probably also occurred in Raccoon Creek in historic times. Ironically, the most serious threat to this endangered species in Ohio may be the impoundment of these small streams by reintroduced beavers.

STREAM ACCOUNTS

Geologic History

The major prehistoric drainage in Ohio was the Teays River. In preglacial times it flowed from what is now the Kanawha River north through Chillicothe towards the present western Lake Erie basin, flanked to the east by the Marietta River. During Nebraskan times it broke northwest along the front of the approaching glacier and flowed into Indiana forming the Nebraskan-Teays (Mahomet) River (Burr & Warren, 1986). The Little Scioto River now flows in the Teays River's old course. This area, in Jackson County, was impounded by the glacier and formed a sizable lake (Braun, 1964) which filled with "Minford silt" (Spreitzer, 1979), the remnant of which is the common swampland of the headwaters of the Little Scioto River and Salt, Symmes, Pine, and Raccoon Creeks. The Teays River may have broke west into the Hamilton River at this stage or the Kansan.

The Kansan glaciation extended further south than had the Nebraskan. The Teays River reversed itself and flowed south towards Portsmouth and then west through Adams County to Cincinnati. Scioto and Ohio Brush Creeks, as well as Eagle and White Oak Creeks, are now in the course of the old Teays River at that stage. At Cincinnati the Teays River joined the Licking River and rejoined the Hamilton River to form the western arm of the new Ohio River. The Ohio River quickly lowered its channel causing the northward flowing streams into the Teays River to reverse their courses south (Coffey, 1958, 1961). This was essentially the end of the Teays River as an above ground system. Excellent accounts of the Teays River drainage history are found in Burr & Page (1986), Hocutt *et al.* (1986), and Robison (1986).

In Kansan or Illinoian times the westbound systems in eastern Ohio were blocked by advancing ice. They broke cols to the east and formed the present Hocking and Muskingum Rivers.

Faunal Similarities between Systems

The results of this study generally support the conclusions of Warren *et al.* (1984). They found the greatest diversity of naiads in Kinniconick Creek in Kentucky to be in the middle reach, a finding in agreement with this study. They attributed the decrease in fauna in the lower stretch to modifications of the Ohio River by locks and dams which impound the river, causing reduced water flow, increased siltation, and inundation of previous riffles and runs. The headwaters support a typically reduced fauna. The middle reach probably has the highest diversity because it is an area of overlap of headwater and downstream faunas, including its own middle reach assemblage. They further state (p.51) that "the proximity of the Ohio River mainstem is an important factor in determining faunal make-up of small tributaries such as Kinniconick Creek." This is not the case for the streams in southern Ohio except for the very lowest reaches. In these systems it is the proximity of Scioto River lowland dispersal routes or previous drainage patterns that is thought to be the key factor.

Distribution through Canals

During the late 1800's and early 1900's the canal system in Ohio included a spur from the Scioto River to the Hocking River. Although the naiad fauna of the Hocking River above the White's Mill Dam has been largely eliminated, subfossil specimens suggest a fauna more similar to the Scioto River than to the present, below-dam fauna. It is possible that some of these species were introduced via this canal connection. Higgins (1858:3) documented the presence of naiads in the Columbus feeder canal:

> [The] Columbus feeder of the Ohio Canal [has] provided highly favorable localities for a certain class of shells suited to a muddy bottom and still waters. Many species have traversed the whole length of the canal, and many species there thrive and become abundant which are quite rare in adjacent waters.

He listed ten species as occurring in the Columbus spur. It is unknown what species, if any, existed in the Hocking River spur. Although it seems likely that at least some interchange was possible between the Scioto and Hocking Rivers, the extent of that cross-over cannot be determined. Clarke & Berg (1959) also suggested that canals helped to disperse unionids, citing five species as possible candidates in New York.

Stream Recovery

There is no question that, in general, the health of riverine habitats is declining. Almost without exception, surveys report on the dwindling numbers and kinds of naiads in streams and rivers being impounded, polluted, and modified (see Starrett, 1971, for an extensive account of the decline of the Illinois River). One has only to realize that one of the greatest areas of diversity of naiads in the world was once in the Ohio River at Louisville, KY, to appreciate this loss (Stansbery, pers. comm.).

This report presents circumstantial evidence that, *on occasion*, streams may recover from pollution and modification and harbor healthy naiad populations. A 1938 Ohio Department of Agriculture drainage map indicated that several streams at that time were considered "polluted" (unspecified cause):

a. Pine Creek from confluence of Hales Creek to confluence of Little Pine Creek. This region now supports a large population of naiads including *Villosa lienosa* and the previously Ohio endangered *Potamilus ohiensis*.

b. Black Fork Symmes Creek. Part of this tributary has been moved from its previous position south of OH Rt. 233 to north of it. This new section now contains one of the most diverse and largest naiad populations in the entire study area, including the largest population of the Ohio endangered *Villosa lienosa* (13 living individuals found at one site). Naiads were generally common throughout Black Fork, but nowhere as abundant as in the transferred section.

c. Federal Creek of Hocking River. Federal Creek contains a healthy population of several species including the previously Ohio endangered *Potamilus ohiensis*.

Other creeks listed as polluted in 1938 remain that way today, most noticeably Little Raccoon and Raccoon Creeks, Indian Guyan Creek, and lower Leading Creek.

Some systems have recovered from severe modifications such as channelization. The previously mentioned section of Black Fork Symmes Creek has been colonized by numerous species. Large numbers of naiads, including *Potamilus ohiensis*, have established themselves in the channelized portion of the Hocking River in Athens, Hocking County. This is similar to the condition existing in the man-made flood control channels of the St. Francis River in Arkansas, where the federally endangered *Potamilus capax* (Green, 1832) has prospered in these highly modified cut-off channels (Dennis, 1985; pers. obs.). It is not known if this is attributable to changes in substrate, fish fauna, food resources, or all of these causes.

It is important to note several caveats to the discussion of stream recovery given above. Recovery, if it occurs at all, may take decades to occur. Reinvasion by the original species back into a system can occur only if that species has existed in the interim in another place. The total degradation of a system containing endemics will never recover its original fauna. Finally, in some cases, the modifications have made the habitat suitable to certain species at the expense of eliminating the majority of the original fauna (see Watters, 1988b, for the Maumee River).

Stream Systems

White Oak Creek

What few historical records exist suggest that this stream may have supported a fauna similar to Ohio Brush Creek and Eagle Creek. A single record of *Villosa lienosa* exists for this system (Jenkinson & Kokai, 1977). Much of the naiad fauna of this creek literally has been removed. From approximately Georgetown to its mouth, unrestrained sand and gravel operations have dredged the river bottom and banks with bulldozer and backhoe until only flat-bottomed, silted pools or bare bedrock remain. Banks have been quarried into vertical walls 3-7 m high. Whatever naiads may have existed in this reach are since gone, and silt generated by these operations may have smothered downstream reaches. The headwaters still support a typical fauna.

Eagle Creek

This creek flows over exposed bedrock through much of its length, but supports a diverse, however sparse, naiad fauna. The uppermost reaches contain curious ecomorphs of *Anodontoides ferussacianus* and *Strophitus u. undulatus* which are nearly inseparable on shell characteristics alone. The creek appears fairly pristine.

Ohio Brush Creek

This may be the most noteworthy system in the survey. This creek lies predominantly in the Lexington Plain, a biologically unique area of limestone bedrock that was not glaciated. Its present course contains part of the ancient Teays River drainage and is predominantly composed of exposed bedrock and dislodged limestone. It is shallow during normal water flow and it superficially resembles White Oak and Eagle Creeks. However, it has supported a disproportionately diverse naiad fauna, 27 species in all, of which five are state endangered, and others rare. In this study a live female of *Lampsilis teres anodontoides* was found in the lower reach. This state endangered species had not been found living within Ohio since 1959. Some components of its fauna may be derived from Scioto Brush Creek through lowland dispersal. A portion of its middle reach, historically rich in rare species, has been degraded. Because of its readily available limestone, quarrying has begun on this creek, and in light of the fate of White Oak Creek, Ohio Brush Creek must be considered in jeopardy.

Scioto Brush Creek

This is a large tributary of the Scioto River and its naiad fauna is similar to other Scioto River branches. As such, it contains some species not found in neighboring systems, although some elements of Ohio Brush Creek may have had their origin in this system. The main stem lies in or very near the course of the Teays River in post-Kansan times, and thus is actually older than the lower Scioto River of which it is now a branch. The state-endangered *Villosa fabalis* and *Villosa lienosa* have been found in this creek. The system is fairly pristine, but there is evidence of some die-off below the town of Otway.

Salt Creek

This is another large tributary of the Scioto River, composed of three forks: Salt Creek proper to the north, Middle Fork Salt Creek running east-west, and Little Salt Creek from the south. Of the three, only the Middle Fork remains relatively unspoiled. All three have joined by the time they reach the town of Richmond Dale, where an extensive sand flat exists that has a rich, and oft sampled, naiad fauna. Three state-endangered or previously state-endangered species have been recorded from Salt Creek. The naiads in the majority of Salt Creek proper have been heavily impacted, apparently by the towns of Adelphi and Laurelville, and only isolated populations remain. Numerous records (OSUM) exist for Little Salt Creek which indicate that as recent as 1965 it had a rich fauna similar to that of Symmes Creek. Collections in this study at the same sites found few or no naiads. This branch may have been polluted by outfalls from the town of Jackson, runoff from clear-cutting, and runoff from construction on U.S. Rt. 35. The Middle Fork has been rarely sampled. It has few accessible sites, and is the smallest and most remote of the three branches. It contains an enormous naiad population for its size, including what is undoubtedly the largest population of the otherwise uncommon *Obovaria subrotunda* in the state. It also contains living *Villosa lienosa*, a new record for this state-endangered species.

Little Scioto River

This relatively clean stream has enormous numbers of naiads in some regions, particularly *Lampsilis radiata luteola*. It contains a wide variety of substrates, from mud to bare bedrock. The lowest reach has typical big-river species. The previously state-endangered *Simpsonaias ambigua* was found in the exposed bedrock region. Its headwaters are derived from the same swamp as Symmes and Little Salt Creek, but apparently lacks *Villosa lienosa*.

Pine Creek

This remote creek, like Symmes Creek, has a healthy naiad fauna throughout most of its length. The previously state-endangered *Potamilus ohiensis* occurs as far upstream as the small Hales Creek tributary. The state-endangered *Villosa lienosa* also occurs in this stream.

Symmes Creek

This creek consistently had the most diverse and numerous naiad fauna along its length of any stream studied. There did not appear to be "dead-zones" below any of the few towns along its length. The stream has its origins in the clay-rich swamp region in Jackson County as cool, clear brooks. These very small streams support an impressive diversity for their size, including the state-endangered *Villosa lienosa* and a curious morph of *Lasmigona complanata*. Downstream portions have typically larger stream faunas. The only specimen of *Actinonaias ligamentina carinata* encountered in this study was found in Symmes Creek.

Indian Guyan Creek

There is evidence that this small creek, adjacent to Raccoon Creek, has suffered the same fate, acid mine runoff, as that much larger system. A single living naiad was found in the extreme headwaters in an intermittent tributary.

Raccoon Creek

The naiad fauna of this, the largest creek in Ohio, has been eliminated by acid mine runoff. No naiads in any condition were found in this creek except for in Lake Rupert. This relatively recent impoundment, at the extreme headwaters of Little Raccoon Creek, has several species typical of impounded areas. The average pH of the Raccoon Creek system over 25 sites was 6.4, with six sites having a pH of 5 or lower. Such acidic water precludes the possibility of any shell material being preserved to indicate what species originally occupied this creek. Raccoon Creek was declared polluted as early as 1938 and records of naiads prior to this are rare. What collections do exist suggest that this large creek had a fauna similar to the neighboring Hocking River or Scioto River. The prospect for recovery of naiads in this creek in the foreseeable future is unfavorable. Unionids have been shown to avoid mine waste areas even if the substrate is suitable (Simpson & Reed, 1973; Morris & Taylor, 1978; Havlik & Marking, 1987), and certainly the pH of this system cannot, at this time, allow any recolonization.

Leading Creek

This short creek shows evidence of having been degraded below Langsville, where several sites were either acidic or heavily silted. Above Langsville the creek supports a large naiad fauna typical of healthy headwater streams.

Shade River

This system has three major tributaries, all unique. The West Branch consists of an orange, course sand substrate with little surface water, but apparently a substantial ground water flow. Although all sites had a neutral pH, no naiads were found. This is undoubtedly due to the very unstable nature of the sand and the general lack of surface water. The Middle Branch contained few naiads except for a large population at its confluence with the West Branch. This fork was heavily silted and oil slicks were present at several sites. The East Branch was the least degraded and contained naiad populations along most of its length.

Hocking River

The Hocking River contained the greatest diversity of naiads of all systems studied. Although 27 species have been recorded from this river, only 13 were found alive in this study. One state endangered species has been found there: *Pleurobema clava*, now extirpated. The complicated distribution of naiads in this river appears to be due to several factors.

The Hocking River canal was built between 1826 and 1843 and extended from Carroll on the Scioto River to Athens on the Hocking River. Because it was a major route for moving coal out of the Hocking Valley, it was heavily used. The advent of the railroad essentially put the canal boats out of business, and the Nelsonville-Athens section was abandoned in 1874. The remaining section was destroyed in the 1884 flood (Peters, 1947). As previously mentioned, naiads were common in some canals and may have dispersed through them to new systems (Higgins, 1858). The Hocking River canal was joined during these times to the Scioto River in the vicinity of Groveport. The extirpated fauna of the upper Hocking River bears little resemblance to the present fauna of the lower Hocking River, but does resemble the Scioto River fauna. How many species, if any, were introduced to the Hocking River from the Scioto River cannot be determined.

The naiad fauna of the Hocking River was severely reduced by iron works outfalls, among other pollutants, from Lancaster and Nelsonville. There is little indication that naiads are repopulating the river upstream of the White's Mill Dam at present, with the exception of a few tolerant species.

Several dams have been constructed on the Hocking River. The first was Barth's Mill

Dam, built in 1805 and destroyed in the 1907 flood. The extant White's Mill Dam, originally constructed as the Herrold's Mill Dam in 1807, is a lowhead dam in Athens (Athens Messenger, 1986). For reasons not yet understood, the majority of the present naiad fauna of the lower Hocking River stops at this dam. Of the 13 species found living in the river below the dam, only three (24%) extend their ranges above it. This is very similar to the distribution of naiads in the St. Joseph River, where several species are found up to, but not above, the dam at Ft. Wayne, Indiana (Watters, 1988b).

Presumably, at some point the naiads of the Hocking River were eliminated by upstream pollution. The present fauna appears to have reentered by two routes. The unpolluted headwater tributaries probably acted as refugia for several species (i.e. *Lampsilis radiata luteola* and *Lasmigona complanata*) which are reinvading the Hocking River proper under suitable conditions. But the majority of the naiads living here are river or big stream species that have recolonized the Hocking River from the Ohio River. Almost without exception these species are not found upstream of White's Mill Dam. It is possible that the area above the dam has concentrated pollutants in its substrate and is unsuitable for naiads. It is also possible that the fish hosts cannot survive above the dam or are incapable of surmounting it.

Big Threemile Creek, Straight Creek, Storms Creek, Long Run and Ice Creek

These are relatively short, high gradient streams that are dry or intermittent much of the year. They support no naiad fauna for most of their length.

DISCUSSION

The zoogeography of the unionids of southern Ohio is the result of the interplay of several large scale biotic and abiotic factors. While it is tempting to reduce unionid distribution to a subset of the host fish range (a biotic factor), both are ultimately linked to abiotic agents. Evidence of such factors in this study include relict drainage patterns, glacial modification, source systems, and random factors (such as lowland flooding and manmade obstructions).

The most important relict drainage pattern in the study area is the Teays River. All of the present systems in unglaciated Ohio were within the drainage basin of the Teays River. Some portions of existing systems lie within the unglaciated channels of the Teays River or its tributaries. The Little Scioto River now flows in the opposite direction of its original Teays River route and portions of Salt Creek now lie in the course of the old Marietta and Albany Rivers. The influence of the Teays River as a zoogeographic factor has been obscured as glacial advances changed the course and direction of the Teays River, and in many cases obliterated it. Its influence may be apparent on a broad scale (Burr & Page, 1986; Hocutt *et al.*, 1986; Robison, 1986) but at the level used in this study its contribution to recent distributional patterns is often masked by more recent geologic and random events.

The distribution of *Villosa lienosa* in Ohio appears to lie within the Teays River drainage. *Villosa lienosa* is a widely distributed species in the south central US, but Ohio is near the northern limit of its range. The present distribution of *V. lienosa* in West Virginia, Ohio, Indiana, and Illinois marks the course of that river in many places. In Ohio, the population in Jackson County lies in tributaries or swampland representing the impounded portion of the Teays River, Lake Teays (Figure 6). The records for Scioto Brush Creek, Little Miami River, and White Oak Creek (OSUM) likewise lie on the course of the Teays River through southern Ohio.

Unlike most of the naiads discussed here, *V. lienosa* occurs in unglaciated regions almost exclusively. Why it remains tied to the Teays River drainage, and has not colonized glaciated regions outside of this drainage, is unknown. Few fishes have a distribution similar to *V. lienosa*. The northern spotted blackbass (*Micropterus punctulatus*) and the northern dusky darter (*Percina sciera sciera*) are somewhat comparable (Trautman, 1981). At this point it is not possible to determine to what extent specific unionid distributions are strictly the result of host fishes ranges.

Five species in the study area were absent or nearly so from unglaciated areas (Table 2). The suggestion that streams in unglaciated land do not contain enough calcium for shell deposition or are otherwise too acidic does not explain the presence of other unionids in the same area. Furthermore, these "missing" species occur in unglaciated regions to the south in Kentucky, Tennessee, and West Virginia, suggesting that unglaciated land *per se* is not the controlling factor. In fact, these areas probably acted as sources of introduction or reintroduction to northern areas as the glaciers retreated (Johnson, 1980). Non-glaciated limestone may act as a buffer in these areas and Clarke & Berg (1959) and Clarke (1973) have shown that the distribution of unionids tends to follow the presence of limestone outcrops in many areas.

Streams in unglaciated land in Ohio have higher gradients than do streams in glaciated areas. For reasons not yet understood, the increased grade of the streams may be detrimental to some unionids or their host fishes. The drainage area, length, and average gradient of the streams in the study area are correlated with the number of unionid species (Figs. 11-13). These three variables are themselves highly correlated.

The presence of the Scioto River is an important factor in the distribution of unionids in the study area. The Scioto River and the two main tributaries covered here, Salt and Scioto Brush Creek, contain species rarely, or not at all found in the remaining systems: *Epioblasma triquetra*, *Quadrula p. pustulosa*, *Villosa fabalis*, and *Villosa i. iris*. Some Scioto River unionid species or their hosts have apparently spread to adjacent systems

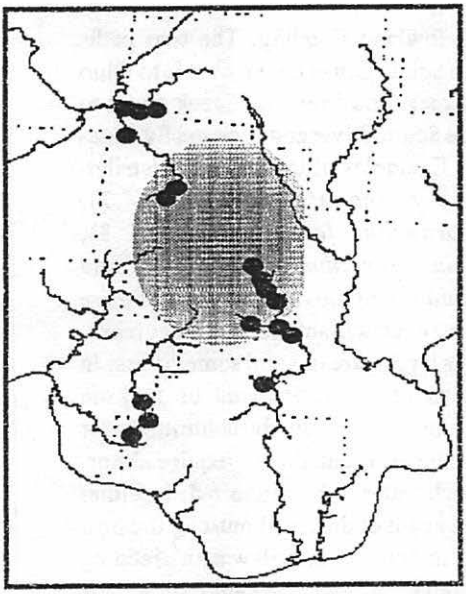


Figure 6. Villosa lienosa. *Shaded area is swampland.*

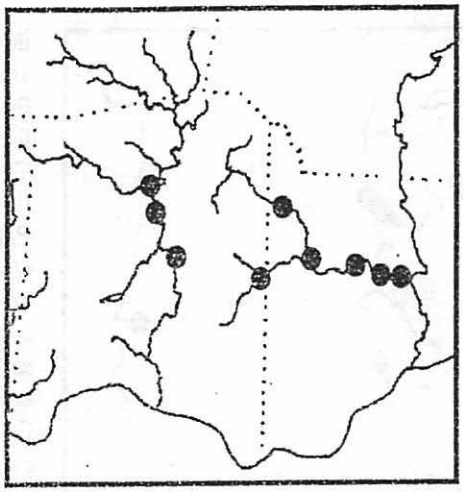


Figure 7. Fusconaia flava. *Area of dispersal.*

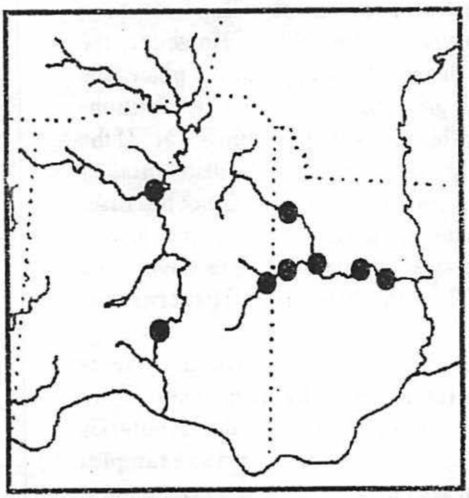


Figure 8. Ptychobranchus fasciolaris. *Area of dispersal.*

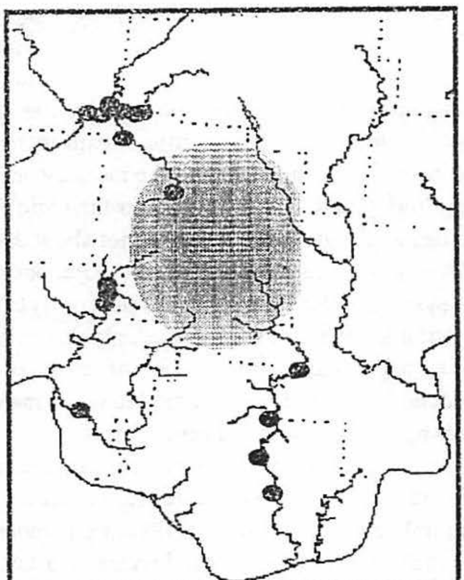


Figure 9. Obovaria subrotunda. *See Figure 6.*

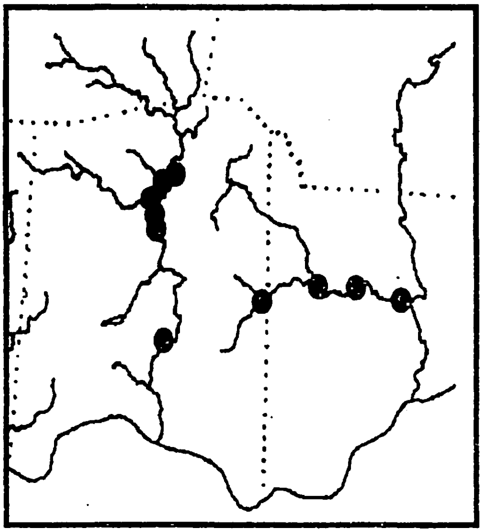


Figure 10. Tritogonia verrucosa. *Area of dispersal.*

through lowland flooding. The two paths are from Scioto Brush Creek west into Ohio Brush Creek, and from Salt Creek south to the Little Scioto River and Pine and Symmes Creeks. Examples of this type of distribution are *Fusconaia flava* (Fig. 7), *Ptychobranchus fasciolaris* (Fig. 8), *Obovaria subrotunda* (Fig. 9), and *Tritogonia verrucosa* (Fig. 10). All of these species may occur in small headwater creeks, as well as larger streams and some rivers. In areas such as the swampland of Jackson County, headwaters may be continuous for much of the year, and do not require abnormally high water to be connected. In either path, the agent of dispersal must be the host fish. No amount of rain will wash a breeding age unionid through a swamp to a new drainage, and unionids are not motile enough to traverse any of the required distances.

It is also possible that the species given as examples of lowland flooding have been dispersed by their host fishes from stream to stream via the Ohio River. However, the lowland route is the shortest, and the mechanisms for dispersal (swamps) are in place (the Jackson County area swamp predates the Ohio River proper). Most of the distributions seem to center about the swampland, not about the confluences with the Ohio River. If the Ohio River was acting as the dispersal route, one would expect species to be distributed in suitable systems independent of their proximity to the Scioto River. But this is not the case. The distributional patterns involve only the immediate tributaries of the Scioto River. However, the downstream reaches of many of the streams included here have been modified, and much of their unionid fauna extirpated. Thus, the distributional patterns seen here may have been due to several causes.

However, lowland flooding has a random element to it in that the timing of such events is not strictly cyclic or predictable. However, the species dispersed by such a method are not randomly selected. Lowland flooding is more likely to involve headwater tributaries than the main stems of streams and rivers. Most of the species here considered as examples of lowland flooding are not strictly big river taxa, but also may occur in the headwaters. The distribution of these species by lowland flooding is considered to be the most plausible and parsimonious of the two dispersal routes.

Human modification of riverine systems is also a random event, in the biological sense.

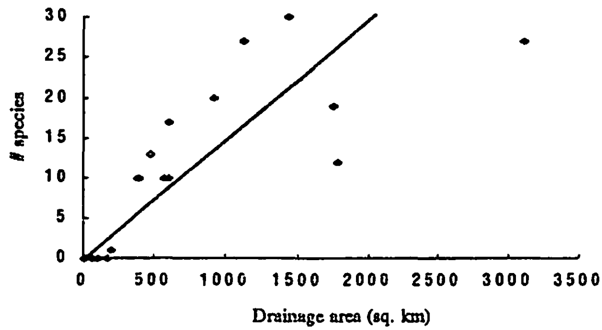


Figure 11. Drainage area vs # species.

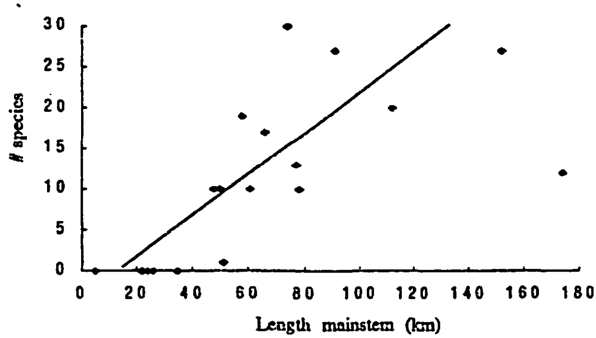


Figure 12. Length mainstem vs # species.

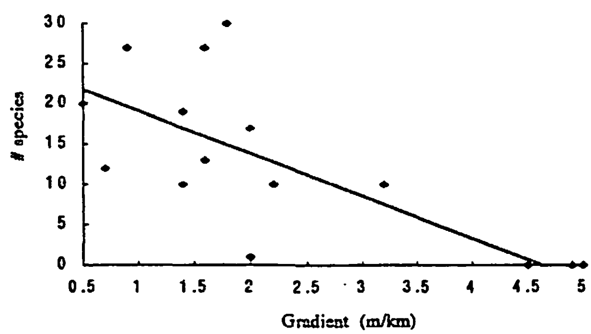


Figure 13. Gradient vs # species.

The presence of dams, bridges, reservoirs, sewage treatment plants, runoff, and other modifications is more dependent on proximity to urban areas, imagined needs, local politics, and lack of opposition, than upon any intrinsic quality of the modification site. The majority of such modifications are detrimental to the unionid fauna of the area. The absence of some species above White's Mill Dam on the Hocking River must be attributed to the physical presence of the structure, although it is not clear if the dam is preventing individuals from moving upstream, or if the dam is containing lethal compounds in the upstream sediments that would eliminate downstream populations. Stripmining has eliminated all but a headwater handful of species in Raccoon Creek, the state's longest creek, and heavily impacted other systems.

But on rare occasion, human's unwittingly modify riverine systems such that the modifications allow support for large unionid populations. However, the species composing these populations are often different from the original ones, and must be considered as introduced species.

ACKNOWLEDGEMENTS

I would like to thank the following: Dr. D. H. Stansbery (Ohio State University), for his invaluable help and discussions; Ms. K. G. Borror (OSU), for explaining the intricacies of the Museum collection records; Dr. T. Cavender (OSU); Mr. J. Condit (OSU); Dr. R. Feltes (OSU); Dr. M. Hoggarth (Ohio Dept. Transportation); and Mr. W. Kasson (Columbus & Southern Electric Co.); all offered their perspectives on naiads and the study area; Mr. W. McCance (Division of Natural Areas & Preserves, Ohio Department of Natural Resources) and Mr. D. Ross (Division of Wildlife, Ohio Department of Natural Resources) for their valuable discussions and suggestions; Mr. C. Dowdy (OSU), for his time and efforts in helping with this report, particularly with the history of Athens County.

This study was funded by grants from the Division of Wildlife and the Division of Natural Areas and Preserves, Ohio Department of Natural Resources.

LITERATURE CITED

ATHENS MESSENGER. 26 Jan. 1986. Advertisement for White's Mill. p.39.

ATHENS MESSENGER. 26 Jan. 1986. 1st dam on Hocking was at Barth's Mill. p.45.

BATES, J. M. 1970. Ohio mussel fisheries investigation. Final Report - Part I. Mussel studies. *U.S. Bureau of Commercial Fisheries, Contract No. 14-17-0004-433, Subproject No. 4-28-R.* 108 pp.

BRAUN, E. L. 1964. Deciduous forests of eastern North America, 596 pp.

BUCHANAN, A. C. 1980. Mussels (naiades) of the Meramec River basin, Missouri. *Missouri Department of Conservation, Aquatic Series*, (17): 1-69.

BURR, B. M. & PAGE, L. M. 1986. Zoogeography of the fishes of the lower Ohio - upper Mississippi basin. Pp. 287-324. *In:* HOCUTT, C. H. and WILEY, E. O. (eds.). *The Zoogeography of North American Freshwater Fishes*. J. Wiley & Sons, New York, New York.

BURR, B. M. & WARREN, M. L. 1986. A distributional atlas of Kentucky fishes. *Kentucky Nature Preserves Commission, Science & Technical Series*, (4): 1-398.

BUTLER, R. S. 1989. Distributional records for freshwater mussels (Bivalvia: Unionidae) in Florida and south Alabama, with zoogeographic and taxonomic notes. *Walkerana*, 3(10): 239-261.

CICERELLO, R. R., WARREN, M. L. & G. A. SCHUSTER. 1991. A distributional checklist of the freshwater unionids (Bivalvia: Unionoidea) of Kentucky. *American Malacological Bulletin*, 8: 113-129.

CLARKE, A. H. 1973. The freshwater molluscs of the Canadian Interior Basin. *Malacologia*, 13: 1-509.

CLARKE, A. H. 1981. The Tribe Alasmidontini (Unionidae: Anodontinae), Part I: *Pegias*, *Alasmidonta*, and *Arcidens*. *Smithsonian Contributions to Zoology*, (326): 1-101.

CLARKE, A. H. 1985. The Tribe Alasmidontini (Unionidae: Anodontinae), Part II: *Lasmigona* and *Simpsonaias*. *Smithsonian Contributions to Zoology*, (399): 1-75.

CLARKE, A. H. & C. O. BERG. 1959. The freshwater mussels of central New York. *Cornell University Agricultural Experiment Station Memoir*, (367): 1-79.

COFFEY, G. N. 1958. Major glacial drainage changes in Ohio. *Ohio Journal of Science*, 58(1): 43-49.

COFFEY, G. N. 1961. Major preglacial, Nebraskan and Kansan glacial drainages in Ohio, Indiana, and Illinois. *Ohio Journal of Science*, 61(5): 295-313.

CUMMINGS, K. S., MAYER, C. A., PAGE, L. M. & BERLOCHER , J. M. K. 1987 Survey of the freshwater mussels (Mollusca: Unionidae) of the Wabash River drainage. Phase 1: Lower Wabash & Tippecanoe Rivers. *Indiana Department of Natural Resources, Section of Faunistic Surveys & Insect Identification Technical Report for 1987*, (5): 1-61.

DENNIS, S. 1985. A recovery plan for the fat pocketbook pearly mussel *Potamilus* (=*Proptera*) *capax* (Green, 1832). *U. S. Fish & Wildlife Service Report*. 57 pp.

HAVLIK, M. E. & MARKING, L. L. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. *U. S. Department of the Interior, Fish & Wildlife Service, Research Publication*, (164): 1-20.

HIGGINS, F. 1858. *A catalogue of the shell-bearing species of Mollusca, inhabiting the vicinity of Columbus, Ohio, with some remarks thereon*. Privately printed, 8 pp.

HOCUTT, C. H., JENKINS, R. E. & STAUFFER, J. R. 1986. Zoogeography of the fishes of the central Appalachians and central Atlantic coastal plain. Pp. 161-211. *In:* HOCUTT, C. H. and WILEY, E. O. (eds.). *The Zoogeography of North American Freshwater Fishes.* J. Wiley & Sons, New York, New York.

HORNE, F. R. & MCINTOSH, S. 1979. Factors influencing distribution of mussels in the Blanco River of central Texas. *Nautilus,* 93: 119-133.

JENKINSON, J. J. & KOKAI, F. L. 1977. *Villosa lienosa* (Conrad, 1834) in Ohio. *Bulletin of the American Malacological Union for 1977*: 82-83.

JOHNSON, R. I. 1980. Zoogeography of North American Unionacea (Mollusca: Bivalvia) north of the maximum Pleistocene glaciation. *Bulletin of the Museum of Comparative Zoology,* 149: 77-189.

MARKING, L. L. & BILLS, T. D. 1980 Acute effects of silt and sand sedimentation on freshwater mussels. Pp. 204-211. *In*: RASMUSSEN, J. L. (ed.). *Proceedings of the symposium on upper Mississippi River bivalve mollusks.* Upper Mississippi River Conservation Committee, Rock Island, Illinois.

MORRIS, J. S. & TAYLOR, R. W. 1978. A survey of the freshwater mussels (Bivalvia: Unionidae) of the Kanawha River of West Virginia. *Nautilus,* 92: 153-155.

OESCH, R. D. 1984. *Missouri naiads. A guide to the mussels of Missouri.* Missouri Department of Conservation. 270 pp.

OHIO DEPARTMENT OF AGRICULTURE, DIVISION OF CONSERVATION. 1938. Map of Ohio showing principal streams and tributaries. 1 map.

ORTMANN, A. E. 1919. A monograph of the naiades of Pennsylvania, Part III. Systematic account of genera and species. *Memoires of the Carnegie Museum,* 8(1919-1921): 1-384.

PARMALEE, P. W. 1967. The fresh-water mussels of Illinois. *Illinois State Museum, Popular Science Series,*(8): 1-108.

PETERS, W. E. 1947. *Athens County, Ohio,* 1: 1-296.

ROBISON, H. W. 1986. Zoogeographic implications of the Mississippi River basin. Pp. 267-285. *In:* HOCUTT, C. H. and WILEY, E. O. (eds.). *The Zoogeography of North American Freshwater Fishes.* J. Wiley & Sons, New York, New York.

SESHAIYA, R. V. 1941. Tadpoles as hosts for the glochidia of the fresh-water mussel. *Current Science (Bangalore City, India),* 10: 535, 536.

SIMMONS, G. M. & REED, J. R. 1973. Mussels as indicators of biological recovery zone. *Journal of Water Pollution and Control Federation,*45: 2480-2492.

SPREITZER, A. E. 1979. The life history, external morphology, and osteology of the eastern sand darter, *Ammocrypta pellucida* (Putnam, 1863), an endangered Ohio species (Pisces: Percidae). *Unpublished Master's Thesis, Ohio State University, Columbus, OH.* 248 pp.

STANSBERY, D. H. 1961. A century of change in the naiad population of the Scioto River system in central Ohio. *American Malacological Union Annual Report For 1961*: 20-22.

STANSBERY, D. H. & BORROR, K. G. 1983. A list of the Recent freshwater bivalve mollusks of the Holarctic region catalogued into the Ohio State University Museum of Zoology collection. *Ohio State University Museum of Zoology Reports for 1983*, (2): 1-3.

STANSBERY, D. H. & COONEY, J. D. 1985. Survey of the unionid mollusks of the Ohio River in the vicinity of the Wm. H. Zimmer Station (Ohio River miles 442.6-445.6). *Final Report to the Cincinnati Gas & Electric Company, Columbus & Southern Ohio Electric Company, & the Dayton Power & Light Company*. 33 pp.

STANSBERY, D. H. & KING, C. T. 1983. Management of Muskingum River mussel (unionid mollusk) populations. *Ohio State University Museum of Zoology Reports for 1983*, (5): 1-79.

STANSBERY, D. H., NEWMAN, K. E., BORROR, K. G. & STEIN, C. B. 1985. Literature records of bivalve mollusks of the Muskingum River System, Ohio. *Ohio State University Museum of Zoology Reports for 1985*, (1): 1-472.

STARRETT, W. C. 1971. A survey of the mussels (Unionacea) of the Illinois River: a polluted stream. *Bulletin of the Illinois Natural History Survey*,30(5): 267-408.

TAYLOR, R. W. 1983.A survey of the freshwater mussels of the Kanawha River from riverhead (Gauley Bridge, WV) to river mouth (Point Pleasant, WV). *Huntington District, U.S. Army Corps of Engineers, Huntington, WV. Contract No. DACW69-82-C-0081*. 62 pp.

TRAUTMAN, M. B. 1981. *The Fishes of Ohio*. Ohio State University Press. 782 p.

TURGEON, D. (ed.) 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. *American Fisheries Society Special Publication*,(16), 277 pp.

WARREN, M. L., CICERELLO, R. R., CAMBURN, K. E. & FALLO, G. J. 1984. The longitudinal distribution of the freshwater mussels (Unionidae) of Kinniconick Creek, northeastern Kentucky. *Bull.etin of the American Malacological Union* ,3(1): 47-53.

WATTERS, G. T. 1986. A survey of the unionid molluscs of the Big Darby Creek System in Ohio. *Final Report to The Nature Conservancy*. 149 pp.

WATTERS, G. T. 1988a. The naiad fauna of selected streams in Ohio. I. Stillwater River of Miami River. II. Stream systems of south central Ohio from the Little Miami River to the Hocking River, excluding the Scioto River proper. *Final Report to the Division of Wildlife, Ohio Department of Natural Resources*. 440 pp.

WATTERS, G. T. 1988b. A survey of the freshwater mussels of the St. Joseph River system, with emphasis on the federally endangered White Cat's Paw Pearly Mussel. *Final Report to the Division of Fish & Wildlife, Indiana Department of Natural Resources*. 127 pp.

WATTERS, G. T. 1988c. A field guide to the freshwater mussels of Ohio. *Division of Wildlife, Ohio Department of Natural Resources.* 105 pp.
WATTERS, G. T. 1990. 1990 Survey of the unionids of the Big Darby Creek system. *Final Report to The Nature Conservancy, Ohio Chapter.* 229 pp.
WILLIAMS, J. C. & SCHUSTER, G. A. 1989. Freshwater mussel investigations of the Ohio River, mile 317.0 to mile 981.0. *Division of Fisheries, Kentucky Department of Fish & Wildlife Resources.* 57 pp.

New Records for Some Species of Alasmidontini

Herbert D. Athearn
Cleveland, Tennessee

The following records for Alasmidontini species are supplementary to those included in a recent monograph of that Tribe by Clarke (Smithsonian Contributions to Zoology, No. 326 (1981) and No. 399 (1985)). These new records are all based on specimens collected by me (unless otherwise indicated) and housed in the Museum of Fluviatile Mollusks, 5819 Benton Pike N.E., Cleveland, Tennessee (37312-6533). These records are deemed significant because (1) they apply to Federally endangered species or (2) they extend the known geographical distributions for other species in peripheral areas. Collection dates are in parentheses.

Pegias fabula (Lea): Cane Creek, Sweetgum, 4.6 mi NE of Spencer, van Buren Co., Tenn. (1967). This record replaces the "Caney Fork" record in Clarke, 1981 (p.15) which is erroneous. P. fabula was also previously common in Collins River at Shellsford, Warren Co., Tenn., but is now gone from that site.

Alasmidonta heterodon (Lea): Acushnet River, 3.2 mi NNE of Acushnet, Bristol Co., Mass. North Branch, 1 1/2 mi NW of Leonardstown, St. Marys Co., Md.

(1959). Tar River, Hwy. 15, 6 mi SSW of Oxford, Granville Co., NC (1978).

Alasmidonta undulata (Say): (all Rhode Island) Pawcatuck River, Burdickville, Hopkinton Twp. (1948). Abbott Run, 1 mi E of Lonsdale, Providence Co. (1949). Charles River, Wood River RR junction, Washington Co., (1951). Wood River, Plainville, Hopkinton/Richmond Twp. boundary, Washington Co. (1951). Brook, outlet of Boone Pond, Arcadia, Washington Co. (1954).

Lasmigona costata (Raf.): South Chickamauga Creek, 1 mi SE of Graysville, Catoosa Co., Ga. (1958).

Lasmigona compressa (Lea): R. St. Francois, 1 mi N of Drummondville, Drummond Co., Que.. R. Becancour, about 1/2 mi above Becancour, Nicolet Co., Que. Wapsipinicon River, 1 mi below Littleton Dam, Littleton, Buchanan Co., Iowa (Hazel Pengston !, 1960).

Lasmigona subviridis (Conrad). Flint River, 6.5 mi E of Gay, Pike & Meriwether Cos., Ga. (1967).

Lasmigona decorata (Lea). Oconee River, about 0.4 mi NW of Wallace Dam Site, Putnam Co., Ga. (J.L. Randolph !).

Simpsonaias ambigua (Say). Sydenham River, Smithsville, Lambton Co., Ont. (1967). Maumee River, Hwy. 101, 3 mi N of Woodburn, Allen Co., Ind. (1 valve, 1967). Elkhorn Creek, 3 mi S of Swallowfield, Franklin Co., Ky. (2 valves, 1950). Smith Fork, 1.2 mi SW of Lancaster, Smith Co., Tenn.. West Fork Stones River, 8.3 mi NW of Murfreesboro, Rutherford Co., Tenn.. Salt River, 2.6 mi S of Mount Washington, Bullitt Co., Ky.

Editor's Note : Mr. Athearn's Museum contains by far the largest private, fully curated, collection of freshwater mollusks in North America and its holdings rival in value those of many of our major research museums. The specimens therein were collected principally by him from throughout the United States and southern Canada over the past 4 1/2 decades. His collection constitutes a valuable scientific resource for malacology.

Shell-fish, Indians, and Horses: Mission San José (1771)

Harold D. Murray
Biology Department
Trinity University
San Antonio, Texas 78212

The regular use of freshwater mussel (unionid) meat for food and shells for ornaments and tools by native Americans is well documented in the literature (Fox, 1979; Murray, 1981; Neck, 1982; Oesch, 1984; Parmalee and Bogan, 1986; and Parmalee, et al., 1982). It is unclear if native Indians of the Texas Coastal Plain utilized unionids as food on a regular basis or only at times when other food sources were scarce. Fox (1979, p. 6) discusses native Indians of the Texas Coastal Plain and states that "The proximity of sites to reliable water sources and the high frequency of occurrence of the remains of a variety of freshwater fauna indicate a subsistence-settlement pattern which focused on the exploitation of riverine environments..." The establishment of Spanish missions in Texas in the early 1700's forever changed (albeit slowly) these nomadic hunters, sometimes poorly fed, to settled agrarians with steady supplies of grain and cattle. With this change the use of unionids by mission Indians abated except during unusual circumstances. One such circumstance (Lanusa, 1771) is recorded in three letters from Father Lanusa (chaplain of Mission San José) to Governor Baron de Ripperdá (administrator of the missions).

Periodically, some of the Indians left the mission returning to pagan practices. The Governor would organize trusted Indians and a few Spanish troops from each mission to return the wayward Indians to the appropriate missions. Father Lanusa of Mission San José was ordered by Governor Ripperdá to supply nine Indians and 42 horses. In a letter dated August 1, 1771, Father Lanusa refused to supply the Indians and horses because, "By using all available horses, they [Indians] could get the necessary sustenance, for horses were constantly used all year long in gathering shell-fish [en mariscar]". "En mariscar" is correctly translated "in gathering shell-fish" for the 1700's as well as today. Nonmission Indians had stolen their cattle forcing them to shell-fishing.

The above quotation begs several questions: 1) how were horses used to gather shell-fish, 2) where were the shell-fish obtained, and 3) what were shell-fish?

The word "gather" might suggest the use of horses to pull a dredge-like object in the water to obtain shell-fish. Horses were used to transport not gather shell-fish based on two lines of evidence. First, relative to not having sufficient numbers of horses, Father Lanusa's same letter later states, "Thus they would be forced to walk or just stop shell-fishing". Second, there is no inventory record of any shell-fish gathering device at this mission. Highly elaborate inventories were kept of items in the mission even to the counting of the last nail.

The site of collection is less definite. The closest water to Mission San José is the San Antonio River (600 m). It is unlikely that Father Lanusa's refusal to obey a direct order would be based on a distance of 600 m. Also, at this point the San Antonio River is within 28.9 km (18.0 miles) of its origin with but a few, thin-shelled mussels (Strecker, 1931, p. 68); thus, the river is an unlikely candidate to support two shell-fishing operations lasting over a year as also mentioned in Lanusa's letter to Ripperdá. If they shell-fished any distance downstream on the San Antonio River, they would encroach on the shell-fish operations of the Presidio of La Bahia (80 km from San José) at Goliad, Texas. A likely collecting area was the lower Atascosa River at the ranch of the Mission San José near Pleasanton, Texas (64 km from the mission) or possibly even another 64 km to where the Atascosa River joins the Nueces River. Both the Atascosa and Nueces rivers support a diverse fauna of at least nine unionid species (Strecker, 1931, p. 69) including several larger species, e.g., <u>Magnonaias nervosa</u> (Barnes, 1823). I suggest that two shelling operations lasting over a year required a river like the Nueces. Shell-fishing in this case is definitely freshwater and not marine. Father Lanusa's final record of comment in this insubordination on August 4, 1771, "...Your Lordship's order to continue shell-fishing in the area immediately surrounding that presidio..." (La Bahia at Goliad, Texas, 60 km from the coast on the San Antonio River) confirms that all references are to freshwater shell-fishing.

Early Spanish missionaries did not taxonomically differentiate hard bodied fishes, crustaceans, and mollusks and called all of them shell-fish. Evidence of this lumping is noted in the diary of Father Gaspar José de Solís (1767) as he travelled from Mexico to San Antonio (1767-1768) for mission inspections. On February 9, 1768 he describes the fauna of the Salado River, Mexico (about 2 days by horse from the Rio Grande). Two expert translators give slightly differing renditions of this 18th century Spanish.

Forrestal (1931) translated Solís' crucial passage of February 9, 1768 as follows, "...[Salado River] is very deep and contains a great quantity of fish of various kinds: piltontes [yellow-catfish], pullones, bagres [species of catfish; siluris bagre], trout, etc., and also shell-fish, such as catanes, abujas and shrimp. It also contains pearls...". Words in brackets are footnotes to the translation. Kress (1932) translated this same passage as, "This river [Salado] is an abundant stream and has many fish - piltontes, pullones, barbel, trout, etc., some shell fish like Catanes abujas as well as prawn. In this river they get pearls...". [The italics were used by the translators and all punctuation is by the translator].

Solís' exact words and punctuation as copied from his diary for this passage are, ":este Río es mui candaloso tiene mucho pescado: Piltontes Pullones Vagre truchas etc. algunos de concha, como Catanes Abujas, como tambien camaron: en este Rio se reogen perlas, ..." The differences in translation are minor except for the handling of the Spanish words "catanes" and "abujas". Since neither author translated the words and since they are called shell-fish, it is important to know what it is or what they are.

Kress (1932) has clearly erred in placing Catanes abujas in a binomial context since the date of Solís' diary is 1768 only 10 years after Linnaeus' 10th edition. It is highly unlikely that Father Solís adopted Linneaus' system in this brief period of time. Also, Solís does not use Linneaus' system in other areas of his diary as he refers to the flora and fauna of the region. Although Forrestal (1931) does not place the two words in a binomial context, he does separate them (with a comma) to imply two separate organisms as was done with "Piltontes" and "Pullones". I propose Solís was, in fact, referring to two different organisms and calling them shell-fish. Are "catanes" and "abujas" references to mollusks? Unlikely, but their meanings are obscure. I suggest that catanes comes from catan meaning sword or saber, and may refer to a fish that is sword-like. Although the Spoonbill (Polyodon sp.) is possible, it does not have a hard body, and its presence in rivers of northern Mexico is doubtful. On the other hand, "Abujas" is a change in spelling of abugas - needle; hence, I propose that a needle-fish is a hard-bodied gar (Lepiosteus sp.). That shell-fish included animals other than mollusks is confirmed by both translators at the end of the sentence saying, "as well as prawn" or "and shrimp".

Exactly what animals Lanusa's Indians were collecting in 1771 in his reference to en mariscar, "to gather shell-fish" (all mollusks, crustaceans and mollusks, hard-bodied fish and mollusks, or some combination thereof), remains a mystery. Since the mission was founded in 1720, no Indian exceeded 51 years in the mission, and many would have been there only a few years because new Indians were added each year. It is reasonable to assume, therefore, that during the food stress of 1771, they resorted to the documented practice of collecting freshwater mussels for sustenance. The inexactness of reference to shell-fish probably includes some hard-bodied fish and the large (240 mm body length) shrimp, Macrobachium sp., which Hedgpeth (1949) recorded for Texas and Solís (1767) mentioned in northern Mexico.

The artifacts of Mission San José have been extensively studied; however, shell-fish remains are rare. The Archeological Center at the University of Texas at San Antonio has 20 unidentifiable, freshwater bivalve fragments from Mission San José. If the mission practiced regular shell-fish for over a year, it is remarkable that more shell-fish remains, including fish, shrimp, and mollusks, have not been recovered.

ACKNOWLEDGEMENTS

I wish to express my appreciation to Drs. Matthew Stroud and Jean Chittenden, Department of Modern Languages and Literature, Trinity University for their assistance.

Literature Cited

Fox, Daniel E., 1979. Archaeological Investigations of Two Prehistoric Sites on the Coleto Creek Drainage, Goliad County, Texas. Center for Archaeological Research, The University of Texas at San Antonio, Archaeological Survey Report, No. 69.

Forrestal, Rev. Peter, 1931. The Solís Diary of 1767. Preliminary Studies of the Texas Catholic Historical Society, 1(6):1-42.

Hedgpeth, J.W., 1949. The North American Species of Macrobrachium (River Shrimp). Texas Journal of Science 1(3):28-38.

Kress, Margaret K., 1932. Diary of a Visit of Inspection of the Texas Misssions by Fray Gaspar José de Solís in the Year 1767-68. Southwestern Historical Quarterly, 35:28-76.

Lanusa, Father Ygnacio, 1771. The San José Papers: The Primary Sources for the History of Mission San Josè y San Miguel de Aguayo from its Founding in 1720 to the Present Time. Translated by Fr. Benedict Leutenegger and edited by Fr. Manon Habig, 1978, Old Spanish Missions Historical Research Library, San José Mission, Incorporated, 280 p.

Murray, Harold D., 1978. Freshwater Mussels of Lake Corpus Christi, Texas. Bulletin American Malacological Union, 5-6

_______________, 1981. Unionids from Indian Sites in McMullen and Live Oak Counties, Texas. Bulletin American Malacological Union, 10-11.

Neck, Raymond W., 1982. A Review of Interactions between Humans and Freshwater Mussels in Texas. J.R. Davis, Editor, In Proceeding of the Symposium on Recent Benthological Investigations in Texas and Adjacent States, 169-182.

Oesch, Ronald D., 1984. Missouri Naiades, a Guide to the Mussels of Missouri. Missouri Department of Conservation, 270 pp.

Parmalee, Paul W. and Arthur Bogan, 1986. Molluscan Remains from Aborginal [sic] Middens at the Clinch River Breeder Reactor Plant Site, Roane County, Tennessee. American Malacological Bulletin, 4(1):25-37.

________, Walter E. Klippel, and Arthur E. Bogan, 1982. Aboriginal and Modern Freshwater Mussel Assemblages (Pelecypoda: Unionidae) from the Chickamauga Reservoir, Tennessee. Brimleyana, 8:75-90.

Solís, Father Gasper José de, 1767. Recorded In Memorias De Nueva España: Documentos Para La Historia Eclesiastica Y Civil De La Provincia De Texas, vol. 27, part 2, p 248-297 vuelta. Transcript Library The University of Texas.

Strecker, John K., 1931. The Distribution of the Naiades or Pearly Fresh-water Mussels of Texas. Baylor University Museum, Special Bulletin no. 2, 69 p.

BRIEF COMMUNICATIONS

Note regarding *Elliptio judithae* Clarke, 1986.- During early October, 1991, in cooperation with Coastal Zone Research, Inc. of Wilmington, N.C., I carried out a partial survey for the federally listed endangered species *Alasmidonta heterodon* (Lea, 1830) in Turkey Creek (an upstream tributary of Little River in the Neuse River System) near Wilson, Wilson County, North Carolina. While searching Buckhorn Reservoir at a point (designated as "Big Finger" by CZR staff) located about 1/2 mile east of N.C. Route 1126, a fresh empty shell of a lanceolate *Elliptio* (probably *E. producta* (Conrad)) was found which exhibited well-marked, widespread, corrugations perpendicular to the lines of growth. Those corrugations are virtually identical to those which were considered by me as the major character which distinguished the non-lanceolate new species *Elliptio judithae* (see Clarke, 1986, *Malacology Data Net* ~~2:76~~), of the Neuse River, from all other species of *Elliptio*.

This find indicates that corrugations of this type are not species-specific and may be caused by parasitism or some other extrinsic agent. It is therefore possible that *E. judithae* will prove to be conspecific with one of the many nominal species of *Elliptio* described by Isaac Lea, but which species that may be remains a question.

Arthur H. Clarke

1(4):78-95.

NEWS

Mr. Fred. R. Woodward, a curator at the Art Gallery & Museum, Kelvingrove, Glasgow, Scotland (U.K. G3 8AG) has recently informed the Editor that as of March 27, 1931, under the Countryside and Wildlife Act, it became illegal in Britain "to kill or injure the freshwater pearl mussel, Margaritifera margaritifera".

Mr. Woodward has also pointed out that although M. margaritifera is now protected in Great Britain,... "professional pearlfishing has provided an additional means of livlihood to Scottish rural communities since Roman times and, provided it is carried out correctly, should not cause undue detriment to the mussel populations concerned. For this reason pearlfishers, one being fulltime, have been in contact in an attempt to draw up regulations to retain their traditional craft at the same time ensuring the future conservation of the pearlmussel stocks. The results of these deliberations are outlined in the hope that they will provide a basis for future legislation to safeguard Scotlands natural and cultural heritage".

A series of regulations were proposed which should be observed by licensed pearlfishers. Although the entire list is too lengthy for reiteration here, since our own mussel fishing procedures are so destructive, and the damage to our unionid fauna from Dreissena polymorpha is likely to be so intense, it seems probable that some of the proposed British regulations, or their equivalents, will soon have to be imposed in North America. Several of the proposed British regulations are therefore given below.

1. The pearl mussel must not be killed, injured, or harmed in any way.

2. The adductor muscles must not be over stretched or torn whilst the inspection (for pearls) is taking place.

3. Only the Official Opening Tongs provided must be used for all inspections and set to a maximum opening of 1.5 cm.

4. Care should be taken when removing a pearl so

as not to unduly damage the area of animal tissue surrounding the pearl.

5. The methods of pearl fishing which are allowable under license are "TRADITIONAL" :-

a/ From the shore, namely by wading, using glass bottomed viewing device and traditional cleft stick.

b/ From a boat, using glass bottomed viewing device and traditional cleft stick.

6. Taking or possession of pearl mussels under the size of 8 cm. will be considered an offence.

7. Pearl fishers must observe any official close season during which it is illegal to fish for pearls. In the first instance it is recommended that this should run from the second week of June to the second week of September inclusive. This coincides with the period during which the mussel liberates its glochidia ... and also with the period of lowest water levels.... Disturbance of gravid mussels at this critical period ... can result in abortion of the glochidia from some individuals which in turn may result in all gravid individuals in the area aborting en masse.

8. Contravention of these conditions will ... result in a minimum fine of one hundred pounds ... and the license being revoked for all time.

ERRATUM. In the last issue of this journal (Vol. 2, No. 5/6, 1989), the paper by Gordon (on Anodonta (Lastena) ohiensis Rafinesque) contained an error in the final paragraph under Addendum (page 161). The last sentence of that paragraph should have read as follows:
"Based on the apparent synonymy of digonata under ohiensis, Flexiplis (type: A. digonata Rafinesque, 1831, by monotypy) would be subordinate to Proptera."

INFORMATION FOR CONTRIBUTORS

Malacology Data Net seeks to enhance progress in malacology by facilitating publication of significant new information about all aspects of marine, freshwater, and terrestrial mollusks. All scholarly contributions are welcome

Editorial style used in this journal follows the Style Manual for Biological Journals available from the American Institute of Biological Sciences, 1401 Wilson Boulevard, Arlington, Virginia 22209. Manuscripts should be submitted in duplicate as camera ready copy, using "letter quality" type, with text in blocks 5 inches wide and 6 1/2 inches high. Use of a word processor is recommended. Each manuscript will be reviewed by at least 2 professional malacologists and, if necessary, will be returned to the author for revision.

If a need for reprints is contemplated that fact should be mentioned in the initial cover letter accompanying the manuscript. A price list will be sent in response for the authors consideration.

Malacology Data Net is published without grant support. Unfortunately the policy of not assessing page charges, which applied since the journal was founded in 1986, cannot be maintained any longer. Therefore beginning with Volume 3, Number 5, authors will be charged the nominal fee of ten dollars a page for typescript or line drawings. If half-tone illustrations (i.e. photographs) are included with the manuscript authors will be charged at cost for plate preparation and reproduction.